Annex 2

Feasibility Study

Cyclone Meena storm surge inundating Rarotonga, Cook Islands – 6 February 2005 (Source: Geoff Mackley)

Enhancing Climate Information and Knowledge Services for Resilience in Cook Islands, Niue, Palau, Marshall Islands and Tuvalu

FEASIBILITY STUDY

CONTENTS

1 – INTRODUCTION

This Feasibility Study supports the Funding Proposal to the Green Climate Fund (GCF) prepared by the United Nations Environment Programme (UNEP) in agreement with the Governments of the Cook Islands, Niue, the Republic of the Marshall Islands, Palau and Tuvalu.

The purpose of the Enhanced Climate Information and Knowledge Services Programme (the Programme) is to support increased resilience to climate variability and change in the five targeted countries. The study is founded on consultations with the five countries' national meteorological services (NMHSs) and with national government and civil society agencies as well as regional organisations and other development partners. It is consistent with national and regional policies, and with international agreements and frameworks to which the Programme countries are parties. It draws on extensive detailed research undertaken by United Nations (UN) agencies, the World Meteorological Organization (WMO), the Australian Bureau of Meteorology (BoM) and the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) into the current and projected future impacts of climate variability and change in the 14 independent Pacific island countries, including the five Programme countries.

Information has been drawn both from in-country visits for focussed discussions with stakeholders and from recent consultations conducted with the NMHSs of 14 Pacific Island countries during the development of the Pacific Islands Meteorological Strategy 2017–2026. It is aligned with the objectives of the Pacific Meteorological Council (PMC) and its Panels, the Pacific Roadmap for Strengthened Climate Services (PRSCS) 2017–26 and key climate-related declarations, which underpin important regional agreements on climate change management and adaptation.

It is sometimes assumed that adaptation to climate change is a process in which the challenge is to anticipate and adjust to gradual changes in average climate. It is already clear that changes can be both large and abrupt. Pacific island countries urgently need the capacity to generate, communicate and use scientifically sound information on the current progress of change and the probable future.

The Cook Islands, Niue, the Republic of the Marshall Islands, Palau and Tuvalu are at the forefront of climate change and face similar problems in dealing with its emerging impacts. Their islands have been occupied for thousands of years by people who have acquired profound understandings of their lands and their climate. Their contribution to anthropogenic climate change is negligible. Their great vulnerability to climate change arises from their geography, the exposure of their populations and their lack of resilience to shocks; their limited adaptation capacity is caused by structural constraints on their financial and human resources.

The shift to decision-making informed by science is essential for their adaptation to long-term changes. That science must be based on more data than is currently available to them, from the limited observation and monitoring networks that their small and narrowly based economies can afford. The Programme will effect a paradigm shift to science-informed evidence-based climate adaptation, risk reduction and multi-hazard early warnings. This will be complemented by a transformation in the way that climate information is communicated to island populations, so that people at "the last mile" clearly understand what is happening and have the capacity to prepare and respond to its impacts.

These five very small Pacific Island countries have similar requirements for climate information services to protect human safety and livelihoods from the effects of a variable and changing climate—they need reliable, timely advice on local weather and climate in understandable formats and they need science-based advice on planning for longer term impacts.

The principal objective of the Programme—Enhancing Climate Information and Knowledge Services for Resilience in 5 Island Countries of the Pacific Ocean—is to support the partner countries as they develop resilience to the impacts of climate variability and change. The five countries will do this through expanding the range and volume of reliable data available to them, strengthening the capacities of their national meteorological services and other agencies to analyse and apply climate data to the functions of climate-sensitive sectors, and improving their communication of useful information so that it reaches everyone who needs it.

The Programme will support increased climate-resilient sustainable development in the Cook Islands, Niue, Palau, the Republic of the Marshall Islands (RMI) and Tuvalu through the achievement of three key GCF-level outcomes: i) Increased generation and use of climate information in decision making; ii) Strengthened adaptive capacity and reduced exposure to climate risks; and iii) Strengthened awareness of climate threats and risk-reduction processes.

The countries will integrate the use of climate information across and within sectors, and develop and adopt demand-driven solutions, which will be achieved through coordinated activities supported by a regional hub. The end-to-end Programme will have measurable impacts on the five countries' resilience to climate change impacts.

This Annex describes issues common to the five countries, summarises the five separate country feasibility studies and includes the individual country studies, which bring together information from in-country consultations and have been endorsed by their respective governments.

2 – REGIONAL OVERVIEW

All the very small island states in the study are situated in the tropics. They experience extreme weather and climate variability, within years and from year to year, and are subject to floods and storm surges, often associated with tropical cyclones, and droughts. Some of them are also exposed to geophysical hazards—earthquakes, tsunami and landslides.

The World Risk Index 2018[1] "confirms the most important results of the previous years. Disaster risks are unevenly distributed, and they mostly affect island nations and countries with low and medium income in Oceania, Asia, and Central America. The Index shows that it is possible to reduce disaster risks by eliminating susceptibility and developing good coping and adaptive capacities. Two highly exposed countries, Japan and the Netherlands, have achieved this particularly effectively. At the same time, they figure among the world's 20 richest countries.

"The World Risk Index 2018 also unequivocally demonstrates that island nations such as Vanuatu, Tonga, and the Solomon Islands are unable to reduce the disaster risk without external support. Even if they were capable of reducing their vulnerability to a considerable degree, their risk value would remain in the high or very high area owing to their very high exposure. For these countries, changes regarding their exposure are also essential. Theoretically, sea-level rise, storms, and floods in particular, all of which especially affect island nations, could be reduced, since they are influenced by global warming. However, the political will among many industrial nations to implement the measures required to achieve the aims of the Paris Agreement is still not sufficiently recognizable. Thus, the countries threatened by natural hazards have fallen into a trap from which they cannot break free on their own."[2]

The five Programme countries are not listed in the World Risk Index, but if anything, they are more at risk than Vanuatu, Tonga and the Solomon Islands, which rank very highly in the Index. The Index states that in a 5-year comparison of 172 countries, disaster risk—the risk that an extreme natural event will lead to a disaster—is at its highest in Oceania,[3] calculating risk based on:

- Exposure to natural hazards such as earthquakes, hurricanes, flooding, drought and sea-level rise;
- Vulnerability as dependent on infrastructure, nutrition, living conditions and economic circumstances;
- Coping capacities as dependent on governance, preparedness and early warning measures, access to health care, social and material security; and
- Adaptive capacities with respect to impending natural events, climate change and other challenges.

Average direct losses from natural disasters in the South Pacific region are estimated at about US$284 million per year,[4] varying significantly from year to year. The total value of infrastructure, building and cash crops at risk from cyclones, earthquakes and tsunami is estimated at USD 112 billion and in some years, losses from one or more natural disasters in a Pacific country can exceed its Gross Domestic Product (GDP).

[1] Hans-Joachim Heintze and others, 2018, WorldRiskReport 2018, Bündnis Entwicklung Hilft
[2] Hans-Joachim Heintze and others, 2018, WorldRiskReport 2018, Bündnis Entwicklung Hilft.
[3] Hans-Joachim Heintze and others, 2018, WorldRiskReport 2018, Bündnis Entwicklung Hilft.
[4] Fiji Times, 20 September 2017, drawing on WB and ILO statistics.

The socio-economic characteristics of Pacific countries contribute to their vulnerability. Most Pacific islanders live close to coasts, subject to storm surges, river flooding and saltwater intrusion into freshwater resources and agricultural land. Pacific Island countries are very aware of their vulnerability to climate and geophysical shocks, and of the impact these can have on their social and economic progress. Most of them are remote from markets and have small populations and narrow resource bases. The economies of all five countries depend heavily on subsistence and commercial agricultural enterprises which, like their growing tourism sectors, are very climate sensitive.

3 – CLIMATE RATIONALE[5]

The climate rationale provides the scientific underpinning for **robust climate analysis to inform climate action** decision-making and ensure that the Programme responds directly to climate change challenges faced by the Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu. It provides the scientific basis for an evidence-based approach to climate change action and facilitates that the set of causal linkages between climate and climate impacts, and between climate action and societal benefits, are fully grounded in the best available climate data and science concerning the most relevant climatic factors.

There is a common perception among Pacific island communities that changes in the weather and climate are already happening and that more change has been experienced in the past decade than at any other time in the past. Local perceptions of climate change include higher temperatures, shifts in seasonal rainfall patterns, changing frequencies of extreme events – such as tropical cyclones and drought – and rising sea levels.[6] The climate rationale contains a comprehensive climate analysis – assessment of the past and current climate and climate projections – as the basis to infer real and potential climate change and related impacts on the communities of the five Programme countries to corroborate what is already being perceived.

In response to the articulated climate change impacts and associated vulnerabilities, the Programme will establish and implement enabling mechanisms to complete the climate information value chain from its climate science basis to evidence-based climate action. This will be achieved through the strengthening of climate information services to facilitate that the value from climate information – and the rationale to which it contributes – can be realised, and that subsequent climate resilience measures informed by the rationale can be successfully executed. The proposed interventions are detailed in sections 7 and 8 of the Feasibility Study.

3.1 DATA AND METHODOLOGY

The climate rationale was developed based on extensive peer review of existing scientific literature and available climate analyses primarily from the Australian Bureau of Meteorology (BoM), the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Intergovernmental Panel on Climate Change (IPCC). The methodology draws on internationally agreed concepts in climate change assessment and projections – as recommended by the World Meteorological Organization (WMO) and its scientific and technical network – and references the best available and accessible climate data, methods and tools. This includes global and regional climate datasets, and best practices for using climate indices, indicators and analysing high impact events.

Data

The observational data used has been collated from national climate databases, the Australian BoM, New Zealand's National Institute of Water and Atmospheric Research (NIWA) and the US National Oceanographic and Atmospheric Agency (NOAA).

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[5] UNEP acknowledges the contributions and review by the Australian Bureau of Meteorology (BoM) / Department of Foreign Affairs and Trade (DFAT) and the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO)

[6] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research. Volume 1: Regional Overview. Volume 2: Country Reports

The majority of data was obtained from the Pacific Climate Change Data Portal, which was developed through the Pacific Climate Change Science Program (2009 – 2011) to provide access to historical climate trends and basic climate information from observation sites across the Pacific islands and Timor-Leste. The Portal was further developed through the Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Program, in particular to include daily data and the WMO Expert Team on Climate Change Detection and Indices (ETCCDI) climate extreme indices and is the main means of sharing information for PACCSAP.

The Portal provides historical point-based data for climate observing sites across the Pacific, including temperature and rainfall variables at daily, monthly, seasonal and annual timescales. Both "raw" and "homogenised" versions of data are contained. The raw data mainly comes from the national meteorological services and have undergone basic quality control checks but no homogeneity adjustments. Homogenised temperature data have adjustments applied to correct for artificial biases caused by changes in the instrumentation or location of the recording site, and changes to the environment around the recording site. Rainfall data has not been adjusted. However, only rainfall records or parts of records that are proven to be homogenous are presented.[7]

The locations of the principal observing stations in the five Programme countries are shown in the table and figure below. The table also indicates the recording period available for each station.

Country	Station	Longitude	Latitude	Period of daily precipitation	Period of daily temperature
Cook Islands	Penrhyn	158.05°W	9.03°E	1951 – 2018	-
	Rarotonga	159.80°W	21.20°S	1951 – 2017	1951 – 2017
Niue[8]	Hanan Airport	169.93°W	19.08°S	1990 – 2017	1990 – 2017
	Alofi	169.92 °W	19.07 °S	1951 – 2017	1951 – 2017
Palau	Koror	134.48°E	7.33°N	1951 – 2017	1951 – 2017
Marshall Islands	Majuro	171.38°E	7.08°N	1951 – 2017	1951 – 2017
Tuvalu	Funafuti	179.22°E	8.50°S	1951 – 2017	1951 – 2017

Table 1. List of stations, their locations and period of record (Source: Pacific Climate Change Data Portal)

[7] Australian Bureau of Meteorology, 2020. Pacific Climate Change Data Portal. Available at: http://www.bom.gov.au/climate/pccsp/

[8] A composite dataset "Hanan Airport" has been utilised for the calculation of extreme climate indices for Niue. In the homogenised dataset, the Alofi data has been 'adjusted' to the climate of Hanan Airport. Available at: http://www.bom.gov.au/cgi-bin/climate/pccsp/site_data.cgi?download=%2Fweb01%2Fncc%2Fwww%2Fpccsp%2FNIU_000002_Rain.hom.csv&ts_period=monthly&data_source=hom&variable=Rain&period=annual&s_yr=&e_yr=&ave_yr=0&unit=A&nat_id=NIU&station=000002

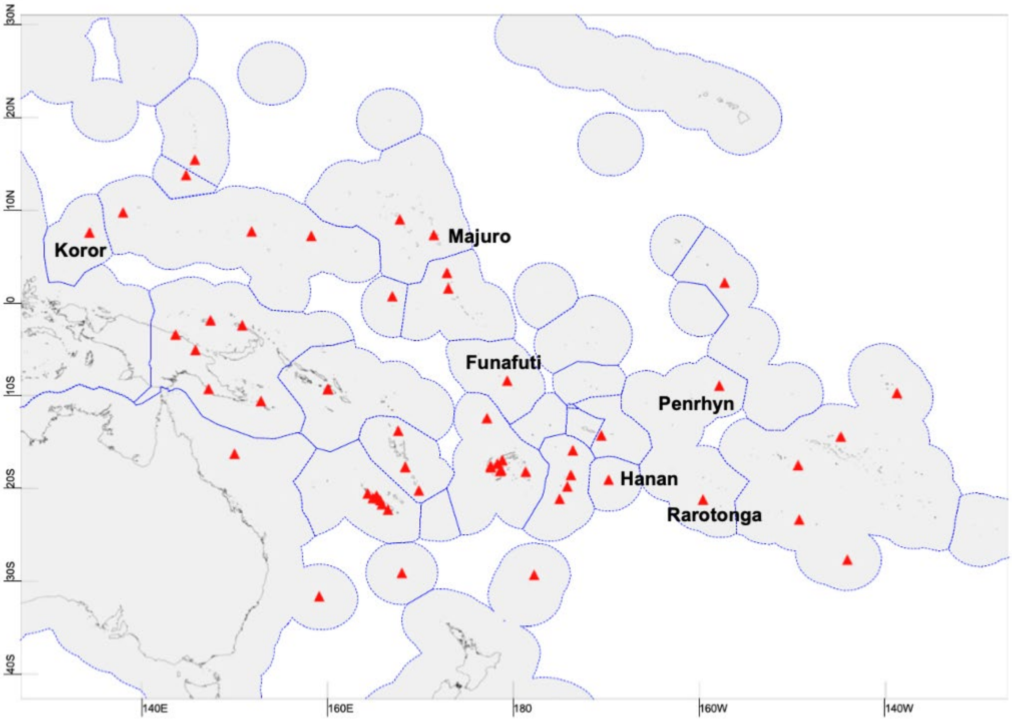

Figure 1. Locations of the main observing stations for Cook Islands (Rarotonga and Penrhyn), Niue (Hanan Airport), Palau (Koror), Marshall Islands (Majuro) and Tuvalu (Funafuti). (Source: Adapted from McGree *et al.*, 2019)

It should be noted that some referenced studies have combined the historical records for Hanan Airport, Alofi and Kaimiti to create a Hanan Airport composite for Niue: "Observations were taken close to Alofi wharf from 1905 to 1971 and adjacent to the current Alofi Police Station from 1977 to 1996. Between 1971 and 1976 observations were taken at Kamiti, 2.4 km south of Alofi. Hanan Airport monthly rainfall from 1905 (daily values from 1915) and air temperature from 1940 have been used".[9]

Amongst others, McGree *et al.* have expressed significant concern in the continued decline in data quality and frequency of observations in the Pacific island region and highlighted that "temperature observations >80 % complete are now largely limited to the principal observation stations in each country". Furthermore, "few metadata are being documented, and this will continue to hinder the homogenisation of meteorological records in the future. Metadata collection is especially important in the current decade" due to the increasing frequency of switching to automated observations.[10]

The need for standardised climate data management protocols, quality control and data homogenisation processes is thus becoming increasing relevant, and will be specifically addressed under Activity 2.3 of the Programme.

Data adequacy

Three criteria for data adequacy have been considered in developing the climate rationale – quantity, quality and availability – to ensure that data used are fit for purpose and reflect the best available science.

[9] Australian Bureau of Meteorology and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports

[10] McGree, S. *et al.* 2019. Journal of Climate. Recent Changes in Mean and Extreme Temperature and Precipitation in the Western Pacific Islands

The observational network coverage is notably insufficient in Pacific SIDS due to lack of staffing capacity and national funding, which are compounded by their vast ocean areas. For example, the land area of Palau represents 0.07% of its EEZ – the largest percentage of the five Programme countries – whilst the land area of Tuvalu represents just 0.002% of its EEZ. As highlighted above, sufficiently 'complete' temperature datasets are mainly limited to the principal observing stations in Pacific island countries. Therefore, whilst accurate point-based observations may be available, derived climate analysis products and forecasts may not be accurate for outer islands distant from the principal observing station in each country. In preliminary analyses of the observational networks of the five Programme countries – for development of the WMO Global Basic Observing Network (GBON) and the Systematic Observations Financing Facility (SOFF) concept – WMO has expressed the need for at least one GBON-compliant observing point per inhabited island as a minimum requirement for each Programme country.[11] Data availability and quantity is therefore highly limited and of inadequate resolution particularly to cover all outer islands of the archipelagos (Cook Islands, Palau, RMI and Tuvalu).

Data quality may be compromised due to limited capacity of NMHSs to perform quality control and data homogenisation. It has been noted that "metadata is most likely incomplete or lacking detail as record keeping tends to focus on the observation enclosure, at times omitting changes in the surrounding environment". Detailed metadata is crucial to facilitate homogenisation of data, which is required to reliably determine that data reflects change in the climate rather than changes to the circumstances under which the observations were taken.[12] Expanding the observational infrastructure and building in-house capacity for weather and climate observations, data management and climate analyses – in alignment with WMO standards – will be a major focus of the proposed Programme.

Remote observations obtained from satellites and reanalyses have been used to supplement in-situ observational data. However, it is noted that reanalyses – particularly in the data sparse Pacific island region – are based on few observations and therefore contain large uncertainties. For example, over Rarotonga (Southern Cook Islands), there is a >20 % underestimation of rainfall by satellites in some months (averaged over the recording period). For surface air temperature, reanalyses datasets tend to be biased to sea surface temperature. McGree *et al.* also highlighted that "global-scale studies on trends in droughts to date present little information on the Pacific as the islands have little visibility at a global scale and Pacific data in global data sets are limited."[13] The climate rationale highlights uncertainties and confidence levels – where calculated – to facilitate more accurate interpretation of the data and observed trends.

Methodology

State of the climate indicators

The climate indicators used are a sub-set of the WMO Global Climate Observing System (GCOS) Essential Climate Variables (ECVs) for the atmosphere and ocean, which describe the key features of the state of the climate in the western tropical Pacific – past, present and future. The indicators – temperature, precipitation, sea level, sea surface temperature and ocean acidification – are based on in-situ observations, satellite data and reanalyses.

[11] Virtual meeting on GBON in the five Programme countries between UNEP, WMO and PSS consultants – 5 June 2020
[12] McGree, S. *et al.* 2019. Journal of Climate. Recent Changes in Mean and Extreme Temperature and Precipitation in the Western Pacific Islands
[13] McGree, S. *et al.* 2016. Journal of Climate. Trends and Variability in Droughts in the Pacific Islands and Northeast Australia

The climate analysis includes the set of extreme indices for temperature and precipitation, which are based on those defined by the WMO ETCCDI[14] and the Expert Team on Sector-Specific Climate Indices (ET-SCI). The definitions are listed in the tables below.

Extreme Temperature Indices	Definition
Highest maximum temperature (TXx)	Monthly maximum value of daily maximum temperature (TX)
Highest minimum temperature (TNx)	Monthly maximum value of daily minimum temperature (TN)
Lowest maximum temperature (TXn)	Monthly minimum value of daily maximum temperature (TX)
Lowest minimum temperature (TNn)	Monthly minimum value of daily minimum temperature (TN)
User-defined hot days (SUx)	Annual count of days with maximum temperature (TX) > 26 to 37 °C (1 °C intervals)
User-defined hot nights (TRx)	Annual count of nights with minimum temperature (TN) > 21 to 32 °C (1 °C intervals)
Cool days (TX10p)	Number of days with maximum temperature (TX) < 10th percentile
Cool nights (TN10p)	Number of nights with minimum temperature (TN) < 10th percentile
Warm days (TX90p)	Number of days with maximum temperature (TX) > 90th percentile
Warm nights (TN90p)	Number of days with minimum temperature (TN) > 90th percentile
Warm spell duration (WSDI)	Annual count of days with 6+ consecutive days when TX > 90th percentile
User-defined WSDI (WSDId)	*Annual count of days with d+ consecutive days when TX > 90th percentile*
Cool spell duration (CSDI)	Annual count of days with 6+ consecutive days when TN < 10th percentile
User-defined CSDI (CSDId)	*Annual count of days with 3+ consecutive days when TN < 10th percentile*
Cooling degree-days (CDDcoldn)	*Annual sum of TM – n (where n is a user-defined location-specific base temperature and TM > n; n = 18 °C is used)*
Diurnal temperature range (DTR)	Monthly mean difference between TX and TN

Table 2. Definitions of ETCCSDI and ET-SCI extreme temperature indices used. Italics indicate indices that are solely ET-SCI sector-specific indices.

Extreme Precipitation Indices	Definition
Max 1-day rainfall (Rx1day)	Monthly maximum 1-day precipitation (PRCP)
Max 5-day rainfall (Rx5days)	Monthly maximum consecutive 5-day precipitation (PRCP)
Simple daily intensity (SDII)	Annual total precipitation divided by the number of wet days in the year; wet days defined as PRCP ≥ 1 mm
Rain days ≥ 10 mm (R10)	Annual count of days with PRCP ≥ 10 mm
Rain days ≥ 20 mm (R20)	Annual count of days with PRCP ≥ 20 mm
User defined rain days (Rnn)	Annual count of days with PRCP ≥ 1, 5, 30, 40, 50, 60, 70, 80 and 100 mm

[14] Australian Bureau of Meteorology, 2020. Pacific Climate Change Data Portal. Available at: http://www.bom.gov.au/climate/pccsp/

Consecutive dry days (CDD)	Maximum number of consecutive days with daily rainfall (RR) < 1 mm
Consecutive wet days (CWD)	Maximum number of consecutive days with daily rainfall (RR) ≥ 1 mm
Very wet days rainfall (R95p)	Annual total precipitation when daily rainfall (RR) > 95th percentile
Extremely wet day rainfall (R99p)	Annual total precipitation when daily rainfall (RR) > 99th percentile
Annual total wet day rainfall (PRCPTOT)	Annual total precipitation in wet days (RR ≥ 1 mm)
Standardised precipitation index (SPI)	*Measure of "drought" using the SPI on timescales of 3, 6 and 12 months*
Standardised precipitation evapotranspiration index (SPEI)	*Measure of "drought" using the SPEI on timescales of 3, 6 and 12 months*

Table 3. Definitions of Definitions of ETCCSDI and ET-SCI extreme precipitation indices used. Italics indicate indices that are solely ET-SCI sector-specific indices.

Country-specific extreme temperature and precipitation indices are provided for Rarotonga (Cook Islands), Hanan Airport (Niue),[15] Koror (Palau), Majuro (Marshall Islands) and Funafuti (Tuvalu), as obtained from the Pacific Climate Change Data Portal. The indices are calculated using homogenised data for the period 1951 – 2017.[16] It should be noted that indices obtained from the Portal calculate trends using the least squares method, which is adequate but subject to outliers. More robust methods of trend calculation are used in the PACCSAP and scientific literature referenced. Differences between the two methods of calculation are usually minor.

Percentile-based threshold levels have been calculated for 5-day windows across the annual cycle using 1971 – 2000 as the base period, i.e. daily rainfall or temperature values are compared relative to varying thresholds throughout the year. Therefore, it is possible to have warm spells during winter, cold spells during summer, or extreme precipitation recorded at any time of the year.

The FClimDex software package was used to calculate the indices. Monthly indices are calculated if no more than three days are missing in a month; annual indices are calculated if no more than 15 days are missing in a year. For threshold indices, a threshold is calculated if at least 70 % of data are present. For spell duration indices, a spell can continue into the next year and is counted against the year in which the spell ends.[17]

Sector-specific ET-SCI indices – user-defined warm and cool spell durations and drought indices – for the Pacific island region are discussed, as calculated by McGree *et al.* The indices were calculated using ClimPACT2v2. Several ET-SCI indices were not analysed due to the time series being unusable. For example, "the number and frequency of heat waves and cold waves in the tropical Pacific was zero for many years; therefore, heat-wave and cold-wave duration, magnitude, and amplitude could not be calculated". This is likely a result of low day-to-day temperature variability on oceanic islands.[18]

High impact events

[15] The "Hanan Airport" dataset is a composite of data from Hanan Airport and Alofi stations.
[16] Australian Bureau of Meteorology, 2020. About Pacific Climate Change Data. Available at: http://www.bom.gov.au/climate/pccsp/about-pi-climate-data.shtml
[17] Australian Bureau of Meteorology, 2020. About the Pacific Climate Extreme Indices. Available at: http://www.bom.gov.au/climate/pccsp/about-pi-extreme-indices.shtml
[18] McGree, S. *et al.* 2019. Journal of Climate. Recent Changes in Mean and Extreme Temperature and Precipitation in the Western Pacific Islands

High impact events are defined here as hydrometeorological events associated with high impacts on loss and damages – and are also referred to as extreme climate events. The main high impact events that affect the five Programme countries are tropical cyclones, extreme rainfall and drought, as well as coastal flooding associated with extreme sea levels.

A tropical cyclone is defined as "a rotating, organised system of clouds and thunderstorms that originates over tropical or subtropical waters and has closed, low-level circulation".[19] Tropical cyclones affecting the Pacific islands are recorded based on the Australian tropical cyclone intensity scale, which describes the severity of a tropical cyclone in terms of categories ranging from 1 (weakest) to 5 (strongest) related to the maximum wind speed.[20] It should be noted that hurricanes and typhoons are classifications of tropical cyclone. However, in the South Pacific, the generic term 'tropical cyclone' is used, regardless of the associated wind strength.[21] Accordingly, use of the Hurricane Severity Index is not relevant to the Pacific island context.

The Standardised Precipitation Index (SPI) and Standardised Precipitation Evapotranspiration Index (SPEI) have been used to analyse trends in historical drought events – including drought frequency, duration and magnitude – as recommended by WMO. The indices measure drought on 3, 6 and 12-month timescales. The SPI ranks as one of the best drought indicators for robustness and reliability.[22]

Socio-economically based indicators

The impacts of climate change on Pacific island populations and their vulnerabilities can be assessed and predicted in relation to socio-economic outcomes. Through a comprehensive consultative process, the Pacific island countries and territories have adopted the five priority areas of the WMO Global Framework for Climate Services – Agriculture and Food Security; Disaster Risk Management; Health; Water; and Energy – and added a further two priorities – Fisheries and Tourism. Section 3.6 outlines the impacts of climate change on these priority sectors as well as on reef ecosystems, which are projected to be significantly impacted by ocean acidification. Indicators used include disease statistics, drinking water and sanitation coverage, GDP contribution, fisheries productivity and tourism revenues.

Emissions scenarios

The climate rationale reports projections of future climate change based on the IPCC Representative Concentration Pathways (RCPs) emissions scenarios, which were used for the climate model simulations carried out under the framework of the Coupled Model Intercomparison Project Phase 5 (CMIP5) of the World Climate Research Programme:

- RCP2.6 (very low emissions);
- RCP4.5 (low emissions);
- RCP6.0 (medium emissions);
- RCP8.5 (very high emissions).

The RCP scenarios span a broader range of possibilities than previous studies based on the B1-low, A1B-medium and A2-high scenarios from the IPCC Special Report on Emission's Scenarios (SRES) – although these scenarios have been referenced where newer studies are not available.

[19] NOAA, 2020. What is the difference between a hurricane and a typhoon? Available at: https://oceanservice.noaa.gov/facts/cyclone.html
[20] Australian Bureau of Meteorology, 2020. What is a Tropical Cyclone? Available at: http://www.bom.gov.au/cyclone/tropical-cyclone-knowledge-centre/understanding/tc-info/
[21] NOAA, 2020. What is the difference between a hurricane and a typhoon? Available at: https://oceanservice.noaa.gov/facts/cyclone.html
[22] McGree, S. *et al.* 2016. Journal of Climate. Trends and Variability in Droughts in the Pacific Islands and Northeast Australia

Projections and downscaling

The climate rationale integrates regional and site-specific climate projections and downscaling from several sources, including the Pacific-Australia Climate Change Science and Adaptation Planning Program (PACCSAP) reports,[23] the Pacific Climate Futures web-tool[24] – built on CSIRO's Representative Climate Futures Framework[25] – the IPCC Fifth Assessment Report (AR5)[26] and recent peer-reviewed scientific literature.

There are various downscaling approaches used for the Pacific (and more generally) for the purpose of generating and applying projections data and information to inform climate impact assessments:

- Dynamic downscaling (using regional climate models);
- Statistical downscaling; and
- Simpler techniques such as delta scaling of observations using a change signal.

There are different limitations and advantages to all of these approaches, and their suitability is dependent on the proposed use. Current best practice is to use a multi-model approach to both the global modelling (CMIP is the most common) and also to explore downscaling results – with structures such as CORDEX being developed to bring together various dynamical and statistical downscaling.

To our knowledge, there are no reliably verified, higher resolution gridded daily downscaled data across the Pacific that are currently accessible or available. There is no CORDEX domain focused over the Pacific and no equivalent international coordinated program. There are various projects or programs that have produced downscaling using a single dynamical or statistical method; however, there is no central access point for these.[27]

Multi-model ensemble projections for the western tropical Pacific have a coarse spatial scale and represent changes over a broad region, rather than at a specific city/town. Site-specific downscaling utilises the Conformal Cubic Atmospheric Model (CCAM) – developed by CSIRO – which produced two sets of dynamically gridded datasets across the Pacific region at 60 km resolution, and dynamic downscaling of six global climate models (GCMs) under the A2 (high) emissions scenario. Regional climate projections of the South Pacific Convergence Zone at up to 50 km resolution are also presented. The authors emphasise that although the high resolution regional climate model (RCM) ensembles had islands present that are missing from global climate model (GCM) simulations; they were unable to resolve within island topographies and hence the climate distribution across islands.[28] This is important because the influence of topology on local climate can cause substantial variation within the Pacific island countries.

Tropical cyclones are usually too small to be explicitly represented in GCMs. Three independent methods were used to assess the ability of climate models to simulate cyclones and future projections:

- "A detection and tracking scheme that looks for features resembling a cyclone (7 out of 17 models with suitable data performed well);
- A detection scheme that looks for environments conducive to cyclone formation (8 out of 13 models with suitable data performed well);

[23] Pacific Climate Change Science, 2020. Reports. Available at: https://www.pacificclimatechangescience.org/publications/reports/
[24] Pacific Climate Change Science, 2020. Pacific Climate Futures. Available at: https://www.pacificclimatefutures.net/en/
[25] Clarke, J.M. *et al.* 2011. Providing application-specific climate projections datasets: CSIRO's Climate Futures Framework
[26] IPCC, 2013. Climate Change 2013: The Physical Science Basis
[27] Consultation with CSIRO, August 2020
[28] Evans, J.P. *et al.* 2015. Climate Dynamics. Regional climate model projections of the South Pacific Convergence Zone

- Empirical techniques that relates cyclone formation to environment conditions (17 models used)."

Both dynamical and statistical were subsequently used as complementary techniques to project future changes in the intensity of tropical cyclone winds and rainfall. [29] The projections are reported in section 3.6.7.

Furthermore, it should be noted that changes in the mean climate are almost inevitably associated with changes in the frequency and intensity of extreme events. For example, a rise in mean temperature may be associated with an increase (decrease) in the number of extremely hot (cold) days, while a rise in mean rainfall may be associated with an increase in the number of heavy rain days, at the expense of light rain days. However, due the inherent complexity of the climate system, changes in extremes are not always consistent with changes in the mean. Therefore, it is generally not appropriate to simply extrapolate mean climate projections when considering extreme events. Instead, a number of descriptive indices[30] and statistical modelling techniques[31] are used to capture changes in the magnitude and frequency of extreme weather events from daily data, described using a number of commonly used extreme maximum temperature, minimum temperature and rainfall indices.[32]

Statistic	Description	Variables
1-in-20-year return value [a]	Extreme daily value that occurs on average only once every 20 years. The change in this statistic relative to the base period (1980 – 1990) is denoted ΔP_{20RV}	Maximum temperature Minimum temperature Rainfall
90th percentile	The value that is only exceeded on 10% of days	Maximum temperature Minimum temperature Rainfall
10th percentile	The value that is surpassed on all but 10% of days	Maximum temperature Minimum temperature Rainfall
Highest 5-day total rainfall [b]	Magnitude of the highest 5-day rainfall total. The change in this statistic relative to the base period (1980 – 1990) is denoted ΔP_{RX5}	Rainfall
Extreme rainfall contribution index [b]	Percentage of total annual rainfall that comes from intense rainfall events (defined as more intense than the 99th percentile). The change in this statistic relative to the base period (1980 – 1990) is denoted $\Delta P_{R99pTOT}$	Rainfall
Rainy day	Any day where more than 1 mm of rain falls	Rainfall
Light, moderate and heavy rain day [c]	Any day where 1 – 10 mm (light), 10 – 20 mm (moderate) or 20 – 50 mm (heavy) of rain falls	Rainfall

[a] Calculated using the Generalised Extreme Value distribution
[b] See http://cccma.seos.uvic.ca/ETCCDMI/ for details
[c] Categories defined by Dai (2006) and Sun *et al.* (2006)

[29] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

[30] Frich *et al.*, 2002; Alexander *et al.*, 2006; Klein Tank *et al.*, 2009

[31] Coles *et al.*, 2001; Kharin *et al.*, 2005; Kharin *et al.*, 2007

[32] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research. Volume 1: Regional Overview

Table 4. Statistics used to project changes in the magnitude and frequency of extreme events. (Source: Australian BoM and CSIRO, 2011)

The use of CORDEX for regionally downscaled projections was considered; however, as highlighted above, CORDEX does not sufficiently cover the five Programme countries and there is no data bank for the Pacific island region. The Swedish Meteorological and Hydrological Institute (SMHI) Climate Information "Site-specific Report" tool was also considered; however, the map resolution is too coarse to be used for Pacific SIDS. The land masses of the five Programme countries are very small and are therefore not registered by the tool.

These limitations highlight the need to increase data availability and site-specific climate analysis capacity in the Pacific island region in order to more accurately predict and respond to the future impacts of climate change.

3.2 TROPICAL PACIFIC REGIONAL CLIMATE

The regional climate of the southern Pacific is influenced by three large-scale atmospheric features:[33]

- **South Pacific Convergence Zone (SPCZ) –** A band of high rainfall that stretches approximately from the Solomon Islands to east of the Cook Islands and is strongest in the Southern Hemisphere summer. It affects most countries in the South Pacific – including Cook Islands, Niue and Tuvalu.
- **Intertropical Convergence Zone (ITCZ) –** A band of high rainfall that stretches across the Pacific just north of the equator and is strongest in the Northern Hemisphere summer. It affects most countries on, or north of, the equator – including Palau and RMI.
- **West Pacific Monsoon (WPM) –** The WPM moves north to mainland Asia during the Northern Hemisphere summer and south to Australia during the Southern Hemisphere summer. The seasonal arrival of the monsoon usually brings a switch from very dry to very wet conditions. It affects countries in the far western Pacific – including Palau, RMI and Tuvalu.

These features represent expansive bands of large-scale wind convergence and high rainfall, which strongly influence intra-annual and inter-annual variability in rainfall, winds, tropical cyclone tracks, ocean currents, ocean nutrients and other environmental aspects.[34] The interplay between these climate drivers causes dramatic changes in weather in South Pacific islands, most obviously during El Niño and La Niña events.

[33] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research. Volume 1: Regional Overview

[34] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

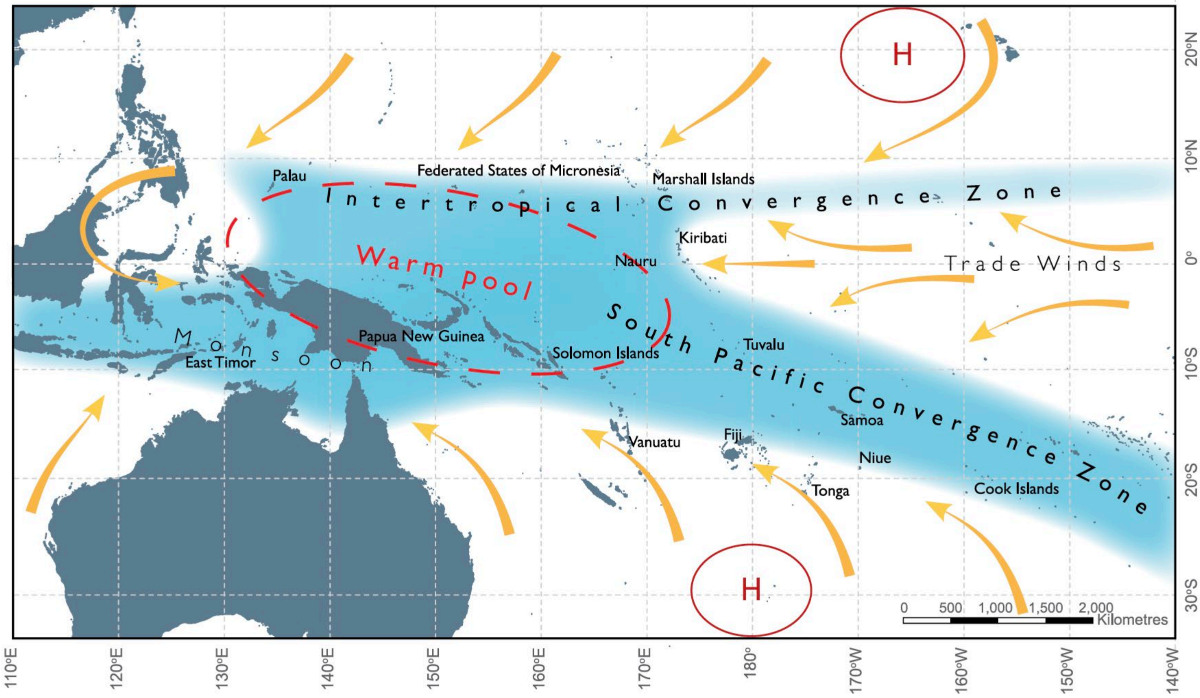

Figure 2. Natural climate drivers of the tropical Pacific. Map showing the average positions of the South Pacific Convergence Zone, Intertropical Convergence Zone and West Pacific Monsoon (all shaded blue) in the western tropical Pacific region in November to April. The yellow arrows show near-surface winds and the red dashed oval indicates the West Pacific Warm Pool. H represents the typical positions of moving high-pressure systems. (Source: PACCSAP)

El Niño-Southern Oscillation

The dominant cause of interannual climate variability in the Pacific is El Niño-Southern Oscillation (ENSO). ENSO is a natural climate cycle with two extreme phases: El Niño and La Niña. If neither phase is apparent, conditions are termed ENSO neutral. El Niño and La Niña events usually develop around May-June and last until the following March to May, with the following effects:

- **El Niño** brings "warmer than average ocean temperatures to the central and eastern Pacific and a weakening of the trade winds. The ITCZ and SPCZ tend to move closer to the equator, so rainfall increases near the equator and decreases in the north-west and south-west Pacific."
- **La Niña** brings the opposite changes to ocean temperatures and a strengthening of the trade winds. "The ITCZ and SPCZ tend to move away from the equator, reducing rainfall near the equator and increasing it to the north of the equator and south-west Pacific".[35]

The extent and timing of the ENSO varies between countries and affects the year-to-year risk of droughts, floods, tropical cyclones, extreme sea levels and coral bleaching. Interannual temperature variation along the equator can be greater than the average variations between seasons. El Niño and La Niña events have distinct impacts on rainfall and can cause large-scale shifts in rainfall patterns due to changes in sea-surface temperature and winds.[36] Table 4 provides a summary of the impacts of ENSO events in the five Programme countries.

[35] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

[36] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

<table>
<tr><th>Country</th><th>Region</th><th>El Niño</th><th>Extreme El Niño</th><th>La Niña</th></tr>
<tr><td rowspan="2">Cook Islands</td><td>North</td><td>Wet
More frequent and intense cyclones</td><td>Wet
More frequent and intense cyclones</td><td>Dry</td></tr>
<tr><td>South</td><td>Dry
More frequent and intense cyclones</td><td>Very dry
More frequent and intense cyclones</td><td>Wet</td></tr>
<tr><td colspan="2">Niue</td><td>Dry
More frequent and intense cyclones</td><td>Very dry
More frequent and intense cyclones</td><td>Wet</td></tr>
<tr><td colspan="2">Palau</td><td>Dry
Lower than normal sea level</td><td>Dry
Lower than normal sea level</td><td>Wet
Higher than normal sea level</td></tr>
<tr><td rowspan="2">Marshall Islands</td><td>North</td><td>Lower than normal sea level
More intense cyclones</td><td>Lower than normal sea level
More intense cyclones</td><td>No consistent impact on rainfall
Higher than normal sea level</td></tr>
<tr><td>South</td><td>Lower than normal sea level
More intense cyclones</td><td>Very dry
Lower than normal sea level
More intense cyclones</td><td>Dry
Higher than normal sea level</td></tr>
<tr><td colspan="2">Tuvalu</td><td>Wet
Lower than normal sea level</td><td>Wet
Lower than normal sea level</td><td>Dry</td></tr>
</table>

Table 5. Summary of the impacts of El Niño and La Niña during November to April in each Programme country. 'El Niño' covers all the years of El Niño, and 'Extreme El Niño' includes only the years 1982/3 and 1997/8. (Source: PACCSAP and Kelman, I.)[37, 38]

Historical extreme El Niño events

An extreme El Niño event is defined by unusually high rainfall over the eastern equatorial Pacific Ocean that exceeds a threshold of 5 mm d^{-1}. There are several additional important features of extreme El Niño events: eastward propagation of sea surface temperature (SST) anomalies; movement of the SPCZ by up to 1000 km towards the equator; and movement of the ITCZ towards the eastern equatorial Pacific Ocean. Extreme El Niño events occurred in 1982/83, 1997/98 and 2015/16 (Figure 3); and severely disrupted global weather patterns[39] – with significant impacts on ecosystems, agriculture, tropical cyclones, drought, bushfires, floods and other extreme weather events.[40]

[37] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools
[38] Kelman, I. 2017. Environment, Development and Sustainability. Pacific island regional preparedness for El Niño
[39] Cai, W. *et al.* 2017. Geophysical Research Letters. Definition of Extreme El Niño and Its Impact on Projected Increase in Extreme El Niño Frequency
[40] Cai, W. *et al.* 2014. Nature Climate Change. Increasing frequency of extreme El Niño events due to greenhouse warming. DOI: 10.1038/NCLIMATE2100

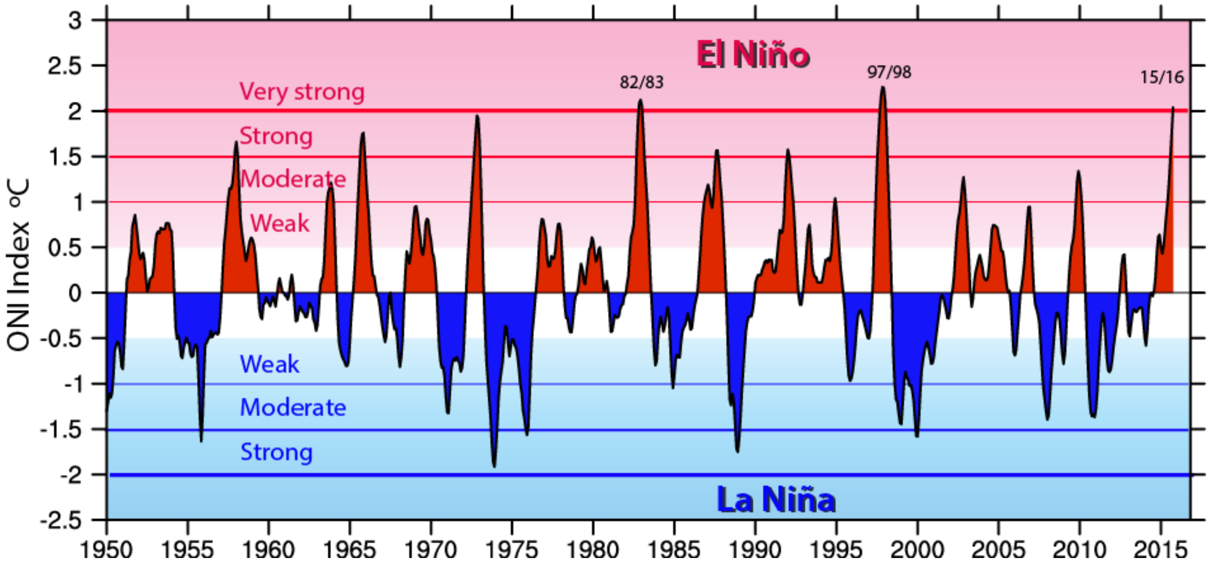

Figure 3. The Oceanic Niño Index (ONI) shows warm (red) and cold (blue) phases of sea surface temperature anomalies in the tropical Pacific Ocean. The ONI uses a three-month running mean. Anomalies must exceed +/- 0.5 °C for at least five consecutive months. (Source: K. Trenberth)[41]

The El Niño event of 2015/16 is one of the strongest events ever recorded and is regarded as comparable to the extreme El Niño event of 1997/98[42] – often described as 'the climate event of the twentieth century'.[43] Significant impacts were experienced across the Pacific island region, mainly associated with below normal rainfall and reduced sea level in the southwest Pacific and increased rainfall and elevated sea level in the central Pacific.

Impacts of the reduced rainfall included "drinking water shortages (from rain tanks, wells and streams) and water rationing, saltwater contamination of freshwater lenses, sanitation and health problems, poor agricultural production, high food prices, and significant costs associated with government drought relief (e.g. for transporting containers of drinking water and emergency food supplies). In Micronesia (Palau and RMI), sea levels were as low as 40 cm below normal. This exposed many coral reefs and, in combination with warmer-than-normal SST, contributed to significant coral bleaching.[44]

Future projections

Climate models do not generally provide consistent projections of changes in the frequency, intensity and patterns of future El Niño and La Niña events. In its Fifth Assessment Report (2013), the IPCC stated that "…there is *high confidence* that ENSO *very likely* remains as the dominant mode of interannual variability in the future and due to increased moisture availability, the associated precipitation variability on regional scales *likely* intensifies…However, natural modulations of the variance and spatial pattern of ENSO are so large in models that confidence in any specific projected change in its variability in the 21st century remains *low*."[45]

Since the publication of the IPCC report, a new generation of climate models and scenarios has become available that indicate robust projected changes in the spatial pattern of interannual ENSO-

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[41] Trenberth, K. and NCAR, 2020. The Climate Data Guide: Nino SST Indices (Nino 1+2, 3, 3.4,4; ONI and TNI)

[42] Paek, H. *et al.* 2017. Geophysical Research Letters. Why were the 2015/2016 and 1997/1998 extreme El Niños different?

[43] Cai, W. *et al.* 2014. Nature Climate Change. Increasing frequency of extreme El Niño events due to greenhouse warming. DOI: 10.1038/NCLIMATE2100

[44] SPREP, 2016. Regional Statement on the Impacts of the 2015/16

[45] IPCC, 2013. Climate Change 2013: The Physical Science Basis

driven variability[46] – particularly with regards to changes in intensity or location of rainfall during El Niño.[47] Cai *et al.* reported in Nature Climate Change that the frequency of extreme El Niño events is projected to double to one event every 10 years under global warming in the period 1991 – 2090. This is supported by a strong inter-model consensus, with 17 out of 20 models simulating an increase in events. The spatial pattern of associated rainfall is expected to remain similar, which suggests that, at a given location, past extreme El Niño impacts will repeat more frequently with global warming.[48] Future El Niño events are expected to be warmer than those experienced in the past, with associated changes in rainfall intensifying in the central-east equatorial Pacific and the western equatorial Pacific.[49]

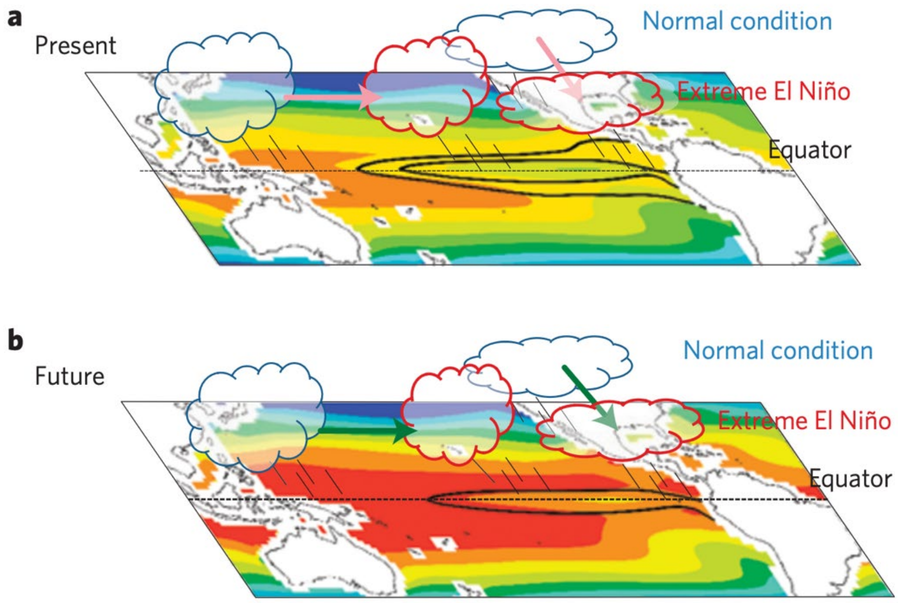


Figure 4. Schematic depicting the mechanism for increased occurrences of extreme El Niño under global warming. In both present-day climate (a) and future climate (b), convection zones in the western Pacific and the ITCZ latitudes shift from their normal positions (indicated by blue clouds) to the eastern equatorial Pacific during an extreme El Niño event (indicated by red clouds). Colour shading indicates mean sea-surface temperatures (SSTs) and black contours indicate SST anomalies. Under greenhouse-gas-induced warming conditions, warming occurs everywhere but at a faster rate in the eastern equatorial Pacific, diminishing the zonal and meridional SST gradients. Strong SST gradients are a barrier to a shift in convection zones. Therefore, in the future climate, shifts in convection zones can be facilitated by weaker changes in SST and thus SST gradients (indicated by one black contour and by green arrows), as compared with the present-day climate in which stronger changes are required (indicated by two black contours and red arrows). (Source: Cai *et al.*)[50]

3.3 STATE OF THE CLIMATE

The following climate indicators are a sub-set of the WMO Global Climate Observing System (GCOS) Essential Climate Variables (ECVs) for the atmosphere and ocean – which, together, describe the key

[46] Power, S. *et al.* 2013. Nature. Robust twenty-first-century projections of El Niño and related precipitation variability
[47] Collins, M. 2014. NOAA Climate.gov News & Features. Climate Change and ENSO: Take 2. Available at: https://www.climate.gov/news-features/blogs/enso/climate-change-and-enso-take-2
[48] Cai, W. *et al.* 2014. Nature Climate Change. Increasing frequency of extreme El Niño events due to greenhouse warming. DOI: 10.1038/NCLIMATE2100
[49] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools
[50] Cai, W. *et al.* 2014. Nature Climate Change. Increasing frequency of extreme El Niño events due to greenhouse warming. DOI: 10.1038/NCLIMATE2100

features of the state of the climate in the western tropical Pacific – past, present and observed trends. Future climate projections are detailed in section 3.5.

3.3.1 Temperature

In the Pacific islands, air temperatures are predominantly determined by the surface temperatures of the surrounding Pacific Ocean. Seasonal temperature variations can also be driven by large land masses such as Australia, Asia and the Maritime Continent that heat and cool at different rates to the ocean. The resultant differences in land-ocean temperatures drive the West Pacific Monsoon and other climate circulations.

Air temperatures remain high and relatively constant throughout the year, with seasonal temperature variability increasing with distance from the equator. The warm waters in the west are known as the West Pacific Warm Pool and the cool waters in the east are known as the Equatorial Cold Tongue.

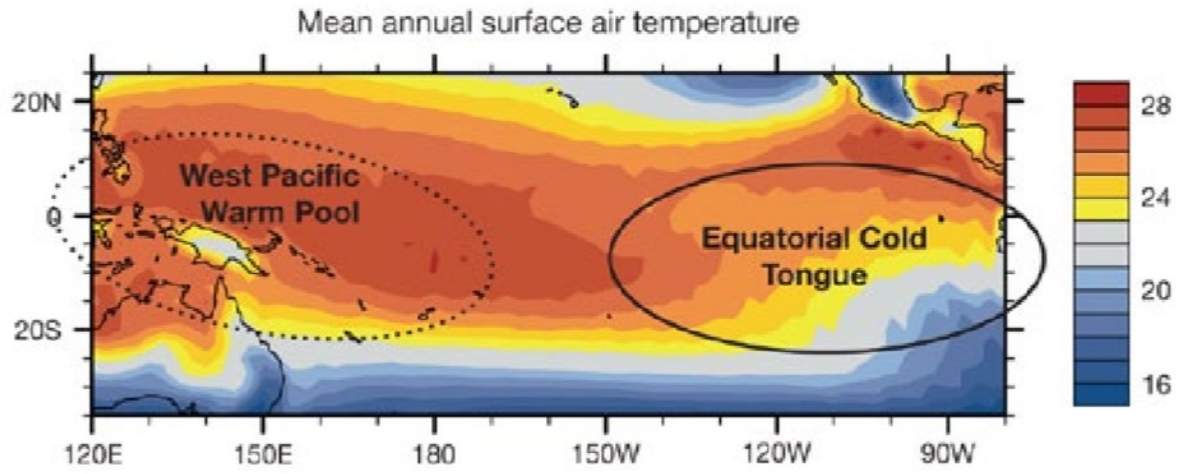


Figure 5. Annual average surface air temperature (°C) in the equatorial Pacific over the period of 1971 - 2000 (Source: Australian BoM and CSIRO)

A seasonal variation in air temperature over the West Pacific Warm Pool is small, and across much of the tropics temperatures in the coldest months are only a few degrees lower than the warmest months. Along the equator, year-to-year variations in temperature can be larger than the average variations between the seasons.

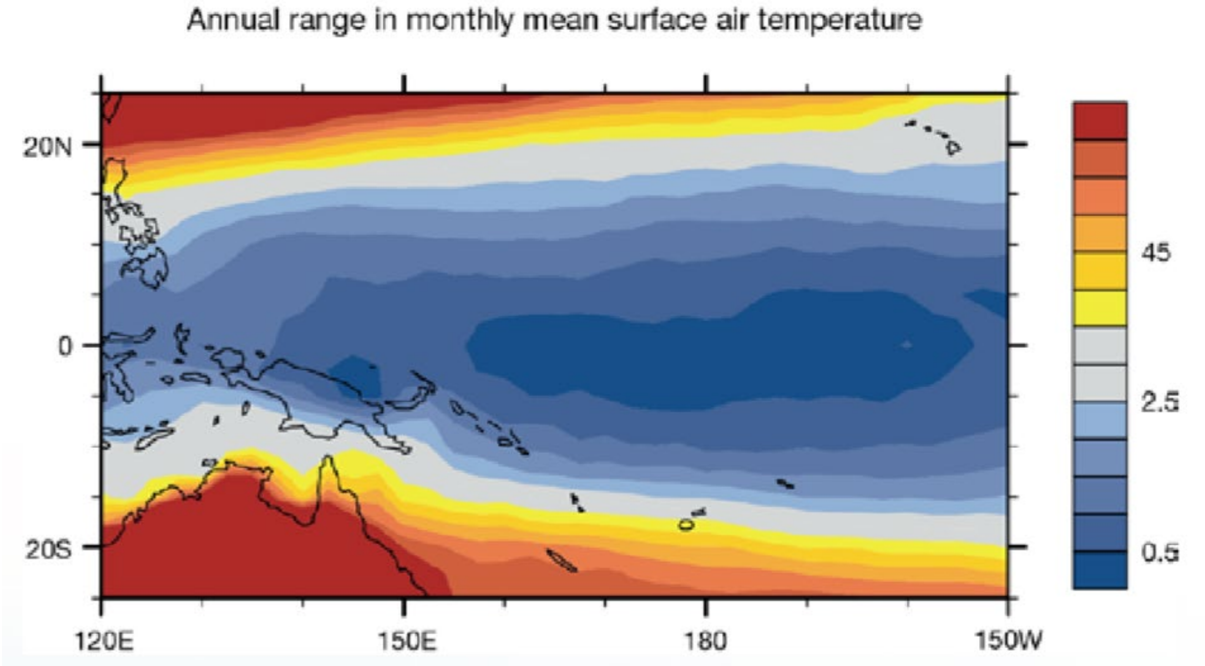


Figure 6. Range in surface air temperature (°C) between average hottest and coldest months over the period of 1971–2000 (Source: Australian BoM and CSIRO)

The IPCC Fifth Assessment Report (AR5) notes that "average temperatures have increased at a rate of between 0.1°C and 0.2°C per decade throughout the Pacific Islands during the 20th Century. Changes in temperature extremes have followed those of average temperatures."[51]

At the Pacific regional level, annual mean temperature increased at a rate of 0.14 °C per decade in the period 1951 – 2015, with rates of warming the same for the December-February, March-May and September-November periods. A slower rate of warming (0.11 °C per decade) was observed for the June-August period. Furthermore, the rate of warming has increased in more recent years: 0.12 °C per decade over 1983 – 2015, compared with 0.09 °C per decade over 1951 – 1982.[52]

[51] IPCC, 2013, Climate Change 2013: The Physical Science Basis. Chapter 14 (pp1275–1276).
[52] McGree, S. *et al.* 2019. Journal of Climate. Recent Changes in Mean and Extreme Temperature and Precipitation in the Western Pacific Islands

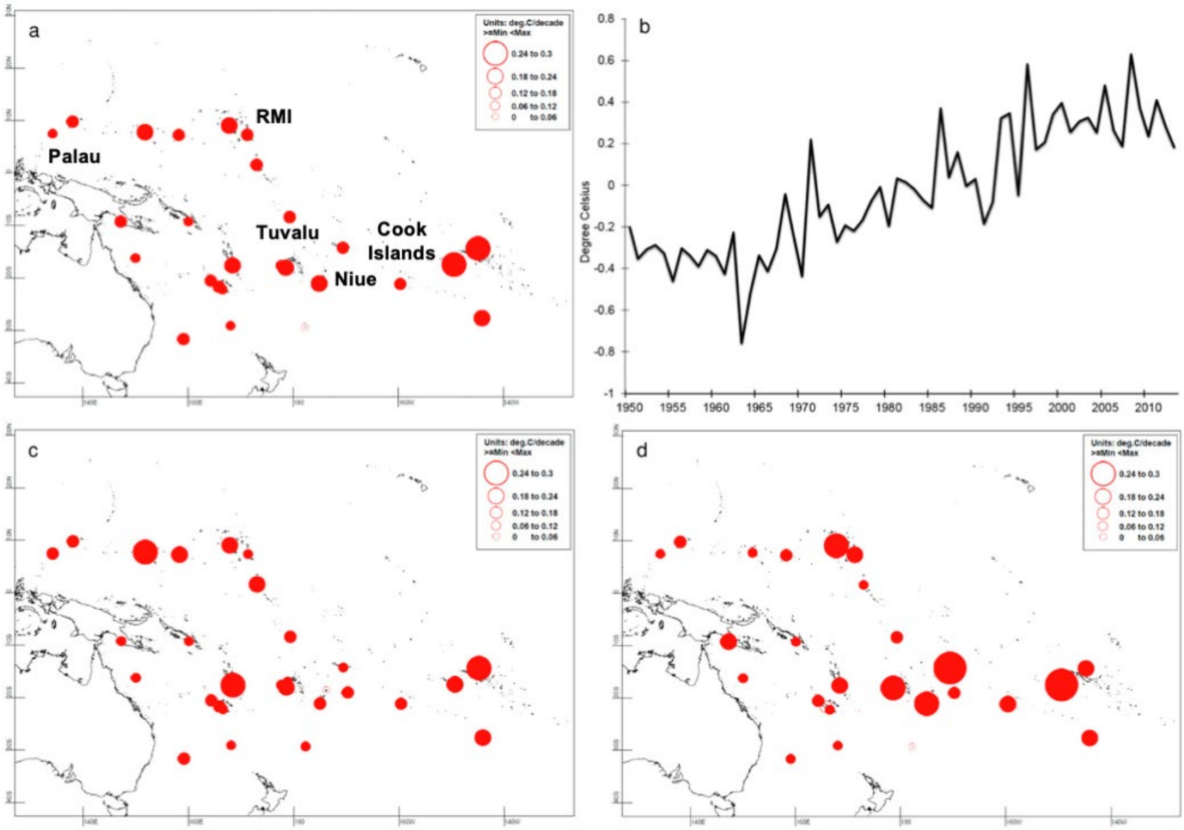


Figure 7. Trends in annual temperature over 1951 – 2015 for (a) mean temperature, (c) maximum temperature and (d) minimum temperature, along with (b) regional mean temperature anomalies relative to the 1971 – 2000 climatology. Solid circles represent trends significant at the 5% level. The size of the circle is proportional to the magnitude of the trend. (Source: McGree *et al.*, 2019 – adapted with the approximate locations of the Programme countries)

The annual number of warm nights and warm days has increased (2.28 % per decade and 2.07 % per decade, respectively) and the number of cold nights and cold days has decreased (1.76 % per decade and 1.70 % per decade, respectively). McGree *et al.* additionally calculated ET-SCI sector-specific indices for the regional annual warm-spell duration (WSD3) and cold-spell duration (CSD3), which indicated that WSD3 increased by 3.97 days per decade and CSD3 decreased by 3.20 days per decade. Furthermore, the ET-SCI cooling degree-days (CDDcoldn) index showed a regional positive trend of 45.59 degree-days per decade. The CDDcoldn index relates to the energy demand needed to cool a building and is important in the Pacific island region due to the frequent use of air conditioning, particularly during the summer months. The positive trend suggests that increased demand for air conditioning – and therefore electricity demand – has significantly increased in the past decades.[53]

[53] McGree, S. *et al.* 2019. Journal of Climate. Recent Changes in Mean and Extreme Temperature and Precipitation in the Western Pacific Islands

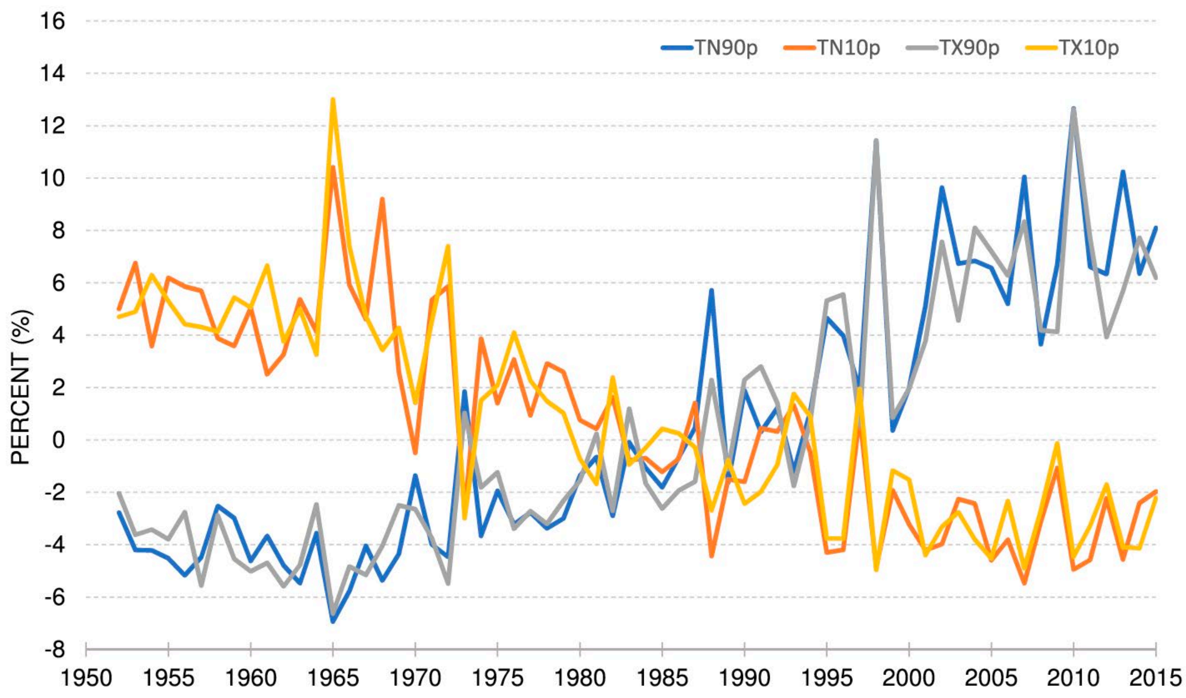


Figure 8. Regional frequency of warm nights (TN90p), cold nights (TN10p), warm days (TX90p) and cool days (TX10p) anomalies relative to the period 1971 – 2000. (Source: McGree *et al.*, 2019)

Country-specific extreme temperature indices

The ETCCDI extreme temperature indices calculated for Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (Marshall Islands) and Funafuti (Tuvalu) were obtained from the Pacific Climate Change Data Portal, with the remaining ET-SCI indices obtained from the BoM archives, and are provided on the following pages. The indices are calculated using homogenised data for the period 1951 – 2015.[54] Following McGree *et al.*, trends and significance were calculated using Kendall's rank correlation tau method as it is less sensitive to the non-normality of data distributions and less affected by extreme values of outliers in the timeseries. However, there are times when serial correlations of the timeseries preclude calculation of the trend by this method; this seems to have particularly been the case at Hanan Airport (Niue) and to a lesser extent at Funafuti (Tuvalu). In these instances, the more standard least squares method was used, which invariably resulted in higher magnitude estimates of temperature trends.

Figures 9 – 14 show the temporal evolution in the highest maximum temperature (TXx), highest minimum temperature (TNx), lowest maximum temperature (TXn), lowest minimum temperature (TNn), annual number of hot days (> 30 °C) and annual number of hot nights (> 26 °C) since 1951. Figures for the remaining extreme temperature indices are provided in Appendix 2.

The trends in extreme temperature indices for each Programme country are summarised in Table 5. Bold italics indicate trends that are significant at the 5% level.

[54] Australian Bureau of Meteorology, 2020. About Pacific Climate Change Data. Available at: http://www.bom.gov.au/climate/pccsp/about-pi-climate-data.shtml

Extreme Temperature Indices	Cook Islands	Niue	Palau	Marshall Islands	Tuvalu
Highest maximum temperature, TXx (°C / decade)	***0.28***	0.10*	***0.13***	0.19	0.05*
Highest minimum temperature, TNx (°C / decade)	***0.20***	0.15*	***0.10***	***0.14***	0.18*
Lowest maximum temperature, TXn (°C / decade)	0.10	0.23*	***0.20***	0.06	***0.12***
Lowest minimum temperature, TNn (°C / decade)	***0.30***	0.07*	0.00	***0.17***	0.14*
User-defined hot days > 30 °C (days / decade)	***6.28***	4.72*	***3.30***	***13.04***	8.12*
User-defined hot nights > 26 °C (days / decade)	0.94	0.06	5.67	26.51	14.13
Cool days, TX10p (days / decade)	***–1.15***	–6.54*	***–0.82***	–0.89	–5.20*
Cool nights, TN10p (days / decade)	***–1.97***	–2.88*	***–0.94***	***–2.26***	–9.38*
Warm days, TX90p (days / decade)	***1.76***	4.03*	***1.58***	***0.99***	18.37*
Warm nights, TN90p (days / decade)	***1.69***	7.99*	***4.07***	***5.24***	8.53*
Warm spell duration, WSDI (days / decade)	0.00	5.49*	0.00	0.00	4.11*
Cold spell duration, CSDI (days / decade)	0.00	0.00	0.00	0.00	0.00
Cooling degree days, base 18 °C, CDDcoldn (days/decade)	***25.27***	-	***38.96***	***56.78***	-

Table 6. Linear trends (via Kendall's rank correlation tau method) in annual extreme temperature indices for the five Programme countries in the period 1951 - 2015. The trend values for each variable are shaded in pink (warming effect), with the largest values shaded darker. Bold italics indicate trends that are significant at the 5% level. Asterisks (*) indicate least squares trend. (Source: Pacific Climate Change Data Portal)

The trends in annual extreme temperature indices, apart from the diurnal temperature range, all indicate a warming climate. Focussing on the statistically significant trends for the five Programme countries, the most noteworthy are summarised below:

- **Increase in daily maximum temperatures (TXx and/or TXn) in the Cook Islands, Palau and Tuvalu**, with the greatest increases (per decade) observed in Cook Islands (0.28 °C increase in highest maximum temperature) and Palau (0.20 °C increase in lowest maximum);
- **Increase in daily minimum temperatures (TNx and/or TNn) in the Cook Islands, Palau and Marshall Islands**, with the greatest increases (per decade) observed in Cook Islands (0.30 °C increase in lowest minimum temperature, and a 0.20 °C increase in highest minimum temperature);
- **Increase in the number of days greater than or equal to 30C in the Cook Islands, Palau and Marshall Islands;** with the greatest increase observed in the Marshall Islands – 13 days per decade.
- **Decrease in the number of cool days (maximum temperature < 10th percentile) in Cook Islands and Palau**;
- **Decrease in the number of cool nights (minimum temperature < 10th percentile) in the Marshall Islands, Cook Islands and Palau**;
- **Increase in the number of warm days (maximum temperature > 90th percentile) in the Marshall Islands, Cook Islands and Palau**;
- **Increase in the number of warm nights (minimum temperature > 90th percentile) in the Marshall Islands, Cook Islands and Palau**;
- **Increase in the number of cooling degree-days (mean temperature – 18) in the Marshall Islands, Cook Islands and Palau**; with the largest trends (per decade) being observed in the Marshall Islands (57 days) and Palau (39 days).

Highest maximum temperature (TXx)

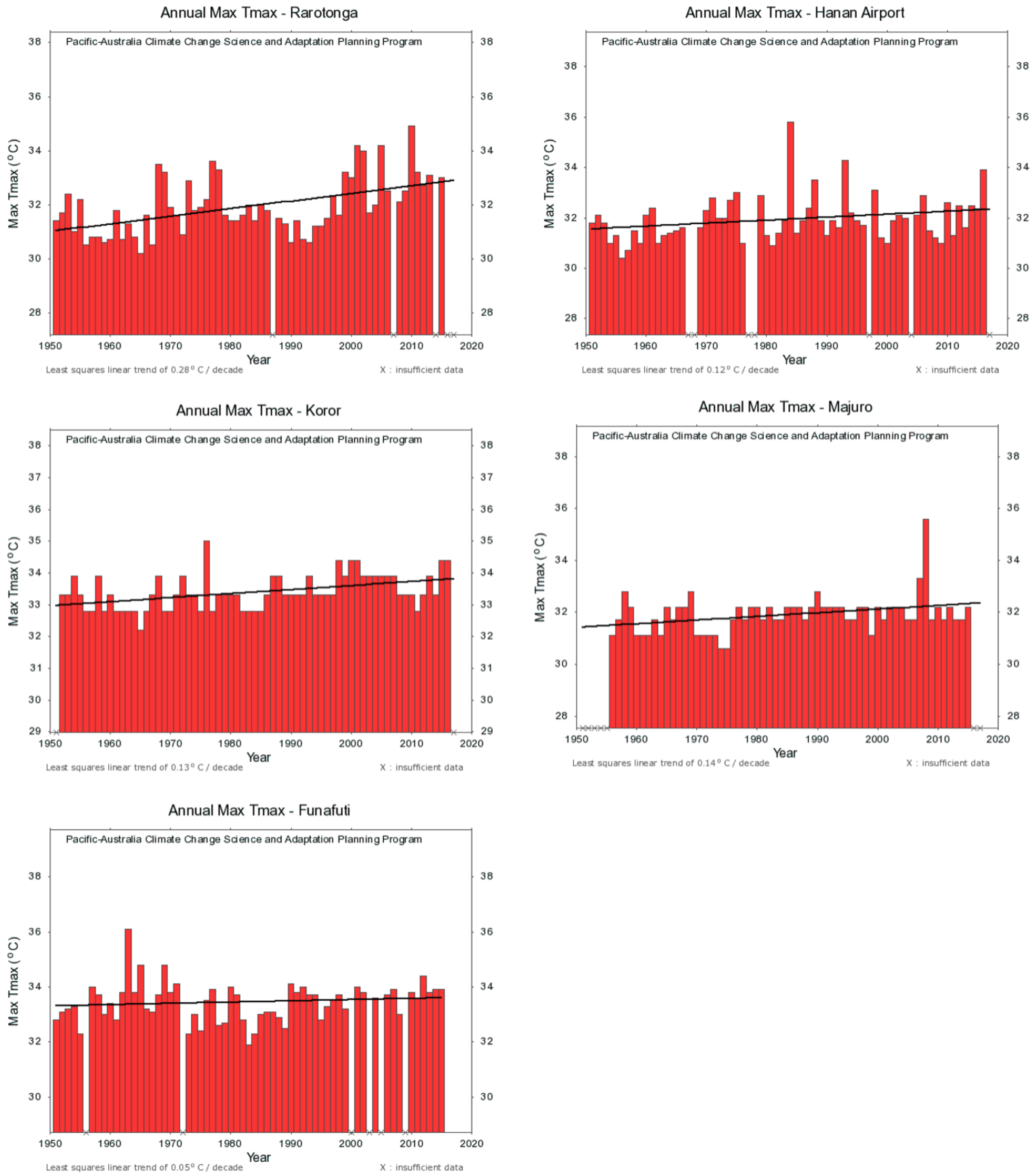


Figure 9. Time series of the annual highest maximum temperature (TXx) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Highest minimum temperature (TNx)

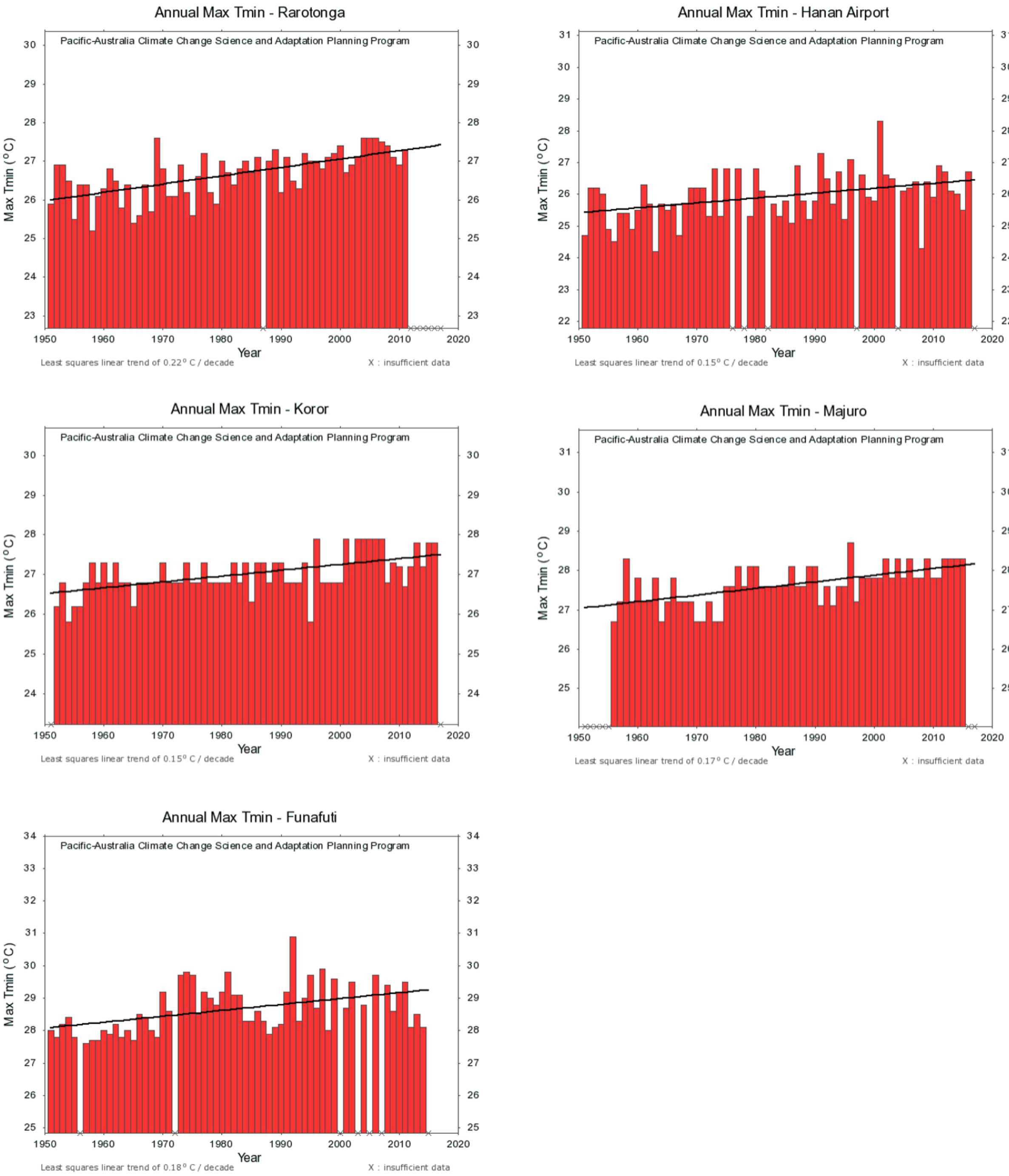
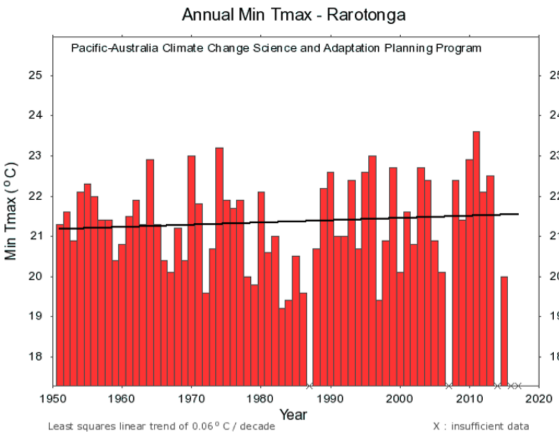
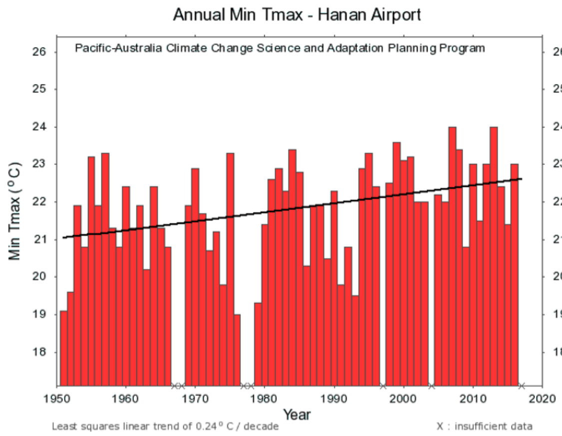
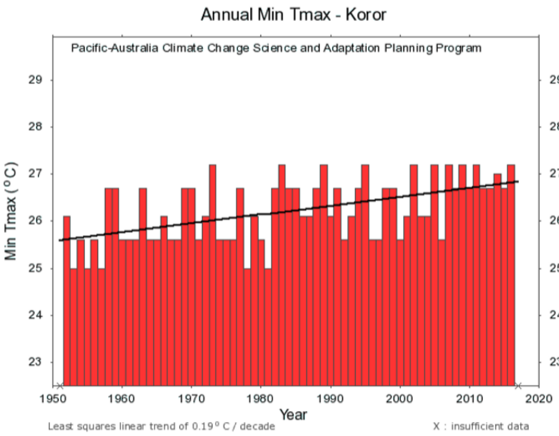


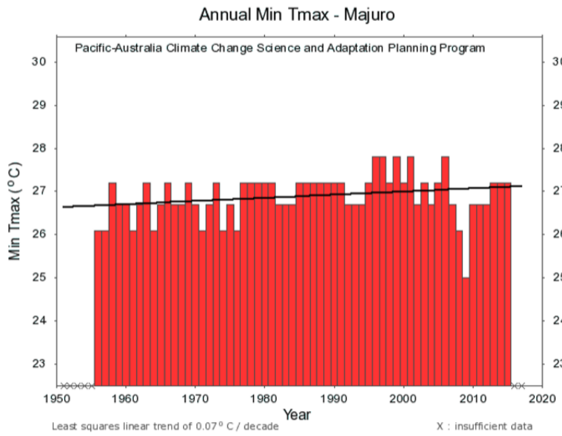
Figure 10. Time series of the annual highest minimum temperature (TNx) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Lowest maximum temperature (TXn)









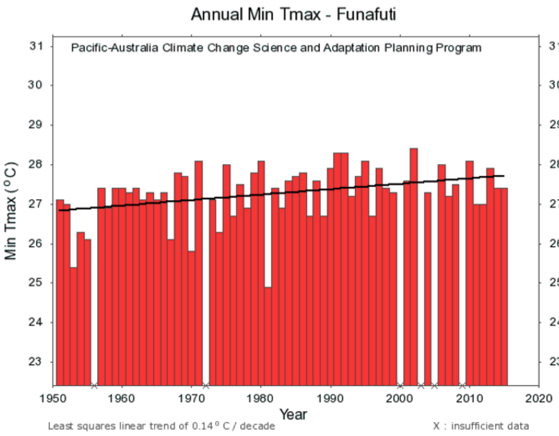


Figure 11. Time series of the annual lowest maximum temperature (TXn) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Lowest minimum temperature (TNn)

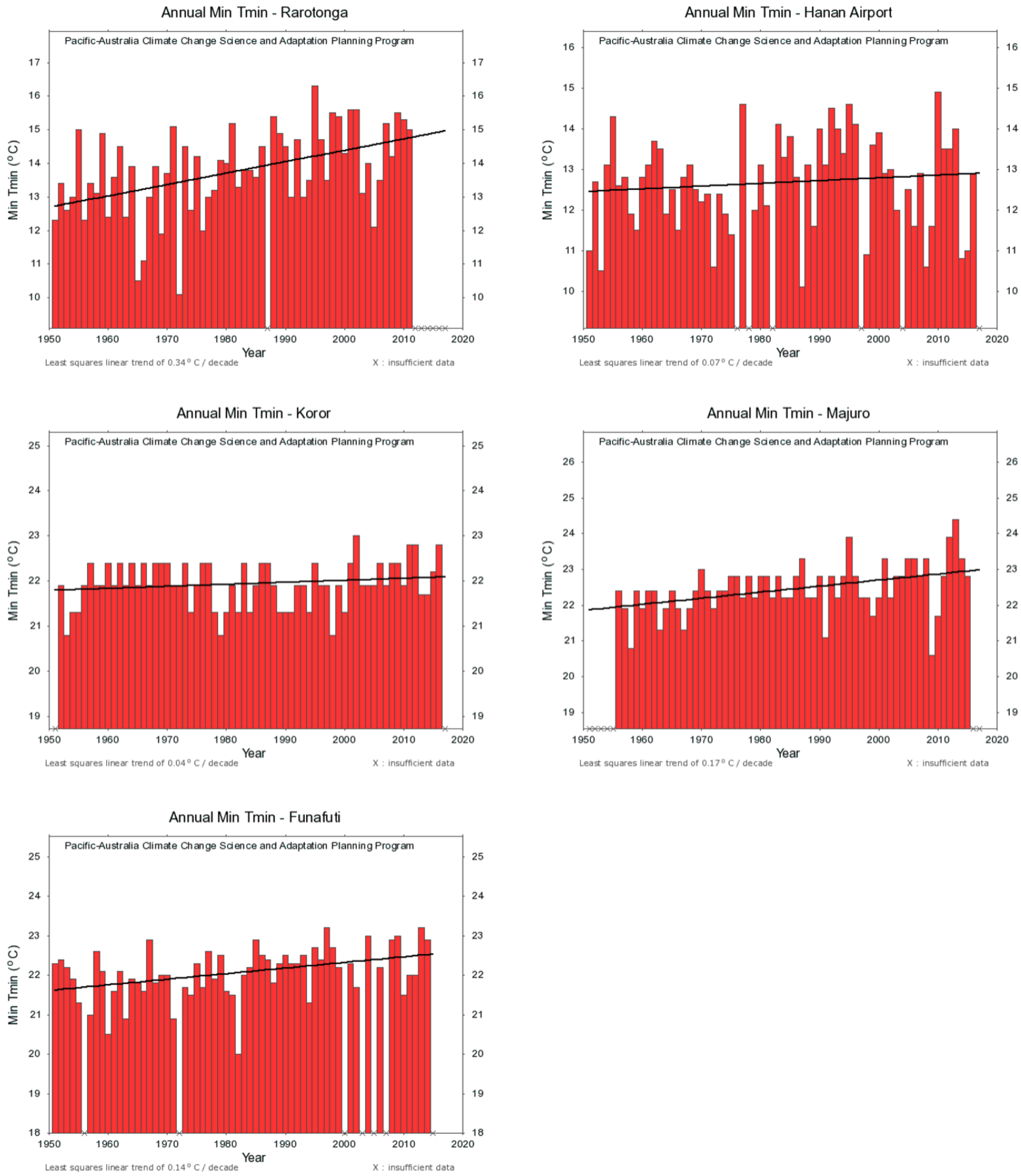


Figure 12. Time series of the annual lowest minimum temperature (TNn) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Hot days > 30 °C (SU30)

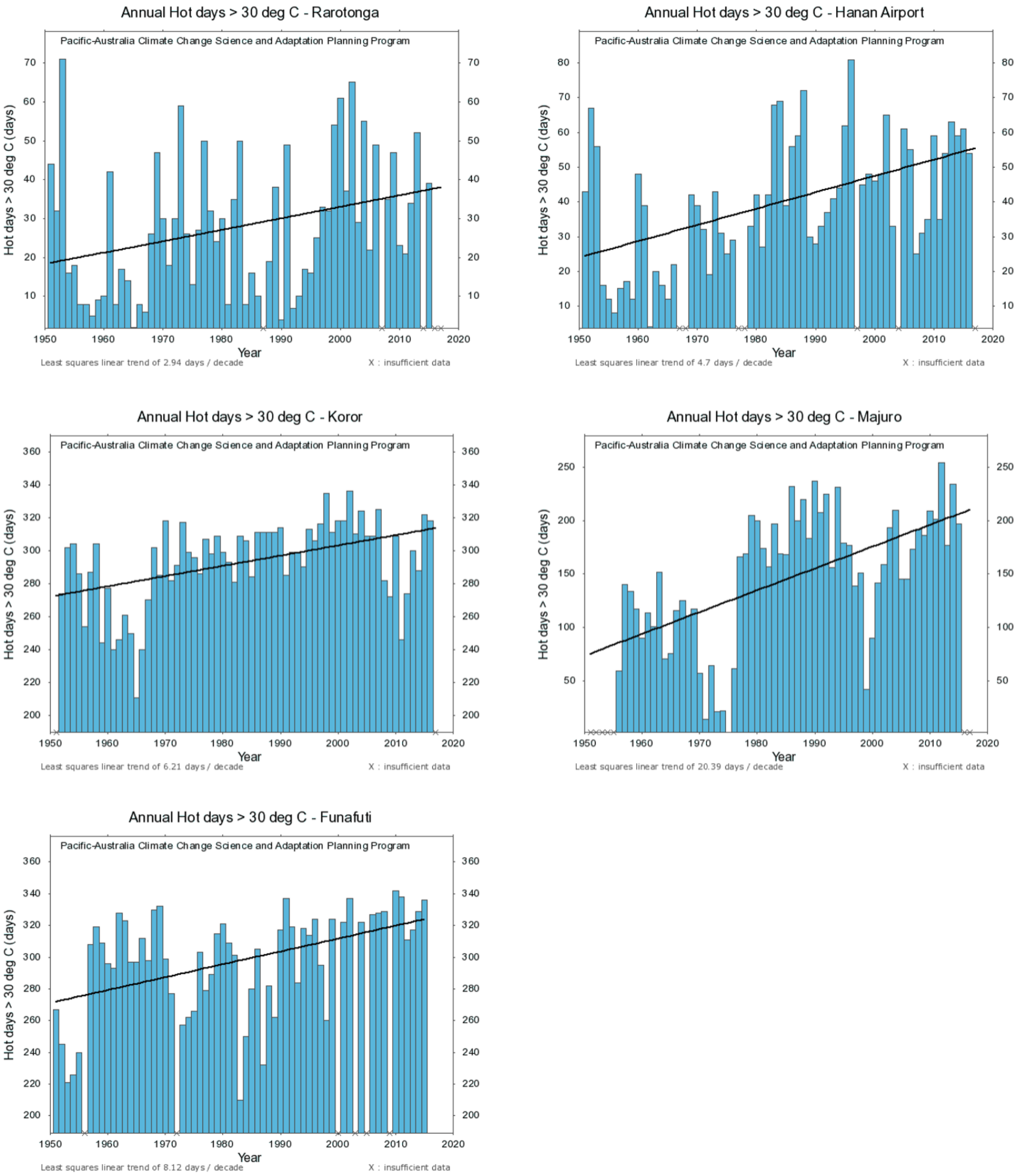
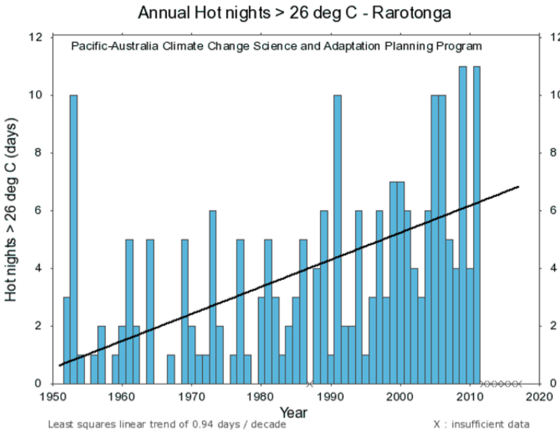
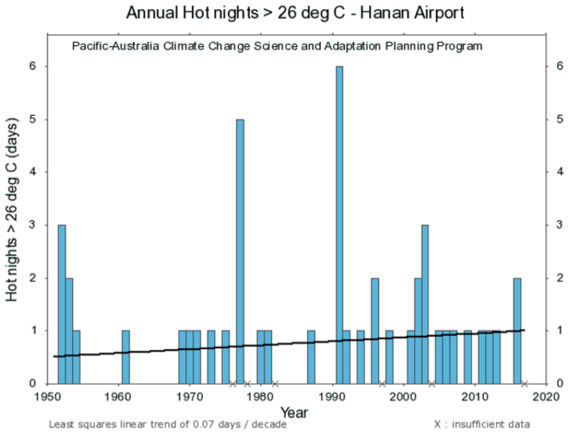
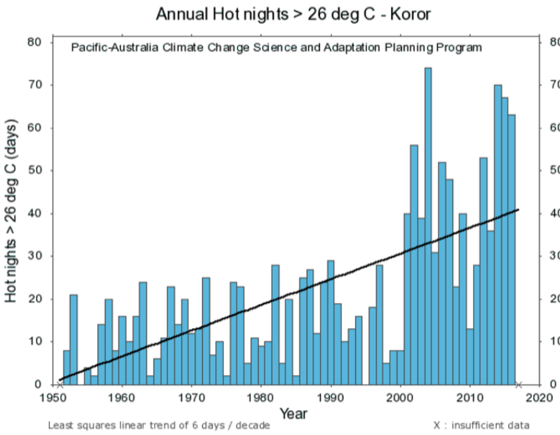


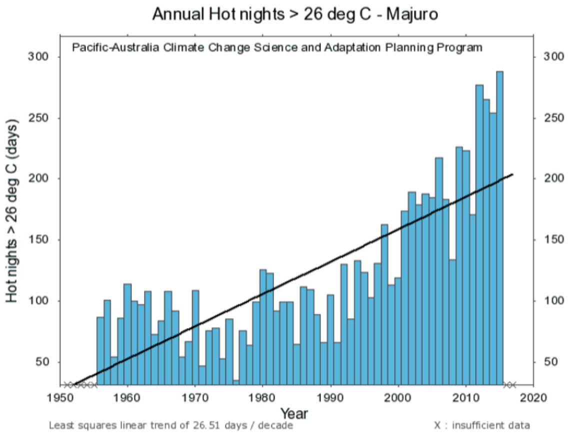
Figure 13. Time series of the annual number of days > 30 °C (SU30) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Hot nights > 26 °C (TR26)









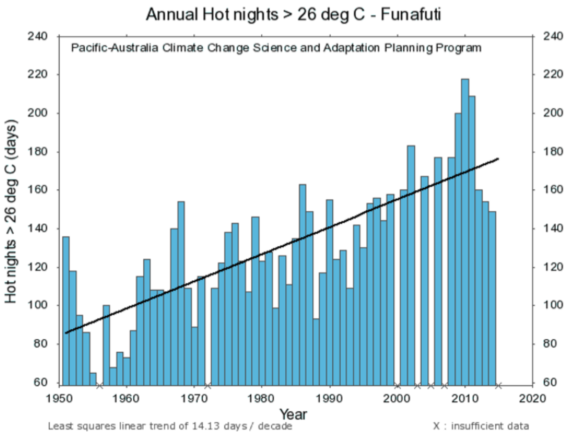


Figure 14. Time series of the annual number of nights > 26 °C (TR26) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

3.3.2 Rainfall

Most of the tropical areas in the central and western Pacific receive very high annual rainfall: evaporation and convection occur where the ocean surface is warm, and when the winds converge this convection is enhanced. The Austral wet season occurs during November to April and the dry season from May to October, with the opposite being the case in the North Pacific. There are some differences between the patterns of average rainfall in December to February and June to August. However, some large-scale features remain year-round where ocean temperatures remain warm and winds converge throughout the year. For example, over the West Pacific Warm Pool (WPWP) rainfall persists throughout the year.[55]

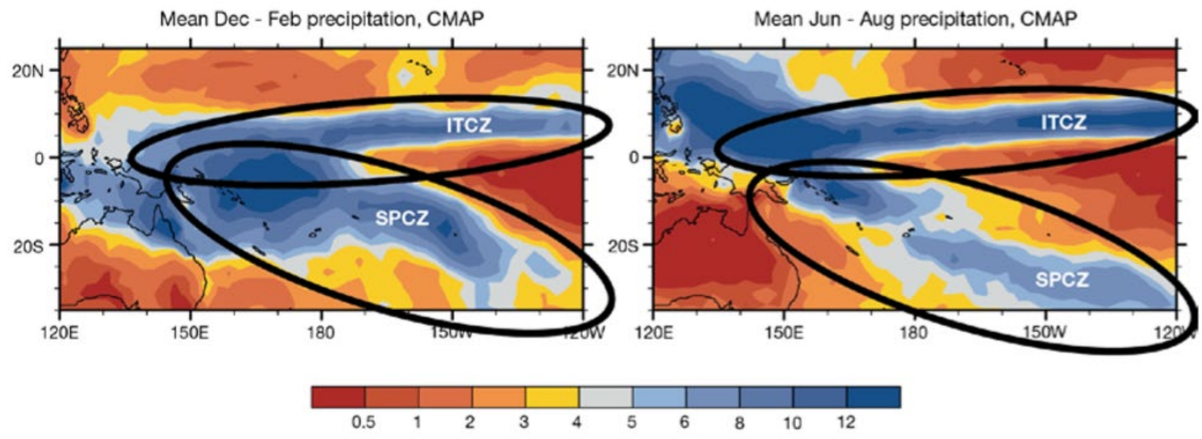


Figure 15. Average rainfall (mm) in the Pacific region for December to February (left) and June to August (right) over the period of 1980 to 1999 (Source: Australian BoM and CSIRO)

Significant rainfall also results from tropical cyclones and storms. In the Pacific island countries affected by tropical cyclones, contribution to annual rainfall is around 5 – 10 %. On some islands with significant topography – such as the volcanic Cook Islands – moist winds are forced upwards, leading to condensation and enhanced rainfall. Differences in local climate can therefore occur as a result of topographic variation and prevailing winds.[56]

Trends in total annual rainfall for the longest available rainfall records indicate a general increase in rainfall totals north-east of the SPCZ since 1951, with mainly declines to the south-west of the SPCZ, and north of the ITCZ just west of the International Date Line (IDL). This pattern of change is generally reflected in March – May and September – November, and to a lesser extent over December – February. However, the pattern of trends has changed markedly in the south-west Pacific over the past two decades, consistent with a shift of the SPCZ back to its climatological position since 1990. While changes in temperature are dominated by background global warming, the tropical Pacific rainfall patterns generally do not demonstrate any systematic long-term trends. Although, there are a few notable exceptions – for example, drying trends in southern RMI over June – August and September – November, and in the southern Cook Islands over March – May.[57]

[55] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional

[56] Australian Bureau of Meteorology and CSIRO, 2011, Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional.

[57] Australian Bureau of Meteorology and CSIRO, 2011, Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional

The sub-regional trends for total rainfall and calculated rainfall indices covering the five Programme countries are shown in Table X below. The Pacific island sub-regions include the North ITCZ – covering Palau and RMI; the Central tropics (CT) – covering the Northern Cook Islands and Tuvalu; and the Southwest SPCZ (swSPCZ) – covering the Southern Cook Islands and Niue. The results show that the greatest changes in extreme rainfall over the past 30 years have not been consistent across the Pacific island region. Rainfall variability has been at the most extreme in the CT sub-region, with the greatest change in the swSPCZ being an increase in the number of days with rainfall.[58]

Index	North ITCZ *Palau, Marshall Islands*	Central tropics *Northern Cook Islands, Tuvalu*	Southwest SPCZ *Southern Cook Islands, Niue*
Total rainfall	14.36	- 279.86	86.29
Rx1day	- 4.42	**- 2.10**	- 5.39
Rx5day	- 5.87	**- 11.54**	- 6.63
R1mm	4.04	- 9.16	**8.55**
R10mm	2.55	- 9.19	3.85
R20mm	0.85	- 4.93	2.03
CDD	**- 0.71**	1.12	- 1.09
CWD	0.15	- 0.71	0.30
R95p	- 60.78	**- 157.90**	27.00
R99p	- 24.85	**- 54.48**	- 7.29
SDII	- 0.18	**- 1.34**	0.00

Table 7. Sub-regional trends for total rainfall and the WMO Expert Team on Climate Change Detection and Indices (ETCCDI) rainfall indices for the period 1981 – 2011. Trends significant at the 5% level are shown in bold. The indices correspond to the following: Rx1day – Max 1-day rainfall; Rx5day – Max 5-day rainfall; R1mm – Days with 1 mm or more rainfall (number of wet days); R10mm – Days with 10 mm or more rainfall; R20mm – Days with 20 mm or more rainfall; CDD – Consecutive dry days; CWD – Consecutive wet days; R95p – Very wet days (above the 95th percentile of days with ≥ 1 mm rain; R99p – Extremely wet days (above the 99th percentile of days with ≥ 1 mm rain); SDII – Simple daily intensity index (average rainfall on days with ≥ 1 mm rain). (Source: Australian Bureau of Meteorology)

Annual rainfall trend analyses for 1981 – 2011 indicate wetter conditions in the West Pacific Monsoon (WPM) region and southwest of the mean SPCZ position (Southern Cook Islands and Niue). In the North Pacific, it has become wetter west of 160°E (Palau) with the ITCZ/WPM expanding northwards west of 140°E. Northeast of the SPCZ and in the central tropical Pacific east of about 160°E it has become drier (RMI and Tuvalu).[59]

[58] Australian Bureau of Meteorology, 2013. International Journal of Climatology. An updated assessment of trends and variability in total and extreme rainfall in the western Pacific

[59] Australian Bureau of Meteorology, 2013. International Journal of Climatology. An updated assessment of trends and variability in total and extreme rainfall in the western Pacific

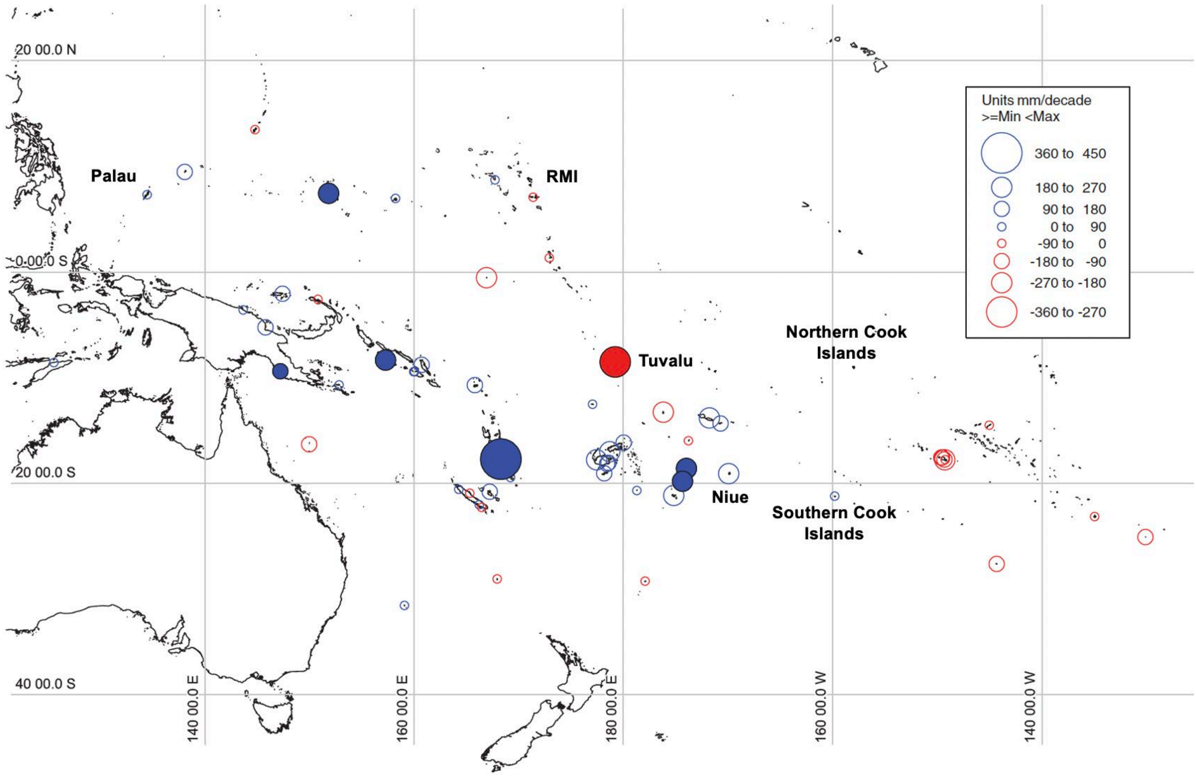


Figure 16. Trend in annual rainfall from 1981 – 2011. Blue circles represent positive trends and red circles represent negative trends. Solid circles represent trends significant at the 5% level. (Source: Australian BoM)[60]

Country-specific extreme precipitation indices

The ER-SCI annual precipitation indices calculated for Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (Marshall Islands) and Funafuti (Tuvalu) were obtained from the Pacific Climate Change Data Portal, with the remaining ET-SCI indices obtained from BoM archives, and are provided on the following pages. The indices are calculated using homogenised data for the period 1951 – 2015. Only rainfall records or parts of records that are proven to be homogeneous have been used.[61] As with temperature, Kendall's method was used to calculate trends and statistical significance.

Figures 17 and 18 show the temporal evolution in the extremely wet day rainfall (R99p) and annual total wet day rainfall (PRCPTOT) since 1951. Figures for the remaining extreme precipitation indices are provided in Appendix 2.

The trends in annual extreme precipitation indices for each Programme country are summarised in Table 7. Bold italics indicate trends that are significant at the 5% level.

[60] Australian Bureau of Meteorology, 2013. International Journal of Climatology. An updated assessment of trends and variability in total and extreme rainfall in the western Pacific. Adapted from Figure 3

[61] Australian Bureau of Meteorology, 2020. About Pacific Climate Change Data. Available at: http://www.bom.gov.au/climate/pccsp/about-pi-climate-data.shtml

Extreme Precipitation Indices	Southern Cook Islands	Northern Cook Islands	Niue	Palau	Marshall Islands	Tuvalu
Max 1-day rainfall, Rx1day (mm / decade)	1.77	3.75	0.00	–3.07	–1.01	–0.82
Max 5-day rainfall, Rx5days (mm / decade)	–0.29	13.61	–0.71	–6.42	–1.89	–7.02
Simple daily intensity, SDII (mm / decade)	–0.11	–0.56	–0.01	–0.08	–0.22	0.05
Rain days ≥ 10 mm, R10 (days / decade)	–1.32	1.18	0.28	–0.77	–1.03	–1.52
Rain days ≥ 20 mm, R20 (days / decade)	–0.76	1.34	0.73	0.00	–1.29	–0.57
Consecutive dry days, CDD (days / decade)	0.36	–0.03	0.00	0.20	***–0.45***	0.16
Consecutive wet days, CWD (days / decade)	–0.25	0.30	–0.19	0.00	0.00	–0.15
Very wet days rainfall, R95p (mm / decade)	–28.08	46.28	–13.22	–27.57	***–56.33***	–21.82
Extremely wet day rainfall, R99p (mm / decade)	0.00	24.62	–4.37	–10.86	–0.42	–2.83
Annual total wet day rainfall, PRCPTOT (mm / decade)	–55.56	86.95	16.16	–27.27	***–90.34***	–58.24

Table 8. Linear trends (via Kendall's rank correlation Tau method) in annual extreme precipitation indices for the five Programme countries in the period 1951 – 2017. The trend values for each variable are shaded in blue (wetter) and yellow (drier), with the largest values shaded darker. Bold italics indicate trends that are significant at the 5% level. (Source: Pacific Climate Change Data Portal)

Although the vast majority of trends in extreme precipitation indices for the five Programme countries are **not** statistically significant at the 5% level, the general impression is one of drying climates at these tropical island locations. Penrhyn (Northern Cook Islands) is the exception, as several of its indices indicate increasing extreme rainfall consistent with a trend towards a wetter central Pacific.

The only statistically significant trends were observed at **Majuro, Marshall Islands**, as summarised below:

- **Decrease in the number of consecutive dry days**, possibly indicating in increase in the occurrence of days with small rainfall totals;
- **Decrease in the total rainfall derived from very wet days (daily rainfall > 95th percentile)**, amounting to 56 mm per decade;
- **Decrease in the total wet day rainfall (daily rain ≥ 1 mm)**, of around to 90 mm per decade.

Extremely wet day rainfall (R99p)

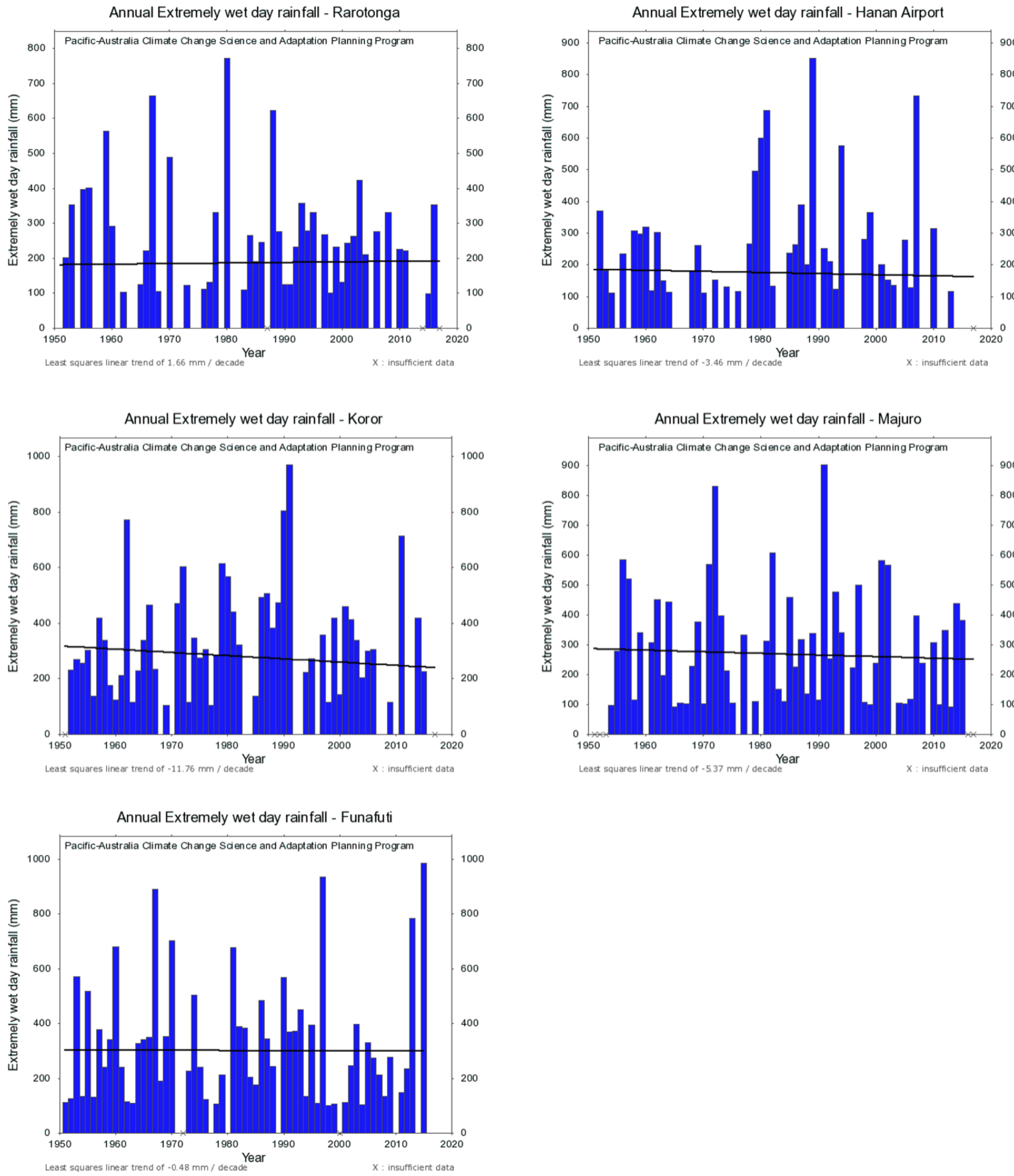
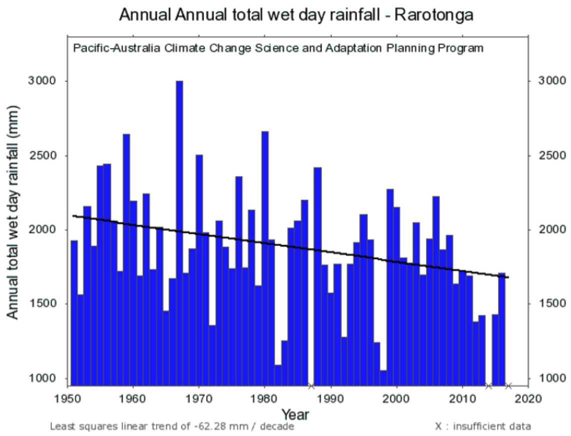
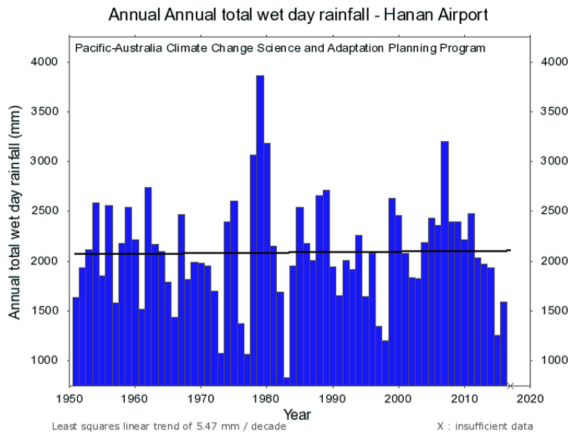
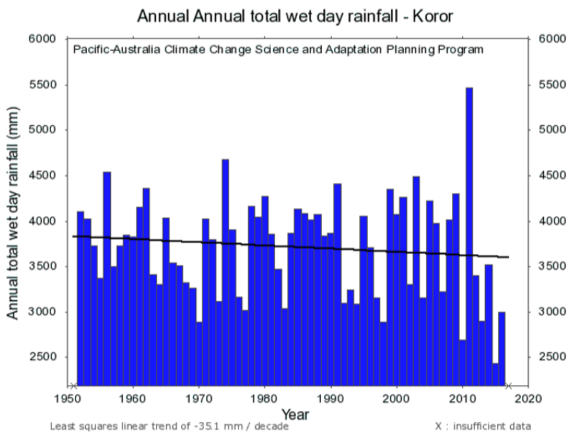


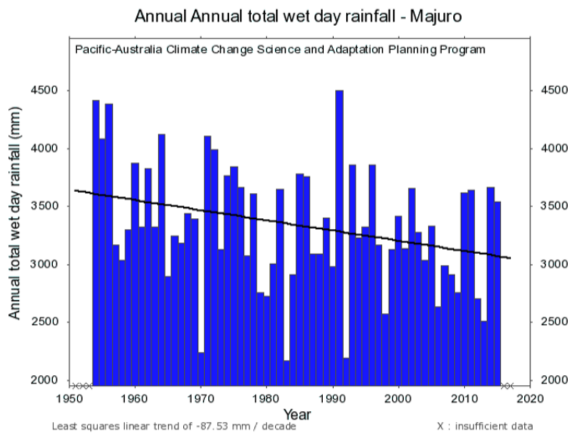
Figure 17. Time series of the extremely wet day rainfall (R99p) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Annual total wet day rainfall (PRCPTOT)









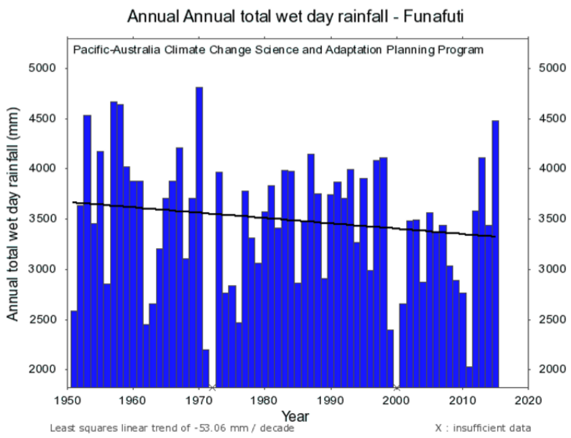


Figure 18. Time series of the annual total wet day rainfall (PRCPTOT) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Seasonal analysis – Cook Islands

The Cook Islands cover two climate sub-regions in the western Pacific, so data is shown for both Southern Cook Islands (Rarotonga) and Northern Cook Islands (Penrhyn). Note that only rainfall statistics are available for Penrhyn. Bold italics indicate trends that are significant at the 5% level. Some annual statistics (Table 5) are not available for seasons.

Rarotonga

Extreme Temperature Indices	DJF	MAM	JJA	SON
Highest maximum temperature, TXx (°C / decade)	***0.16***	***0.26***	***0.26***	***0.23***
Highest minimum temperature, TNx (°C / decade)	***0.19***	***0.16***	0.10	***0.15***
Lowest maximum temperature, TXn (°C / decade)	0.01	0.10	0.10	0.05
Lowest minimum temperature, TNn (°C / decade)	***0.28***	***0.26***	***0.26***	***0.41***
Hot days > 30 °C, TXge30 (days / decade)	***1.77***	***2.22***	0.00	0.00
Cool days, TX10p (days / decade)	–0.96	***–1.18***	***–1.02***	***–1.26***
Cool nights, TN10p (days / decade)	***–1.86***	***–2.10***	***–1.49***	***–1.69***
Warm days, TX90p (days / decade)	0.87	***1.58***	1.19	***1.49***
Warm nights, TN90p (days / decade)	***1.27***	***1.67***	***1.07***	***2.12***

Table 9. Linear trends (via Kendall's rank correlation Tau method) in seasonal extreme temperature indices for Rarotonga, Cook Islands, in the period 1951 – 2015. The trend values for each variable are shaded in pink (warming effect). (Source: Pacific Climate Change Data Portal).

Extreme Rainfall Indices	DJF	MAM	JJA	SON
Max 1-day rainfall, Rx1day (mm / decade)	–0.27	–0.43	–1.85	–0.81
Max 5-day rainfall, Rx5days (mm / decade)	1.00	–4.34	–4.30	1.23
Rain days ≥ 10 mm, R10 (days / decade)	–0.43	–0.54	–0.04	–0.42
Rain days ≥ 20 mm, R20 (days / decade)	0.00	–0.41	–0.04	0.00
Consecutive dry days, CDD (days / decade)	***0.63***	0.00	0.33	0.00
Consecutive wet days, CWD	0.00	0.00	0.00	0.00

(days / decade)				

Table 10. Linear trends (via Kendall's rank correlation Tau method) in seasonal extreme rainfall indices for Rarotonga, Southern Cook Islands, in the period 1951 – 2015. The trend values for each variable are shaded in in blue (wetter) and yellow (drier). (Source: Pacific Climate Change Data Portal).

Penrhyn

Extreme Rainfall Indices	DJF	MAM	JJA	SON
Max 1-day rainfall, Rx1day (mm / decade)	0.51	–0.23	–0.25	0.10
Max 5-day rainfall, Rx5days (mm / decade)	0.85	–0.22	–0.52	0.20
Rain days ≥ 10 mm, R10 (days / decade)	0.04	–0.01	–0.07	0.02
Rain days ≥ 20 mm, R20 (days / decade)	0.03	–0.01	–0.02	0.03
Consecutive dry days, CDD (days / decade)	0.00	0.00	0.00	–0.02
Consecutive wet days, CWD (days / decade)	0.02	0.00	0.00	0.00

Table 11. Linear trends (via Kendall's rank correlation Tau method) in seasonal extreme rainfall indices for Penrhyn, Northern Cook Islands, in the period 1951 – 2015. The trend values for each variable are shaded in in blue (wetter) and yellow (drier). (Source: Pacific Climate Change Data Portal).

Discussion

Warming trends are evident over most seasons and most extreme temperature indices for the Southern Cook Islands (Rarotonga), with many of those trends being statistically significant. In terms of trends in absolute extremes (TXx, TXn, TNx, TNn), all are rising by about 0.15 °C to 0.30 °C per decade, with the exception of TXn (lowest daily maximum), which shows no trend. Therefore, whatever the mechanism is that produces extreme low maxima in the southern Cook Islands, it seems to be unaffected by global warming. The highest maximum (TXx) and lowest minimum (TNn) temperatures have significant rising trends in all seasons, with the strongest trend being 0.41 °C per decade in TNn during SON.

Even though TXn shows no trend, the number of cool days below the 10th percentile is decreasing in each season, significant in all but DJF. The number of cool nights is also significantly decreasing in each season, although the magnitude is quite small. Warm days and warm nights show upward trends in all seasons, with statistical significance lacking in only DJF and JJA for warm days (TX90p).

The long-term trends in rainfall are generally insignificant and much smaller in magnitude than the temperature trends. The only statistically significant trend at either Rarotonga or Penrhyn is a rise in the number of consecutive dry days during DJF at Rarotonga. The trends that do exist, are slightly larger and more consistent across the seasons at Rarotonga than those at Penrhyn.

Seasonal analysis – Niue

Bold italics indicate trends that are significant at the 5% level. Some annual statistics (Table 5) are not available for seasons.

Extreme Temperature Indices	DJF	MAM	JJA	SON
Highest maximum temperature, TXx (°C / decade)	0.01	***–0.26***	***0.20***	***0.31***
Highest minimum temperature, TNx (°C / decade)	***–0.31***	–0.09	***0.66***	***0.26***
Lowest maximum temperature, TXn (°C / decade)	0.14	***–0.33***	***0.32***	***0.70***
Lowest minimum temperature, TNn (°C / decade)	***–1.10***	–0.13	***1.11***	***0.45***
Hot days > 30 °C, TXge30 (days / decade)	***2.00***	0.00	***0.43***	***5.88***
Cool days, TX10p (days / decade)	***–2.08***	***–1.21***	***–1.44***	***–1.50***
Cool nights, TN10p (days / decade)	***–0.84***	–0.60	–0.68	–0.35
Warm days, TX90p (days / decade)	***2.00***	0.28	0.51	***1.43***
Warm nights, TN90p (days / decade)	***2.28***	1.33	***1.84***	***1.92***

Table 12. Linear trends (via Kendall's rank correlation Tau method) in seasonal extreme temperature indices for Niue in the period 1951 – 2015. The trend values for each variable are shaded in pink (warming effect), or blue (cooling). (Source: Pacific Climate Change Data Portal).

Extreme Rainfall Indices	DJF	MAM	JJA	SON
Max 1-day rainfall, Rx1day (mm / decade)	–1.23	–1.31	–0.60	–4.45
Max 5-day rainfall, Rx5days (mm / decade)	3.55	2.31	0.32	–6.57
Rain days ≥ 10 mm, R10 (days / decade)	0.00	–0.19	0.06	0.31
Rain days ≥ 20 mm, R20 (days / decade)	0.00	–0.11	0.05	0.17
Consecutive dry days, CDD (days / decade)	–0.24	–0.07	–0.22	–0.18
Consecutive wet days, CWD (days / decade)	–0.23	0.19	0.00	0.00

Table 13. Linear trends (via Kendall's rank correlation Tau method) in seasonal extreme rainfall indices for Niue in the period 1951 – 2015. The trend values for each variable are shaded in in blue (wetter) and yellow (drier). (Source: Pacific Climate Change Data Portal).

Discussion

Seasonal trends in extreme temperature indices for Niue are mixed in magnitude and sign such that there is no consistency from one season to the next for some of the indices. The DJF season has statistically significant downward (cooling) trends in minimum temperature extremes (TNx and TNn), while MAM has statistically significant downward trends in maximum temperature extremes (TXx and TXn). On the other hand, there are statistically significant upward (warming) trends in all four of these indices in the other two seasons, JJA and SON. The strongest positive trend is +1.11 °C per decade in TNn during JJA, and the strongest negative trend is –1.10 °C per decade in TNn during DJF. The magnitudes of these, and some of the other trends in TXx, TXn and TNx, look excessive. While it is possible that several inhomogeneities have escaped detection, we believe these data to be largely homogeneous.

The number of days reaching 30 °C or higher shows a significant upward trend in all but the MAM season, while the number of cool days below the 10th percentile shows a significant decrease in each season. The results for the other frequency/threshold indicators are mixed:

- Downward trends in cool nights during DJF
- Upward trend in warm days during DJF and SON;
- Warm nights increasing in each season except MAM.

There are no significant trends in any of the seasonal extreme **rainfall** indicators at Niue. Moreover, the weak trends that are recorded are of mixed sign. Therefore, it is concluded that there is no discernible climate change signal in seasonal rainfall extremes for the period 1951 – 2015 at Niue. It is also worth noting that of the five Programme countries, Niue had the weakest signals in annual rainfall extremes.

Seasonal analysis – Palau

Bold italics indicate trends that are significant at the 5% level. Some annual statistics (Table 5) are not available for seasons.

Extreme Temperature Indices	DJF	MAM	JJA	SON
Highest maximum temperature, TXx (°C / decade)	***0.15***	***0.09***	***0.19***	***0.21***
Highest minimum temperature, TNx (°C / decade)	***0.09***	0.00	***0.07***	***0.06***
Lowest maximum temperature, TXn (°C / decade)	***0.13***	***0.19***	0.00	***0.18***
Lowest minimum temperature, TNn (°C / decade)	0.00	0.00	0.00	0.00
Hot days > 30 °C, TXge30 (days / decade)	0.37	0.61	***1.47***	***0.59***
Cool days, TX10p (days / decade)	***–0.49***	***–0.57***	–0.81	***–1.06***
Cool nights, TN10p (days / decade)	–0.06	***–1.69***	***–1.24***	***–1.35***
Warm days, TX90p (days / decade)	***0.82***	0.92	***1.37***	***1.33***

Warm nights, TN90p (days / decade)	***2.94***	***3.48***	***6.42***	***3.83***

Table 14. Linear trends (via Kendall's rank correlation Tau method) in seasonal extreme temperature indices for Palau in the period 1951 – 2015. The trend values for each variable are shaded in pink (warming effect). (Source: Pacific Climate Change Data Portal).

Extreme Rainfall Indices	DJF	MAM	JJA	SON
Max 1-day rainfall, Rx1day (mm / decade)	0.00	–3.00	–2.60	–0.53
Max 5-day rainfall, Rx5days (mm / decade)	–0.41	–4.21	–0.38	–2.34
Rain days ≥ 10 mm, R10 (days / decade)	0.00	0.00	–0.40	–0.26
Rain days ≥ 20 mm, R20 (days / decade)	0.31	0.00	0.00	–0.37
Consecutive dry days, CDD (days / decade)	0.00	0.00	0.26	0.22
Consecutive wet days, CWD (days / decade)	–0.36	0.00	0.30	0.00

Table 15. Linear trends (via Kendall's rank correlation Tau method) in seasonal extreme rainfall indices for Palau in the period 1951 – 2015. The trend values for each variable are shaded in in blue (wetter) and yellow (drier). (Source: Pacific Climate Change Data Portal).

Discussion

Seasonal trends in extreme temperature indices for Palau generally indicate warming, with many values statistically significant at the 5% level. In terms of trends in absolute extremes (TXx, TXn, TNx, TNn), all are rising by 0.05 °C to 0.20 °C per decade, with the exception of TNn (lowest daily minimum), which shows no trend. Therefore, whatever the mechanism is that produces extreme low minima in Palau, it seems to be unaffected by global warming. The strongest trend is +0.21 °C per decade in TXx during SON.

The number of days reaching 30 °C or higher shows a slight upward trend in all seasons, with statistical significance evident in JJA and SON. Consistent with this result, the number of warm days above the 90th percentile (TX90p) is increasing in all seasons (statistically significant in all but MAM), while the number of cool days below the 10th percentile (TX10p) is decreasing in all seasons (statistically significant in all but JJA). We see similar and consistent results with overnight minima: fewer cool nights below the 10th percentile (TN10p), statistically significant in all but DJF; and more warm nights above the 90th percentile (TN90p), with the trends being statistically significant in all seasons.

There are no statistically significant trends in any of the seasonal extreme **rainfall** indicators at Palau. Nevertheless, the weak trends that are recorded suggest a possible decrease in extreme rainfall. Overall, it is concluded that there is no discernible climate change signal in seasonal rainfall extremes for the period 1951 – 2015 at Palau.

Seasonal analysis – Marshall Islands

Bold italics indicate trends that are significant at the 5% level. Some annual statistics (Table 5) are not available for seasons.

Extreme Temperature Indices	DJF	MAM	JJA	SON
Highest maximum temperature, TXx (°C / decade)	***0.10***	***0.06***	0.09	***0.15***
Highest minimum temperature, TNx (°C / decade)	***0.20***	***0.18***	***0.14***	***0.16***
Lowest maximum temperature, TXn (°C / decade)	0.07	***0.17***	0.06	***0.15***
Lowest minimum temperature, TNn (°C / decade)	***0.16***	***0.25***	***0.20***	***0.19***
Hot days > 30 °C, TXge30 (days / decade)	***4.19***	2.06	0.66	***6.83***
Cool days, TX10p (days / decade)	***–1.08***	***–0.88***	–0.84	***–1.28***
Cool nights, TN10p (days / decade)	***–2.27***	***–2.42***	***–2.52***	***–1.44***
Warm days, TX90p (days / decade)	***0.86***	***0.28***	0.33	***0.90***
Warm nights, TN90p (days / decade)	***4.73***	***4.44***	***2.81***	***3.83***

Table 16. Linear trends (via Kendall's rank correlation Tau method) in seasonal extreme temperature indices for Majuro, Marshall Islands, in the period 1951 – 2015. The trend values for each variable are shaded in pink (warming effect). (Source: Pacific Climate Change Data Portal).

Extreme Rainfall Indices	DJF	MAM	JJA	SON
Max 1-day rainfall, Rx1day (mm / decade)	–2.27	0.61	–1.43	–2.11
Max 5-day rainfall, Rx5days (mm / decade)	–2.05	–1.42	–3.95	–0.56
Rain days ≥ 10 mm, R10 (days / decade)	–0.61	0.00	0.45	–0.78
Rain days ≥ 20 mm, R20 (days / decade)	–0.32	0.31	0.00	–0.25
Consecutive dry days, CDD (days / decade)	0.00	0.00	–0.42	0.00
Consecutive wet days, CWD (days / decade)	0.04	***–0.53***	0.00	–0.49

Table 17. Linear trends (via Kendall's rank correlation Tau method) in seasonal extreme rainfall indices for Majuro, Marshall Islands, in the period 1951 – 2015. The trend values for each variable are shaded in in blue (wetter) and yellow (drier). (Source: Pacific Climate Change Data Portal).

Discussion

Seasonal trends in extreme temperature indices for the Marshall Islands indicate warming across the board, with many values statistically significant at the 5% level. In terms of trends in absolute extremes (TXx, TXn, TNx, TNn), all are rising by around 0.05 °C to 0.20 °C per decade, with statistically significant values for both TNx and TNn in all seasons. The rising trend in TXx is not significant in JJA, while the upward trend in TXn isn't significant in JJA and DJF. The strongest trend is +0.25 °C per decade in TNn during MAM.

The number of days reaching 30 °C or higher shows a slight upward trend in all seasons, with statistical significance evident in DJF and SON. Consistent with this result, the number of warm days above the 90th percentile (TX90p) is increasing in all seasons (statistically significant in all but JJA), while the number of cool days below the 10th percentile (TX10p) is decreasing in all seasons (also statistically significant in all but JJA). The trends for cool nights below the 10th percentile (TN10p) and warm nights above the 90th percentile (TN90p) are also consistent with warming: a decrease in the former and an increase in the latter. In addition, the trends for both are statistically significant in all seasons.

There are almost no statistically significant trends in any of the seasonal extreme **rainfall** indicators at Majuro in the Marshall Islands. The only exception was a fall in the number of consecutive wet days during MAM. However, the weak trends that are recorded mainly suggest a possible decrease in extreme rainfall. Overall, it is concluded that there is no discernible climate change signal in seasonal rainfall extremes for the period 1951 – 2015 at the Marshall Islands.

Rainfall trends at Majuro, which is situated towards the southeast of the Marshall Islands, cannot necessarily be extrapolated to the remainder of the country. Two main climate features govern the Marshall's rainfall: the western Pacific warm pool, and the Inter-Tropical Convergence Zone (ITCZ), both of which are modulated by ENSO. Consequently, there are occasions when rainfall anomalies of opposite sign occur simultaneously in different parts of RMI. There are also periods when drought or high rainfall are widespread across the country.

Seasonal analysis – Tuvalu

Bold italics indicate trends that are significant at the 5% level. Some annual statistics (Table 5) are not available for seasons.

Extreme Temperature Indices	DJF	MAM	JJA	SON
Highest maximum temperature, TXx (°C / decade)	0.08	0.09	***0.27***	***0.21***
Highest minimum temperature, TNx (°C / decade)	***0.16***	0.08	***0.18***	***0.14***
Lowest maximum temperature, TXn (°C / decade)	0.02	***0.16***	***0.18***	***0.16***
Lowest minimum temperature, TNn (°C / decade)	***0.13***	***0.17***	***0.19***	***0.17***
Hot days > 30 °C, TXge30 (days / decade)	0.63	***1.74***	***3.02***	***1.74***
Cool days, TX10p (days / decade)	–0.47	***–1.43***	***–1.77***	***–1.54***
Cool nights, TN10p (days / decade)	***–1.92***	***–1.74***	***–2.92***	***–3.53***

Warm days, TX90p (days / decade)	***2.36***	***4.34***	***5.06***	***4.57***
Warm nights, TN90p (days / decade)	***1.73***	***2.36***	***3.19***	***2.56***

Table 18. Linear trends (via Kendall's rank correlation Tau method) in seasonal extreme temperature indices for Funafuti, Tuvalu, in the period 1951 – 2015. The trend values for each variable are shaded in pink (warming effect). (Source: Pacific Climate Change Data Portal).

Extreme Rainfall Indices	DJF	MAM	JJA	SON
Max 1-day rainfall, Rx1day (mm / decade)	–0.33	2.03	–0.60	0.22
Max 5-day rainfall, Rx5days (mm / decade)	–4.58	4.68	–1.50	–2.70
Rain days ≥ 10 mm, R10 (days / decade)	0.00	–0.23	–0.83	–0.52
Rain days ≥ 20 mm, R20 (days / decade)	0.00	0.04	–0.30	–0.27
Consecutive dry days, CDD (days / decade)	***0.18***	0.20	0.00	0.22
Consecutive wet days, CWD (days / decade)	0.00	–0.21	–0.24	–0.26

Table 19. Linear trends (via Kendall's rank correlation Tau method) in seasonal extreme rainfall indices for Funafuti, Tuvalu, in the period 1951 – 2015. The trend values for each variable are shaded in in blue (wetter) and yellow (drier). (Source: Pacific Climate Change Data Portal).

Discussion

Trends in seasonal extreme temperature indices for Tuvalu indicate warming in all instances, with many values statistically significant at the 5% level. In terms of trends in absolute extremes (TXx, TXn, TNx, TNn), most are rising by 0.10 °C to 0.20 °C per decade, with statistically significant values for TNn in all seasons. The rising trend in TXx is significant in JJA and SON; upward trends in TNx are significant in DJF, JJA and SON; TXn has significant rises in MAM, JJA and SON. The strongest trend is +0.27 °C per decade in TXx during JJA.

The number of days reaching 30 °C or higher shows a slight upward trend in all seasons, with statistically significant numbers analysed in all seasons apart from DJF. Consistent with this result, the number of warm days above the 90th percentile (TX90p) is increasing in all seasons (statistically significant in all), while the number of cool days below the 10th percentile (TX10p) is decreasing in all seasons (statistically significant in all but DJF). The trends for cool nights below the 10th percentile (TN10p) and warm nights above the 90th percentile (TN90p) are also consistent with warming: a statistically significant decrease in the former in all seasons, and a statistically significant increase in the latter in all seasons.

There are almost no statistically significant trends in any of the seasonal extreme **rainfall** indicators at Funafuti, Tuvalu. The only exception was a rise in the number of consecutive dry days during DJF. However, the weak trends that are recorded mainly suggest a possible decrease in extreme rainfall.

Overall, it is concluded that there is no discernible climate change signal in seasonal rainfall extremes for the period 1951 – 2015 in Tuvalu.

Rainfall trends at Funafuti, which is situated near the centre of Tuvalu, cannot necessarily be extrapolated to the remainder of the country. There are two main climate features that govern Tuvalu's rainfall: the western Pacific warm pool, and the South Pacific Convergence Zone (SPCZ), both of which are modulated by ENSO. Consequently, there are occasions when rainfall anomalies of opposite sign occur simultaneously from northern to southern Tuvalu. There are also periods when drought or high rainfall are widespread across the country.

Summary of trends in extreme temperature and rainfall indices

Country	Annual Temperature	Annual Rainfall	Seasonal Temperature	Seasonal Rainfall
Southern Cook Islands	Most trends are statistically significant at the 5% level. Nearly all indicate increasing warm extremes and decreasing cool extremes. Most noteworthy: 0.28 °C per decade increase in TXx.	No significant trend in any of the indices. Most indices are smaller in magnitude than those of the Northern Cook Islands and show a tendency towards less extreme rainfall events. Most noteworthy: 28.08 mm per decade decrease in R95p.	Majority of trends are statistically significant, especially in MAM and SON. Nearly all indicate increasing warm extremes and decreasing cool extremes. Most noteworthy: 0.26 °C per decade increase in TXx during MAM and JJA.	Statistically significant increase in CDD during DJF. Drying generally indicated by most indices. Largest: 4.34 mm per decade decrease in Rx5day for MAM.
Northern Cook Islands	N/A	No significant trend in any of the indices. Most indices show a tendency towards more extreme rainfall events. Most noteworthy: 86.95 mm per decade increase in PRCPTOT.	N/A	No significant trend in any of the indices. Small increases in Rx1day and Rx5days in DJF and SON balanced by small decreases in MAM and JJA. Largest: 0.85 mm per decade increase in Rx5day for DJF.
Niue	Statistical significance not available. Nearly all trends (least squares) indicate increasing warm extremes and decreasing cool extremes. Most noteworthy: 8 days per decade increase in TN90p.	No significant trend in any of the indices. A mix of positive and negative values, with a slight majority indicating less extreme rainfall events. Overall, the weakest values of any of the countries. Most noteworthy: 13.22 mm per decade decrease in R95p.	Majority of trends are statistically significant, especially in SON. Nearly all indicate increasing warm extremes and decreasing cool extremes. Most noteworthy: 6 days per decade increase in TXge30 during SON.	No significant trend in any of the indices. A mix of results – some drier, some wetter. Largest: 6.57 mm per decade decrease in Rx5day for SON.
Palau	Most trends are statistically significant at the 5% level.	No significant trend in any of the indices. Most indices show a	Majority of trends are statistically significant, especially	No significant trend in any of the indices. Drying generally

Country	Annual Temperature	Annual Rainfall	Seasonal Temperature	Seasonal Rainfall
	Nearly all indicate increasing warm extremes and decreasing cool extremes. Most noteworthy: 39 days per decade increase in CDDcoldn.	tendency towards less extreme rainfall events. Most noteworthy: 27.57 mm per decade decrease in R95p.	in SON. Nearly all indicate increasing warm extremes and decreasing cool extremes. Most noteworthy: 0.21 °C per decade increase in TXx during SON.	indicated by most indices. Largest: 4.21 mm per decade decrease in Rx5day for MAM.
Marshall Islands	Most trends are statistically significant at the 5% level. Nearly all indicate increasing warm extremes and decreasing cool extremes. Most noteworthy: 13 days per decade increase in TXge30.	Significant downward trend in CDD, R95p, PRCPTOT. Nearly all indices show a tendency towards less extreme rainfall events. Most noteworthy: 90.34 mm per decade decrease in PRCPTOT.	Majority of trends are statistically significant, especially in SON. All indicate increasing warm extremes and decreasing cool extremes. Most noteworthy: 0.20 °C per decade increase in TNx during DJF.	Statistically significant decrease in CWD during MAM. Drying generally indicated by a majority of indices. Largest: 3.95 mm per decade decrease in Rx5day for JJA.
Tuvalu	Statistical significance not available. All trends (least squares) indicate increasing warm extremes and decreasing cool extremes. Most noteworthy: 18 days per decade increase in TX90p.	No significant trend in any of the indices. Most indices show a tendency towards less extreme rainfall events. Most noteworthy: 58.24 mm per decade decrease in PRCPTOT.	Majority of trends are statistically significant, especially in SON. All indicate increasing warm extremes and decreasing cool extremes. Most noteworthy: 0.27 °C per decade increase in TXx during JJA.	Statistically significant increase in CDD during DJF. Drying generally indicated by a majority of indices. Largest: 4.68 mm per decade increase in Rx5day for MAM.

Table 20. Summary of linear trends (via Kendall's rank correlation Tau method) in extreme temperature and rainfall indices, both annually and seasonally, at Rarotonga (Southern Cook Is.), Penrhyn (Northern Cook Is.), Alofi-Hanan Airport (Niue), Koror (Palau), Majuro (Marshall Is.) and Funafuti (Tuvalu), in the period 1951 – 2015.

3.3.3 Sea level

Sea level varies spatially across the Pacific by up to one metre: along the equator, the sea level in the west is about 0.5 m higher than the sea level in the east. Year-to-year sea level can vary by more than 20 cm, which is mainly due to ENSO. During El Niño events, weakened trade winds reduce sea level in the western tropical Pacific and increase sea level in the east. During La Niña, strengthened trade winds cause higher than normal sea levels in the west, and lower than normal levels in the east. Pacific islands within about 10° of the equator – including the northern Cook Islands, Palau, southern RMI and Tuvalu – are most significantly affected by sea-level variations related to ENSO events. The influence of ENSO can be observed at individual island locations, as shown in the figure below.

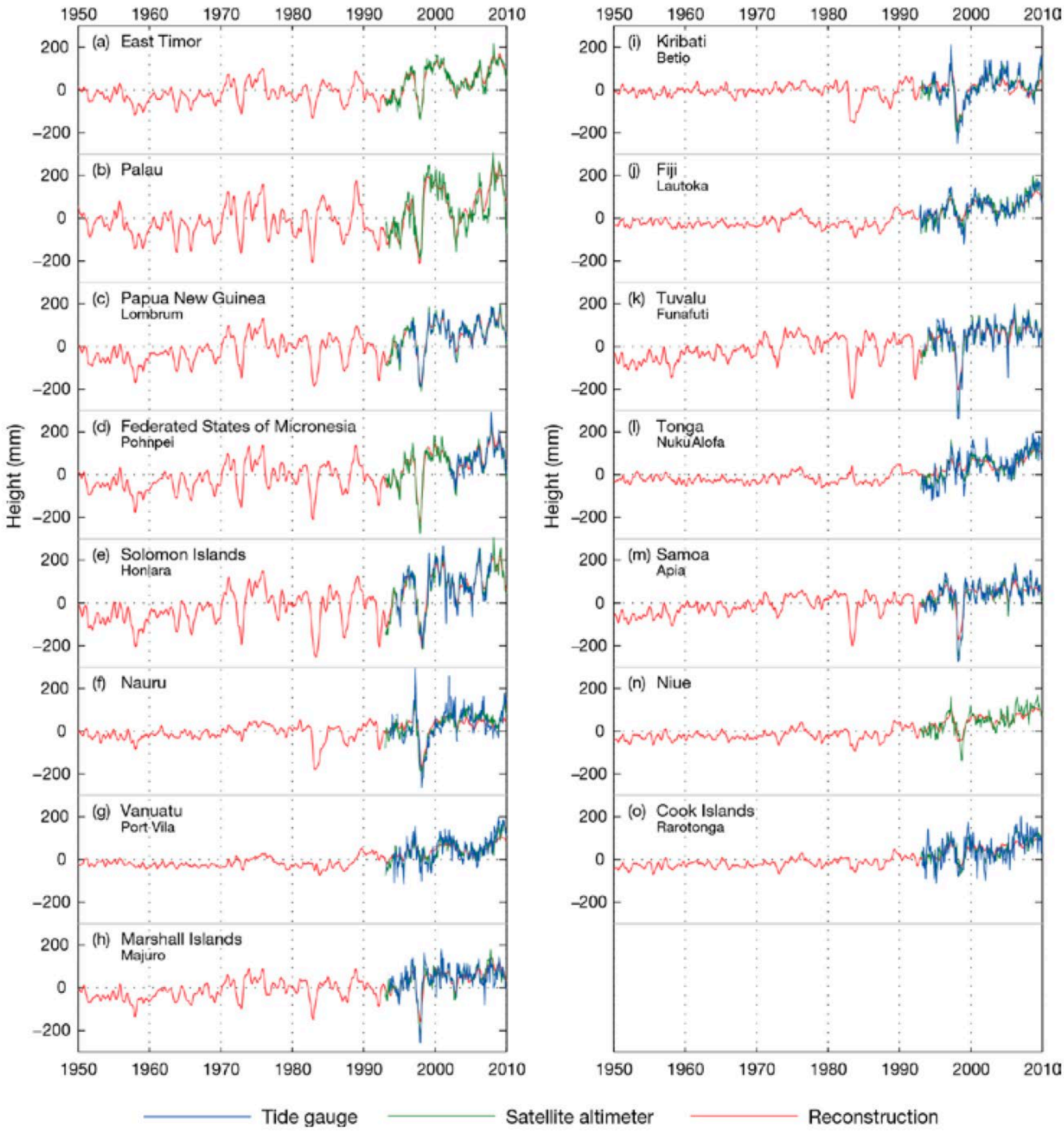


Figure 20. Time series of monthly tide gauge data (blue) from the South Pacific Sea Level and Climate Monitoring Project (where available), satellite-altimeter data (green, from 1993) and reconstructed (red) sea levels using both data sources. Reconstructed sea level uses advanced statistical techniques to combine tide gauge and satellite measurements to estimate pre-satellite sea level from tide gauge measurements alone. (Source: Australian BoM and CSIRO)

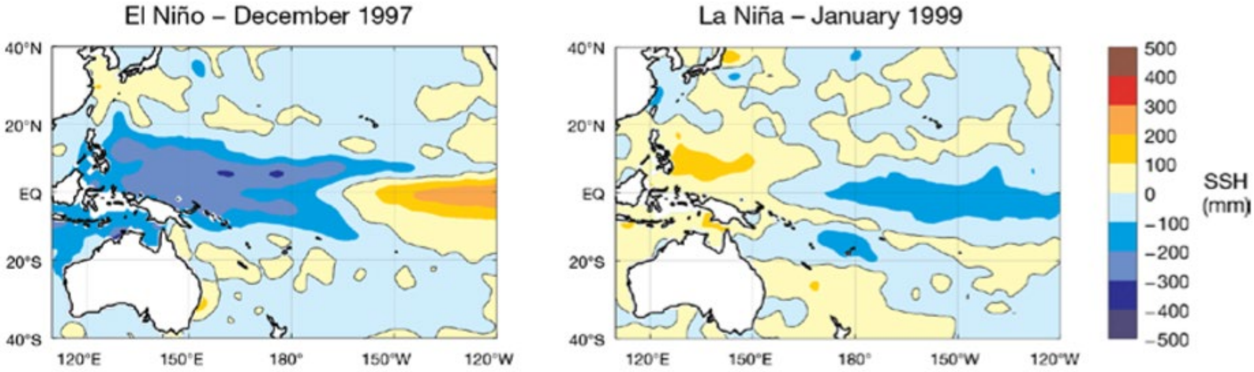


Figure 21. Sea-surface height variation relative to the long-term average (mm) across the Pacific for 1993 to 2011 (Source: Australian Bureau of Meteorology and CSIRO)

Satellite records indicate that global averaged sea level has been rising at 3.2 ± 0.4 mm/year since 1993.[62] The IPCC Fifth Assessment Report notes that "Rates of sea level rise over broad regions can be several times larger or smaller than the global mean sea level rise for periods of several decades, due to fluctuations in ocean circulation. Since 1993, the regional rates for the Western Pacific are up to three times larger than the global mean, while those for much of the Eastern Pacific are near zero or negative."[63]

The regional distribution of sea level rise is important because it is the regional or local sea level change and local land movement that most directly affects populations and the environment. Impacts to populations from extreme change in sea level can consist of the effect of surges, swell, high tides and wind waves. From 1993 to 2009, both the altimeter and in-situ data indicate a higher than global average rate of rise in the western Pacific but, because of the strong influence of ENSO and decadal variability on sea level in the region, this higher rate of rise may not necessarily representative of a longer time span.[64] Some researchers suggest that the high rates of sea level rise in the tropical Pacific Ocean are a result of intensification of trade winds.[65]

[62] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

[63] IPCC, 2013, Climate Change 2013: The Physical Science Basis. Chapter 13 (pp 288,1148).

[64] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional

[65] Merrifield, M.A. and Maltrud, M.E., 2011. Regional sea level trends due to a Pacific trade wind intensification

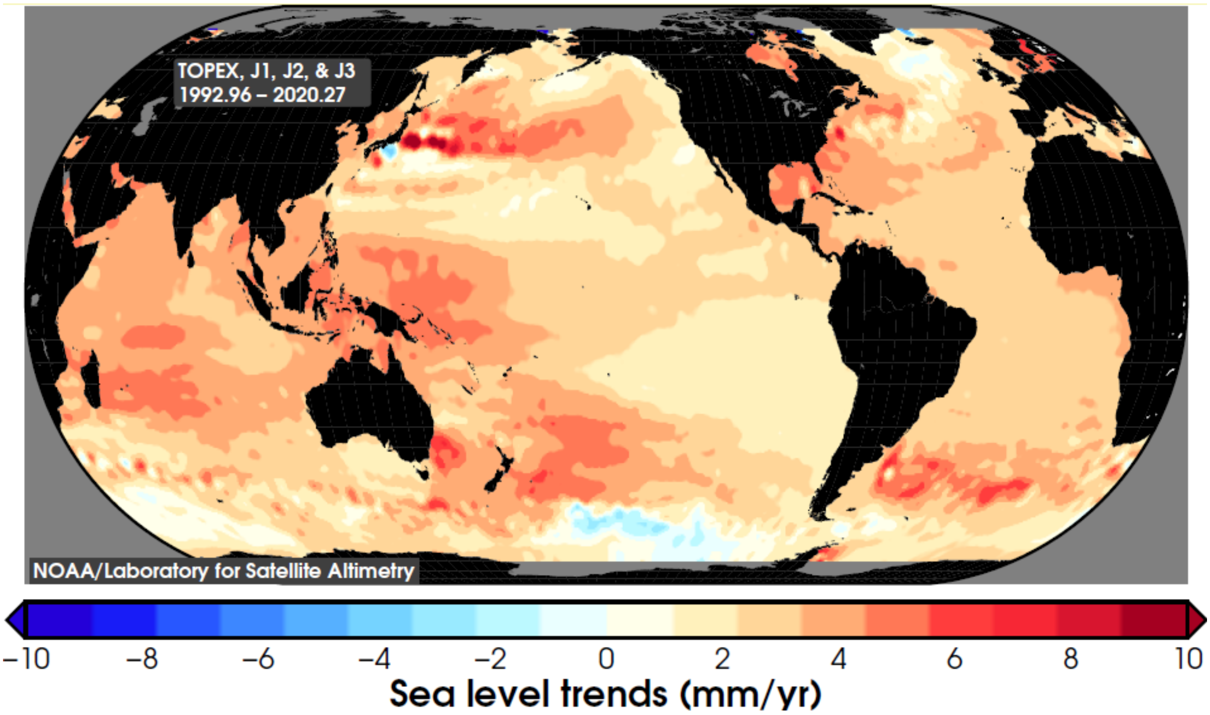


Figure 22. Estimates of sea-level rise based on measurements from satellite radar altimeters. The local trends were estimated using data from TOPEX/Poseidon (T/P), Jason-1, Jason-2 and Jason-3, which have monitored the same ground track since 1992. (Source: NOAA)[66]

Over a longer time period, Church *et al.* studied the tide gauge records in the tropical Pacific region and found that the average rate of relative sea-level rise (relative to land) – and corrected for glacial isostatic adjustment and atmospheric pressure effects – was 2.0 mm/year between 1950 and 2001. The best estimate of relative sea-level rise was obtained for Funafuti (Tuvalu) at 2 ± 1 mm/year. For Majuro (RMI), the relative reconstructed trend was 2.3 mm/year.[67]

[66] NOAA, 2020. Sea level rise maps. Available at: https://www.star.nesdis.noaa.gov/socd/lsa/SeaLevelRise/LSA_SLR_maps.php

[67] Church, J.A. *et al.* 2006. Global and Planetary Change. Sea-level rise at tropical Pacific and Indian Ocean islands

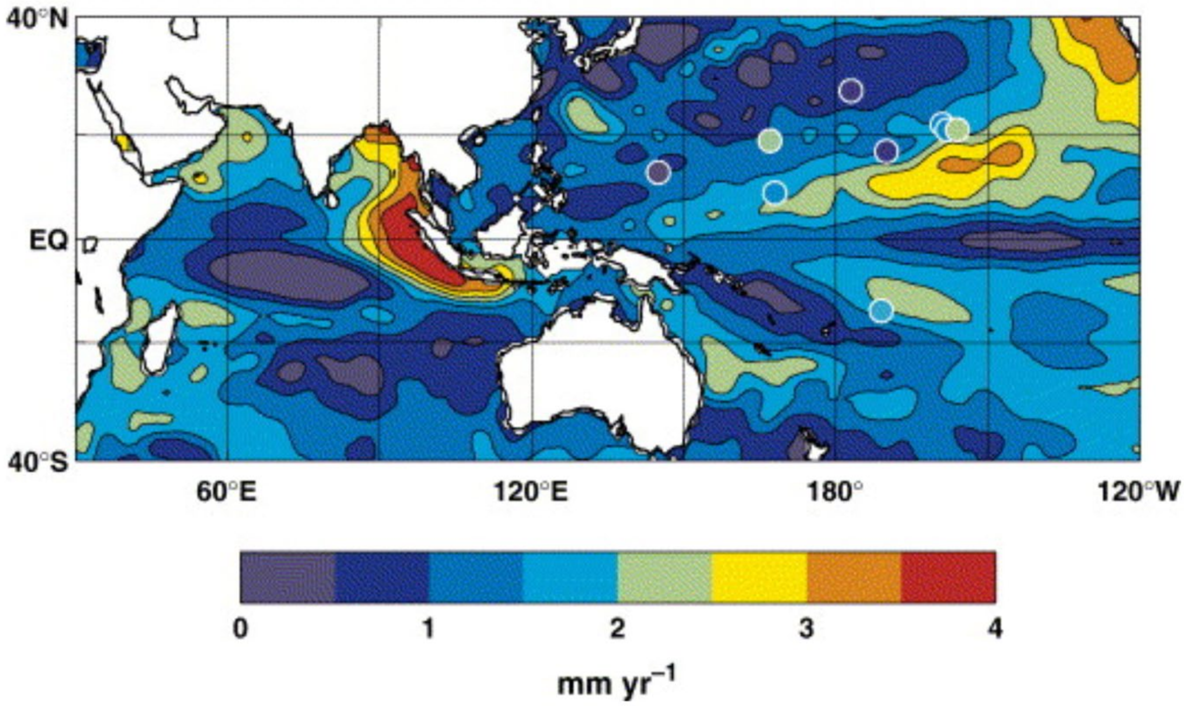


Figure 23. Map of sea-level trends from the reconstruction over the period 1950 – 2001. Trends from the longer tide gauge records are shown by the coloured dots. (Source: Church *et al.*)

3.3.4 Sea surface temperature

Sea surface temperature is an important physical element of the world's oceans. Sea surface temperature (SST) can have significant effects on global climate, as a result of continuous interaction between the oceans and the atmosphere. Increases in SST can lead to increased amounts of atmospheric water vapour over the oceans, which feeds into the weather systems that produce precipitation – increasing the risk of heavy rain. Changes in sea surface temperature can shift storm tracks, and potentially contribute to droughts in some areas.[68]

Interannual variability in SST is predominantly due to ENSO, whilst inter-decadal variability is associated with Interdecadal Pacific Oscillation (IPO) – ENSO-like patterns of variability operating at decadal and inter-decadal time scales. Year-to-year variability in SST due to ENSO is often greater than seasonal changes. The West Pacific Warm Pool is created by easterly trade winds pushing warm surface tropical waters towards the west, and has an average SST of 29 °C. The eastern tropical Pacific Ocean is cooler due to the upwelling of cooler waters by equatorial winds.[69]

[68] United States Environmental Protection Agency, 2016. Climate Change Indicators: Sea Surface Temperature

[69] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

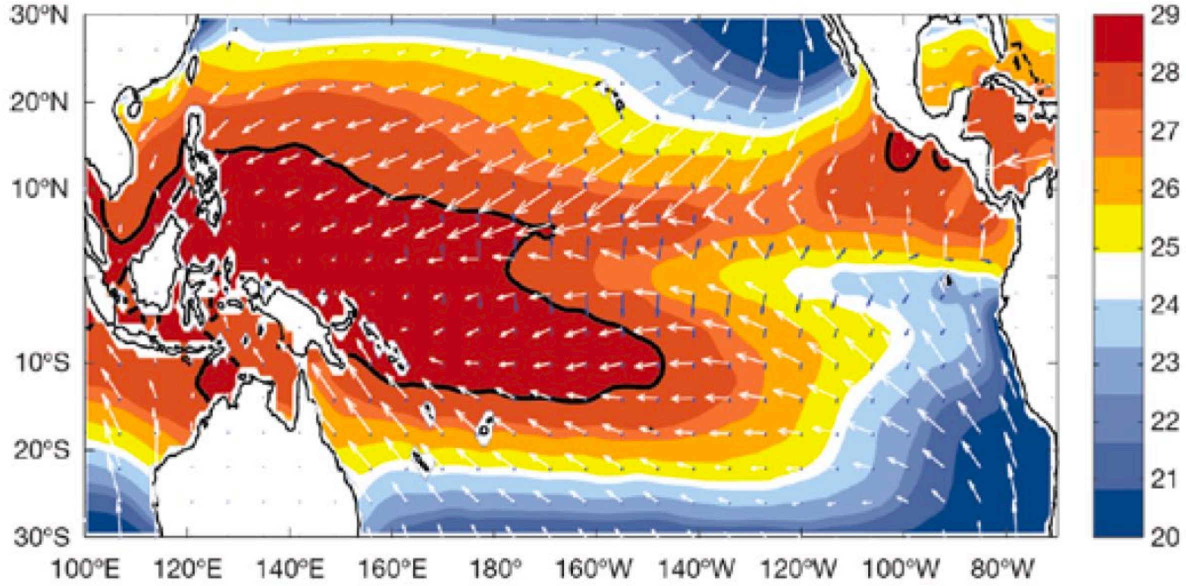


Figure 24. Long-term annual average sea-surface temperature (°C). Black lines indicate the 28.5 °C contours, commonly used for the boundary of the Warm Pool. Quikcat wind vectors (white arrows) and surface Ekman currents (blue arrows, computed from wind stress) are also shown. (Source: Australian BoM and CSIRO)[70]

Sea-surface temperatures in the tropical Pacific have generally warmed since 1950, which has been partly attributed to anthropogenic global warming. However, temperature variations associated with IPO / Pacific Decadal Oscillation (PDO) also substantially influence the background trend. [71] The West Pacific Warm Pool has considerably expanded over recent decades, with the area of water with temperatures exceeding 29.5 °C having increased by 400 – 600 %.[72] The extent to which shifts in IPO/PDO indices are predictable on decadal timescales is the subject of ongoing research.

[70] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional

[71] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional

[72] Cravatte, S. *et al.* 2009. Climate Dynamics. Observed freshening and warming of the Western Pacific Warm Pool

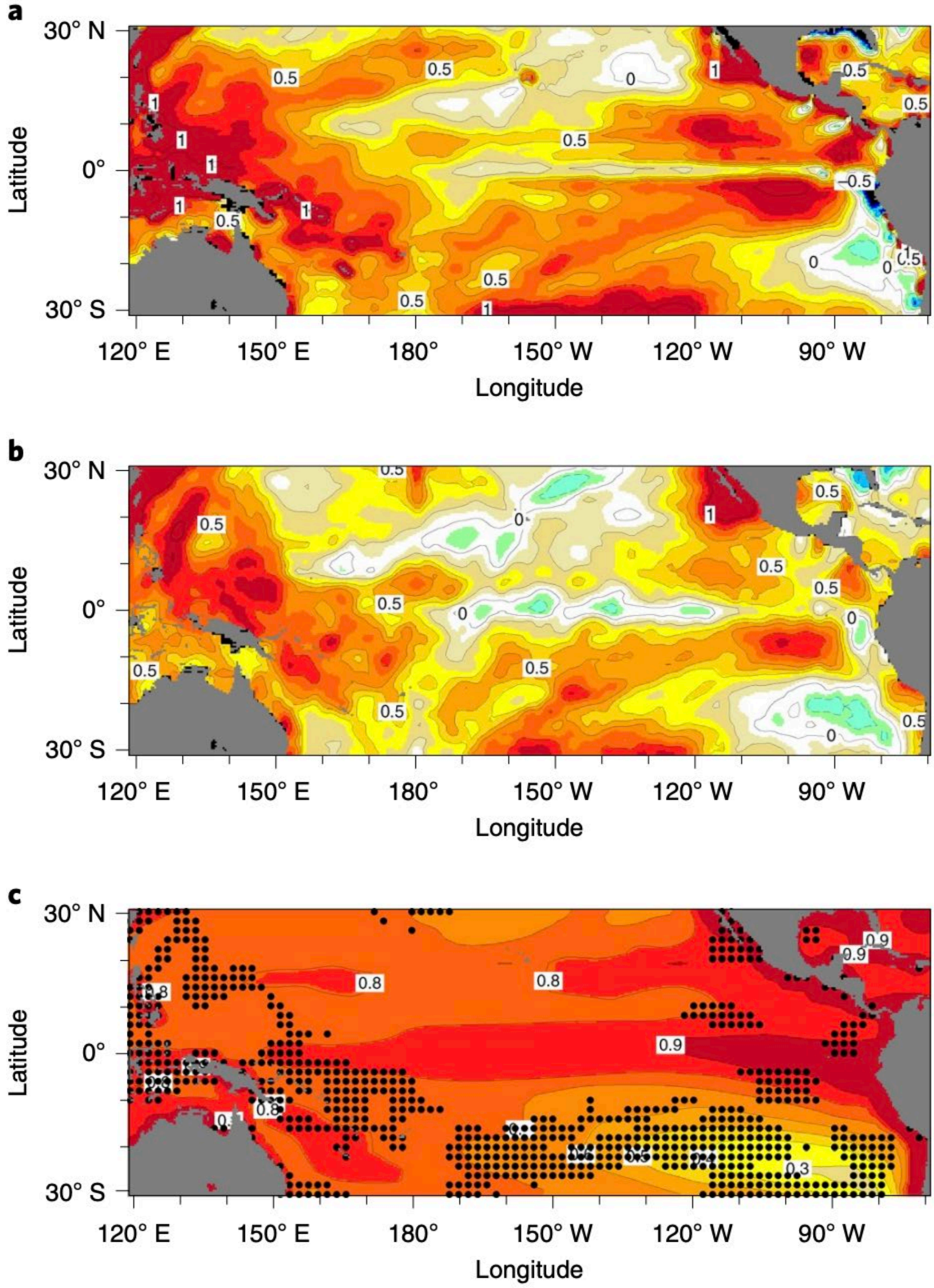


Figure 25. Observed changes in SST (K) from 1958 – 2017 according to ECMWF/ORAS4 reanalysis (a); HadIIST analysis (b); and the multi-model mean of 40 historical and RCP8.5 CMIP5 models. (Source: Seager *et al.* 2019)[73]

[73] Seager, R. *et al.* 2019. Nature Climate Change. Strengthening tropical Pacific zonal sea surface temperature gradient consistent with rising greenhouse gases

3.3.5 Ocean acidification

The ocean is a major sink for atmospheric carbon dioxide – absorbing around one quarter of anthropogenic carbon dioxide emissions per year – and results in ocean acidification. Inter-seasonal and inter-annual ocean acidification varies, with seasonal variation larger than annual changes due to increasing atmospheric carbon dioxide levels. Interannual variability can be influenced by ENSO: less acidity is associated with El Niño events than with La Niña events.

Ocean acidification is measured based on the ocean aragonite saturation state. Aragonite is the most common form of calcium carbonate found in tropical reefs and is used to build marine shells and skeletons – including for coral. Increasing ocean acidification leads to decreasing aragonite saturation. The best conditions for coral to grow is at an aragonite saturation state above 4; below 3, the conditions to grow coral are critically limited.[74]

The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (2019) reported that, since the start of the industrial era (around 1750), oceanic uptake of carbon dioxide has resulted in acidification of the ocean. The pH of ocean surface water has decreased by 0.1 (*high confidence*), corresponding to a 26% increase in acidity.[75] Over this period, aragonite saturation has decreased from 4.2 to 3.8 across the Pacific island region.[76]

Based on data collected in the Pacific region as part of the Joint Global Ocean Flux Study / World Ocean Circulation Experiment CO_2 survey, estimates have been made of ocean aragonite saturation state. In the pre-industrial era, "saturation state values were above 4 throughout most of the sub-tropical and tropical Pacific Island region". By the mid 1990s, "the uptake of anthropogenic CO_2 had resulted in a widespread decline in the aragonite saturation state, with values slightly above 4 only found in the region of the South Equatorial Current and in the western Pacific". Ocean aragonite saturation state has continued to decline, with only the surface waters of the South Equatorial Current – around Cook Islands, Niue and Tuvalu – with aragonite saturation states at or slightly above values of 4.[77]

[74] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

[75] IPCC, 2019. *Special Report on the Ocean and Cryosphere in a Changing Climate.*

[76] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

[77] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional

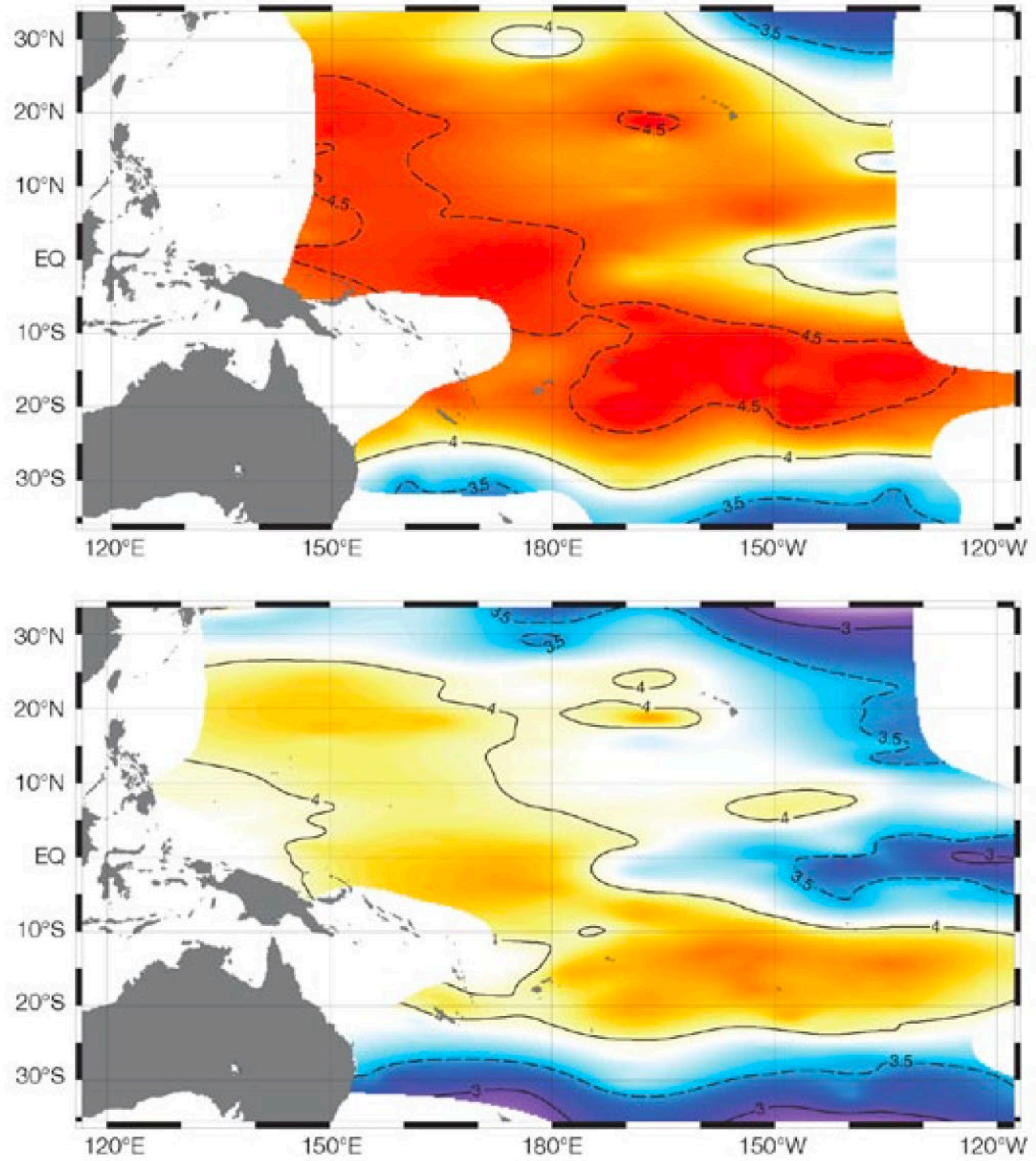


Figure 26. Ocean aragonite saturation state values calculated for the pre-industrial period (top) and for the 1990s (bottom). (Source: Australian BoM and CSIRO)

3.4 HIGH IMPACT EVENTS

3.4.1 Tropical cyclones

The western Pacific is a relatively high frequency region for tropical cyclones. The Southern Hemisphere experiences most of its tropical cyclones during November–April, with a maximum in tropical cyclone frequencies during the January–March period when there is an average presence of one to two cyclones per day (Figure 6).[78] It is not rare for a cyclone to occur in the Southern Hemisphere on either side of the main cyclone season, in May and October.[79] The tropical cyclone frequency is higher in the region west of the dateline and tends to increase and extend further east during El Niño conditions.[80] The most significant hazards related to tropical cyclones are winds, heavy rainfall and storm surges, which in some conditions also result in landslides, coastal flooding and coastal erosion.

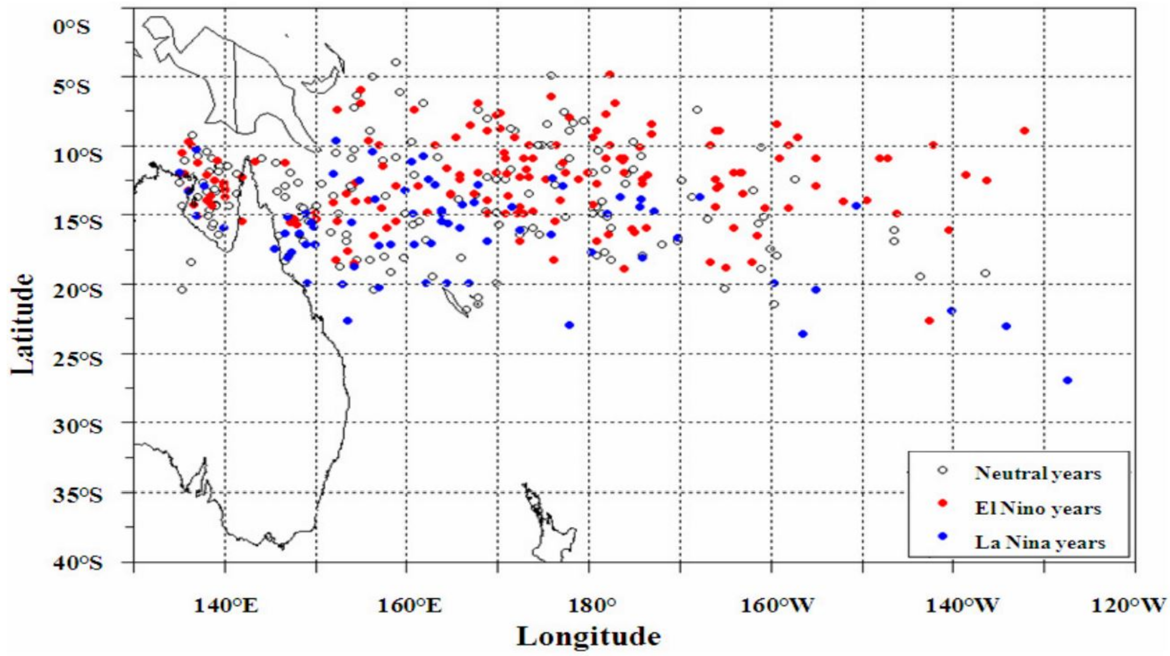


Figure 27. Locations where tropical cyclones formed over the South Pacific Ocean in neutral (grey), El Niño (red) and La Niña (blue) years during 1969–2006 (Source: Annales Geophysicae)[81]

The following table provides details of historical severe tropical cyclone events that reached Category 4 or 5 intensity on the Australian tropical cyclone intensity scale and affected one or more of the five Programme countries. These data show that Cook Islands appears to be most affected by Category 4 or 5 severe tropical cyclones, followed by Niue and Tuvalu.

Name	Dates as a Category 4 / 5	Duration	Sustained wind speeds	Land areas affected	Damage (USD)	Deaths
Val	4 – 17 December, 1991	14 days	165 km/h (105 mph)	**Tuvalu**, Samoan Islands	330 million	16
Joni	3 – 13 December, 1992	11 days	165 km/h (105 mph)	**Tuvalu**, Fiji	1.6 million	1
Gavin	3 – 12 March, 1997	10 days	185 km/h	**Tuvalu**, Fiji, Wallis and Futuna	18.3 million	18

[78] Government of Australia, 2011, PACCSAP Volume 1: Regional.
[79] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional.
[80] Hay, J. E., Pratt, C., 2013, Situation and Needs Assessment of Programming Priorities for Australia's Pacific Disaster Risk Management, Environment and Climate Change (DEC) Development Agenda and Delivery Strategy.
[81] Y. Kuleshov, Fabrice Chane-Ming, L. Qi, I. Chouaibou, Christophe Hoareau, et al, 2009, Tropical cyclone genesis in the Southern Hemisphere and its relationship with the ENSO. Annales Geophysicae, European Geosciences Union,27 (6), pp.2523-2538

			(115 mph)			
Dovi	8 – 9 February, 2003	18 hours	205 km/h (125 mph)	**Niue, Cook Islands**	Minimal	None
Heta	5 – 6 January, 2004	1 day, 12 hours	215 km/h (130 mph)	Samoan Islands, **Niue**, Tonga, Wallis and Futuna	225 million	3
Meena	6 February, 2005	18 hours	215 km/h (130 mph)	**Cook Islands**	20 million	None
Olaf	6 – 7 February, 2005	12 hours	215 km/h (130 mph)	Samoan Islands, **Cook Islands**	10 million	None
Nancy	10 – 17 February, 2005	8 days	175 km/h (110 mph)	**Cook Islands**	Severe	None
Percy	1 – 3 March, 2005	1 day, 12 hours	230 km/h (145 mph)	Tokelau, Samoan Islands, **Cook Islands**	25 million	None
Oli	29 January – 7 February, 2010	10 days	185 km/h (115 mph)	**Cook Islands**, French Polynesia	70 million	1
Pam	12 – 14 March, 2015	2 days, 12 hours	250 km/h (155 mph)	Fiji, Kiribati, Solomon Islands, **Tuvalu**, Vanuatu, New Caledonia, New Zealand	360 million	16
Ula	26 December, 2015 – 12 January, 2016	18 days	185 km/h (115 mph)	**Tuvalu**, Samoan Islands, Tonga, Fiji, Vanuatu, New Calendonia	Unknown	1
Winston	18 – 21 February, 2016	2 days, 18 hours	280 km/h (175 mph)	Vanuatu, Fiji, Tonga, **Niue**	1.4 billion	44
Gita	13 – 14 February, 2018	11 hours	205 km/h (125 mph)	Solomon Islands, Vanuatu, Fiji, **Niue**, Wallis and Futuna, Samoan Islands, Tonga	221 million	2

Table 21. Category 4 (unshaded) and 5 (shaded pink) South Pacific severe tropical cyclones that affected land areas of the five Programme countries in the past 30 years. (Source: Wikipedia)[82, 83]

The Australian Bureau of Meteorology maintains a database of tropical cyclone data in the Australian region since 1970 – the point at which reliable tropical cyclone data because available.[84] Observations for tropical cyclones developing within and crossing the EEZs of the five Programme countries are shown in the following figure and are summarised below. Tropical cyclones tend to affect Cook Islands, Niue and Tuvalu between November and April; and Palau and RMI between June and November. The data reported cover the period between the 1969/70 and 2010/11 cyclone seasons for Cook Islands, Niue and Tuvalu; and between 1977 and 2011 for Palau and RMI.[85]

[82] Wikipedia, 2020. List of Category 4 South Pacific severe tropical cyclones. Available at: https://en.wikipedia.org/wiki/List_of_Category_4_South_Pacific_severe_tropical_cyclones
[83] Wikipedia, 2020. List of Category 5 South Pacific severe tropical cyclones. Available at: https://en.wikipedia.org/wiki/List_of_Category_5_South_Pacific_severe_tropical_cyclones
[84] Australian Bureau of Meteorology, 2020. Tropical Cyclone Knowledge Centre – Past tropical cyclones. Available at: http://www.bom.gov.au/cyclone/tropical-cyclone-knowledge-centre/history/
[85] Australian Bureau of Meteorology and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports

- **Cook Islands:** 74 tropical cyclones developed within or crossed the Cook Islands EEZ, which represents an average of 18 per decade. Interannual variability ranges from zero in some seasons to six in the 1980/81, 1997/98 and 2005/06 seasons. Tropical cyclones were most frequent in El Niño years (28 cyclones per decade) and least frequent in La Niña years (6 cyclones per decade). The neutral season average is 13 cyclones per decade;
- **Niue:** 41 tropical cyclones developed within or crossed the Niue EEZ, which represents an average of 10 per decade. Interannual variability ranges from zero in some seasons to four in the 1979/80 season. There is no statistically significant difference between occurrences in El Niño, La Niña and neutral years.
- **Palau:** 97 tropical cyclones developed within or crossed the Palau EEZ, which represents an average of 28 per decade. Interannual variability ranges from zero in some seasons to seven in 1986. There is no statistically significant difference between occurrences in El Niño, La Niña and neutral years.
- **Marshall Islands:** 78 tropical cyclones developed within or crossed the RMI EEZ, which represents an average of 22 per decade. Interannual variability ranges from zero in some seasons to 11 in 1997. Tropical cyclones were most frequent in El Niño years (50 cyclones per decade) and least frequent in La Niña years (3 cyclones per decade). The neutral season average is 18 cyclones per decade.
- **Tuvalu:** 35 tropical cyclones developed within or crossed the RMI EEZ, which represents an average of 8 per decade. Interannual variability ranges from zero in some seasons to three in 1996/97 and 2005/06. Tropical cyclones were most frequent in El Niño years (12 cyclones per decade) and least frequent in La Niña years (3 cyclones per decade). The neutral season average is 7 cyclones per decade.

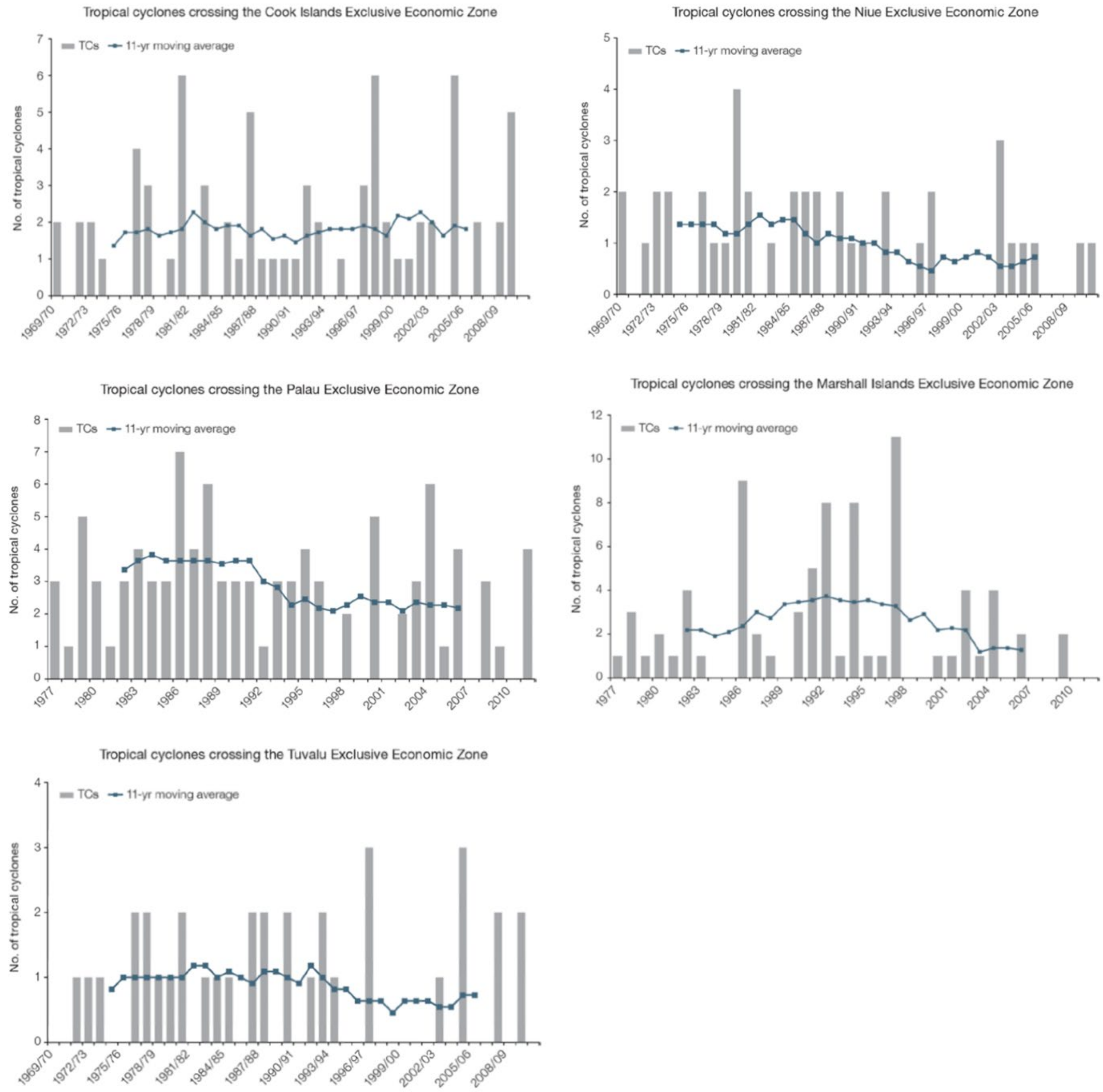


Figure 28. Time series of the observed number of tropical cyclones developing within and crossing the EEZs of the five Programme countries per season. The 11-year moving average is shown in blue. (Source: Australian BoM and CSIRO, 2014)

There are no significant trends in the overall number of tropical cyclones, or in the intensity of tropical cyclones, in the South Pacific Ocean over the period 1981–2007. ENSO plays a significant role in influencing tropical cyclone risk throughout the tropical Pacific.[86] During the El Niño phase, cyclones occurred with greater frequency in Cook Islands, RMI and Tuvalu.[87]

[86] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional

[87] Australian Bureau of Meteorology and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports

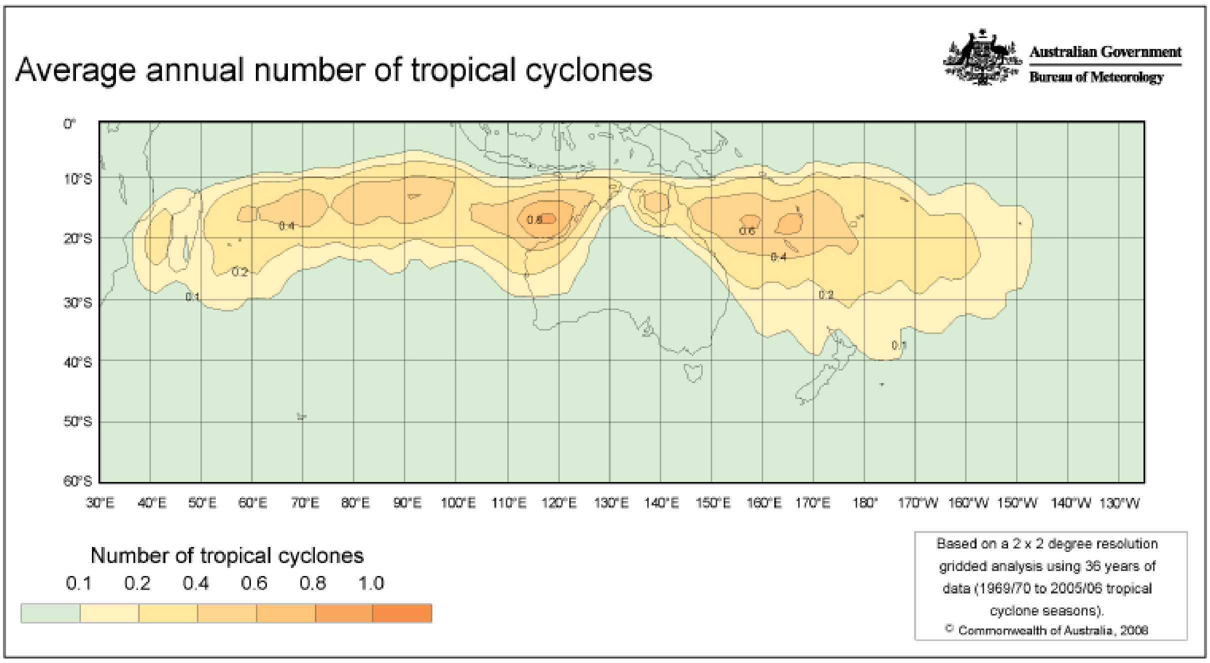


Figure 29. Average number of tropical cyclones per year in the Southern Hemisphere over the period of 1969/70 to 2005/06 (Source: Australian BoM and CSIRO, 2011)

An updated analysis through to the 2010–11 season shows a "slight decrease in the total number of cyclones, with little change in the numbers of the most intense. The record is too short to determine if this decrease is the result of a trend or if it is simply due to natural variability…[T]he absence of overall intensity trends for the south-west Pacific does not discount the possibility of local trends."[88]

3.4.2 Extreme sea level

Extreme sea levels can cause significant coastal impacts. The El Niño – Southern Oscillation (ENSO) has a major influence on sea levels across the Pacific and can influence the occurrence of extreme sea levels. During La Niña events, strengthened trade winds cause higher than normal sea levels in the western tropical Pacific, and lower than normal levels in the east. Conversely, during El Niño events, weakened trade winds lead to a drop in sea levels in the west and a rise in the east. Pacific islands within about 10° of the equator are most strongly affected by ENSO-related sea-level variations.

Tropical cyclones can cause severe short-term sea-level extremes in the Pacific due to storm surges and/or ocean waves. Falling atmospheric pressures associated with cyclones draw the ocean surface upwards at a rate of 1 cm for each hPa drop in pressure, and onshore winds can build up water levels against the coast (wind setup).[89]

3.4.3 Drought

Drought is a recurrent extreme climate event in the Pacific islands; and "there is a perception among Pacific island residents that the frequency and magnitude of drought has increased, particularly in the last couple of decades". McGree *et al.* corroborated this perception in reporting that the drought

[88] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

[89] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional.

frequency, duration and magnitude for the Pacific islands were greater during 1981 – 2010 than during 1951 – 1980. The trend is non-linear, and Interdecadal Pacific Oscillation (IPO) and ENSO were the predominant drivers of drought over the period 1951 – 2010. A strong lagged relationship in the year after the El Niño onset was found for locations southwest of the SPCZ and north of the ITCZ, which includes all five Programme countries.[90]

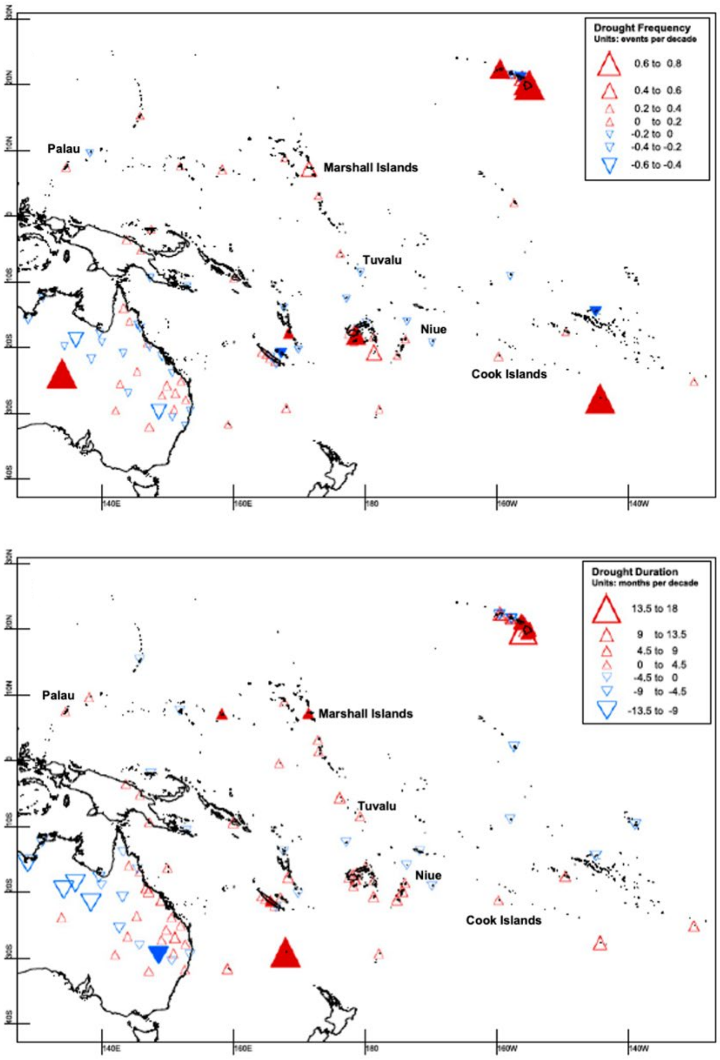


Figure 30. Trends in drought frequency (a) and total drought duration (b) for the period 1951 – 2010. Filled triangles represent trends significant at the 95% level. (Source: McGree *et al.*)

[90] McGree, S. *et al.* 2016. Journal of Climate. Trends and Variability in Droughts in the Pacific Islands and Northeast Australia

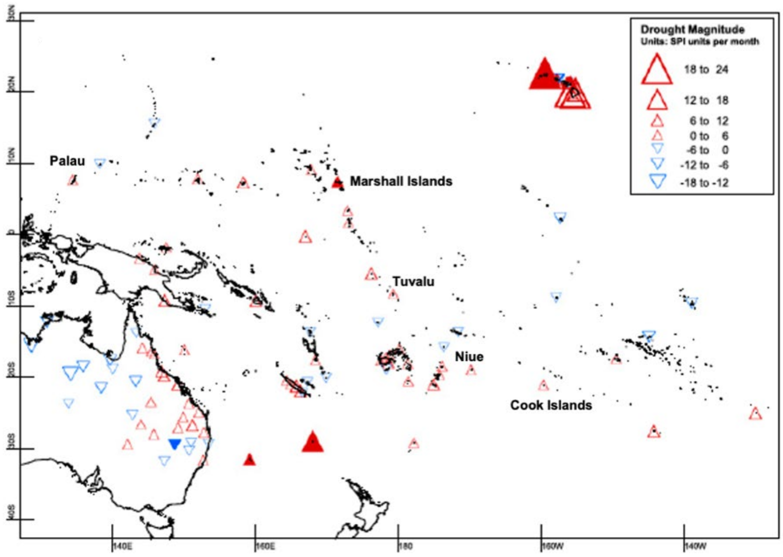


Figure 31. Trends in total drought magnitude for the period 1951 – 2010. Filled triangles represent trends significant at the 95% level. (Source: McGree *et al.*)

A more recent study by McGree *et al.* additionally calculated standardised precipitation evapotranspiration indices (SPEI) for eight annual precipitation subregions of the western tropical Pacific – as defined by cluster analyses. In the north ITCZ subregion – including Palau and RMI – a negative trend in September-November total annual precipitation was associated with increases in drought. No significant trends in drought-specific indices were reported for the regions covering Cook Islands, Niue and Tuvalu.[91]

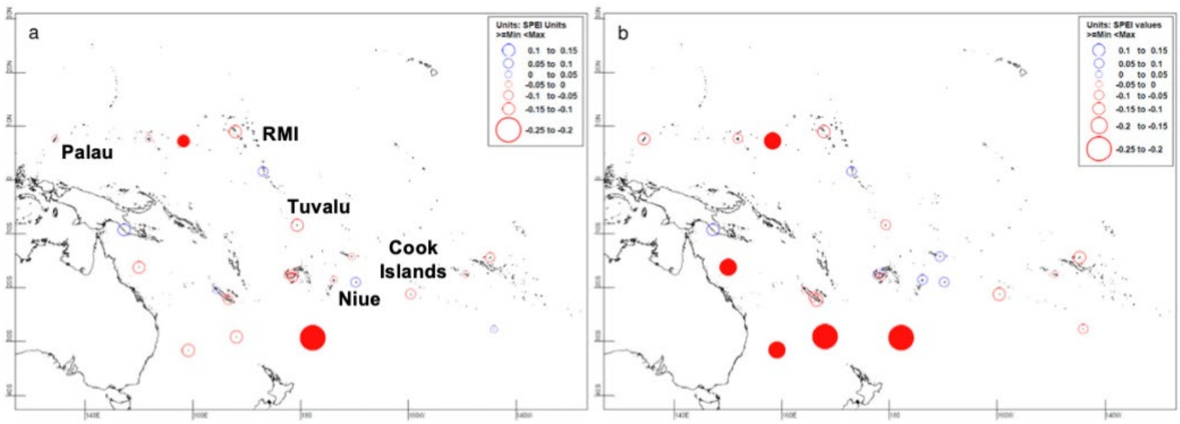


Figure 32. Trends in drought over 1951 – 2015: (a) SPEI-3 for August and (b) SPEI-6 for October. Increases or decreases in drought conditions are represented by red or blue circles, respectively. Solid circles represent trends that are significant at the 5% level. The size of the circle is proportional to the magnitude of the trend. (Source: McGree *et al.* – adapted with approximate locations of the Programme countries)

[91] McGree, S. *et al.* 2019. Journal of Climate. Recent Changes in Mean and Extreme Temperature and Precipitation in the Western Pacific Islands

3.4.4 Climate-related losses and damage

The Pacific is one of the most natural disaster prone regions in the world. The average annual direct losses caused by natural disasters in the South Pacific region are estimated at USD 284 million.[92] Between 1950 and 2013, approximately 9.2 million people were affected by natural disasters in the Pacific region, with 9,811 reported deaths.[93] Cook Islands, Niue, Palau and RMI are among the top 20 countries in the world experiencing the highest average annual losses from natural disasters as a percentage of GDP.[94]

The main recorded contributor to deaths and financial losses in the Pacific region is tropical cyclones.[95] However, it should be noted that data on both cyclones and other causes of death and damage are patchy and incomplete. Climate studies show that predicted higher ocean temperatures will lead to more intense tropical cyclones, with increased wind speed and rainfall.[96, 97]

All five Programme countries have assets, infrastructure and crops at risk of being damaged from natural disasters, with total replacement costs of over USD7.6 billion.[98] Buildings[99] at risk contribute the majority of the total (86.5 %), infrastructure such as major ports, airport, power plants, bridges and roads (13.2 %) and cash crops (0.4 %).[100] Average annual losses (AAL) per capita (USD 2019) for tropical cyclones alone are estimated at: 537 (Cook Islands), 2122 (Niue), 208 (Palau), 119 (RMI) and 336 (Tuvalu).[101] Some historical data is available on the deaths and financial damage caused by climate-related hazards caused by climate-related disasters in the Pacific region starting from 1831, but it most likely underestimates values, especially in earlier years.

[92] World Bank, 2012. Pacific Islands: Disaster Risk Reduction and Financing in the Pacific
[93] World Bank, 2013. PCRAFI Catastrophe Risk Assessment Methodology
[94] World Bank, 2013. Acting on Climate Change and Disaster Risk for the Pacific
[95] See Annex 3 – Economic Analysis
[96] Kang, N. and Elsner, J.B. 2015. Nature Climate Change. Trade-off between intensity and frequency of global tropical cyclones
[97] Patricola, C.M. and Wehner, M.F. 2018. Nature. Anthropogenic influences on major tropical cyclone events
[98] See Annex 3 – Economic Analysis
[99] "Buildings" include residential, commercial, public and industrial properties. See Pacific Catastrophe Risk Assessment and Financing Initiative data and documents. Available from: http://pcrafi.spc.int.
[100] UNDRR DesInventar data
[101] Pacific Catastrophe Risk Assessment and Financing Initiative adjusted for 2019. http://pcrafi.spc.int

Figure 33. Niue's capital Alofi devastated by Cyclone Heta – January 2004 (Source: Peter Bischoff / Getty Images)

Estimated deaths and losses caused by climate-related hazards provided on the UNDRR DesInventar platform are summarised in the table below, with the caveat that the data has significant gaps. For example, few countries quantify or record deaths and subsistence crop losses caused by drought or its long-term impacts on human health, despite these being significant.

Country	Deaths caused by Tropical Cyclones	Losses caused by Tropical Cyclones (USD)	Losses caused by Floods (USD)	Losses caused by Drought (USD)	Losses caused by Storm Surges (USD)
Cook Islands	79	174,828,456	50,000	0	0
Marshall Islands	13	322,800,000	2,010,000	0	500,000
Niue	24	62,422,910	0	0	0
Palau	16	15,000,000	0	0	0
Tuvalu	24	117,663,000	0	15,000,000	0

Table 22. Estimated deaths and losses caused by climate-related hazards. (Source: UNDRR DesInventar)

In 2016, widespread drought across the Pacific region caused states of emergency to be declared in Palau and RMI (and the Federated States of Micronesia). Disruptions to agriculture, tourism and industrial production caused severe economic losses. In Palau, all 21,000 residents were affected and particularly those in remote outer islands where 3-4 % of the population depends entirely on rainwater.[102] In RMI, the estimated economic impact for the 2016 financial year (FY) was approximately USD 4.9 million, including USD 2.9 million in gross production losses in the agriculture, education and industrial sectors. The agricultural sector was the most severely impacted by the drought and suffered a decline of USD 1.77 million in gross production, which corresponds to a 12% drop from normal production levels. The economic effects were equivalent to 3.4% of GDP for FY

[102] EEAS, 2018. PRO-Resilience Action 2016, Palau. Available at: https://eeas.europa.eu/delegations/fiji_de/47210/PRO-Resilience%20Action%202016,%20Palau

2015.[103] Estimated values for economic losses caused by the 2016 drought events were not quantified. However, at the end of 2016, the EU mobilised € 4.5 million from the European Development Fund (EDF) to support the three worst affected countries to build resilience for future El Niño events.[104]

Figure 34. Drought in Ailuk Atoll, RMI – 2013. (Source: PACC)

3.5 VULNERABILITY TO EXISTING CLIMATE VARIABILITY

3.5.1 Cook Islands

The geographical location of Cook Islands means that the country is highly vulnerable to natural disasters, particularly tropical cyclones, storm surge, flooding and drought. Environmental vulnerability assessments conducted by the Pacific Community in 2011 ranked the Cook Islands fifth highest of the 14 independent Pacific island countries—extreme rainfall, drought, wind and the low elevation of many of its inhabited islands contribute to its vulnerability.[105] Extreme events readily become natural disasters because of the Cook Islands' widely dispersed land masses, limited communications capacity and dependence on subsistence agriculture, fishing and tourism.

All coastal areas in the Cook Islands are at risk from high rainfall events, storm surges and damaging winds, but the risk levels for fixed assets along the north coast of Rarotonga are extreme. Exposure to approaching cyclones and the associated storm waves and strong winds combines with a high concentration of valuable fixed assets: the northern coast has the centre of government, commerce, culture and transport (sea and air) for the country. Structures in Avatiu–Rarotonga have an estimated replacement value of NZD48 million.[106]

Since 1955 the Cook Islands has experienced 30 or more natural disasters which have resulted in 34 deaths and cost about USD 47 million. Cyclones account for 86% of past disasters and on average a

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[103] Republic of the Marshall Islands, 2015. Post Disaster Needs Assessment of the 2015-2016 Drought

[104] European Union External Action, 2017. EU and SPC agreement supports FSM, Marshall Islands and Palau to build resilience to El Niño. Available at: https://eeas.europa.eu/headquarters/headQuarters-homepage/30142/eu-and-spc-agreement-supports-fsm-marshall-islands-and-palau-build-resilience-el-ni%C3%B1o_km

[105] Kaly, U.L., Pratt, C.R. and Mitchell, J.,2004: The Demonstration Environmental Vulnerability Index (EVI). SOPAC Technical Report 384

[106] PCRAFI, 2011: Country Risk Profile: Cook Islands. Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), World Bank.

cyclone costs the Cook Islands USD 4.7 million. The total economic cost (damage and losses combined) of Tropical Cyclone Pat in 2010 could have been as high as USD 15 million or 8% of GDP.[107]

In 1997 an UNDAC team conducted a detailed situation assessment of Manihiki after Tropical Cyclone Martin: "The report confirms the severity of the damage to infrastructure (the water and power supply systems, the harbour facilities, airstrip, and 95 per cent of the limited road network were damaged), to private housing (only 21 per cent intact), and to community life (the primary health and education systems have been totally disrupted)." It also emphasises the long term threats to self-sufficiency posed by the degradation of the lagoon, which threatens not only fishing but also the main income generating activity (and a major export from the Cook Islands), black pearl cultivation.[108]

Over a devastating one-month period in 2005, five strong cyclones struck the Cook Islands. Four reached the maximum category 5 rating, causing massive damage to infrastructure and agriculture.[109] The entire taro plantation areas on Pukapuka were inundated by saltwater as the result of a storm surge. It was three years before taro could again be grown on the island. In the same cyclone, many rainwater tanks lost their roof catchments and the few freshwater wells were polluted by seawater. Coconuts could not be used as an emergency food as most had been torn from trees and lay rotting on the ground. The combined effects left the island with no fresh water source until aid arrived. One study tracked the recovery of the freshwater lens on the island and found it took 11 months to recover.[110] The anticipated increase in the intensity of cyclones is one of the most urgent risks faced by the Cook Islands, its small islands and fragile coastal ecosystems.

Effects of disasters on the natural environment and communities tend to be long-lasting, with high rehabilitation and recovery costs. Risks and impacts can differ between the low atoll islands and the higher volcanic islands with their richer soils and more varied ecosystems, but both are highly susceptible to damage from strong winds and the storm surge associated with tropical cyclones. All the Cook Islands experience persistent coastal erosion that threatens roadways, agro-forestry production, habitable dwellings, and shallow coastal aquifers.

Disasters, many of which are exacerbated by climate change and which are increasing in frequency and intensity, significantly impede progress towards sustainable development. Evidence indicates that exposure of people and assets in all countries has increased faster than vulnerability has decreased [111], generating new risks and a steady rise in disaster related losses, with significant economic, social, health, cultural and environmental impacts in the short, medium and long term, especially at the local and community levels. This is the case in the Cook Islands, where increasing population means that more people are exposed to climate risks, including health risks—recent changes have resulted in more suitable environments for many diseases, particularly those borne by mosquitoes. Recurring small-scale disasters and slow onset disasters particularly affect communities like those in the Pa Enua (outer islands) of the Cook Islands. Households and the few and small Pa Enua enterprises constitute a high percentage of all losses.[112]

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[107] ibid
[108] UN Department of Humanitarian Affairs, 1997, Cook Islands Tropical Cyclone Martin Situation Report No. 2.
[109] ibid
[110] Hay J. E and others, 2016, Research and Analysis on Climate Change and Disaster Risk Reduction.
[111] Vulnerability is defined in the Hyogo Framework for Action as "the conditions determined by physical, social economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards."
[112] UNISDR, 2015, United Nations Sendai Framework for Disaster Risk Reduction 2015-2030.

3.5.2 Niue

Niue has a tropical maritime climate and two distinct seasons—a warm wet season from November to May and a cooler dry season from June to October. Its annual average temperature is around 24°C. Its wet season is affected by the movement of the South Pacific Convergence Zone. The average annual rainfall is 2052mm. Torrential downpours of rain during the wet season are common and account for approximately 68% of Niue's total annual rainfall (JNAP, 2012). "Annual rainfall in the wettest years can be almost four times the rainfall in the driest years. Tropical cyclones affect Niue between November and April. El Niño events tend to bring drier than normal conditions, particularly in the wet season. They also bring cooler conditions during the dry season. La Niña events usually bring wetter conditions." [113]

Over the last four decades, Niue has experienced an average of ten tropical cyclones per decade. "Niue is largely unprepared to deal with intense tropical cyclones, given the age and state of disrepair of most homes and other structures on the island and the location of most critical infrastructure along the coast."[114] In 1989, Cyclone Ofa changed Niue from a food exporting country to one dependent on imports for two years, and Niue is still recovering from Cyclone Heta. In 2004 Heta caused USD37 million of damage, three times Niue's GDP at the time, and effectively destroyed the capital city of Alofi and most of the island's infrastructure.[115] The national museum was destroyed, with most of the country's cultural heritage records.

"In addition to cyclone risk, rainfall records since 1905 show high levels of variability from year to year. This long-term observation is supported by Meteorological Service data from the last decade showing that annual rainfall ranged from 1276 mm to 3218 mm. Models suggest that this baseline variability will continue in the future with increased incidence of extreme rainfall events caused by climate change. Rainfall is expected to be less frequent but more intense during dry seasons, creating additional risk of erosion, coastal inundation, and damage to crops (JNAP 2012). According to officials at the Meteorological Service, this rainfall variability has resulted in the loss of entire growing seasons and will make certain crops less tenable moving forward. For example, there has been only one successful mango growing season since 2004 (Ridge to Reef Programme, 2016). Taro, Niue's subsistence crop and primary export, is especially vulnerable given Niue's thin soil. Taro begins to wither after only two weeks without rain (JNAP, 2012)." [116]

3.5.3 Palau

The average daily temperature in Palau is 28°C throughout the year. Changes in the temperature from season to season are relatively small (0.8°C) and strongly tied to changes in the surrounding ocean temperature. The main wet season is from May to October, and the driest months are February to April.[117] Palau's climate is also influenced by the trade winds, used by pre-historic explorers to travel across the Pacific Ocean—from December to March the winds come from the north-east and then during April, their frequency decreases. In May, the winds blow predominantly from south-east to north-east.[118]

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[113] Niue, 2015, Current and Future Climate of Niue PACCSAP.
[114] Ibid
[115] Niue, 2012, Niue's Joint National Action Plan for Disaster Risk Management and Climate Change.
[116] UNDP, 2017, Increasing the resilience of Niue through a comprehensive approach to climate information services and early warning systems.
[117] PACCSAP, 2013, Current and future climate of Palau.
[118] Ibid

On average Palau receives more than about 200 mm rainfall every month, because of its location on the edge of the Pacific Warm Pool and the year-long influence of the Intertropical Convergence Zone. This band of heavy rainfall is caused by air rising over warm water where winds converge, resulting in thunderstorm activity. It extends across the Pacific just north of the equator and is most intense in the Northern Hemisphere wet season. Between June and August, the West Pacific Monsoon brings heavy rainfall to Palau. The Monsoon is driven by large differences in temperature between the land and the ocean. It moves north to mainland Asia during the Northern Hemisphere summer and south to Australia in the Northern Hemisphere winter.[119]

Palau's climate varies considerably from year to year in response to the El Niño Southern Oscillation (ENSO), a natural climate pattern that occurs across the tropical Pacific Ocean and affects weather around the world. There are two extreme phases of the ENSO—El Niño and La Niña—and a neutral phase. In Koror, El Niño events tend to bring dry seasons that are drier and cooler than normal, while La Niña events usually bring wetter than normal conditions. El Niño brings drought to Palau and, according to some estimates, it extends the dry season from its usual 1.5 months to 2-3 months. Drought seriously affects crops and livelihoods in general. During a La Niña event, higher than average rainfall is expected, with more intense and more frequent storms.[120]

Typhoons[121] tend to affect Palau between June and November. In the 42-year period between the 1969 and 2010 seasons, 97 typhoons developed in or crossed into the Palau Exclusive Economic Zone, an average of 23 typhoons per decade. The number of typhoons varies widely from year to year, with none in some seasons but up to seven in others. Over this period typhoons occurred in El Niño, La Niña and neutral years.

"In 1998 an El Niño event bleached 30% of Palau's coral reefs in some areas and in extreme cases 100% of the corals were bleached. During this time, the lowest amount of rainfall was recorded and streams dried up while larger rivers had low flow. Water hours were applied to public water supply systems due to lower intake rates from rivers".[122]

Since 2012, Palau has declared three states of emergency related to natural hazards. In 2012, Typhoon Bopha caused about $6.3 million in initial damages (2.9% of GDP). In 2013, initial damage from Typhoon Haiyan was estimated to be $8.5 million (3.7% of GDP).

In 2016, a severe drought associated with El Niño weather conditions led to water shortages across Palau and generated significant sanitation and hygiene risks. "The city's only dam had dried up and the only alternate source of water, the Ngerikiil River, was at 19 percent capacity. This led to a drop-in school attendance rates, as children were hungry and dehydrated, and faced a high risk of malnutrition due to crop failure, water shortages and poor sanitation".[123] The drought also led to the closure of Jellyfish Lake, a major tourist attraction. Consequently, GDP growth is estimated to have fallen to minus 0.5% in FY2017 as tourist arrivals declined.

The immediate response to the emergencies was funded by budget reallocations and emergency appropriations approved by the Palau National Congress and coordinated through the National Emergency Management Office (NEMO). Palau also received support from development partners for humanitarian relief and reconstruction following the typhoons. However, the immediate

[119] Ibid

[120] SPREP, 2007, Pacific Adaptation to Climate Change (PACC) Palau Project Proposal.

[121] Tropical cyclone is a generic term used by meteorologists to describe a rotating, organized system of clouds and thunderstorms that originates over tropical or subtropical waters and has closed, low-level circulation. A tropical cyclone originating in the north west Pacific is called a typhoon (NOAA), available at <https://oceanservice.noaa.gov/facts/cyclone.html> [August 2019])

[122] SPREP, 2007, Pacific Adaptation to Climate Change (PACC) Palau Project Proposal.

[123] Government of Palau, 2016, Palau Disaster Management Reference Handbook.

response was constrained by weak emergency response systems (including capacity, equipment, institutions, and funds).[124]

3.5.4 Marshall Islands

The Marshall Islands' average temperature is relatively constant year-round. Changes in the temperature from season to season are relatively small around 1°C (2°F) and strongly tied to changes in the surrounding ocean temperature. Both Majuro and Kwajalein have a dry season from around December to April and a wet season from May to November, but rainfall varies greatly from north to south of the group of islands. The atolls to the north receive less than 50 inches (1250 mm) of rain each year and are very dry in the dry season, while atolls closer to the equator receive more than 100 inches (2500 mm) of rain each year.

The Intertropical Convergence Zone brings rainfall to the Marshall Islands throughout the year. This band of heavy rainfall is caused by air rising over warm water where winds converge, resulting in thunderstorm activity. It extends across the Pacific just north of the equator and is most intense and closer to the Marshall Islands during the wet season. Rainfall is also sometimes influenced by the West Pacific Monsoon, which brings wetter conditions when it is active over the Marshall Islands.

The climate of the Marshall Islands varies considerably from year to year due to the El Niño-Southern Oscillation (ENSO). This is a natural climate pattern that occurs across the tropical Pacific Ocean and affects weather around the world. There are two extreme phases of the El Niño-Southern Oscillation—El Niño and La Niña—and a neutral phase. Conditions during La Niña years are generally wetter than normal. El Niño events tend to bring warmer than normal wet seasons and warmer, drier dry seasons.

Typhoons (tropical cyclones), droughts and storm waves are the extreme events that most impact the Marshall Islands. Typhoons affect the Marshall Islands late in the wet season (June to November). In the 33-year period between the 1977 and 2010 seasons, 78 typhoons developed or crossed into the Marshall Islands Exclusive Economic Zone, an average of 22 typhoons per decade. The number of typhoons varies widely from year to year, with none in some seasons but up to 11 in others. During an El Niño event the sea surface temperatures increase in and to the east of the Marshall Islands. This allows more intense typhoons to form.

Droughts generally occur in the first four to six months of the year following an El Niño. Following severe El Niño events, rainfall can be reduced by as much as 80%. The dry season begins earlier and ends much later than normal during an El Niño. Analysis of historical rainfall data shows an increase in drought duration and magnitude in southern RMI since 1951.[125]

Prolonged droughts are devastating to subsistence farmers and gardeners, and quickly cause water stress in urban centres.

3.5.5 Tuvalu

Subsistence farming and fishing are Tuvalu's main economic activities, and these have long been constrained by poor soil quality, limited access to fresh water and the high cost of imported fuel. The sectors most vulnerable to climate variability are water resources, agriculture and fisheries, infrastructure and coastal zone management.

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[124] Ibid.
[125] McGree, S. *et al.* 2016. Journal of Climate. Trends and Variability in Droughts in the Pacific Islands and Northeast Australia

Tuvalu experiences frequent droughts because of its location near the Pacific equatorial dry zone. Dry periods are more severe in the northern than the southern islands, notably in the months of August to October. Dry years in Tuvalu are associated with a positive Southern Oscillation Index (the cold phase of ENSO)."[126] There is a lagged relationship between La Niña and drought, especially for the southern islands, with rainfall suppression beginning several months after La Niña onset. Drought in Tuvalu is estimated to have caused USD15m worth of damage in the period for which data is available.[127] The most recent drought, in 2011, was particularly severe. An emergency was declared, water was rationed, and New Zealand began supplying fresh water and sent two de-salination facilities.

"There are frequent thunderstorms in the wet season. Tropical cyclones mainly develop in the Tuvalu area and move to higher latitudes with a few hitting the islands in the warm, rather than the cold phase of ENSO. Spring tides and tropical cyclones are among the main extreme events that affect Funafuti. As well as high winds and rainfall, tropical cyclones also cause storm surges and swells. The resulting flooding causes agricultural losses, particularly of taro crops, and damage to buildings and roads along the coast. In the 41-year period between 1969 and 2010, 33 tropical cyclones passed within 400km of Funafuti. Over this period, cyclones occurred more frequently in El Niño years."[128]

In 2015 Tropical Cyclone Pam, the largest storm to hit Tuvalu in living memory, inundated entire islands, destroyed critical infrastructure and livelihoods and necessitated a major recovery and reconstruction programme. The cost to the country's economy of losses and damage equated to more than 25 per cent of GDP. It is estimated 45% of the population was displaced.[129]

The Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), administered by SPC's Geoscience Division, has improved disaster risk analysis for earthquakes, tsunamis and tropical cyclones affecting Pacific island countries. PCRAFI's assets database as well as key economic values derived from the World Bank are used to provide a summary of Tuvalu's exposure as at 2017. It is estimated that the replacement value of all the assets in Tuvalu is USD268 million, of which about 85% represents buildings and 14% represents infrastructure.[130]

Even in the absence of climate change, Tuvalu is expected to incur, on average, 0.2 million USD per year in losses due to tropical cyclones. In the next 50 years, Tuvalu has a 50 percent chance of experiencing a loss exceeding 4 million USD and casualties larger than 15 people, and a 10 percent chance of experiencing a loss exceeding 9 million USD and casualties larger than 50 people. [131]

3.6 CLIMATE PROJECTIONS

3.6.1 Temperature

The IPCC's Fifth Assessment Report (AR5) states that the change in global surface temperature by the end of the 21st century is *likely* to exceed 1.5 °C relative to 1850 to 1900 for all RCP4.5, RCP6.0 and RCP8.5. Furthermore, it is "*virtually certain* that there will be more frequent hot and fewer cold

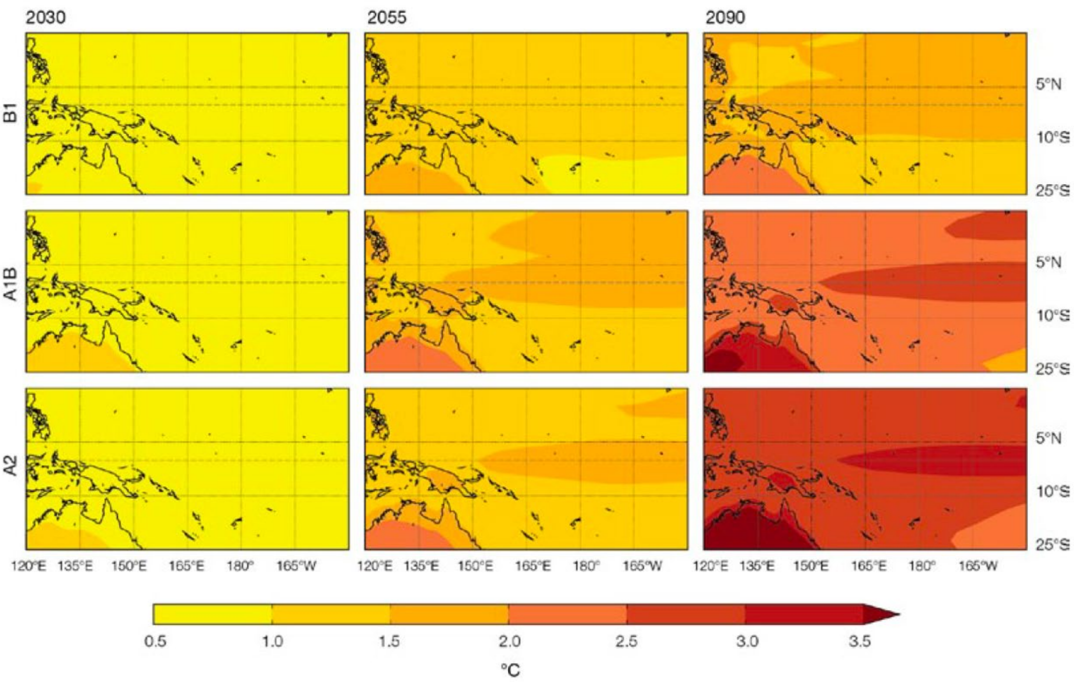
[126] Government of Palau, 2015, Current and Future Climate of Tuvalu, PACCSAP.
[127] UNDRR, Sendai Framework for Disaster Risk Reduction, available at <https://www.desinventar.net/DesInventar/profiletab.jsp?countrycode=pac&continue=y> [August 2019]
[128] Government of Tuvalu, 2011, National Strategic Action Plan for Climate Change and Disaster Risk Management – 2012-2016.
[129] Australian DFAT, 2018. Australia's Commitment to Climate Change Action in Tuvalu
[130] SPC, 2011, PCRAFI.
[131] SPC, 2011, PCRAFI.

temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase."[132]

The magnitude of the projected warming over the Pacific region is about 70% of the magnitude of the global average warming for all emissions scenarios. This finding is linked to the fact that the oceans have been warming and are projected to warm into the future at a lower rate than land areas. The Pacific region is dominated by ocean; therefore, the temperature increases in the region are projected to be less than those generally seen elsewhere.[133]

Compared to the base period 1986 – 2005, climate models indicate that for daily mean temperature:

- By 2030, the projected warming in the western tropical Pacific is around +0.5 to 1.0 °C under all emissions scenarios;
- By 2050, warming under the very low emissions scenario is projected to plateau at around +0.5 to 1.0 °C but under the very high emissions scenario, warming is projected to be around +1.0 to 2.0 °C;
- By 2090, the projected warming is around:
  - +0.5 to 1.0 °C for the very low emissions scenario;
  - +1.0 to 2.0 °C for the medium emissions scenario;
  - +1.5 to 3.0 °C for the high emissions scenario;
  - +2.0 to 4.0 °C for the very high emissions scenario;
- Extreme temperatures that occur once every 20 years on average are projected to increase approximately in line with average temperatures. [134]



[132] IPCC, 2013. Climate Change 2013: The Physical Science Basis

[133] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional – Executive Summary

[134] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

Figure 35. Projected multi-model mean changes in annual mean surface air temperature for 2030, 2055 and 2090, relative to 1990, under the B1 (low), A1B (medium) and A2 (high) emissions scenarios. All models agree on the direction of change in all locations. (Source: Australian BoM and CSIRO, 2011)

There is *very high confidence* that the temperature of extremely hot days and extremely cool days will increase because:

- A change in the range of temperatures, including the extremes, is physically consistent with rising greenhouse gas concentrations;
- This is consistent with observed increases in extreme temperatures around the world over recent decades; and
- All the CMIP5 models agree on an increase in the frequency and intensity of extremely hot days and a decrease in the frequency and intensity of cool days.

The IPCC AR5 concurs that annual average air and sea surface temperature are projected to increase for all tropical Pacific countries. By 2055, under the high A2 emissions scenario, the increase is projected to be 1°C to 2°C. A rise in the number of hot days and warm nights is also projected, and a decline in cooler weather, as already observed. For a low emission scenario, the lower range decreases about 0.5ºC while the upper range reduces by between 0.2°C and 0.5°C. In summary, based on Coupled Model Intercomparison Project 3 (CMIP3) and Coupled Model Intercomparison Project 5 (CMIP5) model projections and recently observed trends, it is very likely that temperatures, including the frequency and magnitude of extreme high temperatures, will continue to increase through the 21st century.[135]

Regional temperature projections

This section presents a series of figures showing regional patterns of temperature change computed from global climate model outputs gathered as part of the Coupled Model Intercomparison Project Phase 5 (CMIP5). The projections are made under the Representative Concentration Pathway (RCP) scenarios – RCP2.6, RCP4.5, RCP6.0 and RCP8.5. Projections for the Pacific islands are split into three regions:

- **Northern Tropical Pacific** – Palau and RMI;
- **Equatorial Pacific** – Cook Islands and Tuvalu (north);
- **Southern Tropical Pacific** – Cook Islands and Tuvalu (south); and Niue.

The time series show annual temperature change relative to 1986 – 2005 averaged over all grid points in each region. Thin lines denote one ensemble member per model, thick lines denote the CMIP5 model mean. On the right hand side, the 5th, 25th, 50th (median), 75th and 95th percentiles of the distribution of 20-year mean changes are given for 2081 – 2100 for the four RCP scenarios.

The maps show 20-year averages in temperature change for the near term (2016 – 2035), for the mid-term (2046 – 2065) and for the long term (2081 – 2100) with respect to 1986 – 2005 for each scenario. For each point, the 25th, 50th and 75th percentiles of the distribution of the CMIP5 ensemble are shown. Hatching denotes areas where the 20-year mean differences of the percentiles are less than the standard deviation of the model-estimated present day natural variability of the differences.[136]

[135] IPCC, 2013. Climate Change 2013: The Physical Science Basis
[136] IPCC, 2013. Climate Change 2013: The Physical Science Basis

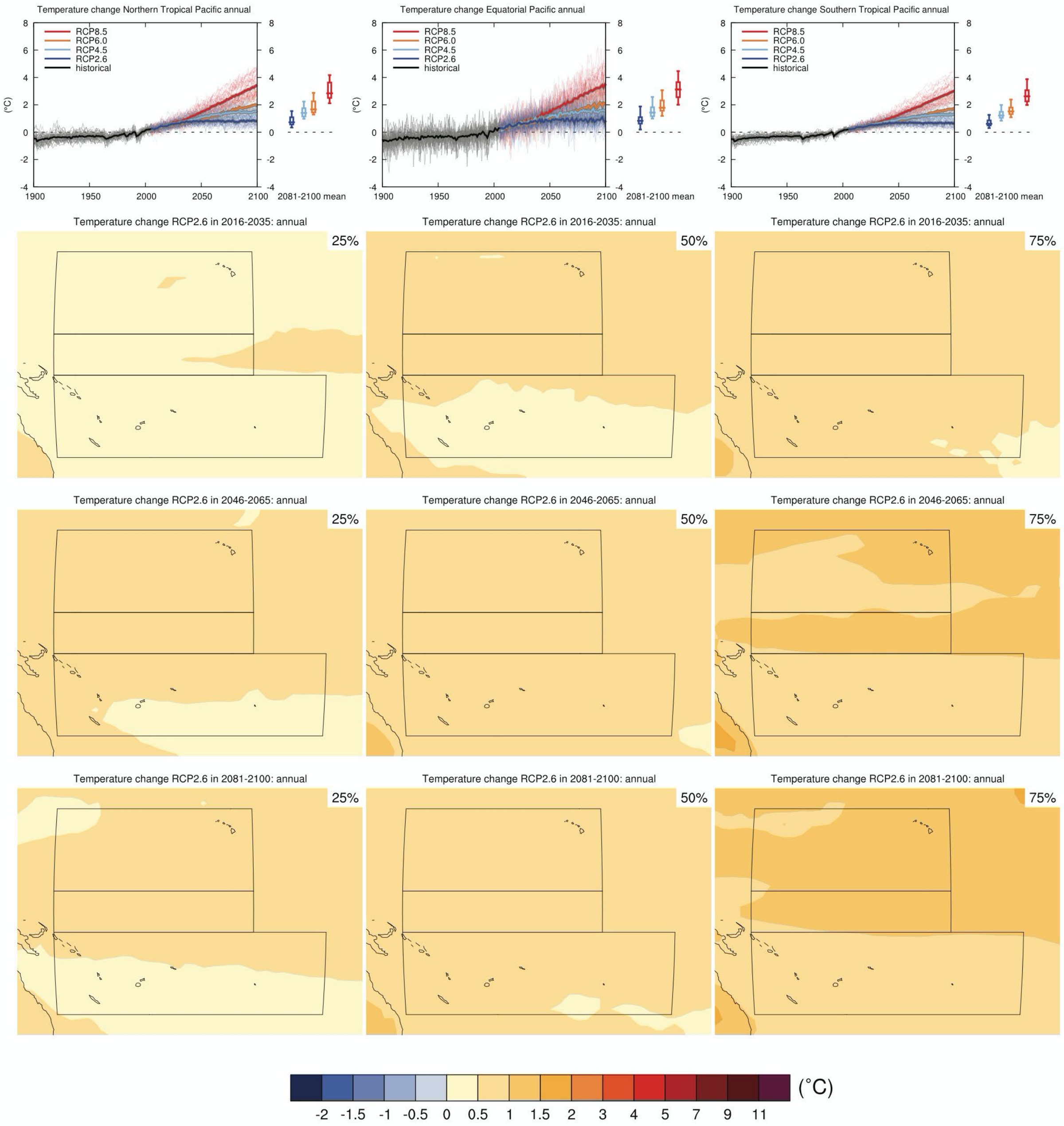


Figure 36. (Top) Time series of annual temperature change relative to 1986 – 2005 averaged over all grid points in the Northern Tropical Pacific, Equatorial Pacific and Southern Tropical Pacific. (Below) Maps of temperature changes in 2016 – 2035, 2046 – 2065 and 2081 – 2100 with respect to 1986 – 2005 in the RCP2.6 scenario. (Source: IPCC AR5, 2013)

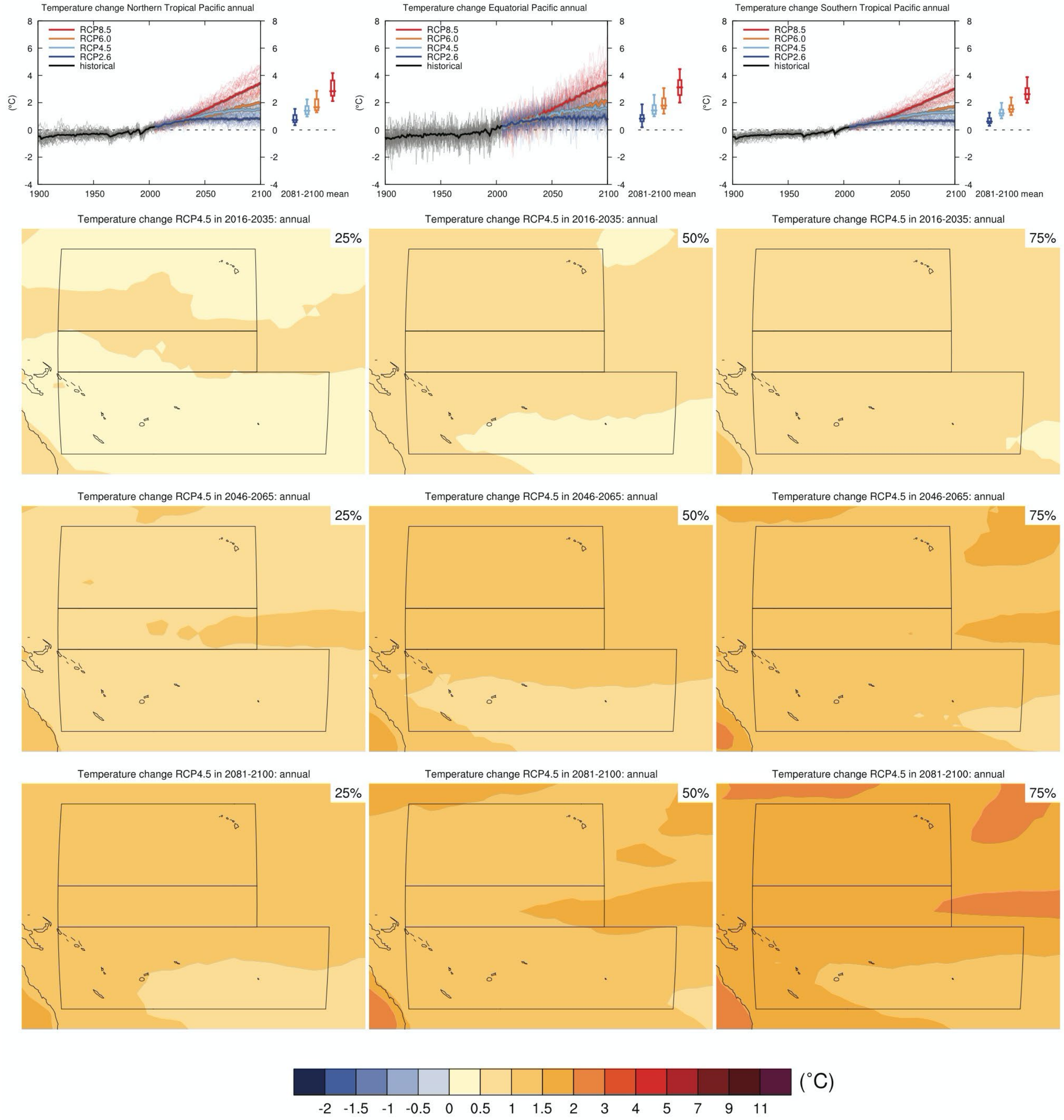


Figure 37. (Top) Time series of annual temperature change relative to 1986 – 2005 averaged over all grid points in the Northern Tropical Pacific, Equatorial Pacific and Southern Tropical Pacific. (Below) Maps of temperature changes in 2016 – 2035, 2046 – 2065 and 2081 – 2100 with respect to 1986 – 2005 in the RCP4.5 scenario. (Source: IPCC AR5, 2013)

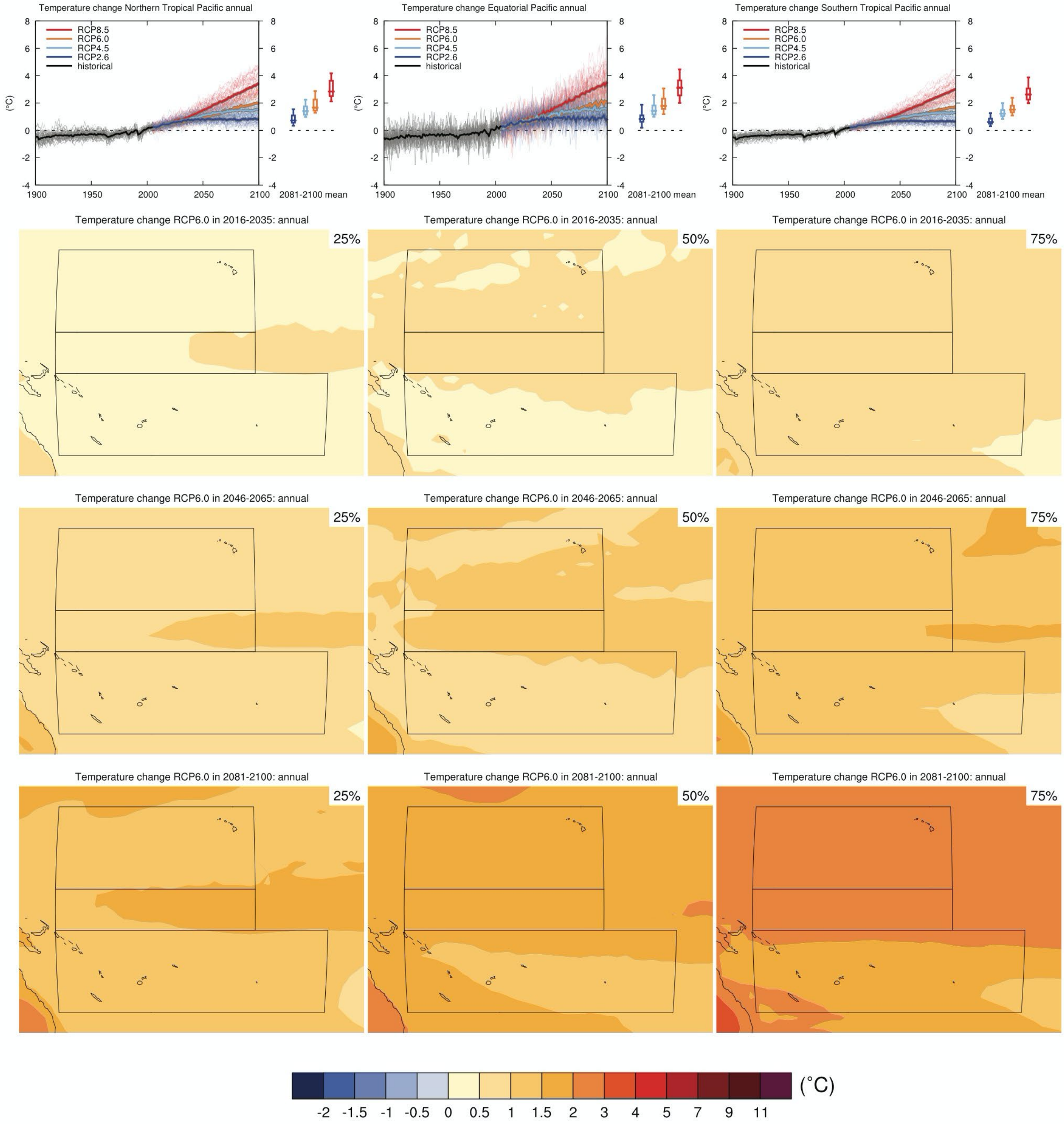


Figure 38. (Top) Time series of annual temperature change relative to 1986 – 2005 averaged over all grid points in the Northern Tropical Pacific, Equatorial Pacific and Southern Tropical Pacific. (Below) Maps of temperature changes in 2016 – 2035, 2046 – 2065 and 2081 – 2100 with respect to 1986 – 2005 in the RCP6.0 scenario. (Source: IPCC AR5, 2013)

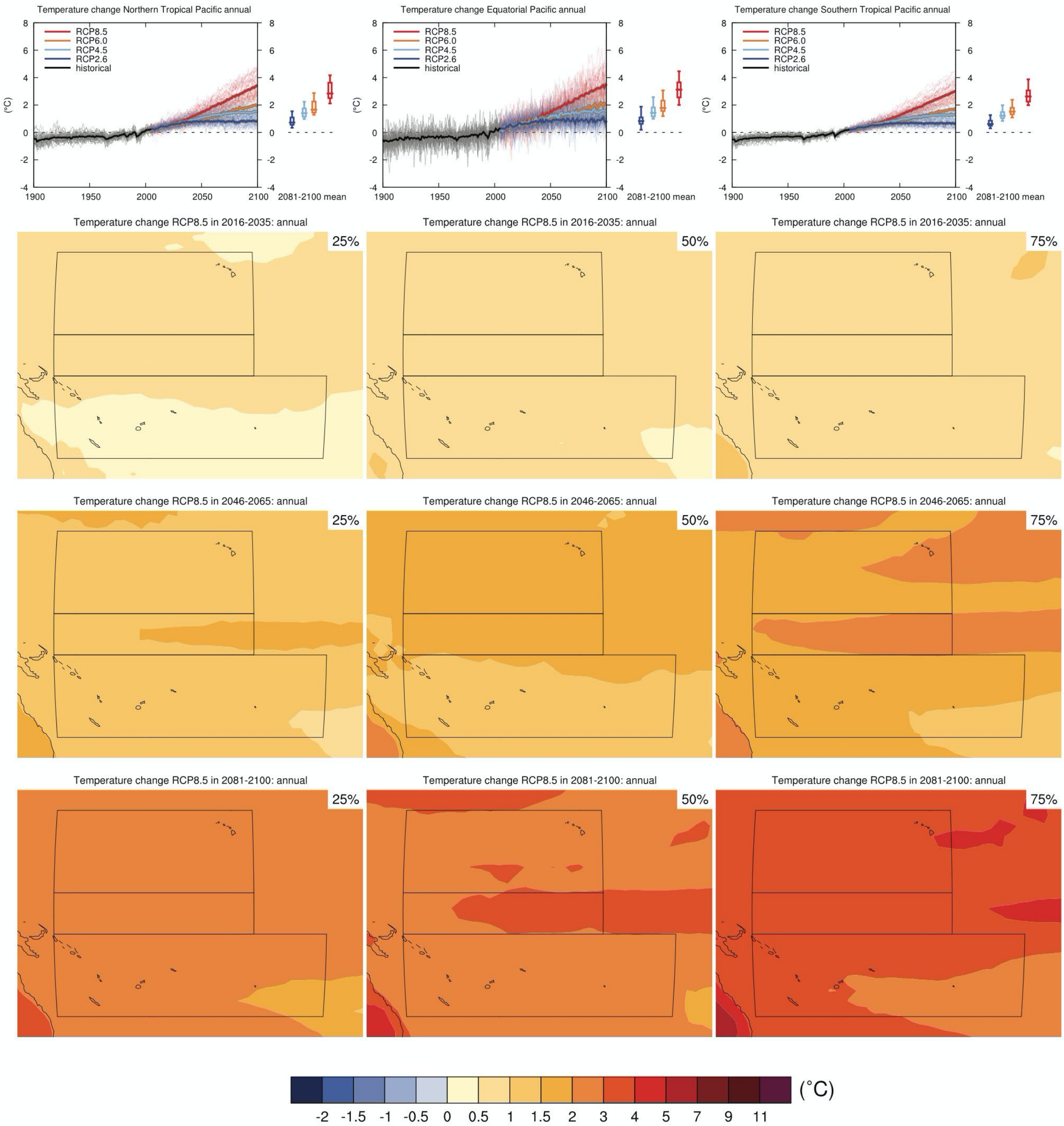


Figure 39. (Top) Time series of annual temperature change relative to 1986 – 2005 averaged over all grid points in the Northern Tropical Pacific, Equatorial Pacific and Southern Tropical Pacific. (Below) Maps of temperature changes in 2016 – 2035, 2046 – 2065 and 2081 – 2100 with respect to 1986 – 2005 in the RCP8.5 scenario. (Source: IPCC AR5, 2013)

Country-specific temperature projections

The historical and simulated mean annual surface air temperature in the five Programme countries are shown in the following figure and are summarised below.[137] Additional values for projected changes are provided in Appendix 2.

Further warming is expected over all countries with *very high confidence*. The temperature on extremely hot days is projected to increase by about the same as average temperature. Under all RCPs, the warming is up to 1.0 °C by 2030 in Cook Islands, Palau and Tuvalu; and up to 1.1 °C by 2030 in Niue and RMI. However, there is a growing difference in warming between each RCP after 2030:

- In the Northern **Cook Islands** by 2090, a warming of 2.0 – 3.8 °C is projected for RCP8.5 (very high emissions) while a warming of 0.5 – 1.2 °C is projected for RCP2.6 (very low emissions);
- In **Niue** by 2090, a warming of 1.7 – 4.2 °C is projected for RCP8.5 while a warming of 0.2 – 1.1 °C is projected for RCP2.6;
- In **Palau** by 2090, a warming of 2.1 – 4.0 °C is projected for RCP8.5 while a warming of 0.4 – 1.2 °C is projected for RCP2.6;
- In northern **Marshall Islands** by 2090, a warming of 2.2 – 4.2 °C is projected for RCP8.5 while a warming of 0.5 – 1.2 °C is projected for RCP2.6;
- In **Tuvalu** by 2090, a warming of 2.0 – 4.0 °C is projected for RCP8.5 while a warming of 0.4 – 1.3 °C is projected for RCP2.6.

[137] Australian Bureau of Meteorology and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports

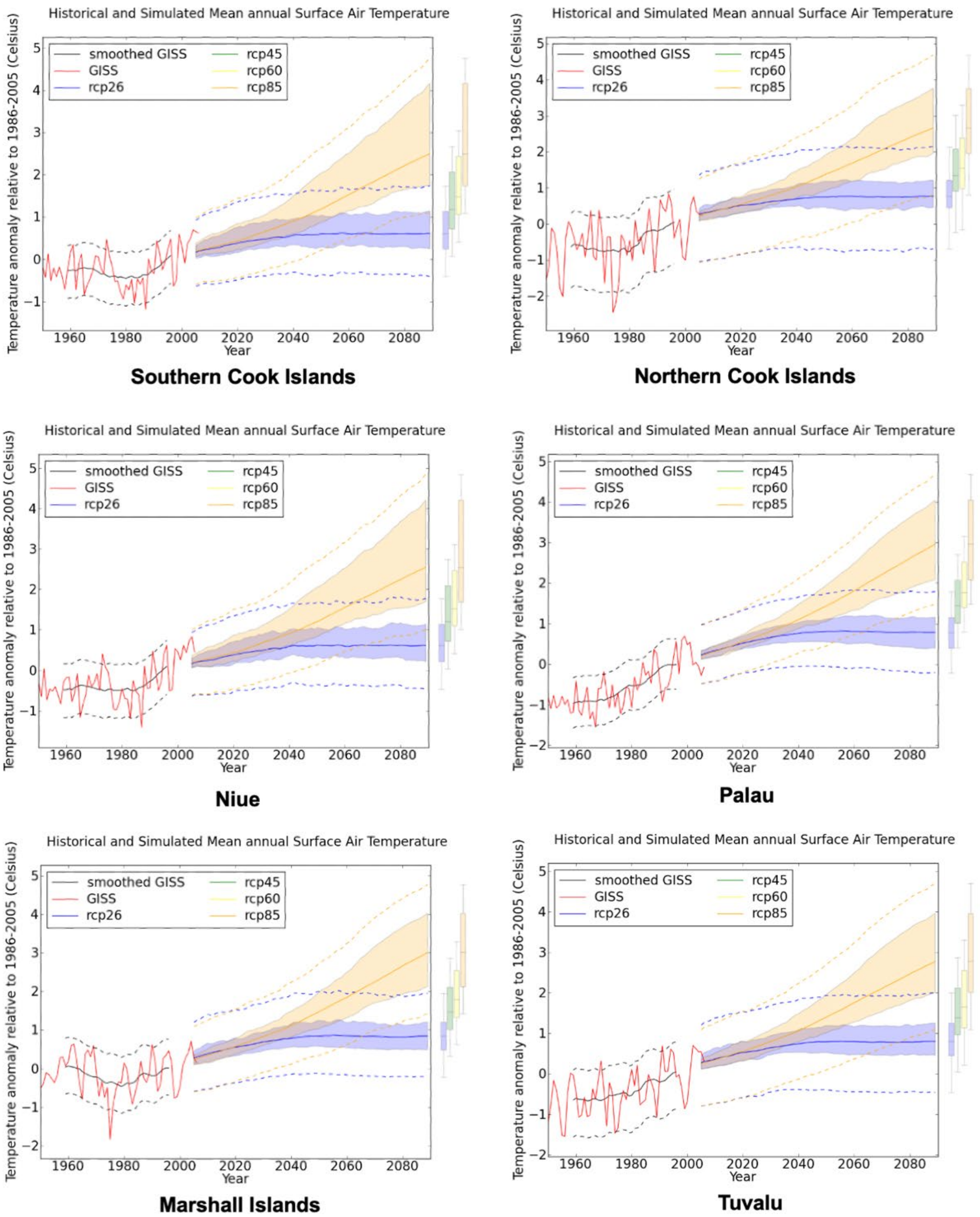


Figure 40. Historical and simulated mean annual surface air temperature in the five Programme countries. The graph shows the anomaly (from the base period 1986 – 2005) in surface air temperature from observations (the GISS dataset, in red) from the CMIP5 models under the very high (RCP8.5, in orange) and very low (RCP2.6, in purple) emissions scenarios. The solid orange and purple lines show the smoothed (20-year running average) multi-model mean anomaly in surface air temperature, while shading represents the spread of model values (5 – 95th percentile). The dashed lines show the 5 – 95th percentile of the observed interannual variability for the observed period (in black) and added to the projections as a visible guide (in orange and purple). This indicates that future surface air temperature could be above or below the projected long-term averages due to interannual variability. The ranges of projections for a 20-year period centred on 2090 are shown by the bars on the right for RCP8.5, 6.0, 4.5 and 2.6. (Source: PACCSAP)

3.6.2 Rainfall

The IPCC's Fifth Assessment Report (AR5) states that the response of the ITCZ, the SPCZ and the WPM to increasing temperatures will dictate how rainfall patterns will change in the tropical Pacific.

Average annual rainfall is projected to increase in most areas of the western tropical Pacific as surface temperatures increase. From November – April, rainfall is projected to increase along the equator, in the north-east near RMI, and in the middle of the SPCZ region (southern Cook Islands, Niue and Tuvalu). For Niue, the seasonal rainfall cycle is projected to intensify – with a decrease in dry season rainfall and an increase in wet season rainfall. Rainfall decreases are projected at the north-eastern edge of the SPCZ near the northern Cook Islands. In the north-western and near-equatorial regions – including Palau and RMI – rainfall during all seasons is projected to increase. Wet season increases are consistent with the expected intensification of the WPM and ITCZ. However, contradictions between direct model outputs, multi-model ensemble projections and physical insights mean that the rainfall outlook is uncertain in regions directly affected by the SPCZ and the western portion of the ITCZ.[138, 139]

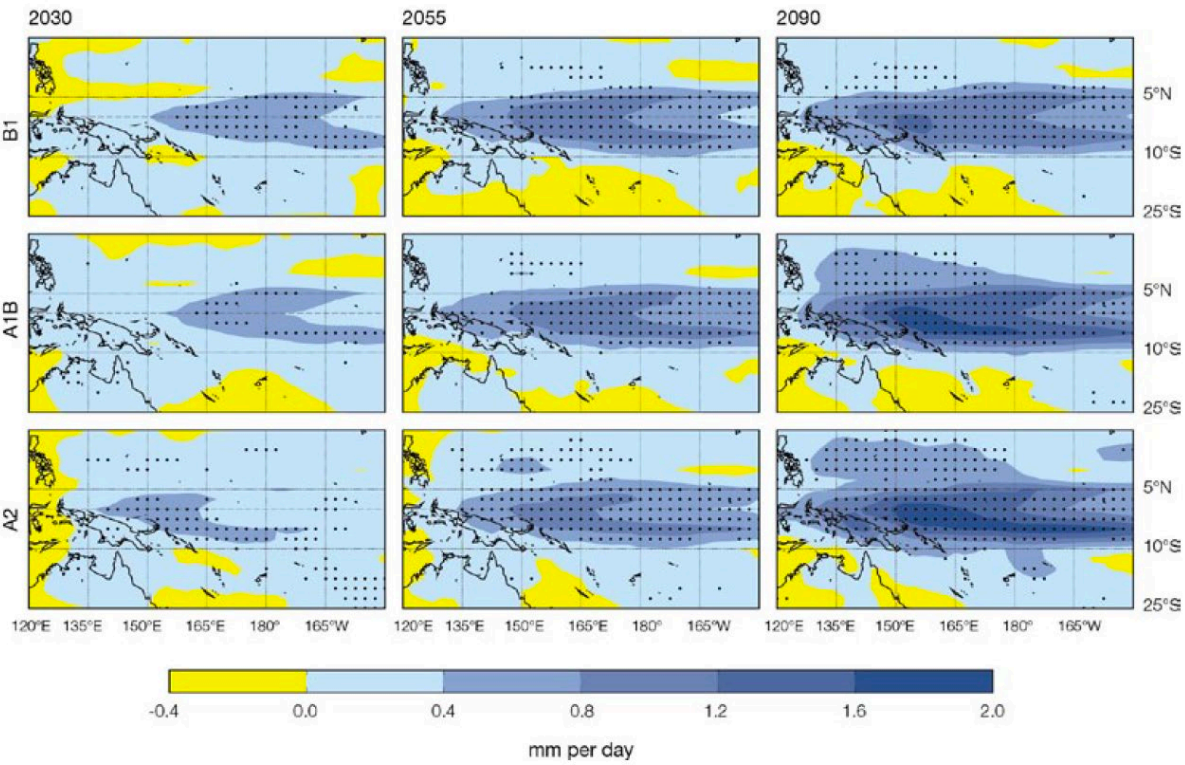


Figure 41. Projected multi-model mean changes in annual rainfall (mm per day) for 2030, 2055 and 2090, relative to 1990, under the B1 (low), A1B (medium) and A2 (high) emissions scenarios. Regions where at least 80% of the models agree on the direction of change are stippled. (Source: Australian BoM and CSIRO, 2011)

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[138] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

[139] IPCC, 2013. Climate Change 2013: The Physical Science Basis

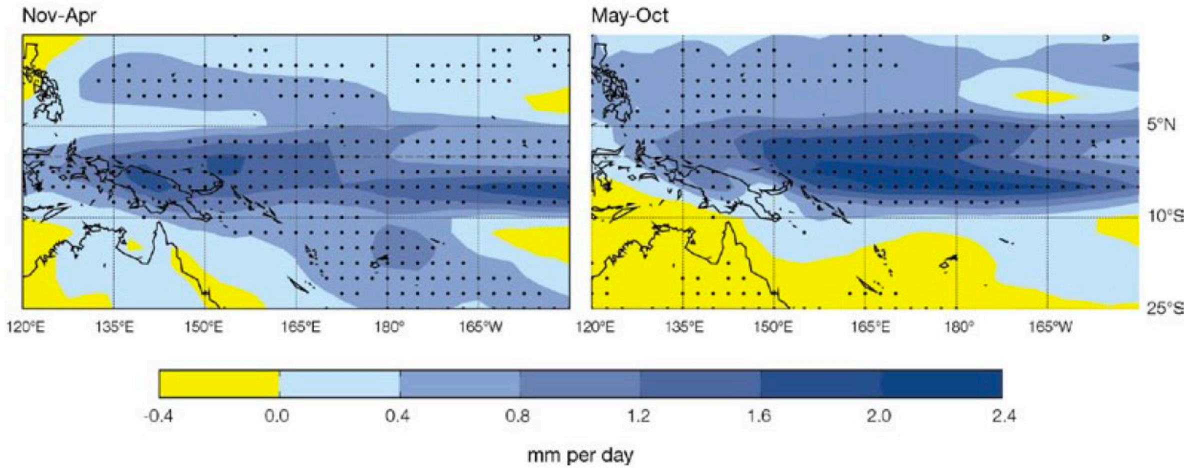

Figure 42. Projected multi-model mean changes in November – April (left) and May – October (right) mean rainfall for 2090, relative to 1990, under the A2 (high) emissions scenario. Regions where at least 80% of models agree on the direction of change are stippled. (Source: Australian BoM and CSIRO, 2011)

Intensification of the ITCZ and SPCZ is *likely* to result in more frequent extreme rainfall days in all Pacific island regions.[140] By 2090, under the very low emissions scenario, extreme rainfall events that currently occur once every 20 years on average are projected to occur once every 7 to 10 years by 2090. Under the very high emissions scenario, they are projected to occur once every 4 to 6 years. In addition, extreme rainfall is projected to increase even in regions where average rainfall is projected to decrease. It should be noted that these projections do not include the contribution from tropical cyclones.

There is *high confidence* that the frequency and intensity of extreme rainfall events will increase because:

- A warmer atmosphere can hold more moisture, so there is greater potential for extreme rainfall (IPCC, 2012);
- Increases in extreme rainfall in the Pacific are projected in all available climate models; and
- An increase in extreme rainfall events within the South Pacific Convergence Zone (SPCZ) region was found by an in-depth study of extreme rainfall events in the SPCZ (Cai et al., 2012). (Relevant to many regions but not all).

There is *low confidence* in the magnitude of projected change in extreme rainfall because:

- Models generally underestimate the current intensity of local extreme events. The simulation of extreme events in the Cook Islands is influenced by the SPCZ biases; or areas influenced by the 'cold-tongue bias';
- Changes in extreme rainfall projected by models may be underestimated because models seem to underestimate the observed increase in heavy rainfall with warming (Min et al., 2011);
- GCMs have a coarse spatial resolution, so they do not adequately capture some of the processes involved in extreme rainfall events; and the Conformal Cubic Atmospheric Model (CCAM) downscaling model has finer spatial resolution and the CCAM results presented in

[140] IPCC, 2013. Climate Change 2013: The Physical Science Basis

Australian Bureau of Meteorology and CSIRO (2011) indicates a smaller increase in the number of extreme rainfall days, and there is no clear reason to accept one set of models over another.

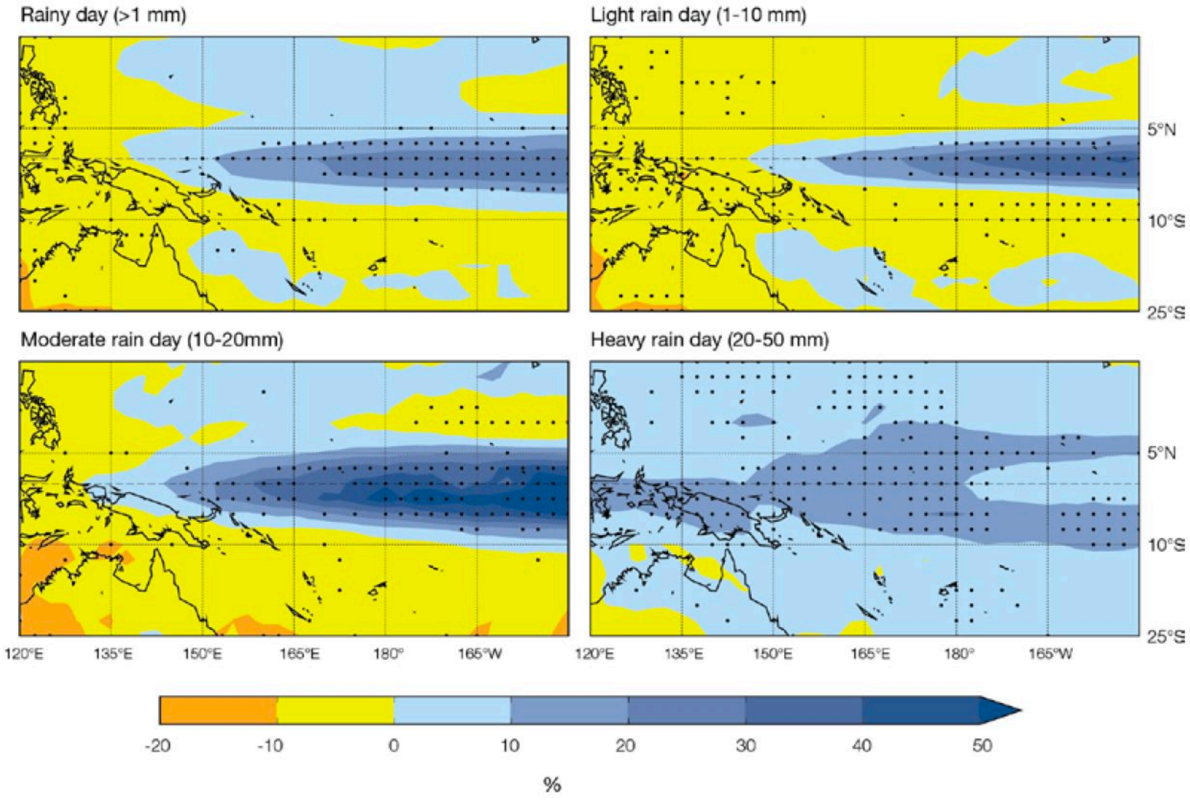

Figure 43. Projected multi-model mean changes in the number of rainy (> 1 mm), light rain (1 – 10 mm), moderate rain (10 – 20 mm) and heavy rain (20 – 50 mm) days between 1990 and 2090 for the A2 (high) emissions scenario. Regions where at least 80% of models agree on the direction of change are stippled. (Source: Australian BoM and CSIRO)

Regional rainfall projections

This section presents a series of figures showing regional patterns of precipitation change computed from global climate model outputs gathered as part of the Coupled Model Intercomparison Project Phase 5 (CMIP5). The projections are made under the Representative Concentration Pathway (RCP) scenarios – RCP2.6, RCP4.5, RCP6.0 and RCP8.5. Projections for the Pacific islands are split into three regions:

- **Northern Tropical Pacific** – Palau and RMI;
- **Equatorial Pacific** – Cook Islands and Tuvalu (north);
- **Southern Tropical Pacific** – Cook Islands and Tuvalu (south); and Niue.

The time series show annual precipitation change relative to 1986 – 2005 averaged over all grid points in each region. Thin lines denote one ensemble member per model, thick lines denote the CMIP5 model mean. On the right hand side, the 5th, 25th, 50th (median), 75th and 95th percentiles of the distribution of 20-year mean changes are given for 2081 – 2100 for the four RCP scenarios.

The maps show 20-year averages in precipitation change for the near term (2016 – 2035), for the mid-term (2046 – 2065) and for the long term (2081 – 2100) with respect to 1986 – 2005 for each scenario. For each point, the 25th, 50th and 75th percentiles of the distribution of the CMIP5 ensemble are shown.

Hatching denotes areas where the 20-year mean differences of the percentiles are less than the standard deviation of the model-estimated present day natural variability of the differences.[141]

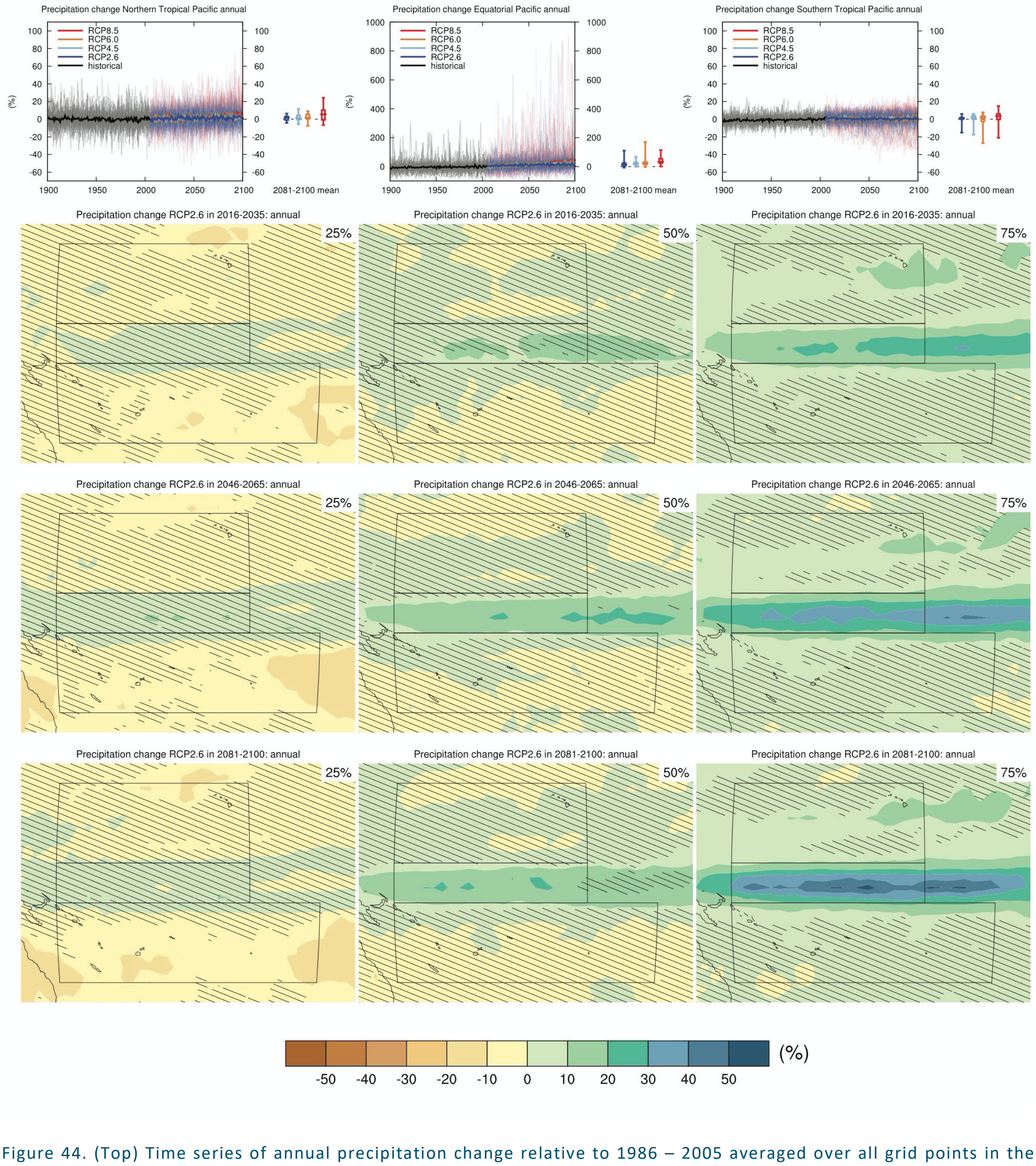

Figure 44. (Top) Time series of annual precipitation change relative to 1986 – 2005 averaged over all grid points in the Northern Tropical Pacific, Equatorial Pacific and Southern Tropical Pacific. (Below) Maps of precipitation changes in 2016 – 2035, 2046 – 2065 and 2081 – 2100 with respect to 1986 – 2005 in the RCP2.6 scenario. (Source: IPCC AR5, 2013)

[141] IPCC, 2013. Climate Change 2013: The Physical Science Basis

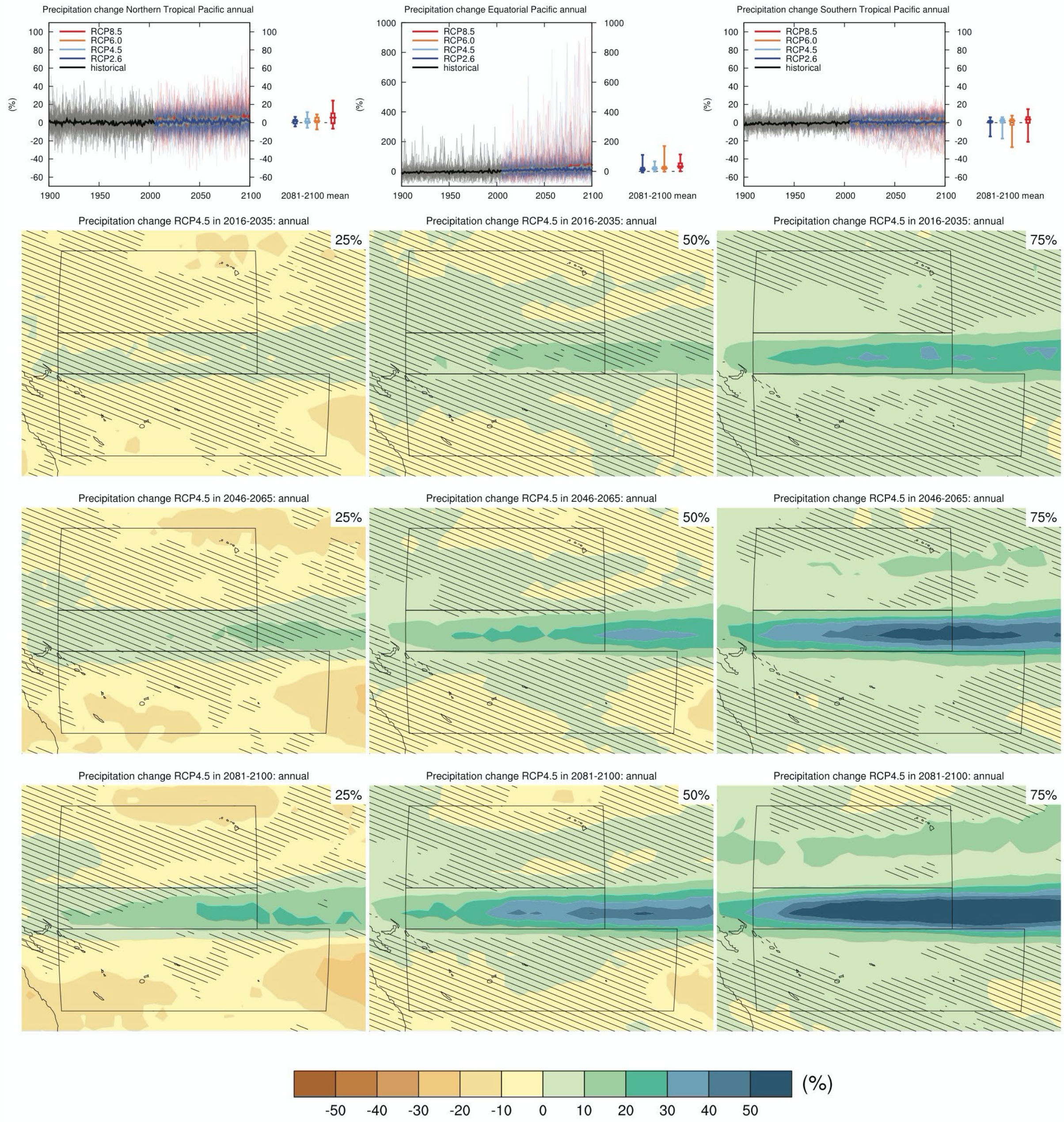

Figure 45. (Top) Time series of annual precipitation change relative to 1986 – 2005 averaged over all grid points in the Northern Tropical Pacific, Equatorial Pacific and Southern Tropical Pacific. (Below) Maps of precipitation changes in 2016 – 2035, 2046 – 2065 and 2081 – 2100 with respect to 1986 – 2005 in the RCP4.5 scenario. (Source: IPCC AR5, 2013)

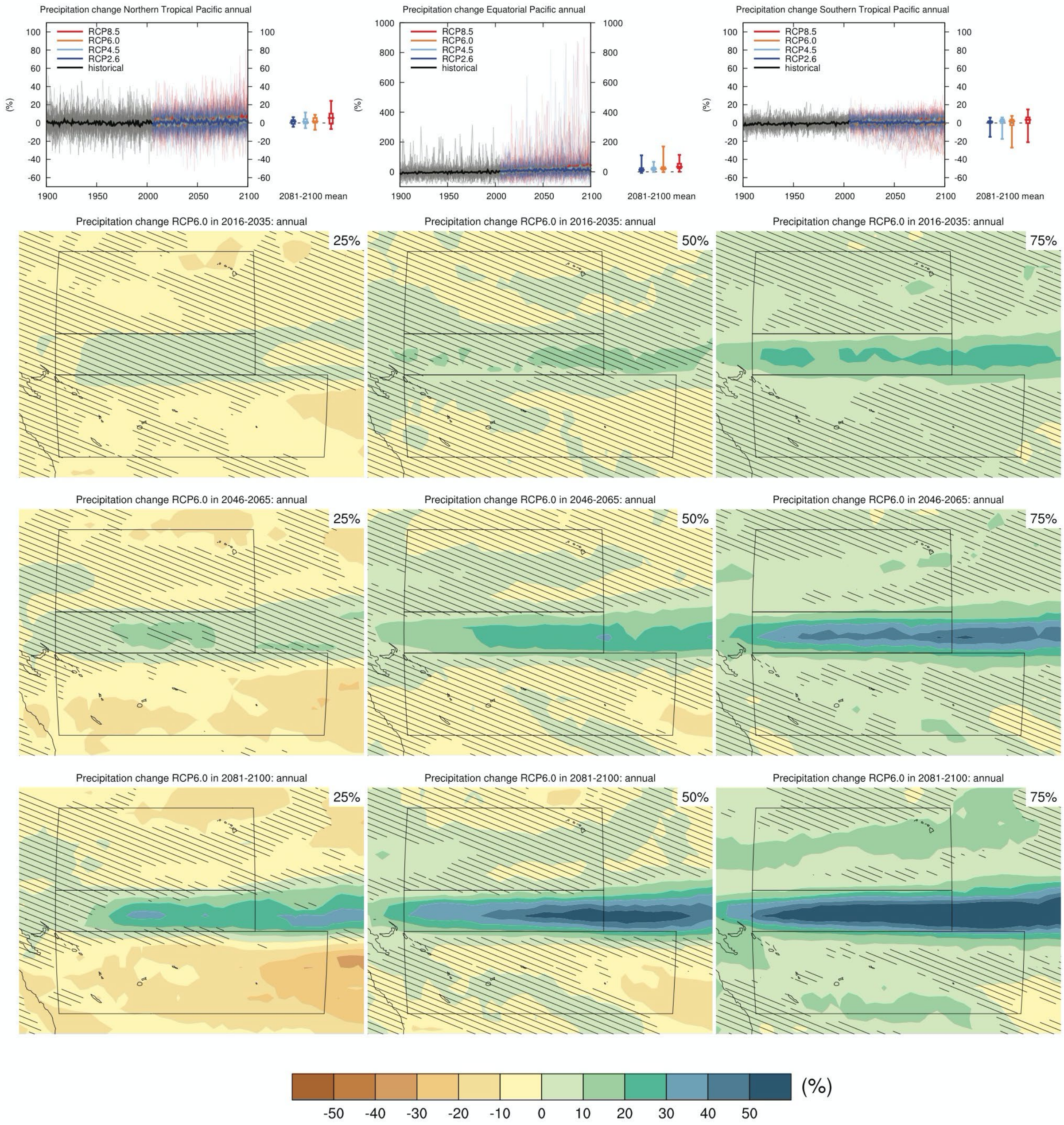

Figure 46. (Top) Time series of annual precipitation change relative to 1986 – 2005 averaged over all grid points in the Northern Tropical Pacific, Equatorial Pacific and Southern Tropical Pacific. (Below) Maps of precipitation changes in 2016 – 2035, 2046 – 2065 and 2081 – 2100 with respect to 1986 – 2005 in the RCP6.0 scenario. (Source: IPCC AR5, 2013)

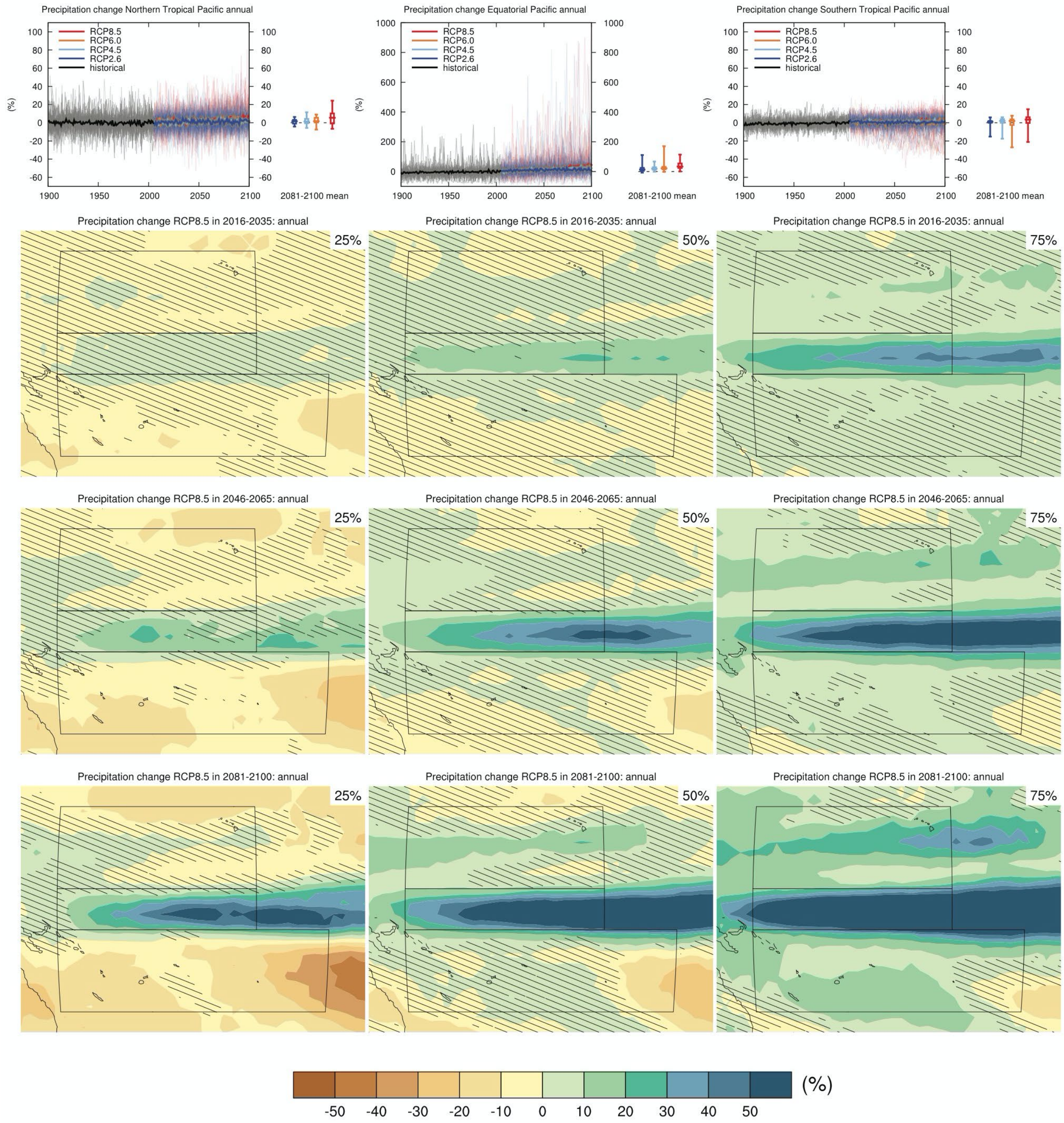

Figure 47. (Top) Time series of annual precipitation change relative to 1986 – 2005 averaged over all grid points in the Northern Tropical Pacific, Equatorial Pacific and Southern Tropical Pacific. (Below) Maps of precipitation changes in 2016 – 2035, 2046 – 2065 and 2081 – 2100 with respect to 1986 – 2005 in the RCP8.0 scenario. (Source: IPCC AR5, 2013)

As highlighted at the start of this section, the impact of global warming on the South Pacific Convergence Zone (SPCZ) will affect how rainfall patterns change in countries within the SPCZ – including the Cook Islands, Niue and Tuvalu. Freshwater resources in these countries are closely related to the intensity and location of the SPCZ, which in turn can have profound effects on extreme climate events experienced in the region.

Evans *et al.* presented the results of two multi-model ensembles of regional climate projections for the south-west Pacific Ocean at up to ~50 km resolution. The high resolution regional climate model (RCM) ensembles has islands present that are missing from global climate model (GCM) simulations, although they were unable to resolve within island topographies and hence the climate distribution across islands. Comparison of the model results with precipitation observations showed that differences are dominated by the choice of RCM; and there was no consensus change in future projections of the SPCZ for the December – February (wet) season. The study concluded that "there is large uncertainty in future changes in the SPCZ and there is no evidence to suggest that future changes will be outside the natural variability."[142] These conclusions support the need for increasing data availability and climate research in the Pacific island region in order to more accurately predict the future impacts of climate change.

Country-specific rainfall projections

The historical and simulated mean annual precipitation in the five Programme countries are shown in the following figure and are summarised below.[143] Additional values and analyses for projected changes are provided in Appendix 2.

In the Southern Cook Islands and Niue, mean annual rainfall increased between 1979 and 2006 but this is not projected to continue in the future, which suggests that the recent increase may be due to natural variability rather than as a result of global warming. The year-to-year variability in rainfall is much larger than the projected change for all Programme countries, even in the highest emission scenario by 2090. Therefore, the effect of climate change on average rainfall may not be obvious in the short or medium term due to natural variability. However, there is *high confidence* that the frequency and intensity of extreme rainfall events will increase in all five countries.

- **Cook Islands:** Long-term average rainfall is projected by most models to stay approximately the same, although the Northern Cook Islands may get drier in the May – October season under the high emission scenario. The influence of topography on the local climate may cause variation between the Northern and Southern Cook Islands.
- **Niue:** Annual mean rainfall is projected to increase or decrease according to different CMIP5 models, although the model average indicates a slight increase for the high emission scenario by 2100. There is greater model agreement for a slight increase in November – April rainfall and little change in May – October rainfall.
- **Palau:** Long-term average rainfall is projected by almost all models to increase. Most models project an increase in May – October rainfall, with little change for November – April rainfall. There will still be wet and dry years and decades due to natural variability, but the long-term average is expected to be wetter.
- **RMI:** Long-term average rainfall is projected by almost all models to increase, with most models projecting an increase in rainfall in both the wet and dry seasons. There will still be wet and dry years and decades due to natural variability, but the long-term average is expected to be wetter.
- **Tuvalu:** Annual mean rainfall is projected to increase or decrease according to different CMIP5 models, although the model average is near zero. Tuvalu is located between a region where rainfall is projected to increase to the north, and a region of little change or slight decrease in the south. Consequently, there is large spread in model projections for both the November – April and May – October seasons.

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[142] Evans, J.P. *et al.* 2015. Climate Dynamics. Regional climate model projections of the South Pacific Convergence Zone

[143] Australian Bureau of Meteorology and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports

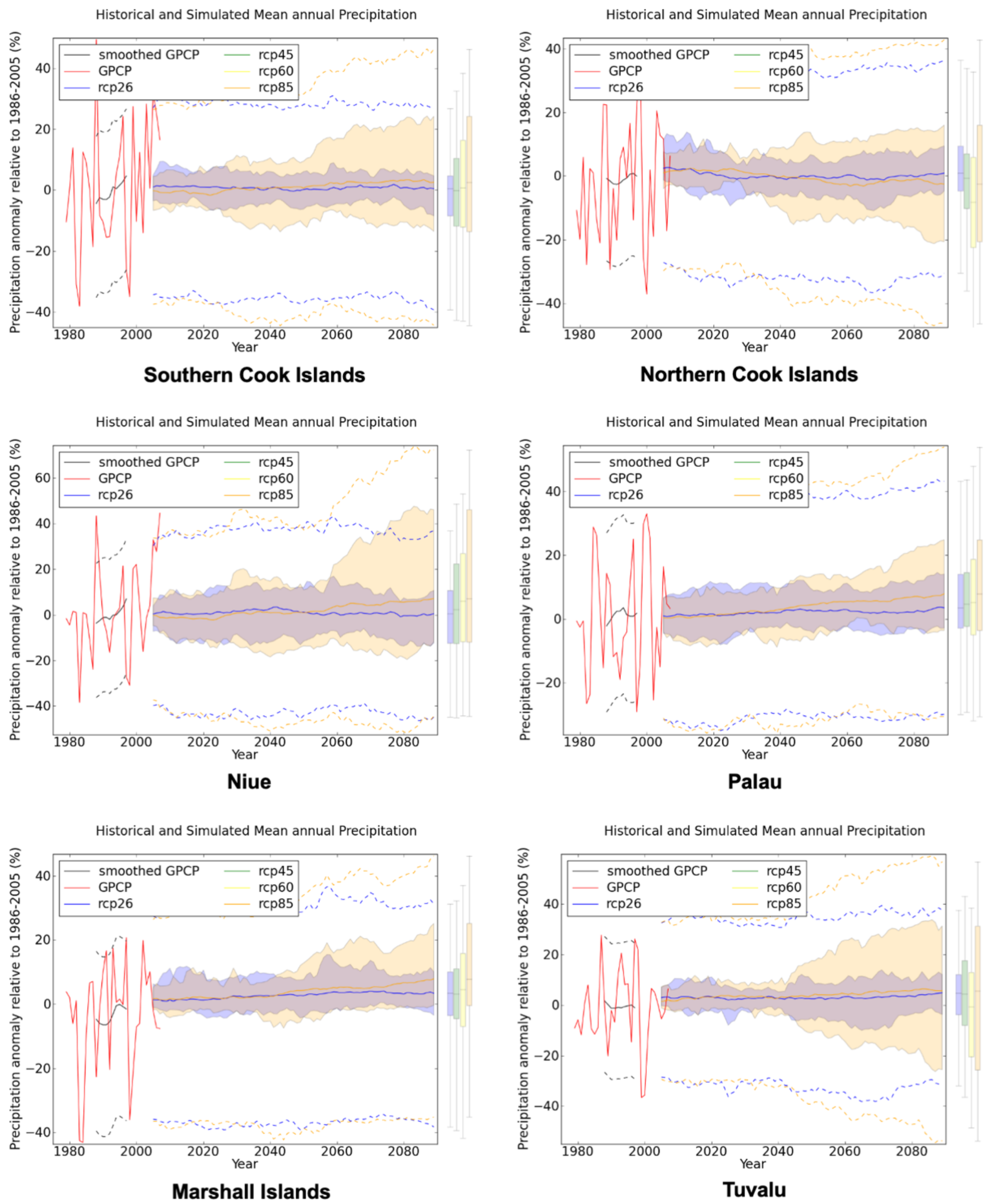
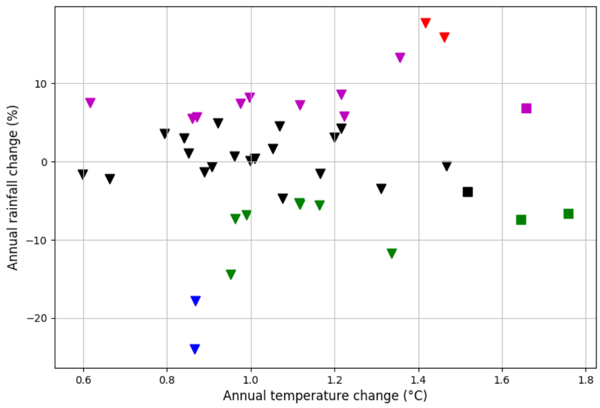


Figure 48. Historical and simulated annual average rainfall time series for the region surrounding the five Programme countries. The graph shows the anomaly (from the base period 1986 – 2005) in surface air temperature from observations (the GISS dataset, in red) from the CMIP5 models under the very high (RCP8.5, in orange) and very low (RCP2.6, in purple) emissions scenarios. The solid orange and purple lines show the smoothed (20-year running average) multi-model mean anomaly in rainfall, while shading represents the spread of model values (5 – 95th percentile). The dashed lines show the 5 – 95th percentile of the observed interannual variability for the observed period (in black) and added to the projections as a visible guide (in orange and purple). This indicates that future rainfall could be above or below the projected long-term averages due to interannual variability. The ranges of projections for a 20-year period centred on 2090 are shown by the bars on the right for RCP8.5, 6.0, 4.5 and 2.6. (Source: PACCSAP)

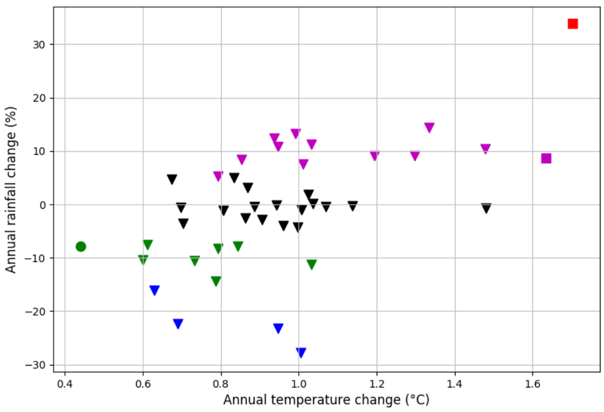
3.6.3 Potential "High Impact" Climate Futures

The potential "High Impact" climate futures for the Programme countries under the RCP4.5 scenario to 2050 are as follows:

- **Cook Islands:** "Warmer and Much Wetter" with annual mean temperature increases of 1.4 °C and annual mean rainfall increases of 17 % relative to 1980-1999. "Warmer and Much Drier" with annual mean temperature increases of 0.9 °C and annual mean rainfall decreases of 21 % relative to 1980-1999.
- **Niue:** "Hotter and Much Wetter" with annual mean temperature increases of 1.7 °C and annual mean rainfall increases of 34 % relative to 1980-1999. "Warmer and Much Drier" with annual mean temperature increases of 0.8 °C and annual mean rainfall decreases of 22 % relative to 1980-1999.
- **Palau:** "Warmer and Much Wetter" with annual mean temperature increases of 1.2 °C and annual mean rainfall increases of 18 % relative to 1980-1999. "Warmer and Much Drier" with annual mean temperature increases of 0.9 °C and annual mean rainfall decreases of 18 % relative to 1980-1999.
- **RMI:** "Warmer and Much Wetter" with annual mean temperature increases of 1.3 °C and annual mean rainfall increases of 23 % relative to 1980-1999. "Warmer and Drier" with annual mean temperature increases of 1.3 °C and annual mean rainfall decreases of 7 % relative to 1980-1999.
- **Tuvalu:** "Hotter and Much Wetter" with annual mean temperature increases of 1.8 °C and annual mean rainfall increases of 25 % relative to 1980-1999. "Warmer and Drier" with annual mean temperature increases of 0.9 °C and annual mean rainfall decreases of 9 % relative to 1980-1999.



Cook Islands



Niue

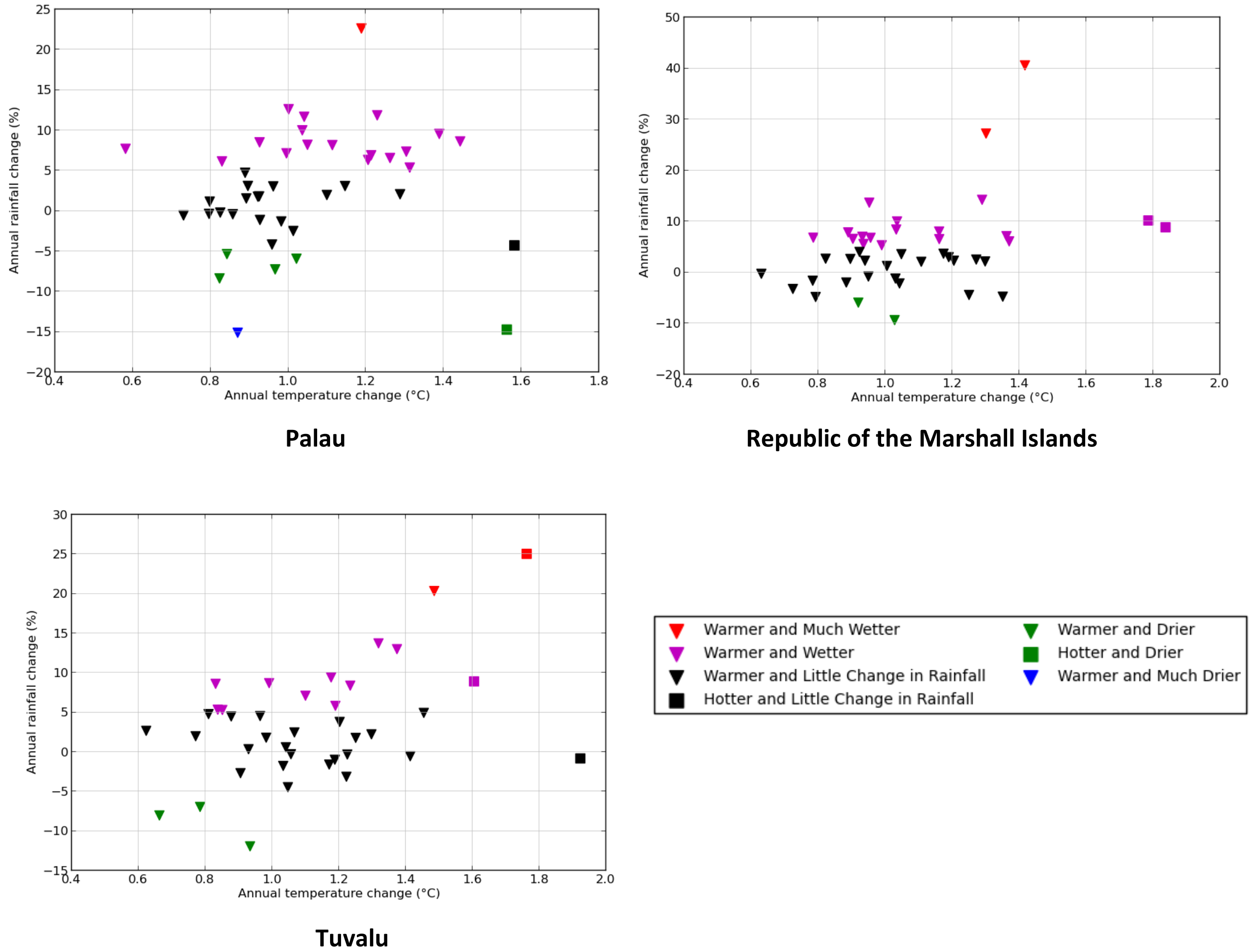


Figure 49. Potential impacts of annual temperature and rainfall change under the RCP4.5 scenario to 2050

3.6.4 Sea-level rise

The IPCC Fifth Assessment Report (AR5) states that global mean sea level will continue to rise in the 21st century and will *likely* be in the range of 0.26 – 0.82 m by 2100, depending on different emissions scenarios. However, sea-level rise will not be uniform and "many regions are *likely* to experience regional sea level changes that differ substantially from the global mean".[144]

Sea-level rise in the western tropical Pacific is projected to be slightly above the global average. Uncertainty in projected contributions from ice sheets in Greenland and Antarctica could contribute an additional 0.1 – 0.2 m.[145] Low confidence in projections of changes in the behaviour of ENSO – which influences sea level in the tropical Pacific – contributes further uncertainty.[146]

[144] IPCC, 2013. Climate Change 2013: The Physical Science Basis

[145] Australian Bureau of Meteorology and CSIRO, 2011, Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional – Executive Summary

[146] IPCC, 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation

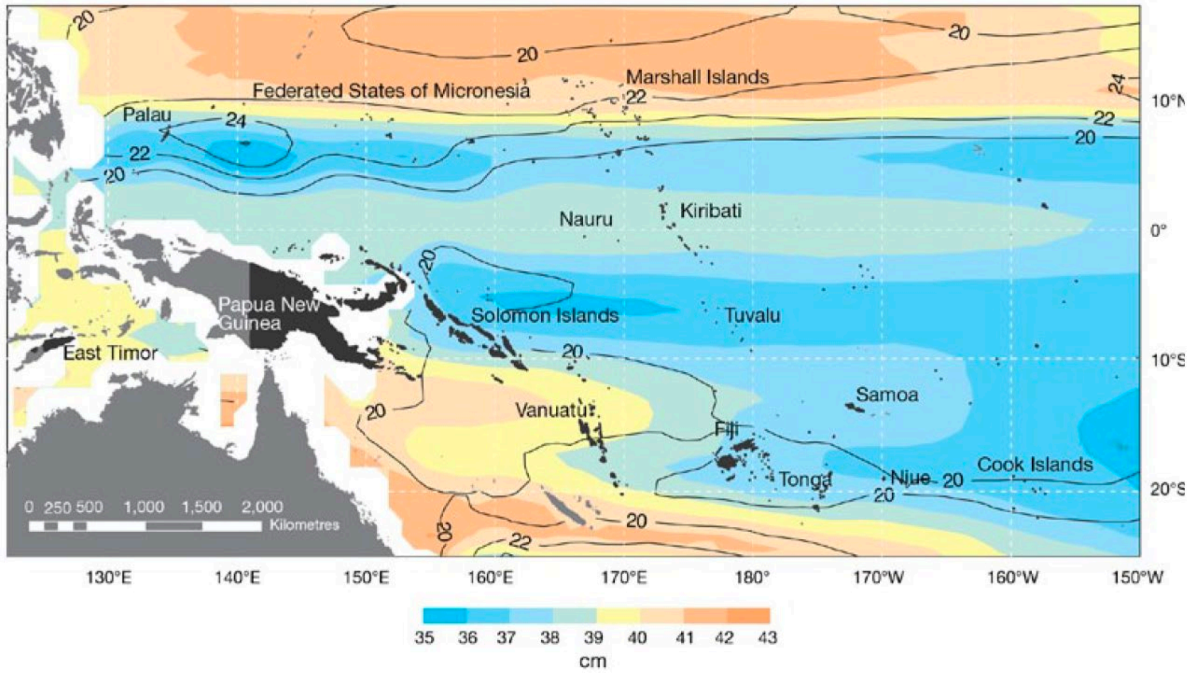


Figure 50. Sea-level projections (in cm) for the A1B (medium) emissions scenario in the Pacific island region for 2081 – 2100 relative to 1981 – 2000. Contours indicate the uncertainty. (Source: Australian BoM and CSIRO, 2011)

The following figures show the observed and projected relative sea level change near the five Programme countries. Interannual variability in sea level will lead to periods of lower and higher regional sea levels, which has historically been between about 17 cm (Niue) and 36 cm (Palau). Similar variation is expected to continue through the 21st century.[147]

[147] Australian Bureau of Meteorology and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports

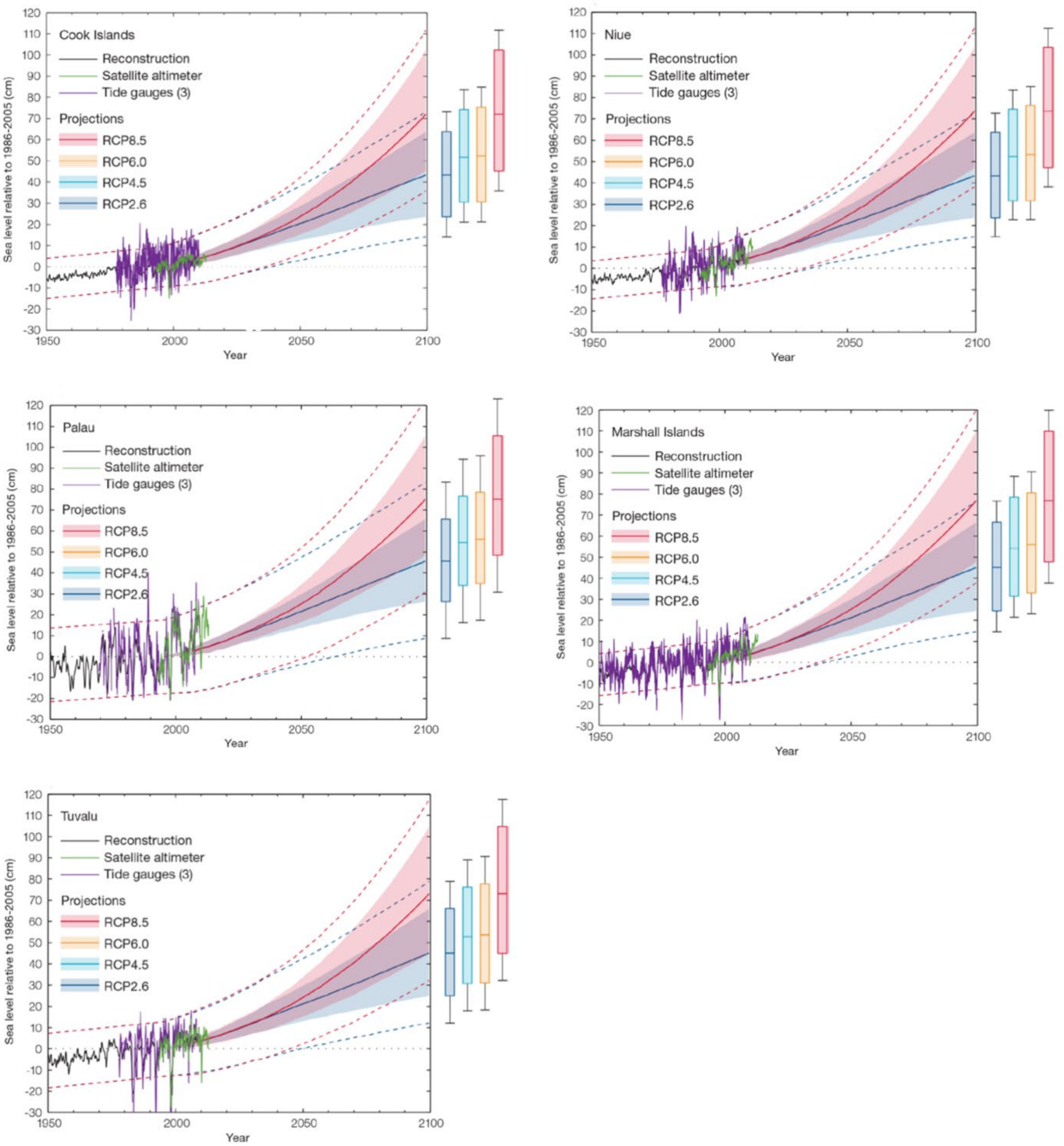


Figure 51. Observed and projected relative sea level change near the five Programme countries. The dashed lines are an estimate of interannual variability in sea level (5 – 95 % uncertainty range about the projections) and indicate that individual monthly averages of sea level can be above or below longer-term averages. (Source: PACCSAP)

3.6.5 Sea surface temperature

The IPCC Fifth Assessment Report (AR5) states that global sea surface temperatures will continue to warm during the 21st century, with the strongest ocean warming projected for the surface in tropical and Northern Hemisphere subtropical regions.[148]

[148] IPCC, 2013. Climate Change 2013: The Physical Science Basis

For the Pacific region, sea-surface temperatures are projected to increase by 1.4 ± 0.7°C, 2.2 ± 0.8°C and 2.6 ± 0.6°C between 1990 and 2090 for the B1 (low), A1B (medium) and A2 (high) scenarios respectively. A maximum warming is projected in the central equatorial Pacific, with the least warming projected in the south-eastern Pacific.

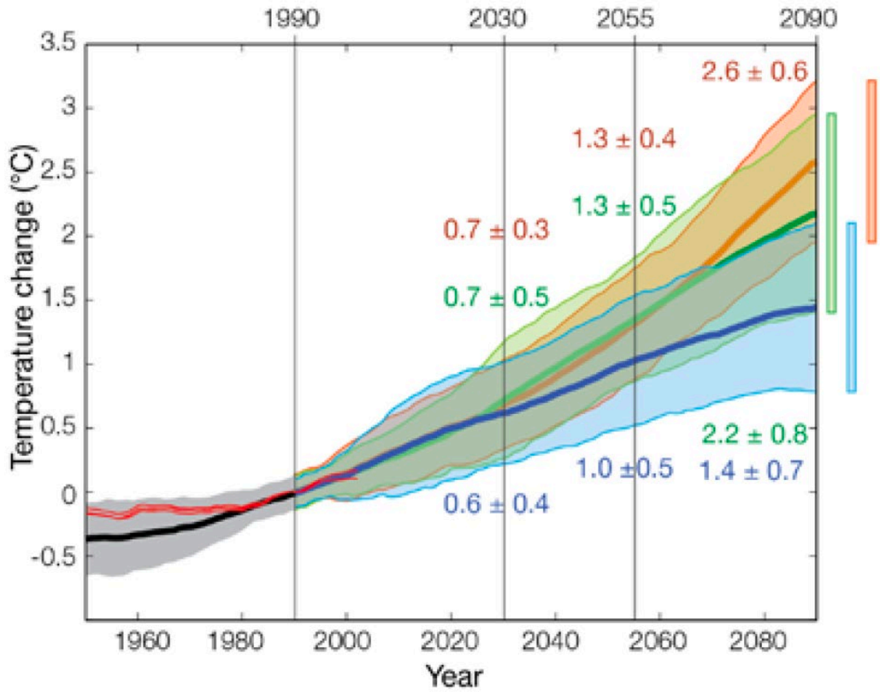


Figure 52. Evolution of multi-model average sea-surface temperatures (°C) for the Pacific region for 1950-1990 (black) three post-1990 scenarios (B1-green, A1B-blue and A2-red). (Source: Australian BoM and CSIRO, 2011)

The West Pacific Warm Pool provides the energy to sustain western Pacific convection and tropical atmospheric circulation and is an important factor in ENSO variability. The Warm Pool – defined as temperatures above 29 °C – is projected to significantly increase in size, with the edge of the pool moving thousands of kilometres to the east over the next few decades.[149]

[149] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional.

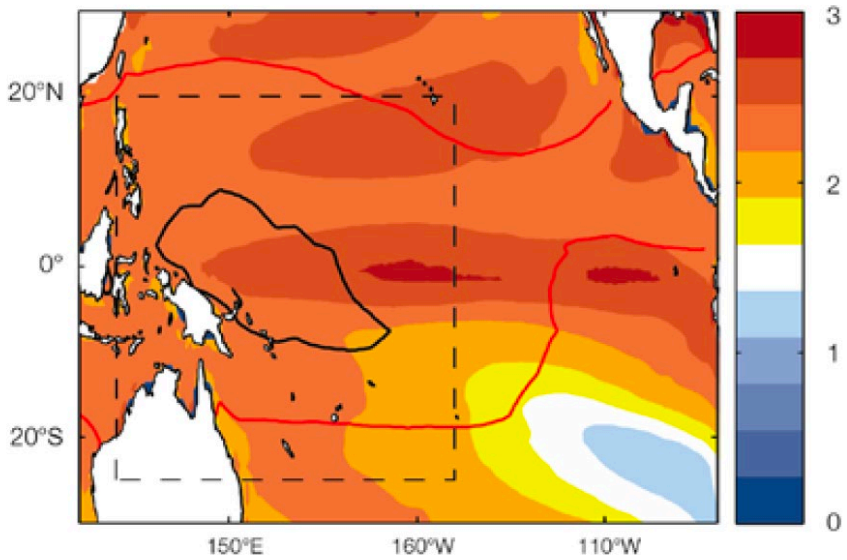


Figure 53. Multi-model mean change in sea-surface temperature (°C) over the tropical Pacific region for the A2 (high) scenario for a 20-year period centred on 2090 relative to 1990. The observed (HadISST) Warm Pool extent (black contour, for waters with mean annual temperature exceeding 29 °C) and projected Warm Pool extent (red contour, computed as 1990 observed SST + projected warming) are indicated.

3.6.6 Ocean acidification

Future changes in ocean pH and aragonite saturation will mostly depend on atmospheric carbon dioxide concentrations and – to a lesser extent – by changes in water temperature and salinity. In its 2019 Special Report on the Ocean and Cryosphere in a Changing Climate, the IPCC reported that "it is *virtually certain* that the future surface open ocean will experience pH drops of either 0.036-0.042 (RCP2.6) or 0.287-0.291 (RCP8.5) pH units by 2081 – 2100, relative to 2006 – 2015". The Pacific Ocean will experience some of the greatest changes in pH due to its lower buffer capacity and upwelling systems.[150] Under the RCP8.5 scenario, the tropical Pacific pH is projected to decrease by 0.15 units from the period 1986 – 2005 into the 2040 – 2060 period, with dramatic changes to aragonite saturation also projected.

[150] IPCC, 2019. Special Report on the Ocean and Cryosphere in a Changing Climate

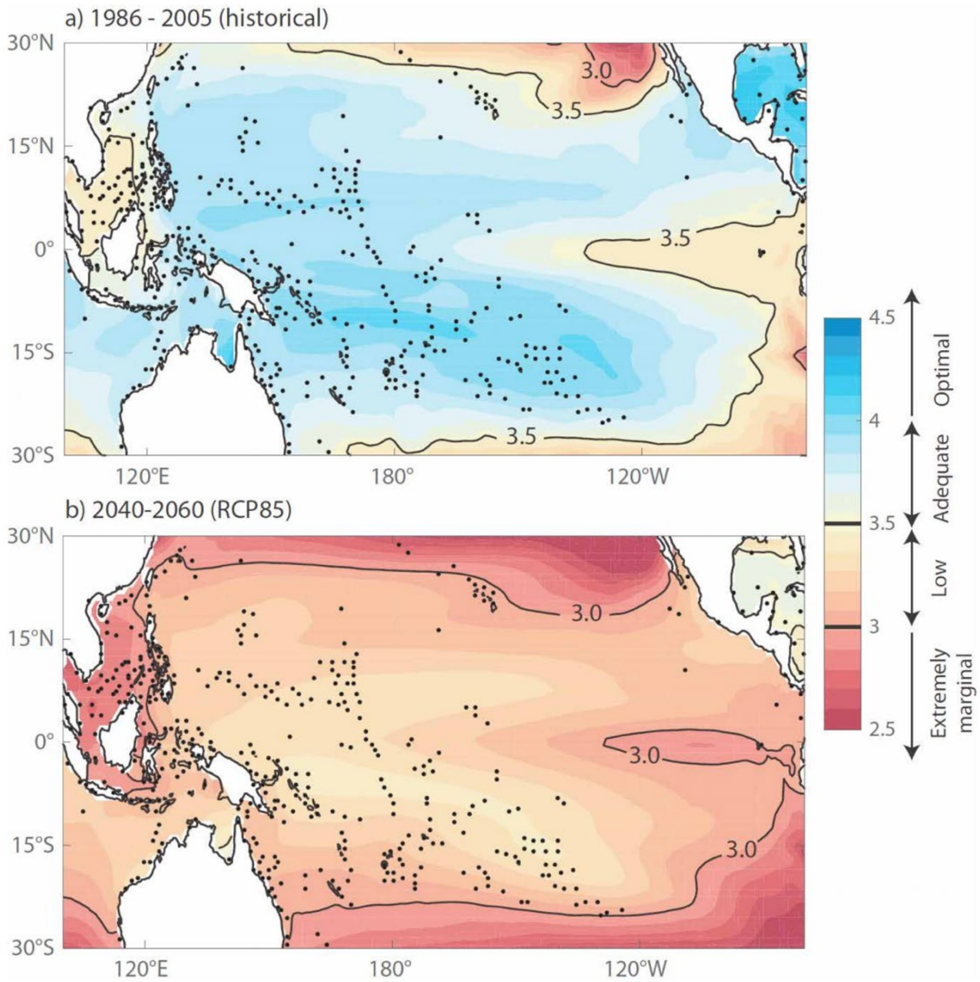


Figure 54. Aragonite saturation state for the periods (a) 1986 – 2005 (based on the multi-model median from the CMIP5 historical simulations) and (b) 2040 – 2060 (based on RCP8.5 simulations). Contour lines of 3 and 3.5 are superimposed. Black dots indicate the location of coral reefs. (Source: SPREP, 2015)[151]

Projected changes in the tropical Pacific Ocean aragonite saturation state were also estimated under the low, medium and high emissions scenarios (B1, A1B and A2, respectively). The results indicated that:

- Magnitude and rate of ocean acidification is proportional to atmospheric CO_2 concentration;
- Aragonite saturation state until 2050 is largely independent of emissions scenarios, which predict similar atmospheric CO_2 concentration;
- Aragonite saturation state from 2051 – 2100 will decline in the entire Pacific island region, with the greatest changes observed under the highest emissions scenario;
- The lowest aragonite saturation state values will occur in the eastern equatorial Pacific, to the east of 160 °W, and the highest values will occur in the South Equatorial Current region, approximately between 5°S and 20°S (Cook Islands and Tuvalu).[152]

[151] SPREP, 2015. Pacific Islands Ocean Acidification Vulnerability Assessment
[152] Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional.

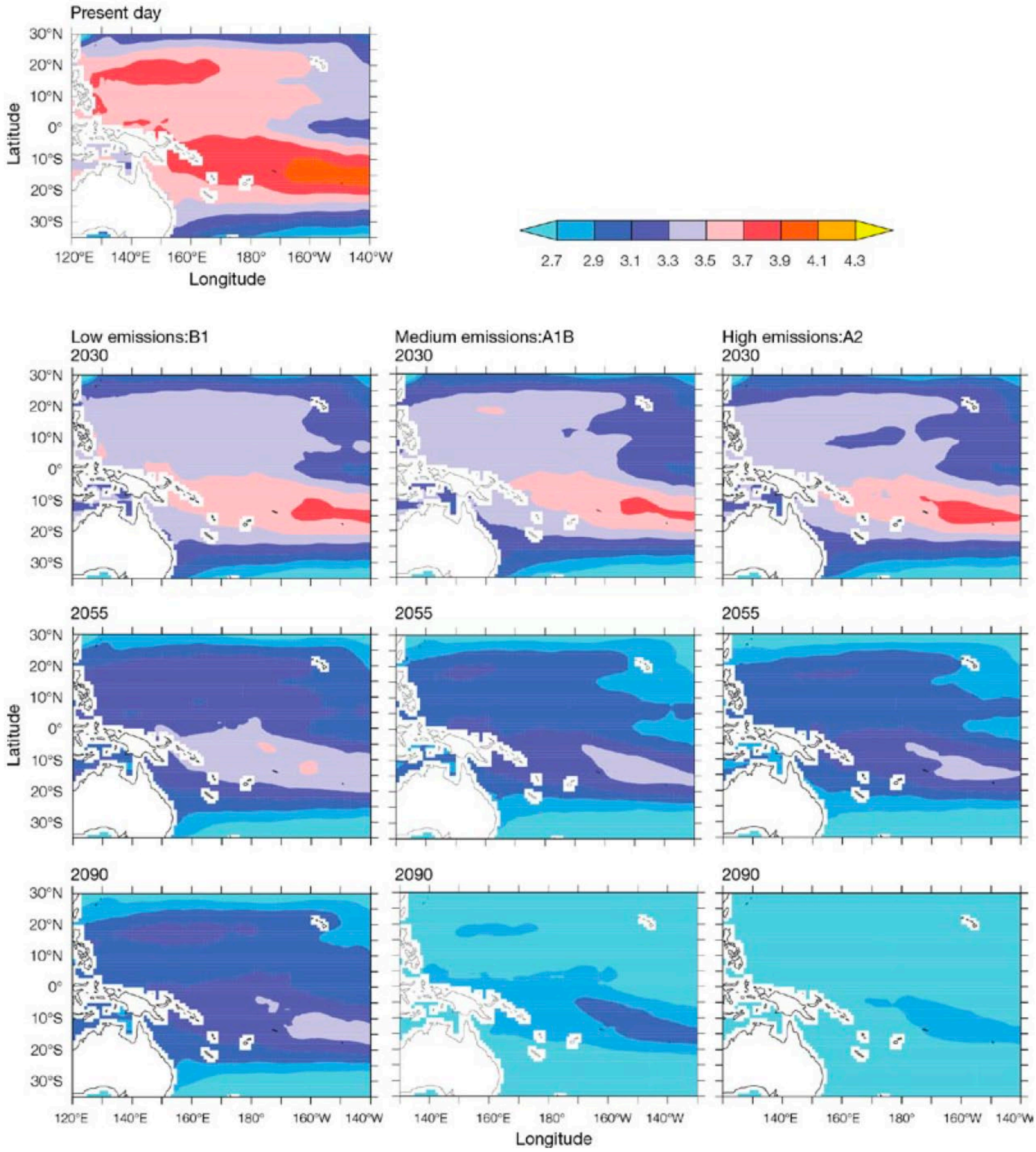


Figure 55. Multi-model mean of annual maximum values of aragonite saturation state in surface waters for the present day and in 2030, 2055 and 2090 for six climate models. The B1 (low), A1B (medium) and A2 (high) emissions scenarios are shown. (Source: Australian BoM and CSIRO)

Country-specific projections for ocean acidification

The projected decreases in aragonite saturation state for the five Programme countries are shown in the following figure and are summarised below.[153]

For all five Programme countries, there is *very high confidence* that aragonite saturation state – an indicator for ocean acidification and a proxy for coral reef growth rate – will continue to decrease as atmospheric CO_2 concentrations increase. Under RCP4.5 and 8.5, CMIP5 models project that the median aragonite saturation state will reach marginal coral reef growth conditions (3.5) around 2030. Thereafter, the aragonite saturation state is projected as follows:

- **RCP 2.6 –** Median state never falls below 3.5 and increases slightly towards the end of the century. This suggests that conditions will remain adequate for coral reef health;
- **RCP 4.5 –** Median state plateaus around 3.2, i.e. marginal conditions for coral reef health;
- **RCP 8.5** – Aragonite saturation state continues to strongly decline to below 3.0. Coral reefs have not historically been found at these values.

The impacts of ocean acidification are likely to affect the entire marine ecosystem and impact on the key ecosystem services provided by reefs. Impacts on reef ecosystems are described in more detail under section 3.6.7.

[153] Australian Bureau of Meteorology and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports

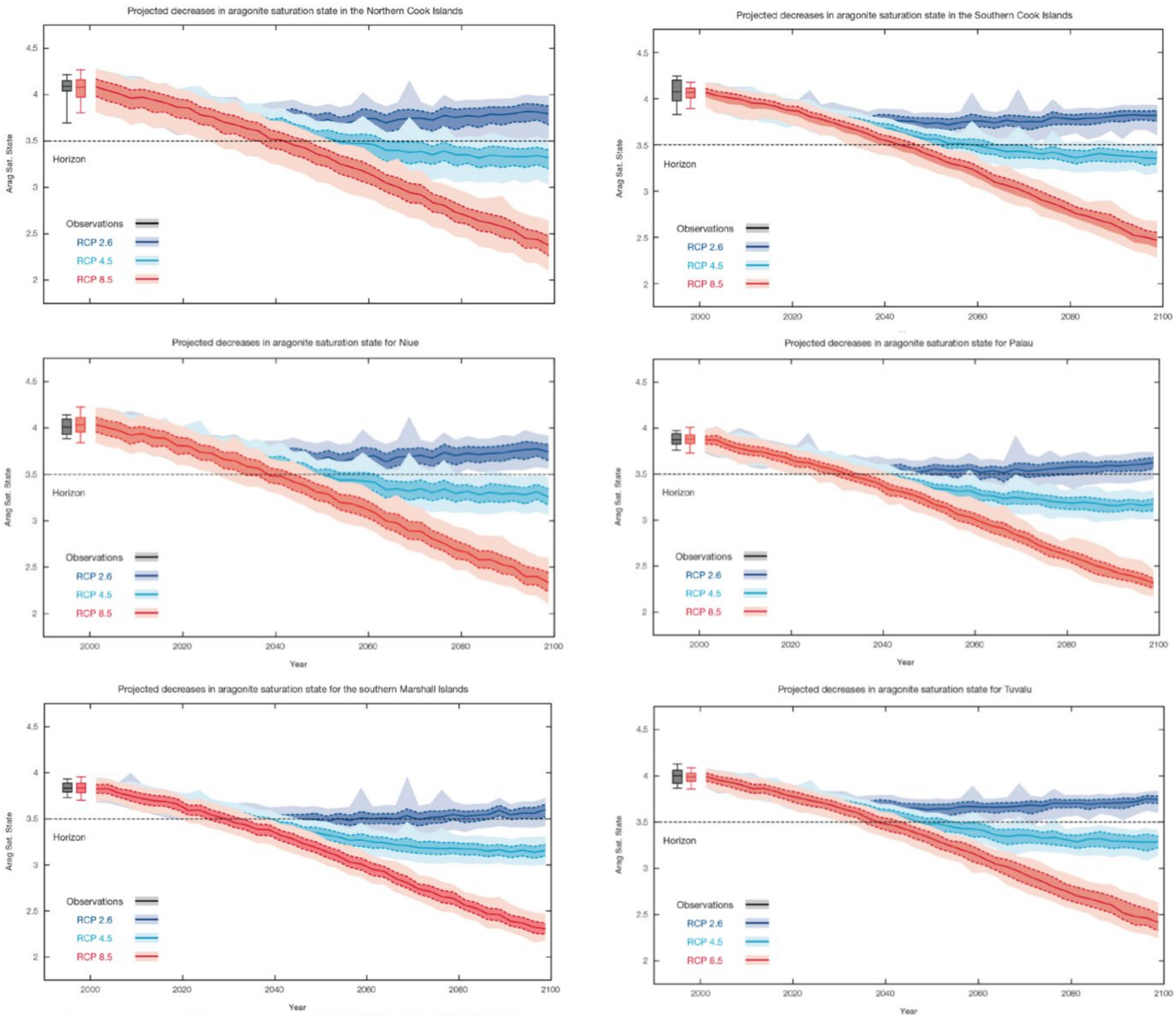


Figure 56. Projected decreases in aragonite saturation state in the Northern and Southern Cook Islands, Niue, Palau, RMI and Tuvalu from CMIP5 models under RCP2.6, 4.5 and 8.5. Median values (solid lines), the interquartile range (dashed lines) and 5% and 9% percentiles (light shading) are shown. The horizontal line represents the transition to marginal conditions for coral reef health. (Source: Australian BoM and CSIRO, 2014)

3.6.7 High impact events

Tropical Cyclones

Projection of realistic future changes in tropical cyclone activity at a regional spatial scale is a challenging issue; partly due to large variations in modelling results[154] and partly due to model deficiencies in representing the large-scale environmental conditions that are known to influence tropical cyclones, including patterns of variabilities such as ENSO and large-scale climate features such as the SPCZ.[155]

Across the Pacific region, tropical cyclones are projected to be less frequent but more severe.[156] The IPCC AR5 report also projects that the Pacific Islands will experience "more extreme precipitation

[154] Knutson, T.R. *et al.* 2010. Nature Geoscience. Tropical cyclones and climate change

[155] Brown, J.R. *et al.* 2011. Journal of Climate. Evaluation of the South Pacific Convergence Zone in IPCC AR4 Climate Model Simulations of the Twentieth Century

[156] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

associated with tropical cyclones", with an increase in tropical cyclone rainfall rate of ~5 – 20% projected by the late 21st century.[157]

Climate models project a non-significant decrease in the future frequency of cyclones in the south-west Pacific and a non-significant increase in the future frequency of cyclones in the northern Pacific. Climate projections do indicate a shift in tropical cyclone intensity, with "relatively fewer cyclones with medium intensity, and increased frequencies of both weaker and very intense cyclones". Furthermore, "a slight reduction in the overall frequency combined with an increased proportion of the most intense cyclones means that most locations in the Pacific will have a higher chance of experiencing severe winds."[158]

A more recent study of tropical cyclone projections for the north-western Pacific reported that the number of tropical cyclones is likely to decrease at Kwajalein (RMI) and that the "likelihood of fewer but stronger storms will necessitate new localised assessments of the risk and vulnerabilities to tropical cyclones in the North Pacific".[159]

Drought

For all emissions scenarios, the frequency of moderate droughts is projected to decline in the central Pacific. Over the eastern equatorial cold tongue region, moderate droughts are projected to occur 3-4 times every 20 years by 2030, decreasing to 2-3 times by 2090. Over the central western Pacific (including southern Palau) moderate droughts are projected to occur 1-2 times every 20 years by 2030, decreasing to 0-1 times by 2090. For the rest of the Pacific island region, moderate droughts are projected to occur 1-2 times every 20 years, with the exception of a decrease in the north – including RMI. The frequency of severe droughts is projected to decrease by 1-2 times every 20 years by 2030 to 0-1 times every 20 years by 2090.[160]

157 Chand *et al.* 2020. A Review of South Pacific Tropical Cyclones: Impacts of Natural Climate Variability and Climate Change
158 CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools
159 Widlanksy, M.J. *et al.* Weather, Climate and Society. Tropical Cyclone Projections: Changing Climate Threats for Pacific Island Defence Installations
160 Australian Bureau of Meteorology and CSIRO, 2011, Climate Change in the Pacific: Scientific Assessment and New Research, Volume 1: Regional

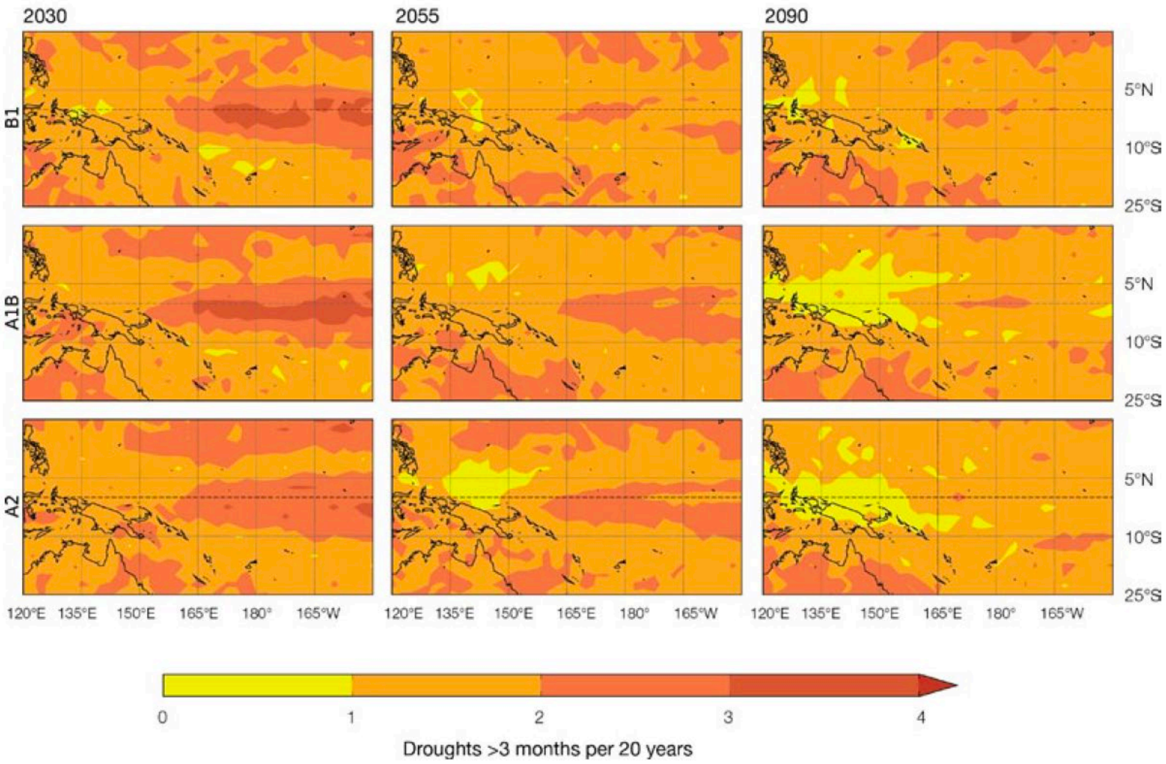


Figure 57. Frequency of moderate drought defined by the standardised precipitation index (SPI) under the B1 (low), A1B (medium) and A2 (high) emissions scenarios for 20-year periods centred on 2030, 2055 and 2090. Frequency is defined as the number of times during the 20-year period where the SPI is between -2.00 to -2.99 for at least three consecutive months. (Source: Australian BoM and CSIRO, 2011)

More recent analyses project an increase in drought at the eastern edge of the SPCZ – including the northern Cook Islands. Projected changes in the average frequency, intensity and duration of drought reflect changes in average rainfall as well as changes in rainfall variability, which is affected by ENSO. Consequently, the results are less certain than for other variables.[161]

Country-specific projections for drought

Drought projections – described in terms of changes in proportion of time in drought, frequency and duration by 2090 under RCP8.5 for the five Programme countries are shown in the following figures and are summarised below.[162]

- **Cook Islands:** The overall proportion of time spent in drought is expected to increase slightly in the Northern Cook Islands and decrease slightly in the Southern Cook Islands. The frequency of extreme droughts is projected to increase in the Northern Cook Islands. The duration of drought events in all categories is projected to stay approximately the same.
- **Niue:** The overall proportion of time spent in drought is expected to decrease, and the frequency of extreme drought events is projected to remain stable. The duration of drought events in all categories is projected to decrease slightly.

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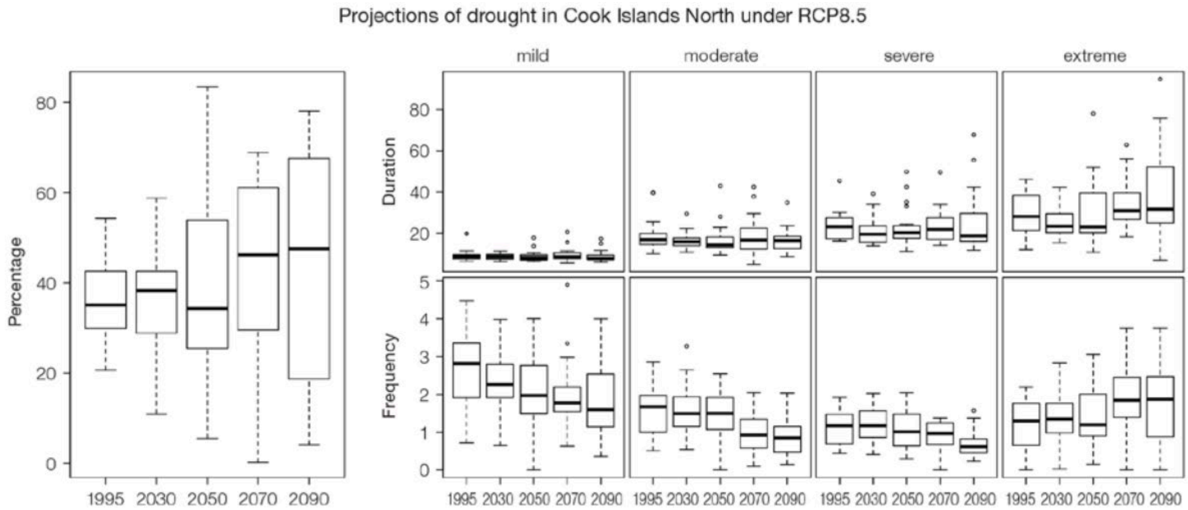
[161] CSIRO, Australian Bureau of Meteorology and SPREP, 2015. Climate in the Pacific: A regional summary of new science and management tools

[162] Australian Bureau of Meteorology and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports

- **Palau:** The overall proportion of time spent in drought is expected to decrease, with the frequency of extreme drought events also projected to decrease. The duration of drought events in all categories is projected to remain stable.
- **Marshall Islands:** The overall proportion of time spent in drought is expected to decrease, with the frequency of extreme drought events also projected to decrease. The duration of drought events in all categories is projected to remain stable.
- **Tuvalu:** The overall proportion of time spent in drought is expected to decrease, and the frequency of extreme drought event is projected to remain stable. The duration of drought events in all categories is also projected to remain stable.

There is *medium* confidence in the direction of change for Cook Islands, Palau and RMI due to *medium* or *high* confidence in the direction of mean rainfall change, and projections are based on a subset of models; and *low* confidence in the direction of change for Niue and Tuvalu due to *low* confidence in the direction of mean rainfall change and projections are only based on a subset of models.

There is *medium* confidence in the projections of drought frequency and duration for Palau due to *medium* confidence in the magnitude of rainfall projections; and *low* confidence in the projections of drought frequency and duration for Cook Islands, Niue, RMI and Tuvalu due to *low* or *medium* confidence in the magnitude of rainfall projections. There is no consensus about projected changes in ENSO events, which directly influence drought.



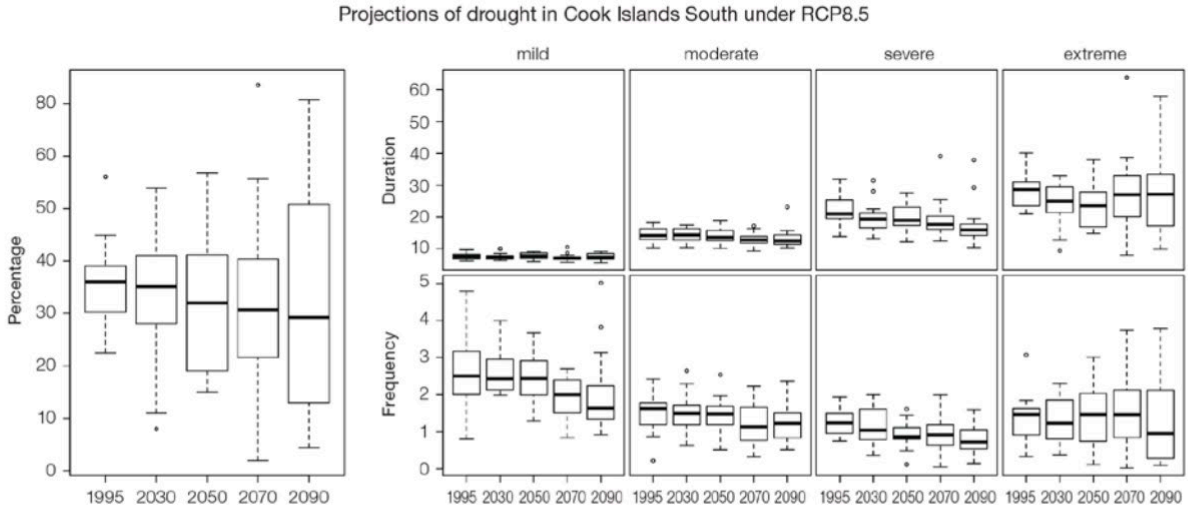


Figure 58. Box-plots showing percent of time in moderate, severe or extreme drought (left hand side), and average drought duration and frequency for the different categories of drought (mild, moderate, severe and extreme) for the Northern Cook Islands (top) and the Southern Cook Islands (bottom). These are shown for 20-year periods centred on 1995, 2030, 2050, 2070 and 2090 for the RCP8.5 scenario. The median of all models (thick dark lines), interquartile range (box), 1.5x the interquartile range (dashed lines) and outlier results (circles) are shown. (Source: Australian BoM and CSIRO, 2014)

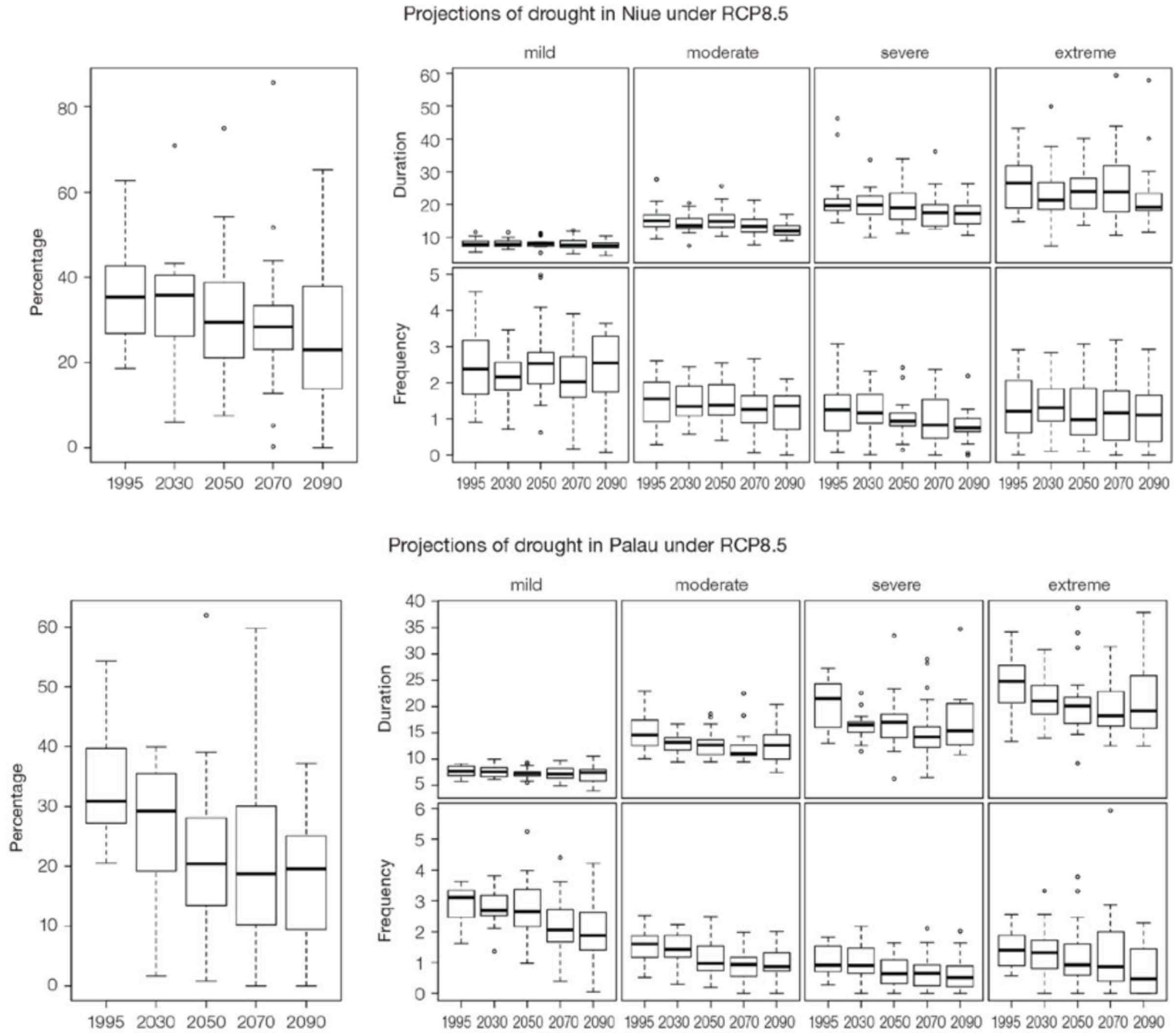


Figure 59. Box-plots showing percent of time in moderate, severe or extreme drought (left hand side), and average drought duration and frequency for the different categories of drought (mild, moderate, severe and extreme) for Niue (top) and Palau (bottom). These are shown for 20-year periods centred on 1995, 2030, 2050, 2070 and 2090 for the RCP8.5 scenario. The median of all models (thick dark lines), interquartile range (box), 1.5x the interquartile range (dashed lines) and outlier results (circles) are shown. (Source: Australian BoM and CSIRO, 2014)

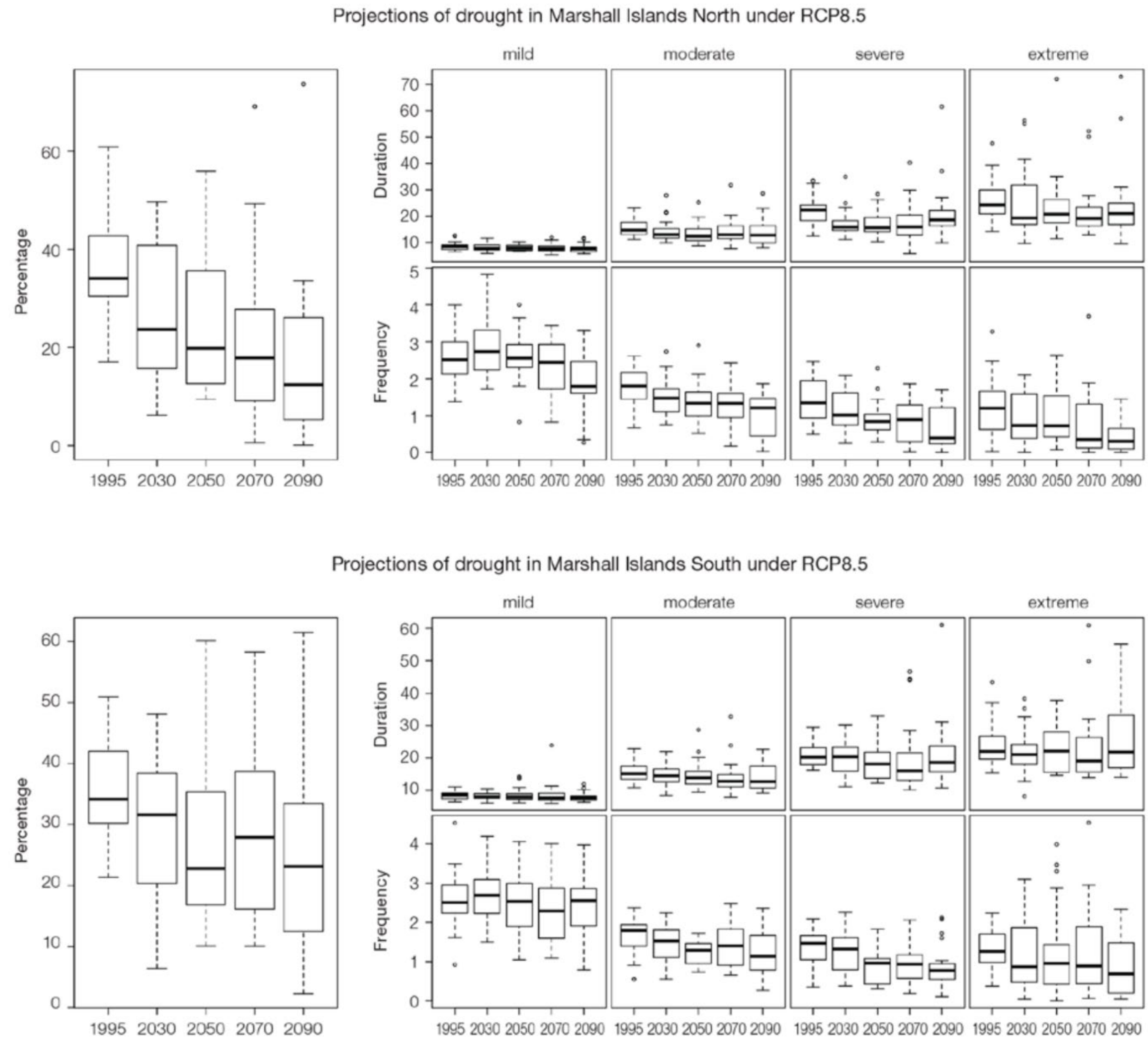


Figure 60. Box-plots showing percent of time in moderate, severe or extreme drought (left hand side), and average drought duration and frequency for the different categories of drought (mild, moderate, severe and extreme) for the Northern Marshall Islands (top) and the Southern Marshall Islands (bottom). These are shown for 20-year periods centred on 1995, 2030, 2050, 2070 and 2090 for the RCP8.5 scenario. The median of all models (thick dark lines), interquartile range (box), 1.5x the interquartile range (dashed lines) and outlier results (circles) are shown. (Source: Australian BoM and CSIRO, 2014)

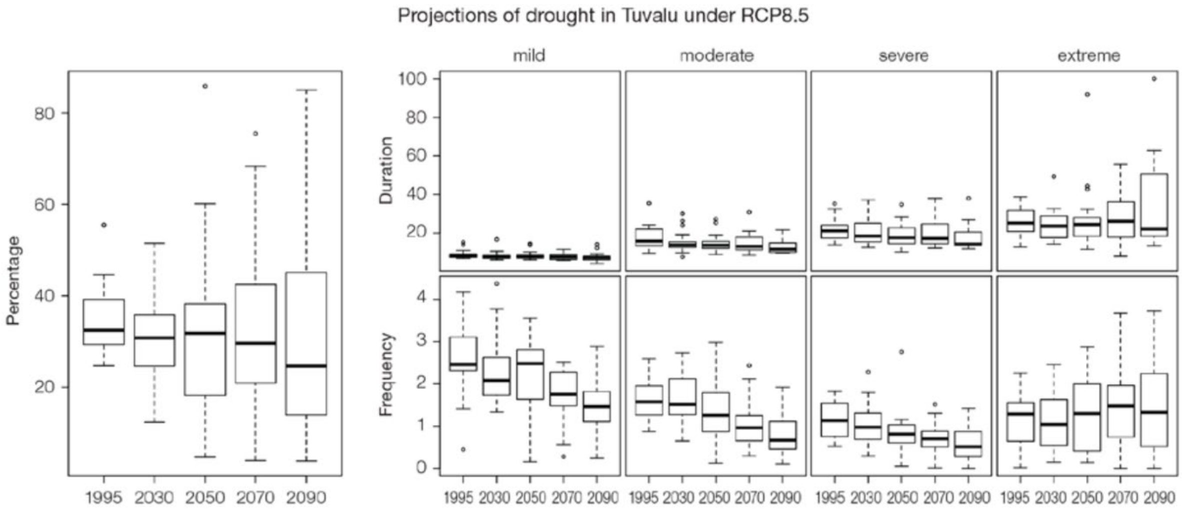


Figure 61. Box-plots showing percent of time in moderate, severe or extreme drought (left hand side), and average drought duration and frequency for the different categories of drought (mild, moderate, severe and extreme) for Tuvalu. These are shown for 20-year periods centred on 1995, 2030, 2050, 2070 and 2090 for the RCP8.5 scenario. The median of all models (thick dark lines), interquartile range (box), 1.5x the interquartile range (dashed lines) and outlier results (circles) are shown. (Source: Australian BoM and CSIRO, 2014)

3.7 SECTOR-SPECIFIC IMPACTS OF CLIMATE CHANGE

Decision makers across all sectors in the Pacific island region are faced with addressing the impacts of climate variability and climate change – rising temperatures, changing rainfall frequency and intensity, ocean warming and acidification, and sea-level rise – as outlined in the above sections. Pollution and overuse of natural resources, such as overfishing and intensive land and water use, and unsustainable development and mining are degrading Pacific island ecosystems and compounding climate change impacts.

This section analyses the sector-specific impacts of climate change on key sectors in the Pacific – agriculture and food security, disaster risk management, energy, health, water, fisheries and tourism – which have also been identified as priority sectors in the Pacific Roadmap for Strengthened Climate Services 2017 – 2026.[163] Given that literature on sectoral impacts in individual Pacific island countries is highly limited in availability, the analysis is presented from a regional perspective. Information specific to the five Programme countries is included, where available.

3.7.1 Agriculture and Food Security

In the five Programme countries, food crops are predominantly grown for subsistence purposes; however, most households are unable to meet their food needs through their own production and rely in part on domestic markets. Staple food crops grown in the Pacific islands include bananas, breadfruit, cassava, coconuts, sweet potato, taro and yams. Wheat flour and rice are important staples that are almost entirely imported. Cacao, coconut, coffee, palm oil and sugar are the main export crops.[164] Traditionally, Pacific island communities grew multiple crops, which conferred some resilience to climate change as not all crops were affected by specific hazards. However, increasing

[163] SPREP, 2016. Pacific Roadmap for Strengthened Climate Services 2017 - 2026
[164] Bell, J. *et al.* 2016. Climate change and Pacific Island food systems

production of monocultural export crops has reduced the diversity of local production and decrease resilience of food supply in the face of climate hazards.[165]

Climate change is adversely impacting on agriculture and food security in Pacific island countries in several ways: affecting both the ability to produce food and the ability to import food. Interannual climate variability has a large influence on agricultural production, and longer-term systematic changes in the climate introduce an additional complicating factor. For coastal communities, food production is compromised by the "effects of erosion, increased contamination of groundwater and estuaries by saltwater incursion, cyclones and storm surges, heat stress and drought".[166] Sea-level rise is a direct threat to taro cultivation – the main agricultural activity on the islands of Palau – which are critical for socio-economic development, as well as important to cultural and religious obligations. At present, once saltwater seeps into or displaces fresh water in their taro patches, farmers abandon the taro plots and move inland or shift to other crops. Deforestation is increasing as people clear steeper slopes to plant. This creates further issues such as erosion, silting of waterways, and destruction of biodiversity in the downstream marine population.[167] In Tuvalu, saline intrusion is enhanced by soil porosity and destroys pulaka crops (swamp taro – the country's main carbohydrate staple) and decreases fruit tree yields of coconut, banana and breadfruit.

Tropical cyclones can cause significant losses in agricultural production, with the potential to destroy tree and horticultural crops for several years after each occurrence. For example, in 2005, Pukapuka (Cook Islands) was completely inundated by storm surges associated with cyclones and strong winds, resulting in loss of agricultural land that took three years to recover.[168] High wind speeds are a significant threat to tree crops such as bananas, breadfruit, coconuts and mangoes.

Increases in extreme weather events such as drought and floods are likely to have greater impact than temperatures changes in the short-to-medium term (2030 – 2050), with devastating effects on agricultural productivity – including grain, horticultural, forestry and livestock production. Key export crops such as pawpaw and taro are highly sensitive to variations in rainfall patterns.[169] Crops such as sweet potato are sensitive to waterlogging and sugar cane is affected by floods. High temperatures affect the formation of sweet potato and yam, and increase the risk of pests and diseases.[170]

Furthermore, the impact of extreme climate events on critical infrastructure undermines both subsistence and commercial agriculture. Damage to equipment for processing and storing food can threaten the effective supply of food; and damages to roads, rails and vehicles can disrupt the supply of goods to markets, which in turn undermines the livelihoods of rural farmers.[171]

The impact of future climate change on agriculture has serious implications for food security in the five Programme countries. Increasing food imports will be required to meet basic caloric needs and the price of imports will rise in real terms, which will cause significant strain on household incomes. Food insecurity will increase unless supplementary sources of income can be found.[172]

3.7.2 Disaster risk management

[165] Barnett, J. 2011. Regional Environmental Change. Dangerous climate change in the Pacific Islands: food production and food security
[166] Barnett, J. 2011. Regional Environmental Change. Dangerous climate change in the Pacific Islands: food production and food security
[167] SPREP, 2009. Palau PACC Country Brief
[168] FAO, 2008. An Assessment of the Impact of Climate Change on Agriculture and Food Security in the Pacific. A Case Study in the Cook Islands
[169] UNFCCC, 2011. Cook Islands Second National Communication
[170] Bell, J. *et al.* 2016. Climate change and Pacific Island food systems
[171] Barnett, J. 2011. Regional Environmental Change. Dangerous climate change in the Pacific Islands: food production and food security
[172] SPC, 2016. Vulnerability of Pacific Island agriculture and forestry to climate change

Disaster risk management and reduction is integral to climate change adaptation. Climate change is projected to lead to more frequent and more intense climate and weather extremes, which – in association with increased exposure – will result in greater damage to human and environmental systems.[173] Pacific island countries are at the forefront of the impacts of climate change and are increasingly exposed to climate-related disasters. There is thus an immediate and growing need to increase disaster resilience in the Pacific island countries. The Pacific Roadmap for Strengthened Climate Services emphasises that with "appropriate use of meteorological, hydrological and climate information as part of a comprehensive multi-sector, multi-hazard, and multi-level approach, considerable achievements can be realised".[174]

3.7.3 Energy

Pacific island countries are heavily dependent on fossil fuels to meet local energy demands; and the cost of energy is among the highest in the world – as much as 200-300% compared to other regions[175] – predominantly due to high fuel transportation costs. Consequently, Pacific SIDS are highly vulnerable to oil price shocks and thus energy insecurity.[176]

"The principal means of energy generation in Pacific Island countries are:

- Oil-fired diesel generators—used whenever other sources are insufficient to meet normal needs. They can be very costly to operate as a principal source of energy, due to the high price of fuel and its transportation.
- Hydropower—available on larger islands where there is suitable topography for constructing reservoirs, e.g. Fiji and Samoa. Their effectiveness can be severely diminished during extended periods of low rainfall/drought.
- Wind generators—can be scaled to meet many levels of demand. They are very effective during persistent periods of trade wind flow.
- Solar photovoltaic electricity systems—can be scaled to some extent to meet a range of demands. Efficiency is subject to levels of cloud cover and of course they only operate during daylight hours.
- Solar water heating systems—similar to photovoltaic systems in terms of effectiveness but are mostly suitable for use on single building scale." [177]

The generation and use of energy resources are highly important to development in the Pacific. Fossil fuel dependence impedes adaptation capacity: increasing demand for foreign exchange for imports – forex spending on imports may constitute over 50% of total export earnings. Developing self-sufficiency in energy production using renewable energy sources can enable import savings to be redirected to adaptation investments and sustainable development.[178] Furthermore, although greenhouse gas (GHG) emissions from SIDS are minute on the global scale, reducing GHG emissions in the Pacific is important for two reasons: i) Every GHG reduction counts; and ii) Reducing emissions

[173] Nalau, J. *et al.* 2015. Climate and Development. The practice of integrating adaptation and disaster risk reduction in the south-west Pacific
[174] SPREP, 2017. Pacific Roadmap for Strengthened Climate Services 2017 – 2026
[175] UNEP, UN DESA and FAO, 2012. SIDS-Focused Green Economy: An Analysis of Challenges and Opportunities
[176] Wolf, F. *et al.* 2016. Energy Policy. Energy access and security strategies in Small Island Developing States
[177] SPREP, Pacific Roadmap for Strengthened Climate Services 2017-2026.
[178] World Bank, 2014. WB-UN High Level Dialogue on Advancing Sustainable Development in Small Island Developing States. SIDS – Towards a Sustainable Energy Future. Available at: https://www.worldbank.org/content/dam/Worldbank/SIDS%20Towards%20Sustainable%20Energy%20Future.pdf

demonstrates feasibility to larger emitters and increases the credibility and moral leverage of SIDS in global climate change negotiations.[179]

In 2012, the Cook Islands, Niue and Tuvalu set the target of 100% renewable energy by 2020.[180] The Niue Strategic Energy Road Map 2015 – 2025 subsequently revised the target as 80% renewable energy generation by 2025.[181] Palau intends to generate 45% of its energy from renewable sources by 2025.[182] RMI aims to have 100% renewable energy by 2050.[183]

Energy production – including the efficiency of production – is highly sensitive to meteorological and climate events. The efficiency and effectiveness of renewable energy systems in particular must take into account local climatic conditions during both their design and operation. For example, information on solar radiation and wind fields is required for the development of solar and wind power; and hydrometeorological information at the catchment domain is needed for hydropower systems. Therefore, partnerships and stakeholder engagement between NMHSs and the energy sector to apply weather and climate information are critical to developing efficient and effective energy systems. Such arrangements will support climate-resilient policy and decision-making aimed at achieving an "optimal balance between supply and demand as well as driving behavioural changes to energy efficiency and savings".[184]

3.7.4 Health

Climate change has significant and diverse impacts on human health: i) primary or direct effects – e.g. injuries and deaths caused by extreme weather events such as cyclones; ii) secondary or indirect effects – e.g. the increasing geographic range of, and population exposed to, vectors that spread disease; and iii) tertiary, diffuse and/or delayed effects – e.g. disruptions to health and social services.

Pacific island countries are some of the most vulnerable in the world to the health impacts of climate change. This vulnerability is on account of their exposure to changing weather patterns, the associated health risks, and their limited capacities to manage and adapt in the face of climate risks. The figure below shows the climate change and health impact pathways relevant to the Pacific island countries.[185]

[179] Betzold, C., 2016. Renewable and Sustainable Energy Reviews. Fuelling the Pacific: Aid for renewable energy across Pacific Island countries

[180] Mitigation Partnership, 2015. 100% Renewable Energy Targets in the Pacific Islands. Available at: https://www.transparency-partnership.net/system/files/migrated_document_files/2012ongoingrenewableenergy_pacificislands.pdf

[181] Government of Niue, 2015. Niue Strategic Energy Road Map 2015 – 2025

[182] Government of Palau, 2015. Intended Nationally Determined Contribution (NDC)

[183] Government of RMI, 2018. Marshall Islands Electricity Roadmap

[184] SPREP, 2017. Pacific Roadmap for Strengthened Climate Services 2017 – 2026

[185] McIver, L. *et al.* 2016. Environmental Health Perspectives. Health Impacts of Climate Change in Pacific Island Countries: A Regional Assessment of Vulnerabilities and Adaptation Priorities

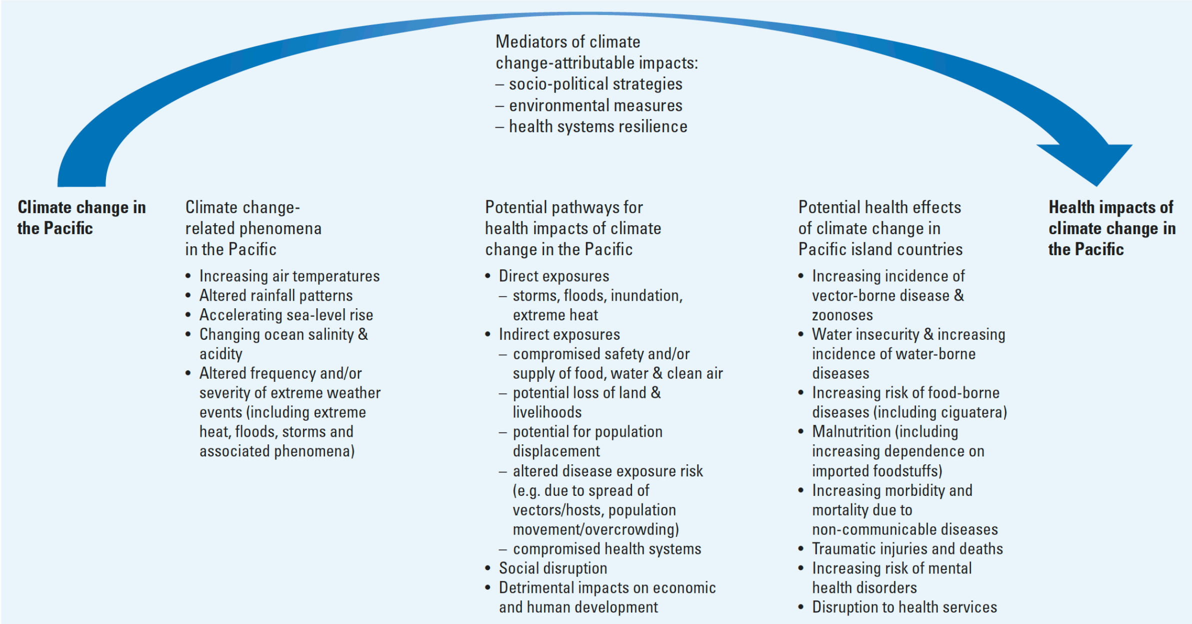


Figure 62. Climate change and health impact pathways relevant to Pacific island countries. (Source: McIver, L. et al.)

Climate-related disasters can cause an increased risk of vector- and rodent-borne diseases (including dengue, malaria, chikungunya, zika and leptospirosis), food- and water-borne diseases (including cholera, cryptosporidium, rotavirus, E.coli infection, giardia, shigella, typhoid and hepatitis A), and biotoxin-mediated illness (ciguatera and shellfish poisoning).[186] Vector-borne disease transmission is related to temperature, whereby warmer temperatures can shorten incubation periods for mosquitoes. Shorter incubation can significantly increase the transmission rate of diseases such as dengue, chikungunya and zika. Temperature also influences the biting rates, diapause and maturity of the protozoan parasite found in sand-flies.[187] Furthermore, torrential rain leads to increased cases of diarrhoea and other water-borne diseases; atypical fluctuations in weather and temperature increase ear, nose and throat illnesses; and higher temperatures lead to heat stress and heat-related illnesses.

McGree *et al.* reported a regional scale positive trend of 45.59 cooling degree-days per decade, which measures the energy demand needed to cool a building. In the Pacific island region, there is often "limited access to electricity beyond the major towns and cities, and the average income is lower than in the western world"; therefore, it is likely that "many Pacific Islanders, especially the elderly, are unable to afford adequate cooling".[188] Increases in warm nights can play a significant role in contributing to heat-wave mortality where air conditioning is uncommon.[189] Consequently, as temperatures rise, the risk of heat-related mortalities in the Pacific region is expected to increase.

The hospital in Funafuti (Tuvalu) has set up a specialist unit to record and analyse climate change related illness. Notably, it reports that the incidence of ciguatera poisoning is increasing in line with rising temperatures: high ocean temperatures stress the corals in Tuvalu's surrounding reefs and they expel the symbiotic dinoflagellates that live in them. These marine plankton, containing neurotoxins, are then eaten by reef fish, rendering the fish poisonous to humans. Once exposed, people who have been affected by ciguatera cannot eat reef fish, which are their principal protein source, without

[186] WHO, Pacific Technical Support, 2015, "El Nino and health in the Pacific."
[187] GCF, 2018, Cook Islands Climate Change Country Programme.
[188] McGree, S. *et al.* 2019. Journal of Climate. Recent Changes in Mean and Extreme Temperature and Precipitation in the Western Pacific Islands. [Under review]
[189] Karl, T.R. and Knight, R.W., 1997. The 1995 Chicago heat wave: How likely is a recurrence?

risking death – a second contact with ciguatera can be fatal. This effectively forces anyone affected to replace local fish with more expensive and less nutritious imported foods.

The Pacific region has additional climate-related health risks of concern that have not been documented to the same extent elsewhere in the world, including noncommunicable diseases (NCDs), mental and/or psychosocial health disorders and ciguatera.[190] The rates of NCDs in Pacific island countries are among the highest in the world;[191] thus, the potential for climate change to act as an additional risk factor for NCDs – due to exacerbating food insecurity and poor nutrition – is of significant concern. In addition, communities in the Pacific region are already being subject to climate-induced forced migration and displacement – both internal and external – which may result in considerable physical and psychosocial health consequences.[192]

3.7.5 Water

"Water is fundamental to life. Population growth, urbanisation, and agricultural use have increased demand for water throughout Pacific Island countries. At the most basic level, people need freshwater supplies for drinking, but even resources for this purpose are being severely stretched in some locations especially when there is an extended downturn in rainfall. Groundwater reserves are being depleted and low-lying atolls are being contaminated by salt-water intrusion due to sea level rise and storm surges.

"There is a large diversity in freshwater resource characteristics in the Pacific which relate to:

- Physical nature of islands (size, topography, geology, etc.);
- Local and broad-scale climate;
- Hydrology and water availability;
- Demography (total population, percentage of urban and rural);
- Culture; and
- Degree of economic development.

Common or naturally occurring sources of freshwater include groundwater, surface water and rainwater. Less common and generally more expensive sources include desalination, importation and recycling of wastewater, e.g. for agriculture. Small islands in particular have more limited water resources, which are more susceptible to natural hazards including droughts, floods, tropical cyclones, earthquakes, tsunamis, volcanic eruptions, landslides, and sea level rise."[193]

At the regional level, the Pacific island countries have the lowest access to improved drinking water in the world and the second lowest sanitation coverage.[194] However, there is significant variation in coverage both between countries and within countries; and regional statistics thus hide the impressive performance of individual countries. Improved drinking water coverage is at least 95% Cook Islands, Niue, RMI and Tuvalu (no data was available for Palau). The proportions of the population in the

[190] McIver, L. *et al.* 2016. Environmental Health Perspectives. Health Impacts of Climate Change in Pacific Island Countries: A Regional Assessment of Vulnerabilities and Adaptation Priorities
[191] Mannava, P., 2015. Asia Pacific Journal of Public Health. Health systems and noncommunicable diseases in the Asia-Pacific region: a review of the published literature
[192] McIver, L. *et al.* 2016. Environmental Health Perspectives. Health Impacts of Climate Change in Pacific Island Countries: A Regional Assessment of Vulnerabilities and Adaptation Priorities
[193] SPREP, Pacific Roadmap for Strengthened Climate Services 2017–2026.
[194] Global Change Institute and the School of Public Health, The University of Queensland, 2019. Water, Sanitation and Hygiene in the Pacific: The need to meet SDG 6

Programme countries using different types of drinking water sources and sanitation are shown in the figures below.[195]

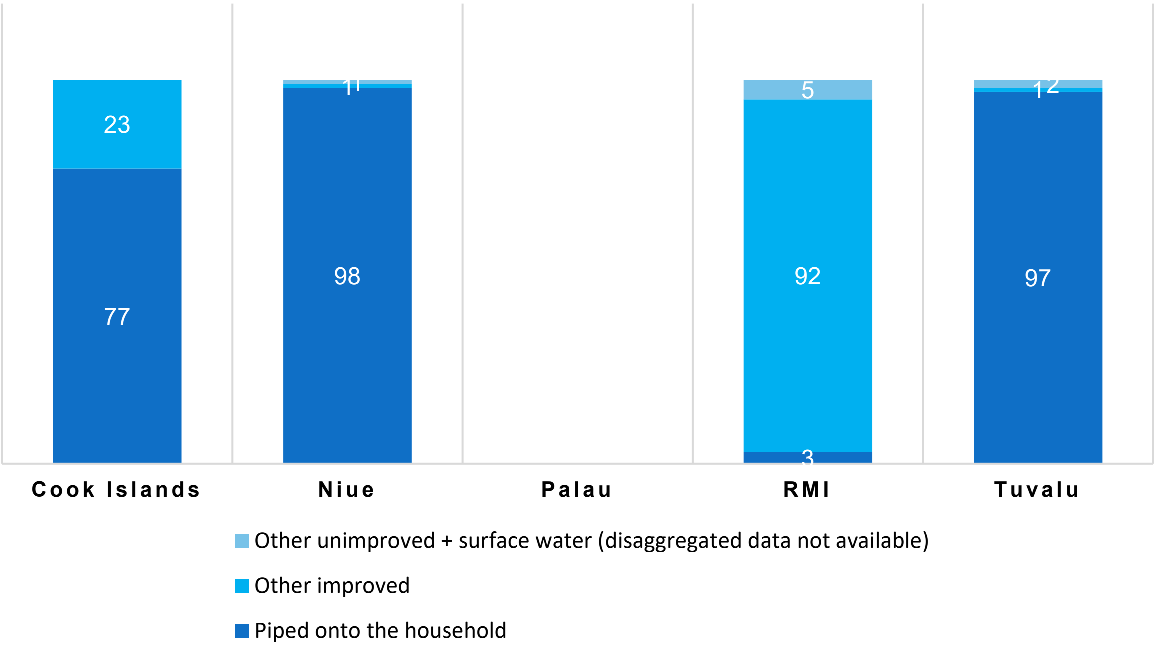
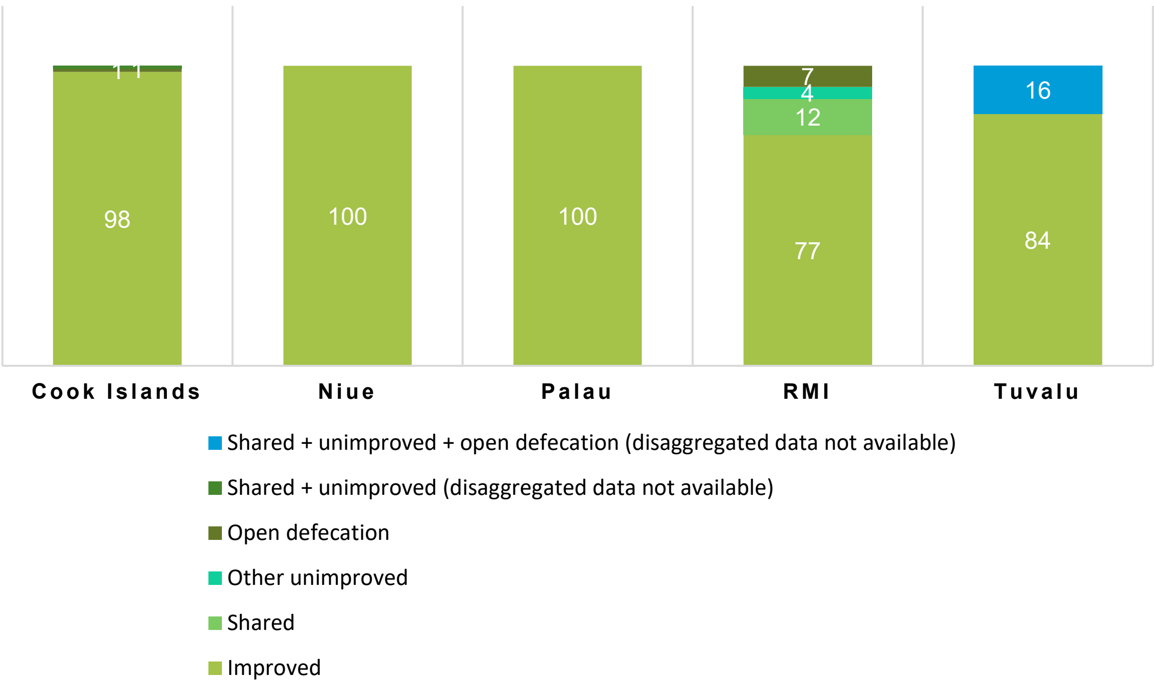


Figure 63. Proportion of the population using different types of drinking water sources in Cook Islands, Niue, RMI and Tuvalu in 2015. N.B. Data unavailable for Palau – however, ADB estimated that 90% of households have access to piped, treated water in 2009.[196] (Source: Country statistics from UNICEF and WHO)



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[195] WHO, 2016. Sanitation, Drinking-Water and Health in Pacific Island Countries. 2015 Update and Future Outlook

[196] Republic of Palau, 2013. Third International Conference on Small Island Developing States. Republic of Palau National Report. Available at: http://wedocs.unep.org/bitstream/handle/20.500.11822/8462/Palau.pdf?sequence=3&isAllowed=y

Figure 64. Proportion of the population using an improved, shared or other unimproved sanitation facility or practising open defecation in Cook Islands, Niue, Palau and RMI in 2015. N.B. Data for Tuvalu is based on figures in 2014.[197] (Source: Country statistics from UNICEF and WHO)

Geographic and economic isolation, and limited human and physical resources, present significant challenges to improving water, sanitation and hygiene in Pacific island countries. The disparity between urban and rural drinking water and sanitation coverage is particularly evident in RMI. The Marshall Islands has the largest number of inhabited islands or atolls (24) of the five Programme countries, spread across an EEZ of 2.1 million km^2, and small rural communities are often too remote – and thus expensive – to equip with improved water and sanitation.[198]

In the Pacific island region, water is the primary means through which climate variability, climate change and natural hazards influence livelihoods and wellbeing.[199] Direct impacts on water resources can occur via increased intensity of rainfall and flash floods leading to contamination of water supplies, which affects water quality; reduced safety of groundwater due to slower recharge and saltwater intrusion from reduced freshwater flow; and changes in seasonality and timing of precipitation. Indirect impacts on water resources may result from pressures on ecosystems and biodiversity and subsequent changes (e.g. changes in species abundance and desertification); demographic changes due to forced displacement; changes to agricultural ecosystems and potential food insecurity; contamination of water resources due to changes to run-off and sedimentation; and sea-level rise.[200]

All five Programme countries are highly dependent on rainfall as the main freshwater source, with particular vulnerability in the low-lying islands (Niue, RMI and Tuvalu) that have no significant surface and/or groundwater resources. In the moderate-sized volcanic island of Rarotonga (Cook Islands), water resources are generally adequate to meet demand, but significant management challenges remain due to high seasonal variability. In Palau, despite its small resident population, water consumption is relatively high due to a growing tourism industry and limited infrastructure for water management. In addition, the agriculture sector depends solely on regular rainfall as few irrigation systems are in place.[201] In Tuvalu, groundwater must be used for washing clothes, bathing and flushing toilets during times of drought. Rapid population growth is increasing demand for already constrained water resources, thus exacerbating the issue.[202]

More intense ENSO events will impact on water supply and island economies.[203] For example, the El Niño event in 1997/98 was one of the most pronounced drought periods in RMI – bringing only 8% of normal rainfall in a four-month period – and led the Government of RMI to declare the entire archipelago a disaster area. Droughts are especially damaging in the atolls lacking sufficient rainwater harvesting and storage capacity, as is the case in most of the outer atolls of the dry northern region (Utrik, Ailuk, Likiep, Wotho, Lae and Namu).[204] The capital of Majuro has its own difficulties with water supply. Tens of thousands of Marshallese rely on town water collected from rainwater runoff from the runway of the Marshall Islands' main airport. The water is channelled to storage reservoirs, filtered,

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197 The WHO and UNICEF Joint Monitoring Program 2014 reported 86.3% total improved urban sanitation coverage and 80.2 % total improved rural sanitation coverage in Tuvalu. This equates to 84% total improved sanitation coverage, assuming that 41.2% of the population lived in rural areas in 2014 (Index Mundi).

198 Hadwen, W.L., 2015. Journal of Water, Sanitation and Hygiene for Development. Putting WASH in the water cycle: climate change, water resources and the future of water, sanitation and hygiene challenges in Pacific Island Countries

199 WHO, 2016. Sanitation, Drinking-Water and Health in Pacific Island Countries. 2015 Update and Future Outlook

200 Hadwen, W.L., 2015. Journal of Water, Sanitation and Hygiene for Development. Putting WASH in the water cycle: climate change, water resources and the future of water, sanitation and hygiene challenges in Pacific Island Countries

201 UNFCCC, 2013. Palau Second National Communication

202 UNFCCC, 2015. Tuvalu Second National Communication

203 UNFCCC, 2011. Cook Islands Second National Communication

204 USGS Scientific Investigations Report 2005-5098. Effects of the 1998 Drought on the Freshwater Lens in the Laura Area, Majuro Atoll, Republic of the Marshall Islands

treated and pumped to people down the atoll. During a normal week the water only flows for 12 hours. In prolonged droughts—a few months without rain—the reservoirs are drained. Some households have small rainwater tanks of their own, but by no means all. Climate change is likely to make access to freshwater, already in limited supply, a very serious issue.[205]

The strong La Niña event that followed in 1998 – 2000 led to acute water shortages in many Pacific island countries – with partial shutdown of the tourism industry required in some extreme cases.[206]

3.7.6 Fisheries and Aquaculture

The Pacific island countries are sometimes referred to as big ocean developing states as they are the custodians of 20% of the 50 largest exclusive economic zones.[207] The region is heavily dependent on oceanic and coastal fisheries for food security, livelihoods, revenue, employment and development. Fish intake is high and is estimated to account for 50 – 90% of animal protein intake in rural areas, and 40 – 80 % in urban areas. Most of the fish eaten by rural communities comes from subsistence fisheries, with little or no cost to the consumer.[208] The contribution of fishing to GDP ranges from 1.0 % (Cook Islands) to 29.5 % (Marshall Islands), as estimated by SPC in 2016.[209]

Climate change is expected to have significant impacts on coastal and oceanic habitats, the fish and invertebrates that they support, and consequently, the productivity of fisheries and aquaculture. Increasing temporal and spatial variability in fish abundance may result from degradation of reefs and mangroves, and changing water turbidity, salinity and temperature. In particular, decreased productivity of demersal fish and invertebrates – which constitute the greatest percentage of total catch in Palau, RMI and Tuvalu – and a more eastward distribution of some tuna species, are expected to present the greatest threat to the use of fisheries resources by Pacific island communities and economies. Invertebrates such as pearl oysters and shrimp, which are important aquaculture commodities, will be affected by increasing ocean temperatures and acidification. The projected changes in coastal fisheries production are shown in the following table.

<table>
<tr><th rowspan="2" colspan="2">Variable</th><th colspan="4">Coastal fisheries category</th><th rowspan="2" colspan="2">Total coastal fisheries
(assumes that the proportions of the three coastal fisheries categories remain constant)</th></tr>
<tr><th>Demersal fish</th><th colspan="2">Nearshore pelagic fish</th><th>Invertebrates</th></tr>
<tr><td rowspan="2" colspan="2">Contribution to coastal fisheries production</td><td rowspan="2">56 %</td><td colspan="2">28%</td><td rowspan="2">16 %</td><td rowspan="2">West</td><td rowspan="2">East</td></tr>
<tr><td>West
(15°N – 20°S and 130°E – 170°E)</td><td>East
(15°N – 15°S and 170°E – 150°W)</td></tr>
<tr><td>Change in production</td><td>2050</td><td>-20 %</td><td>-10 %</td><td>+20 %</td><td>-5 %</td><td>-10 to -20 %</td><td>-5 to -10 %</td></tr>
</table>

[205] Mellgard P, 2015, Available at <https://www.huffingtonpost.com.au/entry/marshall-islands-climate-change_n_56796928e4b06fa6887ea12c> [August 2019]
[206] IPCC, 2007. Fourth Assessment Report
[207] Smith G, 2015, Abstract: The COSPPac Ocean Portal: Providing ocean information for applications in western Pacific small island developing states
[208] Hanich, Q. *et al.* 2018. Marine Policy. Small-scale fisheries under climate change in the Pacific Islands region
[209] SPC, 2016. Fisheries in the Economies of Pacific Island Countries and Territories

due to climate change	2100	-20 to -50 %	-15 to -20 %	+10 %	-10 %	-20 to -35 %	-10 to -30 %
Main direct and indirect effects of climate change		Habitat loss and reduced recruitment (due to increasing temperature and reduced water movement)	Reduced production of zooplankton in food webs for non-tuna species and changes in distribution of tuna		Habitat degradation, declines in aragonite saturation due to ocean acidification		

Table 23. Projected changes in production of the three categories of coastal fisheries, and total coastal fisheries production, in 2050 and 2100 under a high emissions scenario. The main direct and indirect effects of climate change projected to affect each coastal fisheries category are also provided. (Source: Commonwealth Marine Economies Programme)[210]

Increasing variability in fish abundance will differentially affect nutrition and incomes across the five Programme countries. In particular, coastal fisheries may not meet the food security needs of Niue and Tuvalu due to limited productivity and inadequate national distribution networks.[211, 212]

The Western and Central Pacific Ocean has the largest tuna fishery in the world.[213] In 2017, fishing license fees in Tuvalu accounted for 50 % of total government revenue.[214] The predicted increase in frequency or severity of ENSO events due to climate change may affect the amount of fish caught in the EEZs of the Pacific island countries, with resultant impacts on revenue earned from access fees paid by distant water fishing nations. “Climate change may also cause an extension of the present range of tuna to higher latitudes, a decrease in net productivity, increase variability in the catches and so decrease catch per unit of effort with subsequent impacts on the costs of production and prices, and potentially increase pressure on the most valuable species of bigeye and yellowfin in an attempt to offset increasing costs.”[215]

Furthermore, climate change-related increases in storm damages may adversely affect fisheries development due to damage to and loss of fishing vessels, boat launching facilities, fuel facilities, and fish storage and processing facilities. For example, in 2004, damages caused by Cyclone Heta caused subsistence fishing in Niue to cease for several weeks.[216]

Niue’s coastal waters have increased in both surface temperature and acidity levels as a result of climate change.[217] Resulting effects include increased incidents of coral bleaching and die-off, causing changes to fish spawning and breeding grounds and reduced barrier protection (provided by reefs) against storm surges. Fish species critical for food security, such as deep-water tuna, are migrating to higher latitudes and away from Niuean waters. This development is particularly concerning to the Government of Niue, since most households are reliant on fish caught in Niuean waters, mostly

[210] Commonwealth Marine Economies Programme, 2018. Science Review. Effects of Climate Change on Fish and Shellfish Relevant to Pacific Islands, and the Coastal Fisheries they Support
[211] Commonwealth Marine Economies Programme, 2018. Science Review. Effects of Climate Change on Fish and Shellfish Relevant to Pacific Islands, and the Coastal Fisheries they Support
[212] Barnett, J., 2011. Regional Environmental Change. Dangerous climate change in the Pacific Islands: food production and food security
[213] Allain, V. *et al.* 2016. Overview of tuna fisheries, stock status and management framework in the Western and Central Pacific Ocean Island Fisheries in the Pacific: The challenges of governance and sustainability. Available at: https://books.openedition.org/pacific/423?lang=en
[214] IMF, 2018. Tuvalu International Monetary Fund Country Report No. 18/209
[215] Barnett, J., 2011. Regional Environmental Change. Dangerous climate change in the Pacific Islands: food production and food security
[216] Barnett, J., 2011. Regional Environmental Change. Dangerous climate change in the Pacific Islands: food production and food security
[217] Government of Niue, 2015, Niue’s Intended Nationally Determined Contribution

through subsistence fishing [218] and a significant component of Niue's income comes from the sale of fishing licences. The distant fishing nations who negotiate annual licences with Pacific SIDS use sophisticated satellite imaging to determine the most productive fishing grounds and are advantaged over Pacific SIDS in these negotiations.

Changes in currents and warmer water temperatures can cause further risks to marine life, such as increasing the dominance of invasive species like jellyfish. These impacts combine with non-climate factors such as over-fishing of the reef flats in a context where demand for fish already far outstrips supply. Such changing conditions have resulted in reduced access to fish for food security and market-based income, and increased reliance on imported foods to meet island demand. [219]

To prevent overfishing and rebuild overfished stocks under changing and uncertain environmental conditions, effective partnerships between fisheries scientists and managers and climate service providers are needed.

The International Workshop on Climate and Oceanic Fisheries in Rarotonga, Cook Islands in October 2011, *inter alia* reviewed the current understanding and status of marine and oceanic climate and climate variability, in particular in the South Pacific and also the effects of climate and climate variability on seasonal to decadal time scales on oceanic fisheries, including through an evaluation of available historical data on marine climate and oceanic fish abundance.

'While there has been a significant growth in aquaculture throughout the Pacific, less attention has been given to the actual effects of climate variability on productivity or the potential effects of climate change. The potential affects were addressed however in the report of a workshop in Noumea, New Caledonia in June 2012 sponsored by the Food and Agriculture Organization (FAO)/ Pacific Community (SPC) on *Priority adaptations to climate change for Pacific fisheries and aquaculture: Reducing risks and capitalising on opportunities."* [220]

3.7.7 Reef ecosystems

The tropical Pacific region is home to around a quarter of the world's reefs,[221] with RMI among the top ten richest countries in reef resources in the world. Coral reefs are one of the main attractions of the Pacific region's tourism industry. Pacific reefs sustain fisheries and marine ecosystems and act as a natural protection against coastal erosion – maintaining beach and coastal land levels against eroding forces of storms and sea level rise.

Coral reefs are highly vulnerable to climate variability. Increases in sea surface temperature result in coral bleaching, which occurs when water temperature rises 1.8 – 3.6 °C above the warmest normal summer temperatures. This induces coral stress, which causes corals to expel their colourful algae and turn white. Prolonged and intense coral bleaching can lead to coral death. The projected changes[222] in severe coral bleaching risk in the EEZs of the five Programme countries are shown in the table below. Overall, there is a decrease in the time between two periods of elevated risk and an increase in the duration of the elevated risk as sea surface temperature (SST) increases. When bleaching occurs, coral reef recovery is dependent on the severity and extent of the bleaching event. Long-term viability of coral reef ecosystems is threatened once the frequency of severe bleaching events rises above more

[218] J Barnett, 2008, Climate Change and Small Island States: Power, Knowledge and the South Pacific.
[219] Government of Niue, 2012, Niue's Joint National Action Plan for Disaster Risk Management and Climate Change.
[220] SPREP, Pacific Roadmap for Strengthened Climate Services 2017-2026.
[221] WRI, 2011. Reefs at Risk Revisited: Pacific
[222] Australian Bureau of Meteorology and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports

than once every five years.[223] The projections indicate that the Palau EEZ will have the highest coral bleaching risk of the five countries as SST rises.

Temperature change		Cook Islands	Niue	Palau	Marshall Islands	Tuvalu
Change in observed mean	Recurrence	0	0	30 years	0	0
	Duration	0	0	4.9 weeks	0	0
+ 0.25 °C	Recurrence	30 years	0	29.1 years	30 years	30 years
	Duration	2 weeks	0	9.3 weeks	3.5 weeks	4.2 weeks
+ 0.5 °C	Recurrence	28.2 years	30 years	28.8 years	28.0 years	19.1 years
	Duration	6.0 weeks	5.0 weeks	3.7 months	5.4 weeks	7.0 weeks
+ 0.75 °C	Recurrence	10.7 years	16.0 years	7.3 years	13.8 years	4.3 years
	Duration	6.9 weeks	6.9 weeks	7.4 weeks	6.4 weeks	8.7 weeks
+ 1 °C	Recurrence	3.4 years	3.0 years	2.0 years	3.3 years	1.3 years
	Duration	8.8 weeks	8.1 weeks	8.9 weeks	8.9 weeks	10.5 weeks
+ 1.5 °C	Recurrence	1.1 years	1.0 years	4.5 months	9.6 months	6.8 months
	Duration	3.0 months	3.0 months	3.0 months	4.1 months	5.8 months
+ 2 °C	Recurrence	8.5 months	8.4 months	2.7 months	5.1 months	2.9 months
	Duration	4.4 months	4.4 months	8.8 months	7.3 months	8.4 months

Table 24. Projected changes in severe coral bleaching risk for the EEZs of the five Programme countries for increases in SST relative to 1982 – 1999. Recurrence is the mean time between severe coral bleaching risk events. Duration refers to the period of time where coral are exposed to the risk of severe bleaching. (Source: PACCSAP)

The above projections do not take into account factors other than open ocean SST that could additionally influence coral bleaching, for example: temperature variability at the reef scale, which can play a role in modulating large-scale changes; stressors such as ocean acidification, storm damage, fishing pressure and other human impacts, which may limit the ability of coral reefs to cope with elevated temperature; and potential for decrease in the risk of bleaching due to coral adaptation to higher temperatures.[224]

Warming sea surface temperatures increase the incidence of toxic algae that grows on Pacific reefs. In Niue, as in the rest of the South Pacific, ciguatera poisoning is associated with coral bleaching and rates of infection were reported to increase in Niue in the years following Cyclone Heta in 2004. Furthermore, increasing ocean acidification can further exacerbate coral degradation due to reduced carbonate available for reefs to build their calcium carbonate skeletons.[225]

Mass coral bleaching has already occurred in the Pacific and more frequent and severe episodes of bleaching are expected to occur. In 2014 – 2017, the world experienced its longest, most widespread and most severe global bleaching event on record.[226] In some areas of the Marshall Islands, up to

[223] Donner, S., 2009. PLOS ONE. Coping with Commitment: Projected Thermal Stress on Coral Reefs under Different Future Scenarios
[224] Australian Bureau of Meteorology and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports
[225] ADB, 2013. The Economics of Climate Change in the Pacific
[226] Couch, C.S. *et al.* 2017. PLOS. Mass coral bleaching due to unprecedented marine heatwave in Papahanaumokuakea Marine National Monument (Northwestern Hawaiian Islands)

100% of the coral died due to spikes in sea surface temperature.[227] Analysis by the Asian Development Bank estimated that the Pacific coral area in 2000 was around 80% of what would have been in the absence of thermal stress, and that increasing thermal stress will reduce Pacific coral area to 55% in 2050 and 20% in 2100 – from 88% in the base year (1995). By 2100, coral reef cover is projected to be less than 1%. This will have major implications for the tourism, fisheries and coral mining industries, and loss of areas of significant importance to maintaining marine biodiversity.[228]

Furthermore, coral reefs are threatened by unsustainable development practices. In Tuvalu, sand, calcareous algae and shells, and coral are essential to the underlying structure of its islands. Urban development, habitat fragmentation, dredging and extraction of coastal aggregates have led to the destruction of coral reef systems.[229]

3.7.8 Tourism

Tourism is a major economic driver in the Pacific region; particularly in the Cook Islands and Palau, where it accounts for a majority of GDP.[230] In Cook Islands, tourism is estimated to account for around 82% of GDP;[231] in Palau, the service sector – including direct tourism contributions – accounts for more than 80% of GDP and employs three-quarters of the work force.[232] Niue is working towards being one of the world's leading destinations for sustainable tourism and launched its Responsible Tourism Policy in September 2017.[233] The Government of RMI is attempting to develop its tourism industry; however, this is a challenge due to the high cost of access to the islands.[234] In Tuvalu, tourism is proposed to have the highest growth potential of any industry. Long-standing recommendations for development of the tourism sector are stated in its National Tourism Development Strategy 2015-2019.[235]

The inter-relationship between climate and tourism in the Pacific is complex – climate is both a resource to be exploited for economic development, as well as a limiting factor that poses significant risks to both the industry and to tourists.[236] Climate change can impact the tourism industry "by changing the attractiveness of the climate of tourism destinations, by reducing the value of attractions at destinations, and by altering the relative climate of the home countries of tourists."[237] Climate change can also directly impact on environmental resources that serve as tourist attractions in Pacific island countries. Widespread resource degradation such as beach erosion and coral bleaching is likely to negatively affect the perception of destination attractiveness.[238] A study commissioned by the Asian Development Bank predicted that global warming will lessen the Pacific island region as a

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[227] The Guardian, 2014. Major coral bleaching in Pacific may become worst die-off in 20 years, say experts. Available at: https://www.theguardian.com/environment/2014/dec/19/major-coral-bleaching-pacific-may-worst-20-years
[228] ADB, 2013. The Economics of Climate Change in the Pacific
[229] UNFCCC, 2015. Tuvalu Second National Communication
[230] ADB, 2013. The Economics of Climate Change in the Pacific
[231] SPC, 2020. Statistics for Development Division. Economic and Social Impact Indicators. Gross Tourism Receipts % of GDP – 2018. Available at: https://sdd.spc.int/news/2020/04/29/economic-and-social-impact-covid-19-pandemic-pacific-island-economies
[232] Global Tenders, 2020. Economy and Business Opportunities for Palau. Available at: https://www.globaltenders.com/economy-of-palau.php
[233] TRC Tourism, 2019. Niue Working Towards Being One of the World's Leading Sustainable Tourism Destinations. Available at: https://www.trctourism.com/niue-working-towards-becoming-one-of-the-worlds-leading-sustainable-tourism-destinations/
[234] Import-Export Solutions, 2020. Marshall Islands: Country Risk. Available at: https://import-export.societegenerale.fr/en/country/marshall-islands/economy-country-risk
[235] Government of Tuvalu, 2016. Te Kakeega III. National Strategy for Sustainable Development 2016 – 2020
[236] Pacific Meteorological Council, 2016. Pacific Roadmap for Strengthened Climate Services 2017 - 2026
[237] ADB, 2013. The Economics of Climate Change in the Pacific
[238] Wong, P. *et al.* 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Low-Lying Areas

tourism attraction and reduce tourism revenues by around 30% for the Pacific region as a whole, under all climate scenarios.[239]

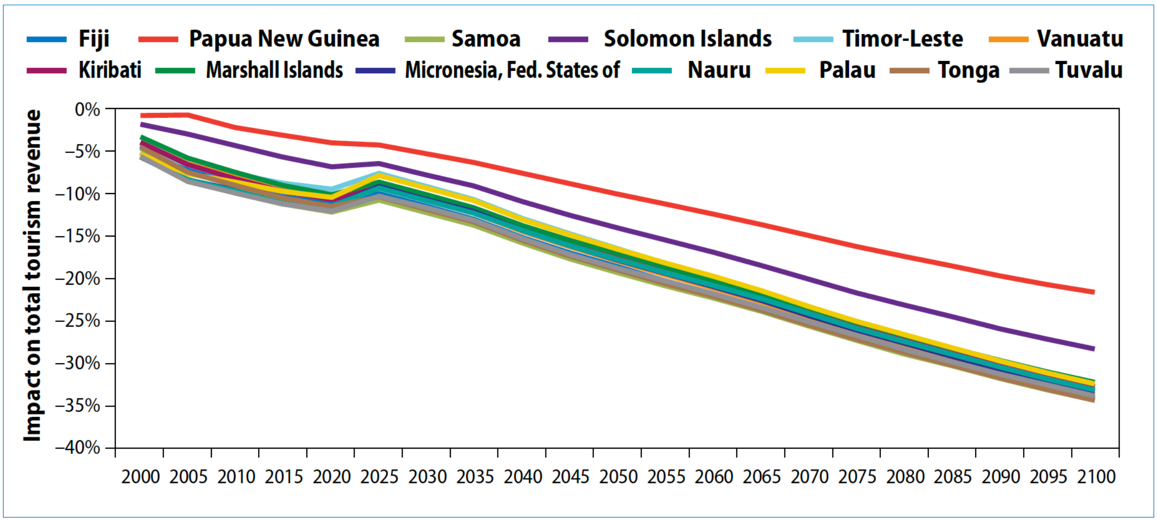

Figure 65. Impact of climate change on national tourism revenue under the A1 scenario. (Source: ADB)

The Pacific Roadmap for Strengthened Climate Services 2017 – 2026 highlighted that "Given the relatively stable year-round climate when compared to other higher latitude tourist destinations, there may be value in implementing the Climate Index for Tourism (CTI), which considers thermal, aesthetic and physical aspects of weather in relation to beach tourism…Communicating with the tourism sector with respect to risk assessment for an upcoming season can at times be problematic, due to attendant economic risks to tourism operators and local businesses servicing the industry. An outlook that portends an increased risk of tropical cyclones, for example, has the potential for deterring tourists from visiting a particular country. Close dialogue between the NMHS and tourist operators and service providers is therefore very important whenever such risks are being highlighted."[240]

3.8 INTERCONNECTIVITY BETWEEN THE COVID-19 PANDEMIC AND CLIMATE CHANGE

As of 12 June 2020, there were 312 reported cases and seven deaths attributed to COVID-19 across the Pacific island region. None of the five Programme countries have yet been affected; however, a State of Emergency was declared in Cook Islands, Palau, RMI and Tuvalu.[241] UNDRR has highlighted that as Pacific island countries enter their cyclone, drought, heatwaves or monsoon seasons, the potential for an **'unprecedented double disaster'** is increasing.[242]

COVID-19 represents a significant challenge for the Pacific island region, on account of several risk factors:

- Limited access to quality health services due to lack of infrastructure, equipment and qualified personnel;

[239] ADB, 2013. The Economics of Climate Change in the Pacific
[240] SPREP, Pacific Roadmap for Strengthened Climate Services 2017–2026.
[241] WHO, 2020. COVID-19 Joint External Situation report 19 – Western Pacific
[242] UNDRR, 2020. UNDRR Asia Pacific COVID-19 Brief. Combating the dual challenge of COVID-19 and climate-related disasters

- Lack of laboratory equipment needed to analyse tests on site, which impedes the identification of cases;
- Tourism increases movement of people to and from the islands (although restrictive measures have been put in place); and
- Restrictions to tourism present a risk to local economies.[243]

In April 2020, the Secretary General of the Pacific Islands Forum emphasised that "climate change induced disasters can exacerbate the COVID-19 crisis" in Pacific SIDS, as exemplified by Cyclone Harold in the Solomon Islands, Vanuatu, Fiji and Tonga.[244] In the aftermath of Cyclone Harold, challenges to disaster relief efforts included the need to quarantine critical humanitarian aid supplies resulting in delays to distribution; limited rescue efforts due to the rescue helicopter pilot being in coronavirus quarantine; delayed recovery support in outer islands due to domestic travel restrictions; and limited budget allocations to address cyclones as scarce resources are transferred to address the urgent needs presented by the pandemic.[245]

The Pacific Community (SPC) has reported that the expected sharp decline in tourist arrivals due to COVID-19 restrictions will hit hard on Pacific island economies that rely heavily on tourism for growth and development – including Cook Islands, Niue and Palau. Similar earnings and job losses can be expected in emerging and nascent tourism destinations, such as RMI and Tuvalu. Weaker demand for tourism link industries such as transport and food may further impede growth and development recovery for many months, and into 2021. The potential economic losses from tourism sector declines are outlined in the table below.[246]

Potential Economic Losses from Tourism Sector Declines						
Economy	**Best case**		**Moderate case**		**Worst case**	
	Estimated economic losses		**Estimated economic losses**		**Estimated economic losses**	
	% of GDP	**USD**	**% of GDP**	**USD**	**% of GDP**	**USD**
Cook Islands	4.61	21.3 million	10.00	46.3 million	16.03	74.2 million
Niue	3.48	1.7 million	6.23	3.5 million	12.94	7.2 million
Palau	4.61	10.3 million	5.43	12.1 million	7.08	15.8 million
RMI	0.49	2.1 million	0.61	2.6 million	0.82	3.5 million
Tuvalu	0.84	1.0 million	1.16	1.5 million	1.58	1.6 million

Table 25. Potential economic losses from tourism sector declines under three scenarios. (Source: SPC)

Under the Moderate Case Scenario – with a 70% decline in tourism outbound and receipts – Cook Islands is expected to incur the highest GDP contribution loss of all 14 Pacific island countries. Under

[243] SPC, 2020. COVID-19: Pacific Community Updates. Regional Challenges. Available at: https://www.spc.int/updates/blog/2020/06/covid-19-pacific-community-updates
[244] Pacific Islands Forum Secretariat, 2020. COVID-19 and Climate Change: We Must Rise to Both Crises. Available at: https://www.forumsec.org/2020/04/17/covid-19-and-climate-change-we-must-rise-to-both-crises/
[245] Climate Analytics, 2020. Coronavirus crisis underscores small islands' climate vulnerability. Available at: https://www.climatechangenews.com/2020/04/17/coronavirus-crisis-underscores-small-islands-climate-vulnerability/
[246] SPC, 2020. Statistics for Development Division. Economic and Social Impact Indicators. Available at: https://sdd.spc.int/news/2020/04/29/economic-and-social-impact-covid-19-pandemic-pacific-island-economies

the Worst Case Scenario – with a 90% decline in tourism outbound and receipts – Cook Islands, followed by Niue, are expected to incur the highest GDP contribution losses in the Pacific island region.

The COVID-19 pandemic highlights how risks rise significantly with compounding extreme events, with social and economic impacts escalating across all areas of life. Despite the decrease in greenhouse gas emissions as a result of the pandemic, SIDS continue to be affected by existing climate change impacts and must address these simultaneously to responding to the pandemic.[247] UNDRR has emphasised the need to "focus on a multi-hazard integrated disaster risk management approach that includes high levels of disaster preparedness and accelerated disaster risk reduction across sectors" as a priority action to enhance the resilience of Pacific SIDS to the dual challenge of pandemics and climate-related hazards.[248]

[247] Climate Analytics, 2020. Coronavirus crisis underscores small islands' climate vulnerability. Available at: https://www.climatechangenews.com/2020/04/17/coronavirus-crisis-underscores-small-islands-climate-vulnerability/

[248] UNDRR, 2020. UNDRR Asia Pacific COVID-19 Brief. Combating the dual challenge of COVID-19 and climate-related disasters

4 – STATUS OF EXISTING CLIMATE INFORMATION SERVICES AND EARLY WARNING SYSTEMS

4.1 BASELINE CLIMATE INFORMATION SERVICES

Each of the five countries has a WMO Category 1 (Basic level) government-funded National Meteorological and Hydrological Service (NMHS), which is able to provide local weather forecasts and seasonal (3 to 9 month) climate projections of probable rainfall across growing seasons. The Cook Islands, Niue and Tuvalu use forecasts generated by the Fiji Meteorological Service in its role as the Regional Specialised Meteorological Centre and the Palau and RMI Weather Services receive forecasts from Pacific Regional – National Weather Services/NOAA.[249] This is a well-established, effective and sustainable approach to provision of very technical services for small countries, and is expected to continue. The NMHSs in all five countries are currently able to generate basic information products (such as the seasonal precipitation forecast) using their national data and the forecasts that they receive. However, the quality of forecasts is dependent on availability of good data from terrestrial and sea surface observation points over a wide geographical area. All five countries have international airports and provide meteorological services to support international civil aviation. Therefore, the NMHSs need a Quality Management System (QMS) in place as well as a competency framework for aeronautical meteorological observers and/or forecasts. Although some steps have been taken in Cook Islands and Niue, none of the countries has an established QMS or aeronautical framework.[250]

The lack of data from their vast ocean areas and widely dispersed outer islands, changing climatic conditions, capacity constraints and lack of coordination among responsible agencies also make it difficult for Pacific SIDS to put in place comprehensive and sustained climate information and multi-hazard early warning systems (MHEWS). None of the five Programme countries has access to adequate ocean data and most do not have climate staff able to work directly with climate-sensitive sector agencies or communities. Issues common to all NMHSs of Pacific SIDS identified in the *Pacific Island Meteorological Strategy 2017–2026*[251] are summarised below. However, it should be noted that the circumstances of the five very small countries in this Programme differ from those of larger Pacific island nations.

- **Weather Services:** Many NMHSs[252] in the region operate with poor infrastructure and with staffing constraints. Communication to communities and other user groups requires strengthening. In addition to training in technical areas, NMHSs require public financial management and IT training.
  - *This applies particularly to very small SIDS, whose forecasts are generated using low-resolution data from too few observation points (Result 2).*
  - *Communication of weather services will benefit from several Programme activities, including the development of accessible language and visual presentation, and the improvement of communication technology and coverage (Results 2 and 3).*

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[249] Services are provided by the US National Ocean and Atmospheric Agency's Pacific Weather Service Headquarters in Hawaii
[250] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre
[251] https://www.pacificclimatechange.net/sites/default/files/documents/PIMS_2017-2026_FINAL-.pdf
[252] This particularly applies to very small Pacific countries such as the five in this proposed Programme.

- *The introduction of public financial management training will enhance the capacity of NMHSs to negotiate more secure base appropriation as the value of their services is demonstrated through this Programme (Result 1).*

- **Climate Services:** As qualified collectors and analysers of national and local climate data, NMHSs have a thorough understanding of climate processes and change and of the practical implications for their countries. NMHSs need to enhance work with other national agencies responsible for adaptation planning, aid coordination, disaster preparedness and risk reduction, and for international advocacy and negotiation. The value of their expertise and local knowledge should be reflected in the allocation of funding for climate change data collection and analysis and adaptation planning.
  - *This applies to the five Programme countries and is a major focus of the Programme. The development of agreements among the national agencies involved in hazard identification and prediction, disaster risk reduction strategies, dissemination and communication of advice on extreme events, and response actions are essential to reducing the impacts of climate change (Results 1 and 3).*
  - *Improved or new legislation where requested, and strategic plans that formalise roles, responsibilities and coordination mechanisms with national agencies, such as disaster management organisations and public broadcasters, will be developed through Result 1.*

- **Ocean Services:** In many Pacific island countries, there is no official purveyor of ocean information, and enquiries are directed to the NMHS. The Strategy has identified ocean services as a long-term goal. Technical skills for ocean services are a priority.
  - *NMHSs report high demand for ocean climate information services. In the absence of observation equipment only low-resolution data is available and it cannot be verified by in-situ observations. This has implications for climate and weather prediction both locally and globally and limits the ability of Pacific SIDS to provide reliable and timely early warnings. This issue is addressed in Result 3.*

- **Hydrology:** To support the needs of NMHSs for drought and flood forecasting, priority needs include data management and sharing, technical support, downscaling modelling on water resource uses, and integration of climate science in water resource planning.[253]
  - *The Programme proposes to invest in proactive data sharing and management at national level through the existing regional GEF-funded "Inform" project.[254] Lessons learnt from previous projects will inform approaches to drought forecasting and management (Results 2 and 4).*

The baseline for climate information services in the five Programme countries, and the priorities they will address in this Programme can be summarised as follows:

The ***Cook Islands*** Meteorological Service (CIMS) provides weather updates, forecasts and warnings. The Second Joint National Action Plan for Climate Change and Disaster Risk Management 2016–2020 (JNAP II) and country consultations highlight the following priorities:

[253] SPREP, 2016, Pacific Island Meteorological Strategy 2017–2026.
[254] https://www.sprep.org/inform

- Need to strengthen the capacity of CIMS to collect and manage data and information on weather and climate variability–especially severe weather and natural hazard events and impacts;
- Capacity building and training;
- Developing Geographic Information System (GIS) capabilities;
- Collecting information, data and traditional knowledge relevant to adaptive fishing and farming;[255]
- Enhancing/extending the current observational network;
- Enhanced dissemination of products (local language, graphical products, newsletters, reports);
- Development of sector-specific products.[256]

In ***Niue***, the Meteorological Service aims to deliver credible and efficient weather and climate information. In its reporting to the Pacific Meteorological Council, Niue identifies the following priorities:

- Increasing capacity of human resource development through capacity building and training to enhance and strengthen weather and climate services;
- Providing sector-specific climate information for fisheries, agriculture, health and tourism;
- Outreach on weather, climate and hazards for village communities;
- Implementation of Climate Early Warning Systems (CLEWS);
- Providing actionable climate information in local language for communities and schools.[257]

In ***Palau***, the National Weather Service (NWS) provides weather, hydrologic, and climate forecasts and warnings. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the community. The national Climate Change Policy (CCP) (2015) highlights disaster risk management as a strategic priority and recognises the role of the Palau National Weather Service and its tracking systems. The Policy identifies priorities as:

- The assessment of climate change and disaster vulnerability/risk at multiple levels;
- Emergency communication;
- Integration of climate change and disaster risk reduction education into school curricula;
- Other disaster preparedness and risk reduction measures.[258]

In the ***Republic of the Marshall Islands (RMI)***, the National Weather Service Majuro has 3 programs: Supervisory; Operation; Forecast and Warnings. The NWS identifies the following priorities:

- The enactment of laws to govern weather services;
- Staff capacity building;
- Better observational coverage;

[255] Cook Islands Government, 2016, JNAP II 2016-2020.
[256] Pacific Science Solutions, 2017, Cook Islands Benchmarking exercise for PIMS.
[257] Reporting on National Priority Actions of the Pacific Islands Meteorological Strategy (PIMS) 2012–2021 in 2017
[258]Government of Palau, 2015, Palau Climate Change Policy.

- The establishment of more additional observing sites in the cooperative climate network.[259]

RMI's second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) highlighted that "Data management also remains a key gap to be addressed in RMI's response to climate change. Topographic data and GIS layers relevant to climate change management in the Marshall Islands remain to be digitized from old maps, created from fieldwork, and/or consolidated. These data are the building blocks needed to develop models to simulate weather events and impacts"[260].

The Joint National Action Plan (JNAP) for climate change adaptation and disaster risk management stresses the need for effective dissemination of early warning products from the Weather Service to government agencies, Non-Government Organizations (NGOs) and communities, along with suitable action / response plans.[261]

In ***Tuvalu***, the Climate Change Policy emphasises the need to understand and communicate climate change and its impacts. Regarding the Tuvalu Meteorological Service, the Policy identifies the following priorities:

- Capacity building for climate services;
- Enabling policy and legislation within the Tuvalu NMHS;
- Replacement and maintenance of old equipment;
- Translating weather and climate information for end users;
- Enhancing public and school awareness of weather and climate information;
- Improving inter-island communication.[262]

The Pacific Island Meteorological Strategy 2017–2026 was developed through an iterative, participative process in which directors and climate officers of the 14 Pacific national meteorological services discussed their existing capabilities, their common constraints and their priorities. Discussions were held before or after related regional meetings and not all directors could attend all meetings, but all have been involved in the process and all countries report biennially to the Pacific Meteorological Council on their progress. There are individual differences among countries but common concerns and interests are clear, and countries are very clear about the structural barriers to change.

All countries prioritise expansion of their climate data collection capacity, specifically to include monitoring of the ocean. All five countries are hindered by limited budgets for replacement or upgrading of observation and other essential equipment. Their staff need training in entry level observation skills, equipment maintenance, forecasting and seasonal prediction expertise, and also in IT and public financial management skills, and these are all challenging to source and fund for small, remote countries. In 2016-2017, WMO conducted a world-wide survey on the status of human resources in NMHSs. The top seven training priorities reported for the RA-V region are shown in Figure 25.

[259] RMI, 2017, Reporting on National Priority Actions of the Pacific Islands Meteorological Strategy (PIMS) 2012-2021.
[260] RMI, 2015, Second National Communication.
[261] RMI, 2014, Joint National Action Plan for Climate Change Adaption & Disaster Risk Management.
[262] Tuvalu, 2012, Climate Change Policy.

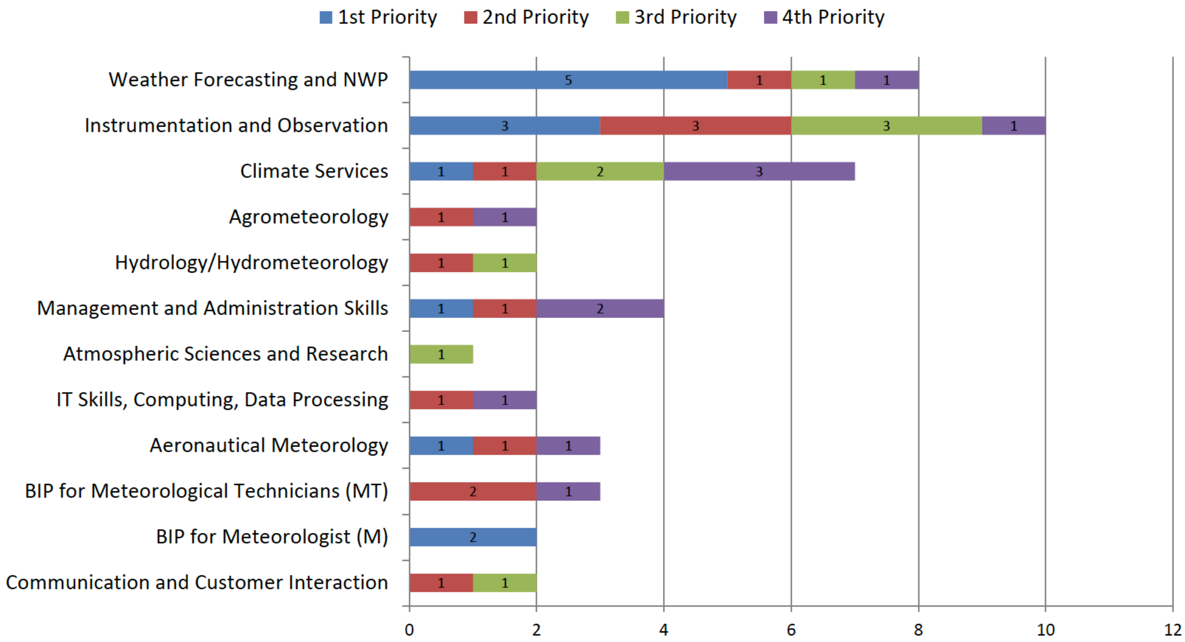

Figure 66. RA-V: Training Priorities in NMHSs (Source: WMO)

In 2018, the UNDP Disaster Resilience for Pacific SIDS (RESPAC) project conducted a study on the feasibility of establishing a Pacific-based WMO Regional Training Centre[263] – see "Existing and previous projects and/or initiatives in the Pacific region" for further details. The NMHSs were asked to indicate which of the PIMS Pacific Key Outcomes (PKOs) they were addressing or planning to address over the next five to ten years (Figure 26). In general, Pacific NMHSs are aiming to improve the quality of their services and increase the number of products in existing service areas, rather than increase the provision of broader types of services. This is apparent in Figure 27, which shows the number of NMHSs listing the given service area in their top three priority areas for education and training. There is a notable demand for professionalisation of the climate, forecasting and marine services areas (dark cyan), whereas improved observations capacity is a priority for technical staff with 2-year or lesser qualifications (light cyan).

Fiji Meteorological Service with JICA support and NOAA's Pacific Island Training Desk are the main providers addressing the education and training needs of Pacific NMHSs. In addition, SPREP through the ongoing COSPPac project, has been focusing on climate data and climate services. However, none of them offer accredited courses or parts thereof; and there is little or no coordination between them on timing or content.

[263] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre

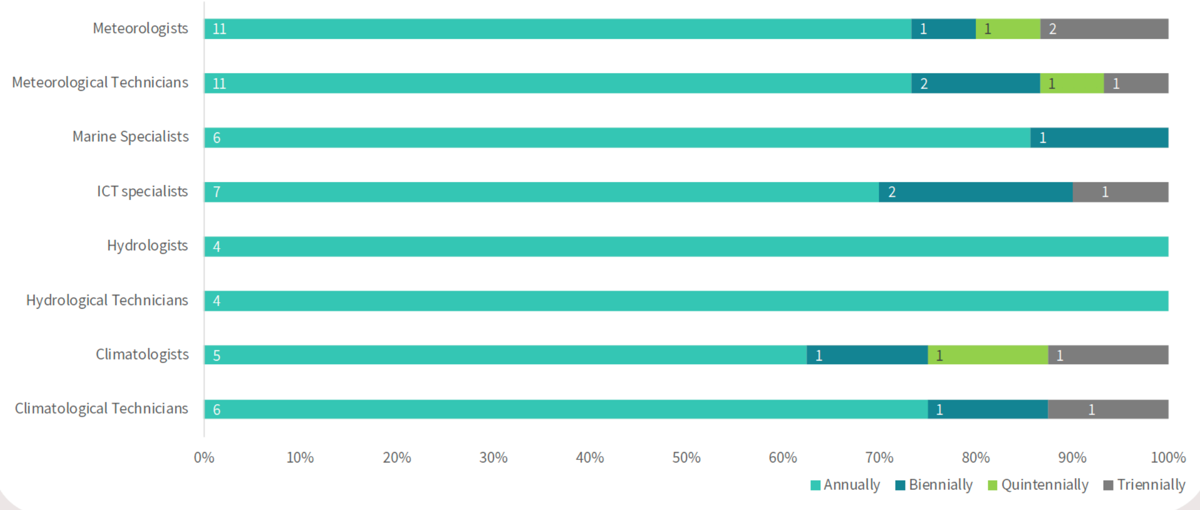

Figure 67. Number of Pacific island NMHSs addressing or planning to address PIMS service areas (Source: UNDP RESPAC)

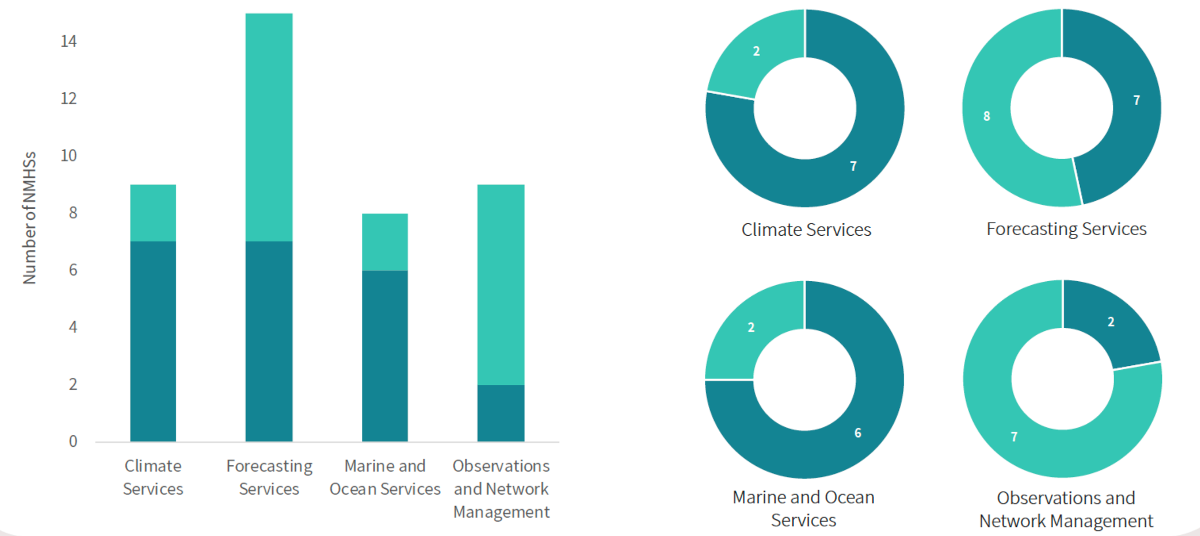

Figure 68. PIMS PKO areas rated in the top three priority areas by staff type (Source: UNDP RESPAC)

All five countries would like to establish formal relationships among the agencies they work with most closely, and to help public and private sector organisations mainstream their use of climate information in their own operations. All five prioritise making climate information accessible, understandable and useful to the people of their countries and particularly to remote communities, ensuring that vital messages reach "the last mile".

Essential services provided by NMHSs underpin economic growth and sustainable development and yet they cannot be consistently provided. Their weather, climate, water and ocean information services are critical to the safety and livelihoods of Pacific island populations, but communication of the information is not reliably reaching everyone who needs it. These services are crucial to reducing vulnerability of Pacific people to climate-related hazards and to enabling them to build their resilience.[264]

[264] SPREP, 2016, Pacific Island Meteorological Strategy 2017-2026.

While the staff of NMHSs in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu have many competencies and are committed to providing climate and weather services, they are constrained by the limits of the human, financial and technical resources available to them.[265]

These common vulnerabilities, climate change impacts and capacity challenges limit the ability of the five countries to provide appropriate climate information services for planning and implementing adaptation interventions across all economic sectors and all governance levels. Moreover, they restrict their capability to safeguard island populations and assets against multiple similar climate-related hazards through effective early warning.

4.2 BASELINE DISASTER RISK MANAGEMENT

In 2016, the Pacific Islands Forum Leaders endorsed the Framework for Resilient Development in the Pacific: An Integrated Approach to Address Climate Change and Disaster Risk Management (FRDP). The Pacific Resilience Partnership (PRP) was established in 2017 to bring together climate change and disaster risk management communities and other partners (e.g. government representatives, relevant sectors and private sector and civil society stakeholders) to support and facilitate effective implementation of the FRDP across the Pacific region. The FRDP provides high level voluntary strategic guidance on how to enhance resilience to climate change and disasters based on three inter-related Goals:

1. Strengthened integrated adaptation and risk reduction;
2. Low-carbon development;
3. Strengthened disaster preparedness, response and recovery.[266]

The Programme will adopt a regional integrated approach to directly address Goals 1 and 2 of the FRDP and will create an enabling environment to support Goal 2.

4.3 FINANCING FOR CLIMATE SERVICES AND DISASTER RISK MANAGEMENT

Many Pacific island countries face significant fiscal challenges to addressing climate change. The cost of adaptation measures required to address climate threats far exceeds many of the countries' financial capacities. External finance is therefore essential to the Pacific islands as means of supplementing government expenditures through the national budget process.[267] The national budgeting and financial arrangements for spending on climate change and disaster risk management for the five countries are provided in the relevant country sections. Regional arrangements are outlined below.

The **Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI) insurance program[268]** was launched in January 2013 and successfully piloted parametric insurance policies for rapid disaster response financing in five Pacific island countries, including Cook Islands and RMI. The insurance

[265] SPREP, Pacific Roadmap for Strengthened Climate Services 2017–2026.
[266] SPC, SPREP, PIFS, UNDP, UNISDR and USP. 2016. Framework for Resilient Development in the Pacific: An Integrated Approach to Address Climate Change and Disaster Risk Management (FRDP) 2017-2030
[267] Stockholm Environment Institute, 2017. Climate finance in the Pacific: An overview of flows to the region's Small Island Developing States
[268] GFDRR and World Bank, 2016. PCRAFI Facility: Phase II. Available at: http://pubdocs.worldbank.org/en/178911475802966585/PCRAFI-4-pager-web.pdf

mechanisms provided an immediate injection of cash for emergency response in the wake of a major tropical cyclone, earthquake or tsunami. The PCRAFI insurance program represents a successful public-private partnership, with the World Bank acting as an intermediary between Pacific island countries and a group of international reinsurance companies. From 2013 – 2016, two payouts were made for an aggregate amount of USD 3.3 million within 10 days of the disasters: i) Tonga received a payout of USD 1.3 million within 10 days of being affected by Tropical Cyclone Ian in January 2014; and Vanuatu received a payout of USD 1.9 million within seven days of being affected by Tropical Cyclone Pam in March 2015.

At the 2015 Forum Economic Ministers' Meeting (FEMM), the Ministers of Finance elected to create the **PCRAFI Facility**, which demonstrates their commitment to manage climate and disaster risk finance at the regional level. In June 2016, the PCRAFI Facility was established as two separate legal entities: i) the Pacific Catastrophe Risk Insurance Foundation (PCRIF); and ii) the Pacific Catastrophe Risk Insurance Company (PCRIC) – with Cook Islands as the host jurisdiction. PCRIF is a collective that owns and governs the captive insurance company – PCRIC. As a captive insurer, PCRIC is mandated to meet the needs of its members in providing sustainable, cost-efficient climate and disaster risk insurance. The arrangement enabled the phased handover of work for the PCRAFI insurance program from the World Bank to the Facility, thus enabling it to incrementally build capacity for long-term regional ownership. The PCRAFI Facility is part of the PCRAFI Program, which encompasses all 14 Pacific island countries.[269]

At the 2018 FEMM, the Pacific Islands Forum Secretariat presented the proposal for a **Pacific Resilience Facility (PRF)**,[270] which seeks to provide an integrated regional financing solution for Forum Island Countries (FICs) with a specific focus on disaster preparedness and climate and disaster risk resilient infrastructure. The proposed PRF has four strategic objectives: i) Strengthen the collective financial resilience of FICs against natural hazard risks in the Pacific region; ii) Provide cost-efficient and contextualised financing options for resilient development projects; iii) Strengthen strategic partnerships with key development partners; and iv) Encourage capacity development in national climate and disaster risk budgeting and financing. A Technical Working Group has undertaken widespread consultations on the fund. However, Pacific Forum Economic Ministers have stated that more work is required before they can endorse it.[271] The PRF is proposed to complement existing regional and national initiatives, such as the PCRAFI Facility.

4.4 WMO GLOBAL BASIC OBSERVING NETWORK (GBON)

The WMO Global Basic Observing Network (GBON) represents a new approach in which the basic surface-based observing network is "designed, defined and monitored at the global level".[272] Establishment of GBON was approved at the 18th World Meteorological Congress in June 2019, in recognition that reliable, real-time global observational data are critical to the quality of forecasts and climate analyses, which in turn are essential for public services that help save lives, protect assets and

[269] GFDRR and World Bank, 2016. PCRAFI Facility: Phase II. Available at: http://pubdocs.worldbank.org/en/178911475802966585/PCRAFI-4-pager-web.pdf
[270] Pacific Islands Forum Secretariat, 2018. 2018 FEMM: The Pacific Resilience Facility. Available at: https://www.forumsec.org/2018-femm-the-pacific-resilience-facility-attachment-1/
[271] Radio New Zealand, 2020. Pacific ministers seek more info on Resilience Facility. Available at: https://www.rnz.co.nz/international/pacific-news/388933/pacific-ministers-seek-more-info-on-resilience-facility
[272] WMO, 2019. New Global Basic Observing Network gets go-ahead. Press Release Number: 07062019. Available at: https://public.wmo.int/en/media/press-release/new-global-basic-observing-network-gets-go-ahead

foster economic prosperity. [273] The development of GBON was welcomed at COP25 by the Subsidiary Body for Scientific and Technological Advice (SBSTA), which re-emphasised the “need for sustained funding to meet the essential needs for global climate observation”.[274]

The Global Basic Observing Network (GBON) concept was approved at the 18th World Meteorological Congress in June 2019 in order to ensure a robust supply of, real-time observational data from the entire global domain to the global Numerical Weather Prediction (NWP) systems. The output from these systems are critical to the quality of forecasts and climate analyses, which in turn are essential for public services that help save lives, protect assets and foster economic prosperity. The GBON design specifications are based on up-to-date observational requirements for global NWP as defined by WMO technical experts, and specify in quantitative terms which parameters to measure, how often, at what horizontal and vertical resolution, and provide advice on which measurement techniques to use. Based on the GBON concept adopted by the World Meteorological Congress, the detailed GBON regulatory material is currently under development, and it will be submitted to the Extraordinary World Meteorological Congress in June 2021 for approval. Expected obligations are provided in Figure 69 below. While the final GBON regulatory material is thus yet to be approved, for the purpose of this Programme, the draft regulatory material which served as the basis for the Congress approval of the GBON concept is used. This approach for the design of the observations-related activities, as discussed with the five countries and the AE, and agreed upon with WMO,[275] will help ensure that the activities proposed represent suitable, feasible and optimal solutions for the national basic observing networks and their contributions to the global public good provided by the NWP systems, regardless of any potential further refinements of the GBON requirements.

The Programme will support the five participating Pacific SIDS to expand and strengthen their observation networks in compliance with GBON. The proposed Programme will thus be a frontrunner for GBON.

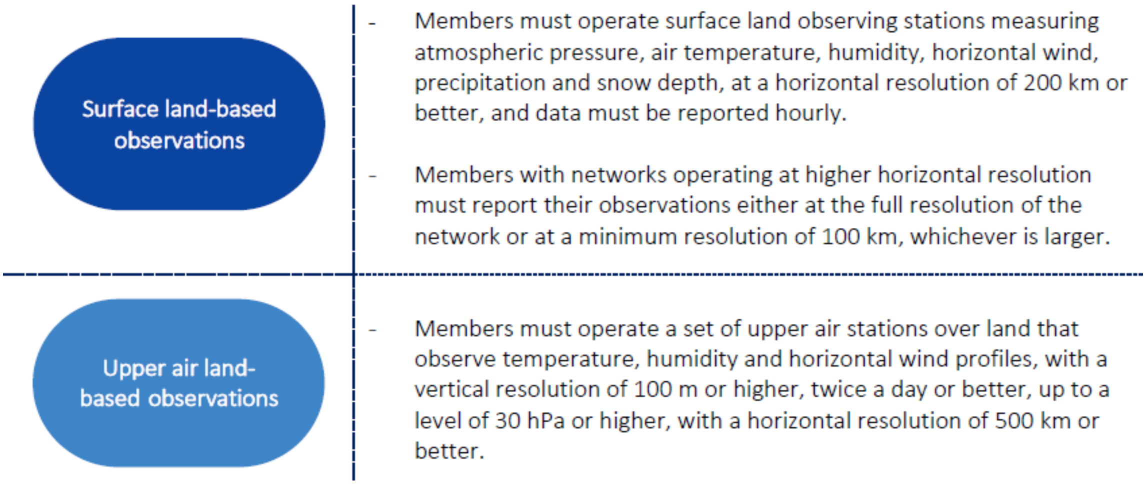

Figure 69. GBON expected obligations (Source: WMO)

[273] WMO, 2019. The WMO Global Basic Observing Network (GBON) Executive Summary. Available at: https://www.wmo.int/pages/prog/www/wigos/documents/GBON/GBON-exsummary.pdf

[274] SOFF, 2020. Systematic Observations Financing Facility. Collaborative thinking workshop. Workshop outcomes and the way ahead. February 25-26 2020, Offenbach, Germany

[275] As formally confirmed by the WMO Director, Infrastructure Department in his message to the AE dated 7 July 2020: “Through this initiative, WMO, in collaboration with the AE and the countries involved has undertaken the review of individual countries' observational gaps based on draft GBON regulatory provisions and current capacity and reporting practice. The resulting proposed activities correspond to an optimal, suitable, and feasible national basic observing network design that responds to country priorities and needs while ensuring consistency with the proposed concept and draft regulatory material for the GBON…”.

4.4.1 Systematic Observations Financing Facility (SOFF)

The Alliance for Hydromet Development was launched at the UN Climate Change Conference in December 2019 by 12 international organisations, including UNEP. As a priority of the Alliance in 2020, the Systematic Observations Financing Facility (SOFF) is being developed as a new financial mechanism "to ensure provision of basic systematic observations as a global public good". The SOFF intends to:

- "Provide equitable, predictable, sustainable, and performance-based finance for developing countries;
- Provide technical assistance for the provision of foundational observational data based on internationally agreed standards that can be quantified and independently verified; and
- Support achievement of GBON compliance by 2025 as the backbone of global weather forecasts and climate information products."[276]

The SOFF aims to address the fundamental mismatch between the current country-based financing of basic observations and the value of these observations as a global public good. In the current system, the provision of systematic observations is perceived to be only a national obligation. Thus, developing countries are expected to finance their own observing systems. However, whilst countries may receive financial support from development and climate finance partners, the funding is "time-limited, typically aimed at capital investment rather than operating costs, and does not recognise the global value creation enabled by observational data from developing countries".[277]

A comparison of Switzerland to any of the five Pacific island countries illustrates the need to fundamentally change the funding model for developing country observations and particularly for SIDS with vast ocean territories. Switzerland is a relatively small but highly developed country, with a surface area of 41,000 km^2 and a GDP of around USD 700 billion. Under the WMO Convention, it is only responsible for providing observational data for its own (land-locked) area. Switzerland spends roughly USD 20 million, i.e. less than 0.003% of its GDP, on its observing network. A similar share of GDP spending for observations for Cook Islands (Area: 1,830,000 km^2, GDP of USD 524.2 million) would amount to ~ USD 15,700; for Niue (Area: 450,000 km^2, GDP of USD 43 million) would amount to ~ USD 1290; for Palau (Area: 603,978 km^2, GDP of USD 284 million) would amount to ~ USD 8520; for RMI (Area: 1,990,530 km^2, GDP of USD 221.3 million) would amount to ~ USD 6640; and for Tuvalu (Area: 749,790 km^2, GDP of USD 42.59 million) would amount to ~ USD 1280. Therefore, even for Cook Islands with the highest GDP of the five Programme countries, a similar share of GDP spending for observations would cover less than half the cost of sensors for a single Automatic Weather Station. It is not reasonable or equitable to expect the Pacific island countries to cover the full costs of observations. It is also unrealistic to expect that the countries will be able to sustain the provision of observations over their territories or territorial waters on national and "aid" resources alone. This is emphasised in the "Plan for a Regional Upper Air Observing Network for the South Pacific", which states that "it is both unrealistic and unreasonable to expect economically small but geographically large countries to shoulder the burden of operating "their" part of even a minimally adequate global weather and climate observing system on their own".[278]

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[276] SOFF, 2020. Systematic Observations Financing Facility. Collaborative thinking workshop. Workshop outcomes and the way ahead. February 25-26 2020, Offenbach, Germany

[277] SOFF, 2020. Systematic Observations Financing Facility. Collaborative thinking workshop. Workshop outcomes and the way ahead. February 25-26 2020, Offenbach, Germany

[278] SPREP. Plan for a Regional Upper Air Observing Network for the South Pacific in Support of the GCOS and EGOS Implementation Plans. Available at: https://ane4bf-datap1.s3.eu-west-1.amazonaws.com/wmod8_gcos/s3fs-public/pacific_region_observing_network_planv6_0.pdf?9keTD5_drD2XvgLOR7qDf248rowdp4Gr

The SOFF is envisaged as a solution to the above. It will provide long-term finance and technical assistance to developing countries – prioritising Africa, Small Island Developing States and Least Developed Countries – beyond the current nationally focused, fragmented and time-bound funding model, to achieve and maintain GBON compliance and data sharing at the global level. This will translate to better weather forecasts, early warnings and climate information products, which are essential for effective climate action. The Programme will seek to establish continued support from SOFF for the five participating countries through the national policies for financing climate services (Sub-activity 1.1.4), which will facilitate sustainability of the Results and Outcomes beyond the Programme's duration.

Economic value of GBON

The SOFF Working Group 1 will demonstrate the value of GBON, including an overview of the economic benefits. The second SOFF workshop to further advance its concept and design, hosted by the WMO President, emphasised that investing in surface-based observations in developing countries makes significant economic sense. "Improvements in coverage and exchange of surface-based observations deliver benefits of at least USD 6 billion per annum and provide the foundation to realise up to USD 51 billion per annum benefits from overall improved forecasting and early warning efforts." It was also acknowledged that the quoted figures very likely underestimate the multiplier effects of implementing GBON across communities, sectors and governments.[279]

4.4.2 GBON Country Gap Analysis

With the objective to advance the concept and design of the SOFF, about 30 organisations are jointly working on multi-partner parallel Working Groups. In order to bring the GBON concept into practice, the SOFF Working Group 2 is conducting implementation case studies, including proposing concrete gap mitigation activities based on existing investments opportunities in selected countries. In-depth country case studies are being undertaken to assess the number of functioning (reporting) stations; number of stations required per draft GBON provisions; and estimates of the resulting number of stations to be newly established, rehabilitated or upgraded. The case studies will also include an institutional and human capacity gap analysis; and provide a more detailed cost estimate for establishing and maintaining GBON compliance in the developing world.

The five Programme countries were selected as initial case studies for the GBON country gap analyses and a relevant GBON approach was agreed upon. Based on the preliminary assessments and discussions with WMO[280] the following outcomes are highlighted:

- GBON obligations should take into account the unique circumstances of SIDS with small land masses and vast marine areas – for example, the land area of Cook Islands (240 km^2) constitutes just 0.012 % of its EEZ (1,947,760 km^2);
- The observations from SIDS are of high value for the global observing network. The SOFF Working Group 2 reported that optimal observations data in the south-west Pacific are estimated to account for 17 % of global forecast improvements;
- The Programme will ensure that all inhabited islands / atolls will have an observing point;

[279] SOFF, 2020. Systematic Observations Financing Facility. Collaborative thinking workshop. Workshop outcomes and the way ahead. February 25-26 2020, Offenbach, Germany

[280] Virtual meeting on GBON in the five Programme countries between UNEP, WMO and PSS consultants – 5 June 2020

- GBON compliance in Pacific SIDS will be achieved through a mix of surface-based AWS, marine observations (e.g. through equipment that the Programme will install under Activity 2.2.), ship-based observations – including through the Voluntary Observing Ship (VOS) program – and selected upper air observations. Together, these will ensure GBON coverage of land surface and ocean areas in the five Programme countries through a significant increase in the density of observation points.

As case studies at the forefront of developing the SOFF initiative, the five Programme countries are in a leading position to demonstrate the value of investing in GBON both to protect local communities and benefit local populations, but also as a critical element of regional and global forecasting and climate analyses. After the Programme implementation period, support from the SOFF is expected to be available to continue maintaining GBON standards in the five Programme countries.

4.4.3 Automatic Weather Stations required for GBON compliance in Pacific SIDS

The Programme aims to provide Automatic Weather Stations (AWSs) in all five countries to enable compliance with GBON requirements and obligations. The continued poor availability of surface-based observational data across these countries limits their ability to provide high quality weather and climate products and services. It is intended that the data from these AWSs will feed into GBON for use in global Numerical Weather Prediction (NWP) and climate reanalysis, which demands high quality data recorded to meet WMO standards. A weather model is only as good as the initial observations – if data inputs do not meet WMO standards, model outputs will be unable to meet WMO standards.

All NMHSs follow WMO guidelines for instrumentation and site selections. The key documents are *Guide to Instruments and Methods of Observation: Volume I – Measurement of Meteorological Variables* and the *WMO-544 Manual on the Global Observing System – Vol 1 (2003)*. WMO-544 states that "All stations shall be equipped with **properly calibrated instruments and adequate observational and measuring techniques**, so that measurements and observations of the various meteorological elements are accurate enough to meet the needs of synoptic meteorology, climatology and of other meteorological disciplines." Furthermore, the purpose of the *Manual on the WMO Integrated Global Observing System (WMO-No. 1160)* is to ensure adequate uniformity and standardisation in practices and procedures. WMO has provided Generic AWS Tender Specifications,[281] which includes detailed specifications for sensors.

Automatic Weather Stations are required to satisfy several needs – both the provision of real-time synoptic data and monitoring of critical warning states such as storms and tide levels; as well as long-term recording and storage of data for climatological uses. The Programme will install AWSs that meet all WMO requirements and are robust to their climatic conditions. The environmental conditions (i.e. warm temperatures, high humidity and salt winds) in hot tropical locations such as the South Pacific are often unfavourable for meteorological sensors and automatic equipment – cheap weather stations often fail within 12 months. In the case of AWS failure, unscheduled visits are required, which may be expensive and difficult to arrange. Therefore, the installation of more expensive, sophisticated and robust AWSs is essential to ensure accurate operation over long time periods with only limited maintenance, as well as being more economical in the longer term (due to high installation and maintenance costs associated with expensive travel).

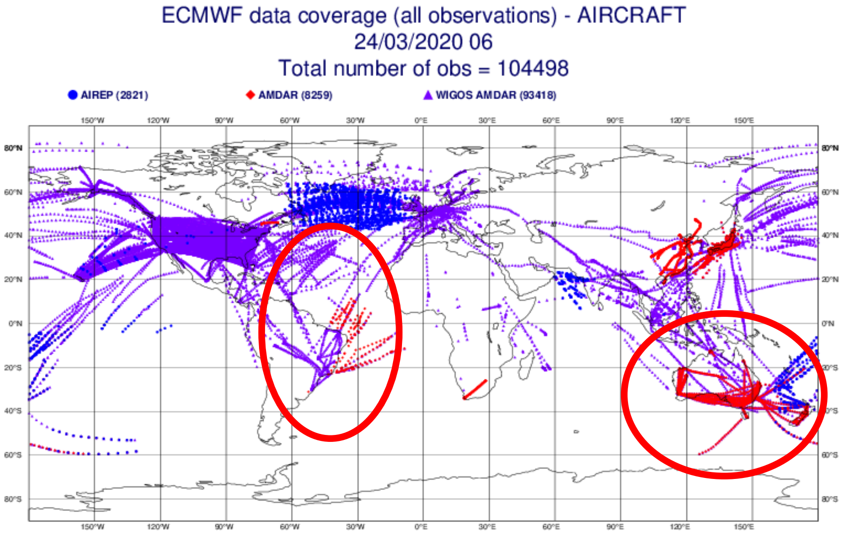
Installation of AWSs that meet WMO and GBON standards is also a prerequisite for eligibility for future funding from the Systematic Observations Financing Facility (SOFF), which is a key element in the

[281] WMO, 2018. Generic AWS Tender Specifications. Available at: https://www.wmo.int/pages/prog/www/IMOP/AWS_Tender_Spec/AWS_Tender_Spec.html

sustainability of Programme investments. The installation of cheaper, inferior AWSs will thus undermine eligibility to SOFF and long-term sustainability. As part of the SOFF Working Groups, WMO estimated the cost of GBON-compliant surface-based observation stations in the five Pacific island countries at USD 74,000 – USD 84,000 per station (see below figure). However, by obtaining quotations from partners and suppliers with a track record in the Pacific, the Programme has budgeted for USD 32,000 per AWS, including configuration, assembly and all sensor calibration in compliance with ISO/IEC standards. This budget is both realistic and necessary to facilitate the installation of AWSs with the greatest possible reliability, maintainability and long-term sustainability for the five Pacific island countries.

4.4.4 Impact of COVID-19 on the global observing system

The World Meteorological Organization (WMO) has reported significant concern about the increasing impact of the COVID-19 pandemic on the quality and quantity of weather observations and forecasts, as well as atmospheric and climate monitoring. As of May 2020, aircraft meteorological observations decreased by an average of 75 – 80% compared to normal, with large regional variations: decreases of around 90% were observed in the tropics and the Southern Hemisphere, where there are already fewer observations available and where many stations are manual rather than automatic. This shows the asymmetric impact of COVID-19.[282]



[282] WMO, 2020. COVID-19 impacts observing system. Press Release Number: 01042020. Available at: https://public.wmo.int/en/media/press-release/covid-19-impacts-observing-system

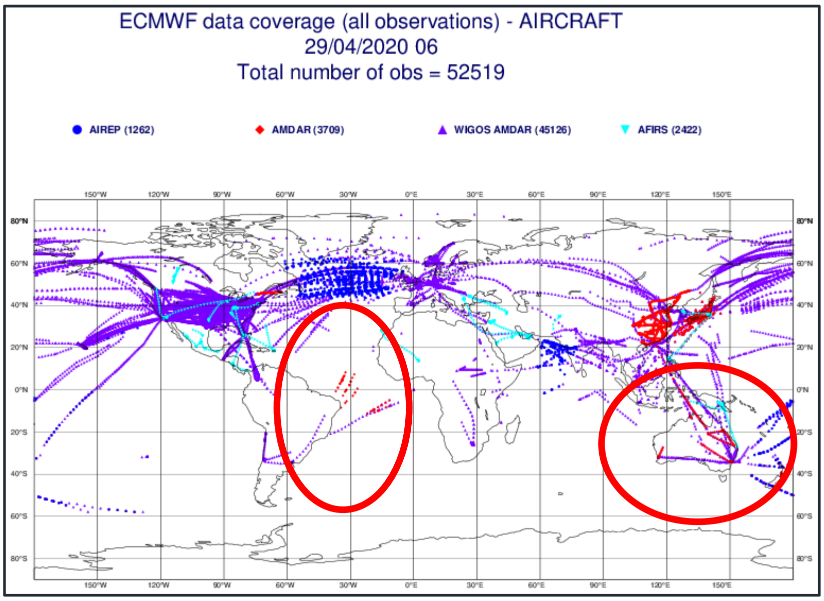


Figure 70. Comparison of European Centre for Medium-Range Weather Forecasts (ECMWF) data coverage on 24 March 2020 and 29 April 2020 (Source: WMO SOFF)

The impact of COVID-19 highlights that the global observing system is vulnerable to various types of crisis, with different parts of the system showing different types of vulnerabilities. Manned systems are vulnerable to mandatory lockdowns; and aircraft observations are data of opportunity, which predominantly rely on commercial airliners contributing to the WMO Aircraft Meteorological Data Relay programme (AMDAR). The AMDAR observing system usually produces over 800,000 high-quality observations per day for air temperature and wind speed and direction, with relevant spatio-temporal information. Humidity and turbulence measurements are also increasingly being reported. A number of NMHSs have increased the frequency of radiosonde flights to mitigate the loss of aircraft observations. However, most of these are in Europe under coordination by the European Meteorological Services Network (EUMETNET) and therefore only more affluent regions of the world have benefited.

Ocean observations have shown good short-term resilience to COVID-19, due to having a high degree of automation. The most significant impact is on the Voluntary Observing Ships (VOS), which has seen a reduction in data availability of around 20% compared to normal levels. However, ocean drifters and floats need to be redeployed; moorings need to be serviced; and ship observing systems require maintenance, calibration and supply work. WMO anticipates that there will be a gradual decline in observations until supply and maintenance activities can resume. [283]

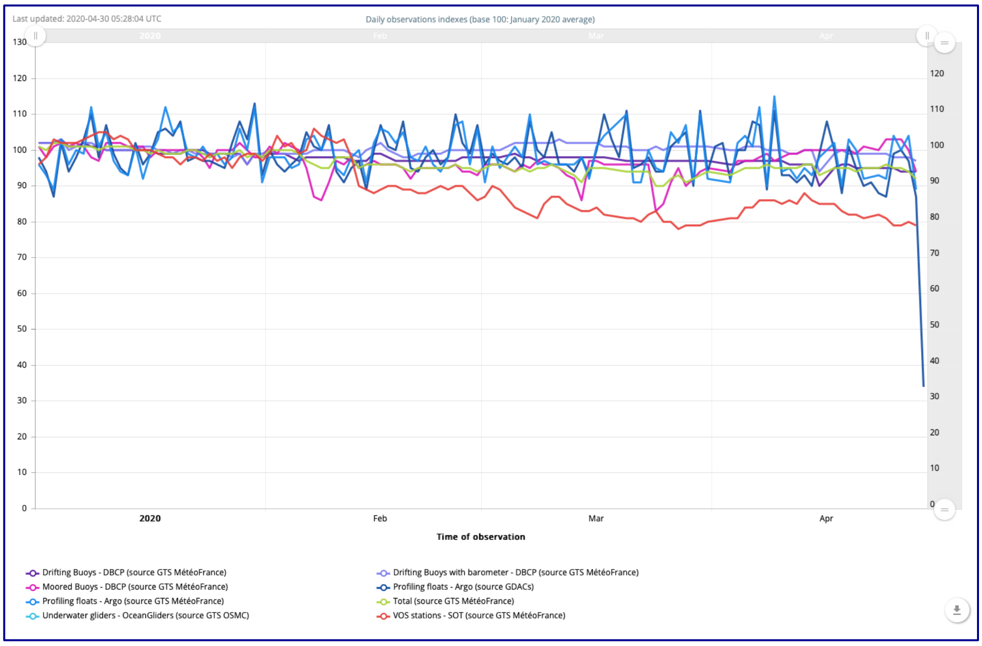


Figure 71. Availability of ocean observations. Ship observations (red) are down to around 80% compared to the pre-COVID-19 baseline. (Source: JCOMMOPS)

Loss of observational data has both short and longer term impacts: the reliability of weather forecasts is reduced; and long-standing climate and ecological monitoring studies could have significant data gaps. Whilst satellites and radiosondes can fill some gaps, some aircraft data is irreplaceable. The UK Met Office estimated that the loss of aircraft observations will increase their forecast error by 1-2 %, with greater inaccuracies for areas where flights are more abundant.[284]

Any lack of observations over one area negatively impacts the quality of forecast and analysis products globally. Resilience in the overall observing system is thus critical. The COVID-19 crisis exemplifies the importance of GBON and SOFF: the transition to automation will improve reporting frequency and resilience; and an increased number of radiosondes will lessen dependence on data of opportunity and improve resilience.[285] Throughout the development and implementation of the Programme, UNEP – as a founding partner of SOFF – will engage with SOFF to ensure that the five Pacific island countries can benefit from its support to sustain their systematic basic observation network as a global public good.

4.5 KNOWN BARRIERS

[283] WMO, 2020. COVID-19 impacts observing system. Press Release Number: 01042020. Available at: https://public.wmo.int/en/media/press-release/covid-19-impacts-observing-system

[284] Nature, 2020. News: How COVID-19 could ruin weather forecasts and climate records. 13 April 2020. Available at: https://www.nature.com/articles/d41586-020-00924-6

[285] SOFF, 2020. Presentation: Outcomes of the joint kick-off meeting 15 May 2020. Working Group 1 & 2

The barriers to provision of essential climate information services to decision-makers are well understood in the five Programme countries but require specialised expertise and external funding to address. Most countries would benefit from most of the following activities:

- Legislation establishing the role and responsibilities of the weather service and ensuring its funding—this particularly applies to RMI and Tuvalu, but all five countries would make efficiency gains from updating and clarification of their NMHSs' mandate and the relationship with national disaster management organisations and other national partners;
- Climate service policy frameworks that structure the science-policy interface;
- Formal standard operating procedures between NMHSs, disaster managers and broadcasters for delivering early warning systems to the "last mile";
- Secure and reliable funding;
- Access to more geographical data, especially for ocean areas;
- Access to expertise for analysis of climate risks and hazards, climate modelling and hydro-meteorological data and tailored hydro-meteorological information to end users;
- Knowledge management, communication and outreach systems especially for widely dispersed island communities (e.g. in an archipelagic country such as the Cook Islands climate risks are amplified for communities on outer islands by a lack of local climate data, unreliable communication links and a lower level of awareness of both risks and available services);[286]
- Improved capacity of vulnerable communities and sectors to interpret and use climate information services;
- Better coordination of projects and programmes focussing on climate information services;
- Resources for delivery of tailored, appropriately-packaged climate information to end-users; and
- Replacement of outdated technologies.

As reaffirmed by the UN General Assembly in the 2019 Political declaration of the high-level meeting to review progress made in addressing the priorities of Small Island Developing States through the implementation of the SIDS Accelerated Modalities of Action (SAMOA) Pathway, SIDS remain a special case for sustainable development as they continue to face the combined challenges arising, in particular, from their geographical remoteness, the small scale of their economies, **high costs and the adverse effects of climate change and natural disasters**.[287] The small size, remoteness and insularity of SIDS pose daunting challenges in amongst others transport logistics. For example, domestic inter-island shipping services in many countries of the Pacific region – especially to outer islands – are infrequent, unreliable and expensive. Similarly, air travel in the Pacific often involves long-haul, multi-leg and expensive flights in the absence of direct flight connectivity.[288] Therefore, the cost of travel, general logistics and transactions in the Pacific regional are comparatively higher than in many other parts of the world.

In particular, past project evaluations in the Pacific have pointed to the high cost and time required for activities covering outer islands: "The SPC lessons learnt process identified a general "rule of thumb" to multiply the overall cost and time for outer island projects by two (compared to main islands) when detailed budgets (based on quotes) and timelines are not available. Where quotes for goods and

[286] IPCC, 2014, Assessment Report 5.
[287] https://undocs.org/pdf?symbol=en/A/74/L.3
[288] https://unctad.org/meetings/en/SessionalDocuments/cimem7d8_en.pdf

services have been obtained, then it is still recommended that a large contingency (up to 20%) be added to the budget for capital works projects in outer islands. This contingency factors in the high risks and uncertainties associated with capital works projects and the unreliable and costly transport to these remote islands."[289]

4.6 OPPORTUNITIES FOR CLIMATE SERVICES IN PRIORITY SECTORS

The Pacific Roadmap for Strengthened Climate Services 2017 – 2026[290] adopted the five priority areas of the Global Framework for Climate Services (Agriculture and Food Security, Disaster Risk Management, Energy, Health and Water) and added two further priorities (Fisheries and Tourism) and identified how climate services can support these priority sectors, as detailed in the following sections.

4.6.1 Agriculture and food security

Year-to-year climate variability has a significant influence on agricultural production, with longer-term systematic changes in climate – which are modifying historical measures of climate variability – have introduced a new complicating factor. Increases in the frequency and intensity of extreme climate events will further impact on grain, horticultural, forestry and livestock production.

Agricultural studies and activities in Pacific island countries that climate services can support include:

- Responses of traditional crops to existing environmental drivers such as climate variability and extremes and soil nutrient interactions;
- Responses of island crops to increased CO_2;
- Developing and enhancing capacity to model crop and cropping systems;
- Estimating appropriate stocking rates for areas involved in industrial livestock production;
- Identifying adaptation strategies for farming systems utilising risk profiles associated with climate variability and change;
- Examining the economic value of specific operational seasonal climate forecasts to support agronomic management decisions for the production of staple food crops – e.g. assessing the risk of shortages in specific crops; and
- Developing a Communication, Partnership and Engagement Strategy.

4.6.2 Disaster risk management

The appropriate use of meteorological, hydrological and climate information as part of a comprehensive multi-sector, multi-hazard and multi-level approach will facilitate considerable achievements in enhancing disaster resilience in the Pacific island countries. Climate services can support disaster risk management through a number of means, including:

- Interannual climate prediction provides opportunities to make earlier assessments of natural hazard risk and disaster potential – e.g. seasonal climate outlooks enable governments to

[289] http://ccprojects.gsd.spc.int/wp-content/uploads/2016/06/5.-Overall-GCCA-PSIS-Evaluation-Report-Final.pdf
[290] SPREP, 2016. Pacific Roadmap for Strengthened Climate Services 2017 - 2026

assess the likelihood and hence manage the consequences of extreme climate events such as tropical cyclones, extreme rainfall and drought;

- Support for risk assessments on multiple timescales, from several weeks through seasonal to decadal timescales, that can inform long-term investments and strategic planning – for example, in coastal zone management, development of new building codes, and the retrofitting infrastructure to withstand more frequent and severe hazards;
- Development of extreme climate event monitoring systems and response strategies – e.g. national drought response plans; and
- Establishment and/or strengthening of national climate risk early warning systems (CREWS) and early warning for severe weather events or climate extremes.

4.6.3 Energy

Energy production is highly sensitive to meteorological and climate events. Examples of how climate services can support enhanced efficiency and effectiveness of energy systems include:

- Information on solar radiation and wind fields for the development of solar and wind power;
- Hydrometeorological information at the catchment domain for hydropower operations; and
- Partnerships and stakeholder engagement in applying weather and climate information for energy systems development and production, which can support policymaking and management decisions aimed at achieving an optimum balance between supply and demand, as well as drive behavioural changes to energy efficiency and savings.

4.6.4 Health

Climate change can have significant impacts on the health outcomes of Pacific island populations. The Pacific Roadmap for Strengthened Climate Services highlights that "Understanding the often-complex relationships between climate and health is fundamental to mitigating the associated risks…health and climate services communities must work together to ensure that climate information is interpreted and applied effectively."[291] Climate services can minimise the health impacts of climate variability and change through:

- Predictions on weekly to seasonal timescales that provide outlooks for climate-sensitive diseases – such as vector-borne diseases (e.g. malaria and dengue fever), or diseases that increase in severity with the onset of dust in the dry season (e.g. meningococcal meningitis);
- Outlooks provide further opportunities to plan interventions such as mobilising community health workers to raise awareness of health risks in vulnerable communities and increase the readiness of the healthcare system to respond to epidemic outbreaks.

4.6.5 Water

Climate services can support improved water resource management through:

[291] SPREP, 2017. Pacific Roadmap for Strengthened Climate Services 2017 – 2026

- Climate and water data collected on weekly, seasonal and annual timescales and at regional, national and local levels are essential to develop effective water management strategies, including flood and drought preparedness and response;
- Climate data and information underpins agricultural water resource planning, management and assessment of future needs for both subsistence and industrial-scale users; and
- Support for calculations of the frequency and duration of heavy rainfall, probably maximum precipitation, low-flow and flood forecasting.

4.6.6 Fisheries and aquaculture

Fisheries are sensitive to climate variability and longer-term climate change, with different fish population responding in different ways. Climate services can support both subsistence and commercial fisheries and aquaculture, including through:

- Collaborative partnerships with biological and fisheries researchers and management agencies to better monitor and understand the impacts of short-term variability and longer-term change on oceanic fisheries;
- Developing fisheries climate early warning systems and impact advisories;
- Identifying risk assessment or management evaluation tools that incorporate climate variability to improve the ecosystem approach to fisheries management and inform integrated coastal zone management;
- Provision of downscaled coastal information for use in Fish Aggregation Device programs;
- Developing national ocean services portals, including national tailoring of existing regional portals such as the COSPPac Ocean Portal;
- Undertaking lagoon monitoring for aquaculture; and
- Improving understanding of the sensitivity of pearl and seaweed industries to rising sea temperatures.

4.6.7 Tourism

All tourism destinations and operators are sensitive to climate variability and extreme weather events; and climate is a key influence on travel planning and the travel experience.[292] Climate services can support the tourism industry in a number of ways, including through:

- Implementing the Climate Index for Tourism (CTI), which considers thermal, aesthetic and physical aspects of weather in relation to beach tourism; and
- Close dialogue with tourist operators and service providers to facilitate effective climate risk management whilst minimising the economic risks of “negative” climate outlooks that may deter tourists.

[292] Scott, D. and Lemieux, C., 2010. Weather and Climate Information for Tourism

5 – EXISTING AND/OR PREVIOUS PROJECTS AND INITIATIVES IN THE PACIFIC REGION

5.1 REGIONAL PROGRAMMES AND PROJECTS

There are several ongoing and previous projects and initiatives addressing aspects of climate information and early warning services in the Pacific region, which are outlined below. Country-specific activities are further detailed in the respective sections of this document.

The **Pacific Climate Change Science Program (PCCSP)**[293] conducted in 2009-11 generated the most detailed scientific assessments of climate change to date for the 14 Pacific SIDS. The program culminated in the delivery of the comprehensive report – *Climate Change in the Pacific: a Scientific Assessment and New Research.*[294] The Report presents a peer-reviewed scientific assessment of the climate in the region: analysis of large-scale climate phenomena such as El Niño-Southern Oscillation, seasonal variability and past climate trends, and regional climate change projections; and individual country reports that provide country-specific projections and relevant climate information. The Report and its 2015 updates are used in this proposal.

The **Finnish-Pacific Project (FINPAC)**[295] was coordinated by SPREP and implemented in collaboration with the IFRC, University of the South Pacific, NMHSs and National Red Cross Societies from 2013-16. National Disaster Management Offices were also closely involved. FINPAC aimed to improve climate change adaptation in Pacific SIDS through two key components: i) Enhanced capacity of NMHSs to deliver and communicate timely weather and climate services; and ii) Strengthened ability of communities to use and apply meteorological data and information for disaster risk management.

Through the community-centred component, FINPAC used a multi-stakeholder partnership approach to establish community early warning systems (CEWS) in eight Pacific island countries (including Cook Islands, RMI and Tuvalu) that were specific to the context of each community. This facilitated that the system and warning / response information produced were people-centred and well understood. FINPAC created awareness in technical institutions on the importance of investing in community-based early warning and showed that partnership with 'last mile' institutions – such as the Red Cross – ensures that technical information is understood at the community level.

The International Federation of Red Cross and Red Crescent National Societies (IFRC) highlighted that most current financing mechanisms available to governments for disasters are activated and accessed in response to a disaster, whereas financing to support disaster preparedness action prior to disaster events – such as investments in early warning systems – are not readily available. To further the successful implementation of CEWS under the FINPAC project, a feasibility study was undertaken around Forecast-based Financing (FbF – see Programme Output 3.3) in the Pacific. The feasibility work on FbF, which focused on Solomon Islands, Papua New Guinea and Fiji, seeks ultimately to make funding available to governments and the Red Cross to support anticipatory action as well as response.[296] The outcomes of this work have informed development of the Programme.

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293 Pacific Climate Change Science, 2020. Available at: https://www.pacificclimatechangescience.org/about-us/

294 Pacific Climate Change Science, 2012. Report: Climate Change in the Pacific: Scientific Assessment and New Research. Available at: https://www.pacificclimatechangescience.org/publications/reports/report-climate-change-in-the-pacific-scientific-assessment-and-new-research/

295 Pacific Meteorological Desk & Partnership, 2020. Finland-Pacific (FINPAC) Project Description. Available at: https://www.pacificmet.net/project/finland-pacific-finpac

296 IFRC, 2018. Case Studies: Red Cross Red Crescent Disaster Risk Reduction in Action – What Works at Local Level

The **Disaster Resilience for Pacific SIDS (RESPAC)** Project,[297] implemented by UNDP from 2016-19, aimed to improve Pacific SIDS resilience to climate-related hazards through i) Strengthened early warning systems and climate monitoring capacity; ii) Strengthened preparedness and planning mechanisms and tools to manage disaster recovery processes; and iii) Increased use of financial instruments to manage and share disaster-related risk and fund post disaster recovery efforts.

In 2018, RESPAC conducted study to examine the feasibility of a Pacific-based WMO Regional Training Centre (RTC). The study team visited 13 of the 15 NMHSs of the Pacific Meteorological Council (PMC) and a survey was completed by 14 of the countries – including all five Programme countries. The team also visited Guam and Honolulu as they work closely with Palau, RMI and the Federated States of Micronesia in the provision of meteorological services and in the training of their staff. NOAA's Pacific Island Training Desk (PITD) in Honolulu also provides training to most of the Pacific countries included in the study. The Feasibility Report concluded that there is scope to set up a Pacific-based RTC, which would respond to regional demand for education and training for operational forecasting, climate services, marine and ocean services, ICT and equipment maintenance and repair.[298]

The Fifth Meeting of the PMC (7-9 August 2019) reviewed the recommendations of the Report and developed an Action Plan for next steps in the establishment of the Pacific RTC. The recommendations were categorised into four groups:

1. **RTC Framework** – The main actors in advancing the RTC Agenda will be SPREP (as the parent body for the PMC), the University of the South Pacific (USP), and Fiji Meteorological Services (FMS). Collaboration with the Australian Bureau of Meteorology (BoM) COSPPac project, NIWA and the Pacific Island Training Desk (University of Hawaii) will be required to support introduction of Basic Instructional Package (BIP) for Meteorological Technicians (MT) and BIP-for Meteorologists (M) courses.
2. **Implementation** – A three tier training programme is suggested: Certificate Level 2 (Basic Observers and Instrument Technicians); Level 3 (Advanced Level Meteorological Technicians); and Level 4 (Senior Level Meteorologists).
3. **Linkage to the Pacific Climate Change Center** – This could be a potential means to launch advanced level courses and provide space for advanced research and analysis in the climate change discipline.
4. **Backstopping arrangements** – The PMC Working Papers stated that arrangements should align to the existing PMC framework and its associated panels.

The Meeting reported that UNDP has secured additional funds from RESPAC to sub-contract USP to undertake preparatory work on curriculum development and preparation of the BIP-MT and BIP-M courses. The Government of Fiji, through the Ministry of Infrastructure and Transport (MOIT) and FMS, are upgrading infrastructure facilities at the Laucala office in anticipation of future partnership with USP to deliver the courses.[299]

The GEF-funded **"Inform"** project[300] is being implemented by UNEP and executed by the Secretariat of the Pacific Regional Environment Programme (SPREP) in the 14 Pacific island countries from 2017-21. Inform is establishing a network of national and regional data repositories and reporting tools to

[297] UNDP, 2020. Disaster Resilience for Pacific Small Island Developing States (RESPAC) Project. Available at: https://www.pacific.undp.org/content/pacific/en/home/projects/respac-project.html
[298] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre
[299] PMC, 2019. Fifth Meeting of the Pacific Meteorological Council (PMC-5) Working Papers. Agenda Item: Progress on the Regional Training Centre Feasibility Study
[300] SPREP, 2020. About the Inform project. Available at: https://www.sprep.org/inform

streamline existing environmental data and support the monitoring, evaluation and analysis of environmental information for planning, forecasting and reporting requirements. The Programme will utilise the repositories to manage each country's national climate data.

The **Climate and Oceans Support Program in the Pacific (COSPPac)** project,[301] implemented by the Australian Bureau of Meteorology (BoM) since 2012, aims to enhance the capacity of Pacific islands to manage and mitigate the impacts of climate change and tidal events. COSPPac is supporting stakeholders to analyse and interpret climate, oceans and tidal data for the development of forecasting and reporting tools. The Program comprises three main components:[302]

- The **Climate and Oceans Monitoring and Prediction (COMP) Project Phase 3** is supporting 10 Pacific island countries – including Cook Islands, Niue and Tuvalu – to develop their capacity in seasonal forecasting and in tailoring forecasts to the needs of farmers, water resource managers, public health authorities and other users.
- The **Pacific Sea Level Monitoring (PSLM) Project Phase 5** is recording, analysing and disseminating highly accurate data on sea levels from tide gauges hosted by 13 Pacific countries. Data is used by the international scientific community to monitor climate change, and by Pacific island countries and their development partners to generate practical applications.
- The **Capacity Development and Communications (CD&C) Project** is coordinating capacity development with Pacific NMHS staff through training, workshops, attachments and exchanges. The project also coordinates the introduction of new products and services generated by COMP and PSLM to participating NMHSs.

In late 2013, a separate **IT Section** was added, which is dedicated to ensuring quality, relevance and consistency of IT services across the whole Program. COSPPac is being delivered in partnership with regional and international agencies including the Australian Government Department of Foreign Affairs and Trade, Geoscience Australia, the Pacific Community (SPC) and SPREP.

The **Global Climate Change Alliance: Pacific Small Island States (GCCA: PSIS)** project[303] is an EU-funded initiative that was implemented by SPC in nine Pacific island countries – including the five Programme countries – from 2011-16. The project supported the participating countries to design and implement on-the-ground climate change adaptation projects in conjunction with mainstreaming climate change into policies, plans and budgets, alongside training and capacity building activities. The overall assessment was that the project was highly effective and successful in increasing the capacity of participating countries to adapt to climate change. The Final Evaluation Report identified a number of best practices and lessons learned, including: i) Project incorporated on-ground adaptation projects complemented by climate change mainstreaming and capacity building; ii) Recruitment of competent national coordinators fosters national ownership and was a key success factor for most projects; iii) Embedding senior staff in other regional organisations (e.g. SPREP) fosters regional collaboration and enhances efficiency; iv) Regional and national level training helped build country capacity across common and country-specific needs to support both project delivery and ongoing climate change adaptation; and v) Funding of 'South-South' exchange initiatives fosters a regionally-led approach to knowledge sharing. The assessment also highlighted that significant challenges to implementing projects within the Pacific region included transport logistics (unreliable, infrequent and expensive inter and intra-country transport) and both capacity and capability constraints across the government

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[301] COSPPac, 2020. About COSPPac. Available at: http://cosppac.bom.gov.au/about-cosppac/
[302] COSPPac, 2015. Independent Progress Review – Climate and Oceans Support Program in the Pacific
[303] SPC, 2016. EU GCCA: PSIS. Available at: http://ccprojects.gsd.spc.int/eu-gcca-psis/

and private sector. SPC identified a general "rule of thumb" to multiply the overall cost and time for outer island projects by two (compared to main islands) when detailed budgets and timelines are not available. These best practices and lessons learnt will be taken into account throughout the Programme development and implementation cycle.

The **Republic of Korea-Pacific Islands Climate Prediction (ROK-PI CLiPS)** project,[304] implemented by the APEC Climate Center (APCC) and SPREP from 2014-17, built a regional mechanism to provide locally tailored seasonal climate prediction information and training on downscaled climate predictions in the 14 Pacific island countries. The project developed and launched the CLIK-P and PICASO forecast tools tailored for the Pacific. CLIK-P is a web-based dynamical multi-model ensemble (MME) prediction tool optimised for the Pacific region. PICASO is a hybrid statistical-dynamical seasonal forecast software based on the MME data housed in CLIK-P. A series of trainings, application guideline development, and participatory development activities were conducted to ensure the sustainability of the regional mechanism. The PICASO software launch and the overall completion of the ROK-PI CliPS was applauded for its success during the Second Pacific Ministerial Meeting on Meteorology (PMMM-2) and Fourth Pacific Meteorological Council (PMC-4) meetings held in Honiara, Solomon Islands in 2017.[305] The ROK-PI CliPS project was approved for a second phase and is scheduled to be completed in 2021. Through the second phase, the project is updating the forecast tool to address NMHS concerns regarding conflicting seasonal climate models by developing a Consensus Climate Outlook (CoCO) function.

The **Climate Risk and Early Warning Systems (CREWS) Pacific SIDS Project** "Pacific: Strengthening Hydro-Meteorological and Early Warning Services"[306] is being implemented by WMO in seven Pacific island countries, including Cook Islands, Niue and Tuvalu. The objectives of the project are: i) Strengthened governance structures and mechanisms of the Regional Specialised Meteorological Centre in Fiji (RSMC Nadi) and the seven NMHSs that it serves; ii) Enhanced regional and national facilities and capacities to produce impact-based forecasts and risk-informed warning of extreme and high impact hydrometeorological events; and iii) Enhanced delivery of services and products to MHEWS stakeholders for decision support. The project is also supporting the Pacific islands not served by RSMC Nadi, including Palau and RMI – for example, through the development of long-term strategic plans for their NMHSs (planned for Q3 and Q4 2020).[307] As of June 2020, the project was noted to be on track in terms of expenditure, with slight delays in delivery due to travel bans and national restrictions as a result of COVID-19. Key outcomes related to the Programme countries include:

- IT training for entry level NMHS staff to build capacity in currently used and new IT products and website development – including operationalisation of the Cook Islands Meteorological Service website;
- Regional impact-based forecast and warning services training and workshop for NMHSs and national disaster management agencies;
- Establishment of community-based early warning systems in selected communities in Niue, Palau and RMI;

[304] Pacific Meteorological Desk & Partnership, 2019. Project Description – ROK-PI CliPS. Available at: https://www.pacificmet.net/project/republic-korea-pacific-islands-climate-prediction-services-project-rok-pi-clips-phase-1
[305] Fourth Pacific Meteorological Council (PMC-4) Final Report, 2017 https://www.pacificmet.net/pmc/meetings/pmc-4
[306] CREWS, 2020. Pacific: Strengthening Hydro-Meteorological and Early Warning Services. Available at: https://www.crews-initiative.org/en/projects/pacific-strengthening-hydro-meteorological-and-early-warning-services
[307] CREWS, 2020. Pacific 1.0 Achievements and Rationale for Additional Financing

- National drought consultation workshop in Tuvalu (2017) and development of a Drought Monitoring Plan for Funafuti;
- Approval of the Tuvalu Strategic Plan and meteorological bill.

The Programme will implement "Contributions to Value" approaches proposed under the CREWS project, including use of gender-sensitive indicators in assessments of NMHS capacities and regional assessments; people-centred early warning systems focused on reaching communities that are not currently well connected with the NMHS; promote coherence through cooperation with ongoing projects and initiatives; and promote an active dialogue with beneficiaries to find solutions to their identified EWS-related problems.

A proposal for **Phase II of the CREWS Pacific SIDS Project** covering all 14 Pacific island countries intends to further strengthen RMSC-Nadi, regional coordination mechanisms and provide country level support to facilitate more integrated and inclusive early warning systems in the Pacific – with an increased focus on coordination with disaster management offices and co-production with targeted beneficiaries. The proposed outcomes are:

1. *Improved Governance* – Development of bills, legislation, socioeconomic assessments and National Strategic Plans for meteorology, hydrology and disaster management; and improved regional coordination mechanisms.
2. *Enhanced Product Co-Development and Accessibility* – Development of national integrated Early Warning System (EWS) plans and EWS training; and a high-resolution Numerical Weather Prediction (NWP) model in Fiji (RSMC-Nadi products are used by Cook Islands, Niue and Tuvalu).
3. *Enhanced Service Delivery* – Improved quality of accessible services provided for priority sectors and stakeholders to better respond to climate hazards.
4. *Enhanced Communication and Awareness Programs on Early Warning* – Development of knowledge products and publications.
5. *Strong Inclusion of Gender and Persons living with Disabilities in EWS* – Development of a guidance document to mainstream gender and disability.

In June 2020, at the 11th Meeting of the CREWS Steering Committee, the allocation of USD 4.8 million to fund Phase II of the project was approved, "pending inclusion of the comments raised at the meeting…[T]he approval depends on the availability of funds in the CREWS Trust Fund."[308] WMO indicated at the meeting that "the funds would allow the island countries in the region to detect, monitor and forecast severe high-impact weather events. Additional services to be developed include access to longer-term seasonal predictions and operational early warnings and response plans that ensure the most vulnerable people in the communities receive warnings."[309]

The Programme will partner with CREWS for the delivery of community based EWS interventions under Result 3. Interventions could subsequently be replicated in other communities through the proposed Phase II project, thus facilitating scale-up of the Programme.

[308] CREWS, 2020. CREWS/SC.11/Decisions
[309] WMO, 2020. Financing increased for early warning systems in Small Island Developing States. Available at: https://public.wmo.int/en/media/news/financing-increased-early-warning-systems-small-island-developing-states

5.2 CONTRIBUTION TO REGIONAL AND NATIONAL ADAPTATION PRIORITIES

The Programme will contribute to achieving the objectives agreed in the **Pacific Island Meteorological Strategy 2017–2026**[310], the **Pacific Roadmap for Strengthened Climate Services 2017–2026**[311] and the **Honiara Ministerial Statement** on Sustainable Weather, Climate, Oceans and Water Services for a Resilient Pacific: these are guiding documents for the Pacific Meteorological Council, the Pacific Ministerial Meeting on Meteorology and other relevant bodies.

- The *Pacific Island Meteorological Strategy 2017–2026* is a key reference and guidance document for this Programme. The Programme will directly address many of the PIMS's identified "Pacific Key Outcomes" in the priority areas of improved weather services, disaster risk reduction, improved climate and hydrological services, integrated observing and communication systems, and coordinated support for NMHSs.
- The *Honiara Ministerial Statement* emphasised the importance of climate and weather information, noting that 80% of disasters in the region are caused by severe weather events. It also emphasised the importance of ocean and aviation services to sustainable economic growth, public safety and security, and of compliance with national obligations under the Safety of Life at Sea (SOLAS) Convention and International Civil Aviation Organization (ICAO) regulations.
- The *Roadmap* identifies key actions for implementing the Global Framework for Climate Services (GFCS).[312] This Programme responds directly to the activities prioritised in the *Roadmap* under the GFCS pillars: climate services information system; observations and monitoring; research, modelling and prediction; and capacity development. The *Roadmap* also emphasises the importance of maintaining institutional capacity to support and coordinate national climate services: the Pacific Meteorological Council has created the virtual Pacific Islands Regional Climate Centre (PI-RCC) Network to host and provide climate data and information services.

Most recently, at the 50th Pacific Islands Forum in August 2019, leaders reaffirmed their recognition that the greatest threat to Pacific Nations is climate change. Leaders emphasised the need for greater intra-regional and inter-sectoral collaboration particularly in relation to sustainable fishery resources, which are dependent on marine ecosystems.[313]

At the national level, Pacific island countries have identified climate information as a priority area in their national strategies and plans—INDCs/NDCs, NAPAs, NAMAs and NAPs—and are committed to achieving progress. Pacific countries' NAPAs note that awareness and education on weather and climate and on the implications of climate change for communities are critical steps in adapting to climate change. A few illustrative country examples of priorities that will be addressed by this Programme are:

- The ***Cook Islands*** Second Joint National Action Plan for Climate Change and Disaster Risk Management 2016–2020 (JNAP II) includes priority actions to enhance national capacity to provide early warnings for slow and fast-onset hazards; and to improve climate and disaster research and monitoring, information generation, management and sharing. Furthermore, the JNAP II prioritises community-based integrated vulnerability assessment, climate change adaptation and strengthening of disaster risk management and planning.[314]

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[310] SPREP, Pacific Islands Meteorological Strategy 2017–2026.
[311] SPREP, Pacific Roadmap for Strengthened Climate Services 2017–2026.
[312] Global Framework for Climate Services, GFCS in action, available from <https://gfcs.wmo.int//> [August 2019]
[313] Pacific Islands Forum, 2019. *Kainaki II Declaration for Urgent Climate Change Action Now*.
[314] Cook Islands Government, 2016, JNAP II.

- ***Niue's*** National Climate Change Policy identifies the following objectives "1. Awareness Raising – To promote public awareness and improve stakeholder understanding of the causes and effects of climate change and climate variability, as well as on vulnerability, adaptation and mitigation responses; 2. Data Collection, Storage, Sharing, and Application – To improve and strengthen the collection, storage, management and application of climate data, including greenhouse gases and emissions, to monitor climate change patterns and its effects."
- One of the strategic goals identified in ***Palau's*** Climate Change Policy (2015) is to establish the enabling framework 'to build safe, resilient, and disaster prepared communities in Palau" by strengthening mechanisms for control, coordination, decision making, accountability, and organisational arrangements for disaster management and disaster risk reduction.[315] Palau's Nationally Determined Contribution (NDC) stresses the importance of partnership, finance, technology support and capacity development to implement the national climate change policy.
- The Joint National Action Plan (JNAP) for climate change adaptation and the Disaster Risk Management National Action Plan (DRM NAP) of the ***Republic of the Marshall Islands*** express priorities such as mainstreaming "natural hazard risk considerations (climate-related, geophysical and others)… in all relevant processes of development and budgetary planning at all levels and in all relevant sectors"; "regularly updating its climate vulnerability assessments"; putting in place "people focussed early warning systems and emergency communications"; improving "national and local capacity to undertake vulnerability and adaptation assessments and planning"; improving "awareness of the causes and impacts of climate change and disasters…including what constitutes an effective adaptation response."
- One of the goals of ***Tuvalu's*** National Climate Change Policy (2012–2021) is "Improving Understanding and Application of Climate Change Data, Information and site-specific Impacts Assessment to Inform Adaptation and Disaster Risk Reduction Programmes." It also highlights the need to provide modern infrastructure and adequate well trained and competent human resources to gather, process, archive and facilitate the rapid exchange of data and products; build capacity to maintain high standards of observation instruments, equipment and data backup system; build and enhance partnerships and cooperation and improve communication systems for sharing of climate information within the Pacific countries with the help of their NHMSs; and improve protection of life and property through early warning services.[316]

5.3 ALIGNMENT WITH INTERNATIONAL STRATEGIES AND AGREEMENTS

The Programme will contribute to long-term social, economic and environmental benefits from avoided human and economic losses and healthier ecosystems in five of the Pacific region's most vulnerable countries. The urgent need to reverse the cycle of decline in ocean health is emphasised in the proclamation of the UN Decade of Ocean Science for Sustainable Development (2021–2030). The Decade will provide a unifying framework to strengthen international cooperation in the study, conservation and sustainable use of the ocean and its resources; and enable countries to achieve all of their ocean-related Agenda 2030 priorities.[317]

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[315] Government of Palau, 2015, Palau Climate Change Policy.
[316] Tuvalu, 2012, Tuvalu Climate Change Policy.
[317] UNESCO, 2019. United Nations Decade of Ocean Science for Sustainable Development. Available at: https://www.oceandecade.org

The Programme is fully aligned with the Sustainable Development Goals (SDGs), the Paris Agreement, the Sendai Framework and the SAMOA Pathway as follows:

- SDG 13 on urgent action to combat climate change and its impacts and related target 13.1 to "Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries", which is the focus of this Programme.

- The Paris Agreement, which in Article 7, Sub-paragraph 7(c) calls for "strengthening scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making".[318]

- The Sendai Framework for Disaster Risk Reduction 2015–2030[319], which in paragraph 33 b) stresses that it is important "To invest in, develop, maintain and strengthen people-centred multi-hazard, multisectoral forecasting and early warning systems, disaster risk and emergency communications mechanisms, social technologies and hazard-monitoring telecommunications systems; develop such systems through a participatory process; tailor them to the needs of users, including social and cultural requirements, in particular gender; promote the application of simple and low-cost early warning equipment and facilities; and broaden release channels for natural disaster early warning information."

- The SAMOA Pathway adopted by the Third International Conference on Small Island Developing States in 2014.[320] This Programme will address the highlighted needs for *increased accessibility to technical assistance for early warning systems, risk assessment and data, observation equipment and disaster risk management; data sharing and networking to strengthen and enable beneficial and durable national, sub-regional, regional and global cooperation; improved baseline monitoring of island systems and to address gaps in capacity for gaining access to and managing climate data/information to raise awareness and share environmental data in an effort to increase resilience to the impacts of climate change*. Resolution A/74/L.3 on the High-Level Midterm Review of the SAMOA Pathway was adopted by the UN General Assembly in October 2019.[321] Paragraph 31 (i); specially requests: "[T]he United Nations Environment Programme to further strengthen support to small island developing States, including through dedicated programmes".

5.4 COHERENCE AND COMPLEMENTARITY

The Programme will build on and leverage previous investments in climate observation networks as outlined in the following table.

Previous activities to build the observation network in the Pacific	How the Programme builds on and leverages previous investments

[318] United Nations, 2015. Paris Agreement
[319] United Nations. Sendai Framework for Disaster Risk Reduction 2015-2030
[320] https://sustainabledevelopment.un.org/samoapathway.html
[321] https://www.un.org/ga/search/view_doc.asp?symbol=A/74/L.3&Lang=E

Climate and Oceans Support Program in the Pacific (COSPPac) – BoM – 2012-2022 Installed tidal gauge in Niue in 2015 and continue to support the maintenance of the tidal gauges in Tuvalu, RMI and Cook Islands. SPC technical officers work alongside Geoscience Australia specialists on the maintenance and calibration of the 13 earth monitoring stations linked to the tide gauges, funded by COSPPac.	**Installation of portable tide gauges (Penrhyn and Pukapuka – Cook Islands) and generation of local tide calendars.** There are benefits for both the hosting country and for the international scientific community: data from the portable gauge may be quite different from long-term data streams; and local tide calendars can be generated. In countries with very widely dispersed land masses, existing tide gauges will not give accurate information for distant islands. The inaccuracy can be, and has been, dangerous particularly for tourists and sailors unfamiliar with the islands. For Cook Islands, Pukapuka is close to the Tonga trench – the origin of many Pacific tsunamis – therefore the portable tide gauge may also collect useful data on ocean responses to seismic activity. **The National Ocean Portals to be developed for Palau and RMI will integrate data from the global tide gauge network.**
Climate Risk and Early Warning Systems (CREWS) Initiative for the Pacific Small Island Developing States – WMO – 2015-2020 Procurement of wave buoys and pressure sensors for Tuvalu	**Establish an integrated ocean and coastal impact monitoring program combining remote sensing and in-situ ocean and coastal impact data; develop downscaled wave, circulation and inundation models at country, island and lagoon scales; calibrate Sentinel-2 satellite-derived information using in-situ data (e.g. from wave buoys); integrate data into existing local databases and the Pacific Ocean Portal – the region's centralise platform for ocean data visualisation; supported by in-country training on maintenance of monitoring equipment.** The Programme will integrate data from all relevant available sources – including those deployed under the CREWS Project – to improve the accuracy of the monitoring program and facilitate the development of location-specific ocean outlooks. Furthermore, the Programme will leverage to specialised technical knowledge of SPC, which is implementing the CREWS Project, to ensure complementarity with existing initiatives.
Disaster Resilience in Pacific Small Island Developing States (RESPAC) – UNDP – 2016-2019 Installation and testing of five Automatic Weather Stations (AWSs) in Cook Islands	**Installation of new/upgraded AWS and Automated Weather Observing Systems (AWOS) in all five Programme countries in compliance with the Global Basic Observing Network (GBON) requirements and obligations.** The Programme will strengthen the network of land-based observation stations measuring atmospheric temperature, humidity, horizontal wind and precipitation to ensure GBON compliance of the five countries and facilitate data to be fed into the GBON for use in global Numerical Weather Prediction (NWP), which will support enhanced forecasting as a global public good. **Training of NMHS staff; recruitment of local technicians for Cook Islands, RMI and Tuvalu; and local technical support for Niue to conduct annual maintenance of the AWS / AWOSs.** Currently, there is only one trained technician each at Cook Islands Meteorological Service (CIMS) and Tuvalu Meteorological Service (TMS) and two trained technicians at RMI Weather

	Service Office to implement the demanding schedule of calibration and maintenance required. The CIMS and TMS technicians have no back-up. Training, recruitment of technicians and provision of additional technical support will enable the NMHSs to adequately maintain the expanded networks. **Provision of spare sets of AWS sensors and calibration kits for all five countries; supported by laboratory training for NMHS technicians on instrument assembly and calibration.** Lack of technical and financial capacity for observations and maintenance is a major cause of observation stations ceasing to operate in the Pacific island region. For example, now spares were provided for the AWSs installed under the RESPAC project in Cook Islands. **Installation of AWSs on four inter-island shipping vessels for regular reporting on the weather in open waters; supported by O&M training for on-board crew and CIMS technical staff designed to ensure that staff can support vessel AWS maintenance beyond the Programme.** The additional data will improve the accuracy of forecasting of weather events for Rarotonga and the southern Cook Islands. Equipment will be compatible with the international Voluntary Observing Ship Scheme (VOS) and the international Convention on Safety of Life at Sea (SOLAS). All shipboard observations will be transmitted to the Global Telecommunication System (GTS) / WMO Information System (WIS) and be integrated with satellite communications. This will facilitate that Cook Islands contributes to improving the quality and availability of observational data, as a global priority to enhance weather and climate services and products through the WMO Integrated Global Observing System (WIGOS).
Training of Tuvalu NMHS technicians on AWS maintenance	**Installation of eight new/upgraded AWS and one AWOS at Funafuti; supported by laboratory training for assembly and calibration, O&M; preparation of operational competencies workbook; site inspections and post-installation calibration support.** Tuvalu does not currently have an AWS. The Programme will leverage the technical capacity built under the UNDP project to enable Tuvalu Meteorological Service (TMS) staff to put their skills into operation. Installation of the AWS/AWOS will improve the ability of TMS to monitor and report on the current weather in real-time, including the provision of timely METAR and SYNOP data to the WMO GTS for improved global weather forecasting services over Tuvalu. Near real-time data transmissions will also enable the Regional Specialised Meteorological Centre in Fiji (RSMC-Nadi) to provide improve Terminal Aerodome Forecasts (TAFs) for Funafuti International Airport. Improved accuracy of TAFs will facilitate more risk-informed decision-making of aviation services, thus lowering the

	probability of costly wrong decisions – as well as improving the safety and security of air operations. Aviation forecasts have been considered to be incremental cost recovery services.[322] The Programme will explore opportunities for cost-recovery in the aviation sector through the climate services market assessments (Activity 1.1.2).
Finnish-Pacific Project (FINPAC) – SPREP – 2013-2017 Capacity building for the implementation of a Quality Management System (QMS)	**Establish QMS in all five countries facilitated by experts from the WMO network; supported by training and workshops, with the aim of obtaining certification in compliance with ISO9001:2015.** FINPAC trained a regional roving QMS team available to Pacific NMHSs to provide audits and help towards certification. The team was only called out once (by Samoa from Solomon Islands). NMHSs cited financial constraints for not utilising this opportunity. None of the five Programme countries has an established QMS. The Programme will build in-country capacity for NMHS staff to implement QMS, which will facilitate that quality standards are maintained without reliance on external support. This will also contribute to NMHSs delivering WMO's Essential-category 2 level services.
Rehabilitation of a number of "silent" (non-functional) meteorological stations that are part of the Regional Basic Synoptic Network (RBSN) N.B. Assessment of all RBSNs was done and the main needs for rehabilitation were identified. Actual rehabilitation did not start.[323]	**Procure equipment to strengthen the network of land-based observations to facilitate compliance with GBON requirements and obligations.** This will include procurement of equipment to upgrade / rehabilitate current "silent" meteorological stations where possible to maximise cost effectiveness and use of existing infrastructure.

Table 26. Previous activities to build the observation network in the Programme countries and how the Programme builds on and leverages previous investments

[322] Leigh, R.J. 1998. An Economic Analysis of Terminal Aerodrome Forecasts with Special Reference to Sydney Airport

[323] Danish Management A/S and ECO Consult, 2018. Final evaluation of the Finnish-Pacific project

6 – METHODOLOGY

The interventions set out in the proposal have been selected by the participating Governments as their highest priorities for support through this Programme. Within the parameters of the Programme, as set out in the Concept Note, all five countries have considered carefully what activities from among those suggested would be of most value to them.

In each country a programme was drafted with the NMHS Director and the National Designated Authority for interaction with the GCF (the NDA), reflecting the results of in-country consultations with a wide range of stakeholders and proposing a group of interventions that formed a structured programme, addressing well-understood barriers to developing resilience to climate change impacts.

The Directors of the five national meteorological services attended a validation workshop in June 2019 in Rarotonga with development partners (all participants were in Rarotonga for a COSPPac Steering Committee meeting) to finalise their respective draft proposals. The Cook Islands NDA also contributed to the validation.

The development partners gave presentations on services and products they could offer to the Programme. The Programme's funds are not tied to particular providers and countries negotiated with SPC, BOM, New Zealand's National Institute for Water and Atmospheric Research (NIWA) and the US National Ocean and Atmospheric Administration (NOAA) on products, training, attachments, community work, maintenance schedules and other services to achieve the most appropriate programme of high priority, achievable interventions for their countries' circumstances.

The result is a demand-driven programme with each country in accordance with best development practice. Many people in each country contributed to wide ranging discussions on ways resilience to climate change impacts might be advanced, what their Government and its development partners are already doing and how the proposed Programme can contribute. The final list is the activities that respondents believed are most likely to be effective, most feasible and most consistent with work already being implemented or planned. Their intention is that the Programme will effect a paradigm shift in their country to evidence-informed climate adaptation by sectors and communities.

The activities that make up this Programme build on previous projects and take into account proposals being planned, designed or considered by other development partners: each partner Government's aid coordination agency works to improve donor harmonisation in its climate activities. The activities proposed here contribute to a coherent structure enabling each NMHS to generate a richer body of climate data, shared consistently with related agencies, and to communicate useful and accessible data to its Government, climate-sensitive sectors and communities. The integration of climate information and shared data in key policies, strategies, plans and budgets will provide a foundation for informed, climate resilient decision-making.

One of the most significant activities in this proposal relates to the new ocean services. The ability to observe and monitor ocean processes with modern equipment will add a vast source of data for Pacific meteorology services and for the international scientific community. The addition of ocean data constitutes a major step up in the capacity to provide an evidence base for national planning and adaptation to change.

The Programme proposes end-to-end ocean services. SPC and BOM will install monitoring equipment such as buoys, and will maintain the Pacific Ocean Portal, making the new data available and helping countries to use it in ocean information products. SPC will support NMHS staff in developing new skills in marine meteorology and oceanography and will provide practical support for monitoring the health of lagoons, vital to island livelihoods in many ways.

The Programme-hired National Ocean Expert in each of the five meteorology services will lead sector workshops introducing information users to the potential for the new data to inform their work. S/he will engage with communities to explain the contribution that data from remote sensing devices can make to understanding extreme events and improving warning times.

The NMHSs will achieve a major advance in the assistance they can give to search and rescue authorities, inter-island boat operators, fishers and recreational seafarers, and the contribution they can make to the Global Maritime Distress and Safety System (SOLAS).

The new data will create a foundation for new activities presently impossible and allow a far better informed understanding of climate change processes manifesting in the Pacific Ocean and affecting the whole planet.

The generation of accurate local information for climate and ocean services, for local users and for reducing the human and financial costs of long-term change and extreme events has obvious value. As well, there are significant benefits for global understanding of climate change when reliable observation data is available from widely distributed Pacific Islands, providing in situ (on-ground) data from across vast areas of otherwise inaccessible ocean. The value of the data that can be collected by very small SIDS is likely to be much greater than the cost to the global community of assisting small national meteorological services.

Equally important is the comprehensive approach to engaging with communities at risk from extreme climate events. The Programme will make it possible for NMHS staff to undertake thorough, planned collaborations with all their communities over the term of the Programme, and to develop communication methods for information and warnings that are understood and trusted. Also essential is the negotiation and development of institutional structures that will formalise the NMHSs' roles in the provision of services to climate-sensitive sectors and in emergencies.

The situation of each partner country and the programme of activities it has identified are described in more detail in the individual sections of this Feasibility Study.

7 – PROPOSED INTERVENTIONS AND TECHNICAL FEASIBILITY

RESULT 1 – STRENGTHENED DELIVERY MODEL FOR CLIMATE INFORMATION SERVICES AND MHEWS COVERING OCEANS AND ISLANDS

The effective delivery of user-tailored climate services is essential for the provision of climate information to assist with decision making and climate-resilient sustainable development.[324] Pacific NMHS advice can significantly reduce climate risks if the advice has a recognised formal role in disaster preparation, warnings and management and in long-term planning for climate change impacts by infrastructure, health, tourism, agriculture, fisheries and other climate-sensitive sectors. While Pacific NMHSs have competencies in monitoring and analysing weather and climate patterns, they are constrained by poor infrastructure and limited human, financial and technical resources.[325] Furthermore, all Programme countries lack clarification and/or formalisation of their NMHS's mandate and its relationship with National Disaster Management Authorities, other national institutions and sectors. While some of the Programme countries have a Meteorology Act that sets out the mandate and functions of their NMHSs in relation to weather services, none has an Act that adequately covers the roles of its NMHS in disaster warning and management, or in providing advice on climate change. Furthermore, with the exception of Tuvalu, none of the Programme countries allocates for climate change programming in the national budget and any disaster funds are limited to immediate relief efforts rather than pre-emptive disaster risk management actions.

Therefore, Programme Result 1 will assist each country to establish a coherent National Framework for Climate Services (NFCS) to coordinate, facilitate and strengthen collaboration among national institutions for enhanced climate information services and products, supported by effective coordination mechanisms to integrate climate information and disaster risk knowledge into the decision-making of climate-sensitive sectors. Continuing, regular stakeholder engagement will inform the development of tailored, accessible products and services that serve the practical needs of end users. This will lead to increased understanding of and use of NMHSs' information and advice, and reduced losses from climate variability and extreme events. Moreover, NMHS staff will gain cumulative experience in communicating with non-scientists to achieve practical outcomes and ensure that essential climate information reaches "the last mile".

Long-term sustainability of climate services and disaster risk management will be achieved through strengthened institutional and stakeholder partnerships as a result of the NFCSs, identification of opportunities for private sector engagement and investment based on detailed market assessments, and the development of financial policies to ensure that the five NMHSs have the means to sustain and ensure the ongoing operation of their mandated services in order to mitigate weather-, climate-, and water-related risks. This will facilitate national climate funding, including through cost-recovery mechanisms from sectors, where feasible, beyond the Programme's lifespan, based on the value chain captured in the figure below.[326]

[324] WMO, 2018, Step-by-step Guidelines for Establishing a National Framework for Climate Services.
[325] SPREP, Pacific Roadmap for Strengthened Climate Services 2017-2026
[326] The World Bank, 2013. Weather and Climate Resilience. Effective Preparedness through National Meteorological and Hydrological Services

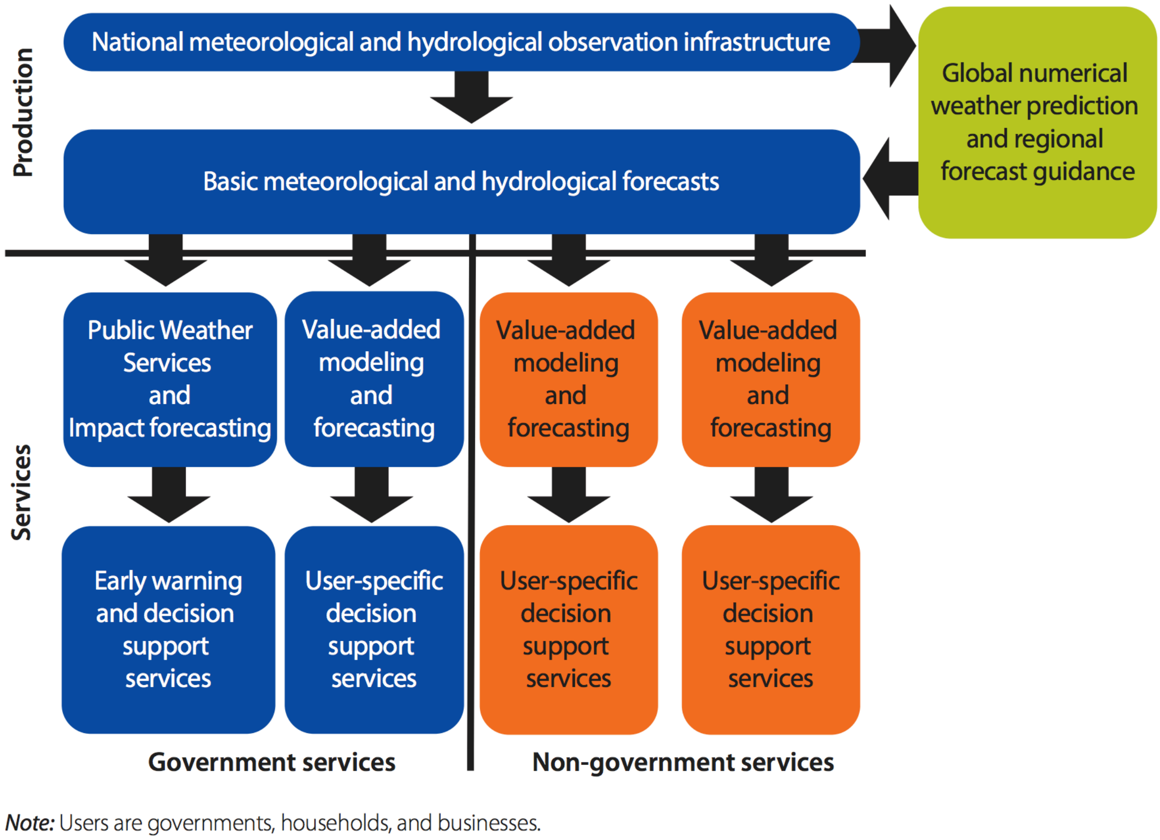

Figure 72. Value chain for weather and climate services.

Activity 1.1 Strengthen institutional and policy frameworks and delivery models for climate services

Under this Activity, the Programme will establish comprehensive institutional and policy frameworks and delivery models for strengthened climate services, including the development of a National Framework for Climate Services (NFCS) in all five countries and national meteorological strategies and legislation in Palau and RMI. The frameworks will be supported by effective coordination mechanisms to mainstream climate risk knowledge into the decision making of climate-sensitive sectors. Moreover, each country will conduct a climate services market assessment and develop a policy for sustainable financing and delivery of climate services. Amongst others, engagement with the development of national budgets will enable justification of the value of climate services, strengthen existing funding for disaster relief and contribute to the identification of long-term sources of funds.

1.1.1 Develop National Frameworks for Climate Services

Each country will develop a National Framework for Climate Services (NFCS) to coordinate, facilitate and strengthen collaboration among national institutions for enhanced use of climate information and provision of climate services and to facilitate a long-term sustainable business model for national climate services.[327] This will put into practice the five pillars of the Global Framework for Climate Services (GFCS) in the five countries as follows:

[327] WMO, 2018. Step-by-step Guidelines for Establishing a National Framework for Climate Services

- User Interface Platform (UIP): a structured means for users and NMHSs as climate information providers to interact at all levels.
- Climate Services Information System: the mechanism through which information about climate (past, present and future) is routinely collected, stored and processed by the five NMHSs to generate products and services that inform often complex decision-making across a wide range of climate-sensitive activities and enterprises.
- Observations and Monitoring: to be implemented under Result 2 of this Programme.
- Research, Modelling and Prediction: to be implemented under Result 2 of this Programme with a focus on climate modelling and prediction of its impacts on ocean areas and islands.
- Capacity Development: to be implemented across the four Programme Result areas (as described in section C.3).

In a series of consultative workshops with government agencies (including representatives of key climate-sensitive sectors such as agriculture and food security, health, disaster risk management, energy, infrastructure, transport, tourism, etc.) and all stakeholders with a role in the climate services value chain (from production and co-development through to use at the local level), NMHSs will communicate what information they can generate and how it can be applied to policy and practice. Sectors will present how they currently use climate information, what additional information would be useful to receive, and how they would like to work with the NMHS. This will help stakeholders to identify and agree on more specific functions, relationships and services to ensure that their operations take into account climate change impacts. The outcomes of the workshops will be used to establish the NFCSs and to develop a suite of sector-specific climate information products. These decisions will be revisited each year during the National Climate Outlook Forum (NCOF) and modified according to feedback and learnings. The process will be repeated in the second, third and fourth years with the private sector, NGOs and community representatives respectively. The NFCSs will therefore serve the following functions in the five countries:

- A platform for institutional coordination, collaboration and co-production amongst relevant technical departments across line ministries at national and sub-national levels, NMHSs, and technical experts to develop and deliver user-oriented climate services.
- Support the development of a legal framework by articulating collaboration at the national level to generate and share user-oriented climate services for use by the relevant social and economic sectors. The framework will support the Governments of Palau and the Republic of the Marshall Islands (RMI) who will develop national meteorological strategies and legislation to clarify and formalise the mandate of their NMHSs.
- An opportunity to bridge the gap between available climate services and user needs at national, sub-national and local levels through the User Interface Platform, which will continuously identify user needs for climate services, communicate available climate products and services to users in the relevant sectors, and obtain feedback from users on climate products and services.
- A vehicle for scientific coordination to monitor the state of the climate at the national level and disseminate climate knowledge outputs for policymaker actions founded on scientific evidence through the Climate Services Information System.

- A functional chain for linking climate knowledge with action on the ground so as to maximise the application of climate information and products, including the identification and removal of bottlenecks for improved delivery of climate services.
- An opportunity for enhancing the contribution of climate science to the development of national adaptation plans, disaster risk reduction and management, Sustainable Development Goals and national development policies by enhancing the integration of climate information and products into decision-making as well as into national policies.

Also essential is the negotiation and development of institutional structures that will formalise the role of NMHSs in the provision of services to climate-sensitive sectors and in emergencies. The Programme will support each NMHS in developing and formalising agreements with related national agencies (disaster management organisations, public broadcasters, public works departments, public health authorities) on roles and responsibilities.

Meteorological Act

The RMI Weather Service is not governed by a Meteorology Act, but by the Compact of Free Association (COFA) with the US, which came into effect in 1983 and in 2003 was renewed for another 20 years. This treaty arranged for the United States' National Weather Service (NOAA) to provide weather services and related programmes in the Republic in accordance with Article VII (Weather Services and Related Programmes) of COFA. According to Sections 5 to 13 of Article VII of COFA, US NOAA NWS provides weather services through the Weather Services Office (WSO) Majuro.

In the first year of this Programme, the RMI Weather Service proposes to engage a legislative drafting consultant to prepare a draft Meteorology Act for submission to Parliament. The Act should mandate the responsibilities of the WSO for provision of weather and climate services, clearly state its role in early warning and disaster management, formalise its relationship with allied agencies, and provide budget security.

The consultant will work with the Ministry of Justice, Immigration and Labor and with NOAA to ensure the draft is consistent with RMI's existing legislation, takes the Compacts of Free Association (COFA) into account and looks to the future. The national disaster management agency, disaster relief agencies and media organisations will be consulted to ensure the draft legislation supports their collaboration with the WSO. The consultant may also consult with WMO, which has advised other Pacific island countries on developing a Meteorology Act, and with NOAA, BOM or NIWA on model legislation.

Meteorological Strategies

The Palau and RMI Weather Services Offices (WSOs) will each engage an international consultant, supported by a local consultant, to draft a National Meteorological Strategy: for Palau, its objective is to document the process by which the WSO will put the Pacific Islands Meteorological Strategy and the Pacific Roadmap for Strengthened Climate Services into operation; in RMI, the consultancy will document the process by which RMI will put its proposed Meteorology Act into operation. In each country the consultant will undertake two principal tasks:

Review stage

- Review sectors' use of weather and climate information services, including use and demand within the public and private sectors, and by communities.

- Review existing national sector policies and institutional and governance arrangements as they relate to climate variability and change and consider how the National Meteorological Strategy can promote better use of climate information.
- Review previous consultations, investigations and analyses of the mainstreaming of climate information into sectors' decision-making processes, focusing on the five GFCS primary sectors— Agriculture, Tourism, Water, Fisheries and Infrastructure—and on the use of weather and climate information services in early warning systems.

Drafting stage

- Conduct preparatory work with each government agency to ensure their interests are taken into account in the Strategy.
- Conduct workshops with the private sector, NGOs and community representatives to ensure their input to the Strategy.
- Facilitate a public workshop to validate and finalise the draft.

The two Weather Services may need to seek additional resources so that they can put their National Meteorological Strategies into effect.

1.1.2 Conduct market assessment to explore viable opportunities for climate information services in sectors and business segments

The global market for weather and climate information services (WCIS) is rapidly increasing. Total expenditure on WCIS in 2014/2015 was over USD 56 billion, which represents an increase of over 35 % from 2011.[328] Investments in WCIS generate strong, positive returns: the benefit-to-cost ratio of improvements in NMHSs for disaster loss reduction range from 4:1 to 36:1 in developing countries;[329] and publicly available weather and climate information can stimulate a larger, revenue-generating private market for WCIS.[330] However, significant disparities exist in the global commercial WCIS market and "decision-making in developing countries may be compromised if public and private organisations are reliant on less specialised free services, rather than specific, tailor-made commercial WCIS."[331]

Accordingly, this Sub-activity will support the five Programme countries to understand their existing climate services markets and potential sustainable climate services models; and utilise a value chain approach to mobilise private sector finance in climate services delivery. In the longer term, this will support establishment of a foundation for a cycle of investment, service enhancement, research and development, and re-investment, which has already created commercial markets for climate services in developed countries.[332]

The Programme will conduct a detailed market assessment in each country, which will assess the following:

- **Involved actors in climate services** – This include providers, intermediaries and users: i) Government agency/s (including the NMHS) responsible for the operation of the national meteorological infrastructure and provision of public weather and climate services; ii) Academic (university) research community, which usually plays a major role in advancing the

[328] Georgeson, L. et al. Science Advances. 2017. Global disparity in the supply of commercial weather and climate information services
[329] WMO, 2015. Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services
[330] USAID, 2018. Climate Information Services Market Assessment and Business Model Review
[331] Georgeson, L. et al. Science Advances. 2017. Global disparity in the supply of commercial weather and climate information services
[332] SAID, 2018. Climate Information Services Market Assessment and Business Model Review

scientific basis for service provision and training staff who move into service provision; iii) Media entities that often work in close partnership with the NMHS to deliver essential services to the public; iv) Private sector and other providers, including commercial providers of value-adding tailored services and specialist in-house service providers of major sectors; and v) Users, which consists of the general public, as the users of basic services, and the economic and social sectors and organisations as the users of specialised, tailored services.[333]

- **Regulatory environment** – National policy and legal frameworks can significantly impact private sector involvement in climate services. Constrained laws and policies allow for some private sector involvement in the supply of commercial products and value additions to public data services, whilst permissive laws create an enabling environment to develop the climate services market and amplify public sector investments at a greater rate.[334] The market assessment will analyse the current regulatory environment for climate information and early warning services in the five Programme countries and subsequently identify policy incentives to unlock barriers to private sector investment;
- **Supply and demand analysis** – In basic terms, the net benefit of hydrometeorological services is "what they are worth to their client, based on their demand, minus the cost to NMHSs of supplying the services".[335] Significant scope exists for NMHSs to generate income and thus enhance the net benefits of their services through value-adding processes that tailor services to more specialised applications and decisions. However, NMHSs often lack the technical and managerial capacity to facilitate this.[336] The Programme will support the five NMHSs to identify country-relevant sector and business needs for climate services (for example, level of information, scales and access required);
- **Private sector engagement** – Building on the analysis of supply and demand, the Programme will support NMHSs to engage with the private sector – including through the National Climate Outlook Forums (Sub-activity 1.1.3) – to identify private sector sponsors' interest in the generation, translation and transfer function and in purchasing climate-related information. In particular, this will focus on engagement with the Pacific islands' main economic and climate-sensitive sectors of fisheries, tourism and agriculture.
- **Business models** – The Programme will analyse business models for climate services that are successful in other countries, with a focus on Small Island Developing States (SIDS). This will include case studies on private sector company provision of climate services as well as government-led initiatives. The objectives of the analysis will be to identify: i) common business models; ii) types of climate services provided; iii) geographic and end-user reach; iv) technological innovations; v) opportunities and barriers to growth; and vi) models for public-private partnerships.

Based on the above analysis, the Programme will support the five countries to identify opportunities to develop value-added climate products and services; and potential for public-private partnerships and private sector investment in climate services. Private sector engagement will improve the cost-effectiveness of NMHSs and increase potential for catalysing innovation in climate information technologies. This Activity will also inform development of the national policies for financing climate services in Sub-activity 1.1.4.

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[333] WMO, 2015. WMO-No. 1153. Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services
[334] USAID, 2018. Climate Information Services Market Assessment and Business Model Review
[335] WMO, 2015. Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services
[336] USAID, 2018. Climate Information Services Market Assessment and Business Model Review

1.1.3 Mainstream climate risk knowledge into sectors

National Climate Outlook Forum

Each country will undertake a systematic five-year process of mainstreaming climate considerations into government, private and community sectors through a value chain approach of linking climate knowledge to action.[337] In the second half of the year each NMHS will run a National Climate Outlook Forum (NCOF), before the onset of the cyclone season (October/November for Cook Islands, Niue and Tuvalu; April for RMI and Palau) and after the Pacific Islands Climate Outlook Forum (PICOF), a regional meeting attended by all Pacific national meteorological services. The PICOF outlines the regional climate outlook, including expectations for the cyclone season and the ENSO prediction.

The participants in the earlier workshop (for government agency officers) will be better prepared to understand the Outlook and how it supports specific advice and information for their sectors. The NCOF will be fine-tuned in response to the contributions of workshop participants, as they explain how they use the NMHS's advice.

In years two, three and four, each NMHS will hold similar 2-day workshops successively with the private sector, NGOs and community organisations, combining information about the climate, how it is changing and what the implications are for their country and their sectors. The NMHS will give a presentation on the products and analyses it can generate and help the participants to articulate what information they want, and the formats in which it will be most useful to them. The NCOF will be presented to all stakeholders as usual in year five after the NFCS review workshop.

Climate Information Services Sector Action and Communication Plan

Building on the NCOF process, each country will draft a Climate Information Services Sector Action and Communication Plan for key sectors. The plans will address sector-specific needs for information services relating to both disaster risk reduction and management, and effective climate change adaptation; and will outline a process to test the best ways of regularly communicating climate information to sectors. Based on the plans, a Sector-Specific Climate Training Programme will be developed and delivered to facilitate uptake of climate information services by key sectors and their stakeholders.

Country-specific climate risk knowledge mainstreaming

Each country will undertake specific climate risk knowledge mainstreaming activities based on their needs. These include: i) conducting vulnerability assessments and incremental climate change costing to inform the National Infrastructure Investment Plan (NIIP) in Cook Islands; ii) delivering an annual briefing to Niue's Parliamentary Ministers on the climate outlook and use of its data to inform climate-resilience planning; and iii) conducting crop climate change risk assessments to inform agricultural crop planning in Tuvalu.

The National Climate Data Consultants (detailed under Results 2 and 4) will play a key role in keeping climate risk information on the agendas of sector agencies. Their responsibilities include regular liaison with ministerial and departmental staff, making relevant data discoverable by agencies and their development partners for planning processes, and facilitating the addition of new data to the national data portal to improve the quality of monitoring and evaluation processes. This will also contribute to generating and accessing essential data and information for the Nationally Determined Contributions (NDCs) under the UNFCCC in each country.

[337] WMO, 2018. Step-by-step Guidelines for Establishing a National Framework for Climate Services

1.1.4 Develop national policies for financing climate services

This Sub-activity will provide the foundation for the establishment of a financially sustainable business model for climate services in the five Programme countries. Based on the NFCSs established under Sub-activity 1.1.1, the Programme will develop national policies focused on the sustainable financial management of climate services, which will facilitate that the five NMHSs have the means to sustain and ensure the ongoing operation of their mandated services in order to mitigate weather-, climate-, and water-related risks.[338]

Cook Islands, Niue, Palau and RMI do not have an established national climate finance policy or dedicated Fund. However, RMI organised a workshop in May 2019 to explore the setup of a national climate finance mechanism, in collaboration with the NDC Partnership.[339] The workshop resulted in agreement on a "Climate Finance Action Plan"[340] to strengthen climate financing in RMI. The Programme will coordinate with the Climate Finance subgroup in RMI to ensure that development of the national policy is aligned with, and facilitates, climate services-oriented actions outlined in the Plan. In Tuvalu, a Climate Change and Disaster Survival Fund – the "Tuvalu Survival Fund" (TSF) – was established in 2015. The TSF is intended to support both immediate disaster response efforts and longer-term responses to future climate change impacts and natural disasters.[341] The Programme will work with the TSF Board and Committee to enhance the functions of the existing Fund to ensure that Tuvalu's national climate services are adequately and sustainably financed.

Given the specific circumstances of the five Programme countries—their extremely small economies, remote locations, large marine areas and numerous scattered islands, the financial policies will be carefully developed with the support of the World Meteorological Organization (WMO) to ensure their tailoring to the realities of Pacific SIDS. In line with World Bank guidance,[342] the financial policies will cover the following elements:

- Opportunities for greater cooperation between the public and private sectors and academia given that many economic sectors increasingly depend on meteorological information for safe and efficient operations.
- Opportunities for win-win situations that fulfil the public sector responsibility to help the economically disadvantaged while meeting the needs of enterprises for climate services. To this end, the Programme will ensure partner governments are made aware of the economic value of climate information in, for instance, reducing the need for dangerous marine rescues, reducing the need for transport of drinking water to outer islands in drought, and reducing the costs of recovery from cyclone damage.
- Opportunities to coordinate and/or integrate financing for climate services and disaster risk management to strengthen existing disaster relief funds and establish reliable funding for disaster preparedness activities, which are often limited to ad-hoc donor funding. This would facilitate a more efficient and streamlined approach to implementing often overlapping actions for climate change adaptation and disaster risk management.

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[338] World Bank, 2013. Weather and Climate Resilience. Effective Preparedness through National Meteorological and Hydrological Services

[339] NDC Partnership, 2019. Press Release: Marshall Islands Takes Next Steps on National Climate Finance Mechanism. Available at: https://ndcpartnership.org/news/marshall-islands-takes-next-steps-national-climate-finance-mechanism

[340] Republic of the Marshall Islands, 2019. RMI Climate Finance Action Plan. Available at: https://www.dropbox.com/s/1e6ker0nnfe42cf/RMI%20Climate%20Finance%20Action%20Plan%20-%20Final%20Draft%20-%20May%202019.docx?dl=0

[341] Tuvalu, 2015. Climate Change and Disaster Survival Fund Act 2015

[342] Ibid.

- Identification of elements for a sustainable financial model for NMHSs based on the climate services value chain, which highlights the different roles of NMHSs in providing basic forecasts and warnings to protect society from the adverse effects of severe weather (a public good typically supported by governments) but also in providing specialised value-added services to government agencies and individual businesses (which may offer opportunities for cost-recovery from governmental and non-governmental sources).

- Potential to establish National Climate Funds (NCFs) as mechanisms that support countries to manage their engagement with climate finance by facilitating the collection, blending, coordination of, and accounting for climate finance directed towards climate services.[343] According to UNDP guidance,[344] these funds could have the following goals:

    - Collect sources of funds and direct them toward climate change activities that promote national priorities;
    - Blend finance from public, private, multilateral and bilateral sources to maximise a country's ability to advance national climate priorities;
    - Coordinate country-wide climate change activities to ensure that climate change priorities are effectively implemented; and
    - Strengthen capacities for national ownership and management of climate finance, including for "direct access" to funds.

  Functions of NCFs could include:

    - Support goal setting and the development of programmatic strategies for climate resilience;
    - Fund capitalisation;
    - Management of partnerships;
    - Provide project approval and support implementation;
    - Supply policy assurance;
    - Provide financial control;
    - Manage performance measurement, including monitoring and reporting on activities and resource disbursement; and
    - Provide and support knowledge and information management.

- Potential for continued support from the Systematic Observations Financing Facility (SOFF) as part of the Alliance for Hydromet Development, which was launched in December 2019 by 12 international organizations including UNEP. The SOFF is envisaged to ensure provision of basic systematic observations as a global public good by providing equitable, predictable, sustainable, and performance-based finance as well as technical assistance to developing countries for the provision of foundational observational data as per the Global Basic Observing Network (GBON) standard adopted by the WMO Congress. GBON aims to improve the global availability of the most essential surface-based data by defining the obligation for

[343] UNDP, 2015. Blending Climate Finance Through National Climate Funds.
[344] Ibid.

countries to implement a minimal set of surface-based observations for which international exchange of observational data will be mandatory.

By the last two years of the Programme, the five countries are expected to be ready to negotiate cost recovery for new information products, adding to the value of Programme investments. WMO and NZMet have experience in evaluating the market for cost recovery and will be invited to assist with the development of the financial policies for climate services in the Cook Islands, Niue and Tuvalu. Palau and RMI Weather Service Offices are part of NOAA; and plans for cost recovery may reflect that relationship.

Over the term of the Programme information products will be developed and demonstrated that have commercial value in countries with climate-sensitive industries. For instance, good climate data has potential value for the Cook Islands' pearl farming industry: forecasts of ocean temperatures can influence decisions about seeding and harvesting. Long range (3 – 9 month) rainfall forecasts enable tourism operators to ensure they have adequate potable water supplies, and climate forecasts can enable them to advertise expected particularly good surfing seasons.

However, making this transition will take several years as foreseen in the implementation timeframes of Sub-activities 1.1.1, 1.1.2 and 1.1.3. NMHSs must be able to demonstrate convincingly the utility of new products before they can begin to establish a commercial value for them. As the five NMHSs develop capacity in generating climate information, they may be able to monetise specialised products for the tourism, shipping, insurance and other industries. While climate data is shared freely by all WMO members, including the five SIDS, guidelines permit the sale of products tailored to the specific needs of users as foreseen in Sub-activity 1.1.2.

In these five very small SIDS, most agriculture is subsistence farming, which is critical to their populations' wellbeing, particularly for people in outer islands. Subsistence fishing is also a vital resource. In both instances, climate information and forecasting is an essential public good and not amenable to monetising, even though the development of tailored information products is proposed.

Pelagic fishing is undertaken by distant fishing nations with access to more sophisticated fish location technology than will ever be available to Pacific SIDS: the value of climate information is in informing license negotiations between SIDS and industrial-scale fishers. This information should also be provided as a public good to SIDS and the Pacific Forum Fisheries Agency, which supports them in these negotiations.

The Programme will contribute to preparation for cost recovery and sustainable financing for the five Programme countries. The Programme-hired National Climate Experts will be supported by the Programme in articulating the cost/benefit of new products to national decision makers: for instance, the saved costs of reduced search and rescue operations from new ocean climate services; the saved costs of reduced cyclone loss and damage from impact-based early warnings and advice; the reduced costs of bulk water deliveries when drought early warnings are acted upon; and the increased accuracy of climate and weather services derived from an expanded array of properly maintained equipment.

The National Programme Implementation Managers will ensure that Programme inputs—staff costs and operations and maintenance costs—are recorded correctly and transparently as detailed, disaggregated line items at an appropriate point in the financial year to ensure they are included in the country's national budget preparations. This process will ensure that the Programme-hired consultants and equipment costs are established as line items in successive budget documents, and make the actual costs clear.

Participation in the development of the national budget will enable the Managers to justify the value of local consultants and of new equipment in cost/benefit terms. Itemized staffing, operation and management expenses, recorded in at least three or four successive annual budget documents, will establish an understanding of the real costs. Treasury officials will be aware that, after five years, these line items will transition from Programme funding to base appropriation for the agency recruiting local consultants and that a long term source of funds must be identified for O&M costs, since these are likely to be too high to be carried by the five very small SIDS. The Programme will contribute to the identification of a long-term source of funds. The value of the additional good quality data from new equipment will be high, to the region and the international community, and this is expected to facilitate the recruitment of O&M funds. For Palau and RMI, the cost will be borne by NOAA.

At the same time, as cost recovery becomes possible during the term of the Programme, it is essential that any income sourced from climate information products is also clearly shown in national budget papers. The income will be receipted into the country's consolidated revenue stream, but it should be clear that it notionally offsets NMHS costs.

RESULT 2 – STRENGTHENED OBSERVATIONS, MONITORING, MODELLING AND PREDICTION OF CLIMATE AND ITS IMPACTS ON OCEAN AREAS AND ISLANDS

In response to priorities identified in regional and national strategies and plans, confirmed by in-country consultations with a wide range of stakeholders, this component will focus on strengthening and modernising the national meteorological services, focusing on their ability to collect data from a wider geographical range and to use the extra data. This will be achieved through the installation of new and upgraded infrastructure and equipment to extend the geographical coverage of climate and weather observations; training and support for observations, monitoring and maintenance; and the establishment of robust Quality Management Systems.

Despite its critical significance in generating severe weather events and driving the global climate system, the equatorial and sub-equatorial region stretching eastward from the Indian Ocean into the Pacific Ocean is one of the most poorly observed regions of the world. The data deficiencies can be attributed to its predominantly oceanic character, the sparse and irregular distribution of its inhabited islands, and the overall lower economic capacity of countries in the region compared to those of North America, Europe, Australia, New Zealand and elsewhere.[345]

The increasing availability of meteorological and oceanographic data derived from satellites has helped to fill gaps in observing systems worldwide but, as for model generated data, remotely sensed data cannot fully supplant the need for data from in-situ (on-ground and sea level locations) observations. For example, the measurement of the key meteorological parameters of atmospheric pressure and vertical wind profile are currently not well measured from satellites.

It has been shown that systematic upper air observations in the Pacific region tend to have the highest measured impact of all ground-based measurement on the quality and accuracy of weather and climate analysis and prediction not only locally, but globally. The resulting products underpin the establishment and operation of all hydrometeorological early warning systems as well as other weather and climate related services.[346] Improving a national observing capability benefits not only the host country but also the entire global forecasting capability. Sustained surface pressure and upper air wind observations are vital to maintain and improve global numerical weather prediction (NWP) and climate models wherever they may be based. All countries need the outputs from numerical

[345] WMO, 2017, Enhancing Early Warning Systems to build greater resilience to hydrometeorological hazards in Pacific Small Island Developing States: Draft Feasibility Study

[346] WMO, 2017, Enhancing Early Warning Systems to build greater resilience to hydrometeorological hazards in Pacific Small Island Developing States: Draft Feasibility Study

weather prediction models and climate models as fundamental inputs to climate risk analyses and early warning systems. Improved ground-based surface and upper air observing systems in the equatorial and sub-equatorial Pacific are critical to achieving these goals locally, regionally and across the entire globe.[347] Many studies have shown that a better observing system in the tropical Pacific would lead to improved skill and lead times for forecasts as far afield as Europe and Africa.[348]

The five Programme countries recognise that remote sensing data expands and complements conventional observations and enables observations at local and regional scales. They all have access to Himawari-8, the latest generation geostationary satellite run by the Japan Meteorological Agency (JMA). The five countries use satellite data at varying levels, but they also understand that investment in maintaining and expanding their national in-situ measurements is essential, noting that remote sensing depends on in-situ monitoring for essential calibration and validation.[349]

While several observing sites for both ground and upper air data have been established throughout the region over the years, many are no longer functioning. The reasons include obsolescence, unavailability of trained observing staff, lack of technical and financial capacity for equipment maintenance and replacement, and the ongoing need to fund the supply of consumables;[350] limited internet access and unreliable electrical power systems hamper communications. All these factors compromise documentation of the extent, rate and intensity of local climate fluctuations and overall change.[351]

This Programme will enable all five countries to expand their observation networks with robust and well supported equipment. Strengthened observations, monitoring, modelling and impact-based forecasting will underpin national multi-hazard early warning systems and make innovations such as Forecast-based Financing possible. Programme Result 2 will also include activities that strengthen and institutionalise the linkages between NMHSs and other key actors and end-users. It will improve the quality of the information used by the countries and their development partners in planning adaptation activities.

Furthermore, in its June 2020 Briefing Note, the Global Ocean Observing System (GOOS) highlighted that "Despite its significant impacts on the ocean observing system, the Covid-19 crisis can also be an opportunity for us to look at how to build greater resilience into the system."[352] The Programme will contribute to resilience building in the ocean observation system through installing autonomous observing instruments, ensuring robust equipment maintenance schedules, and supporting increased coordination between the Pacific island countries.

Programme Result 2 will support implementation of the Global Framework for Climate Services (GFCS) helping to address deficiencies in the Observation and Monitoring Pillar of the GFCS in Cook Islands, Niue, Palau, RMI and Tuvalu. This is fully in line with the *Pacific Roadmap for Strengthened Climate Services 2017–2026,* which proposes several regional and national actions within the GFCS pillars as shown in the below figure.

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[347] WMO, 2017, Enhancing Early Warning Systems to build greater resilience to hydrometeorological hazards in Pacific Small Island Developing States: Draft Feasibility Study.
[348] ECMWF, Advancing global NWP through international collaboration, available from < https://www.ecmwf.int/> [August 2019]
[349] ibid
[350] Consumables are disposable or non-recoverable items used routinely in observing programmes, and typically include such items as balloons and radiosondes.
[351] WMO, 2017, Enhancing Early Warning Systems to build greater resilience to hydrometeorological hazards in Pacific Small Island Developing States: Draft Feasibility Study.
[352] Global Ocean Observing System, 2020. Briefing Note: Covid-19's impact on the ocean observing system and our ability to forecast weather and predict climate change

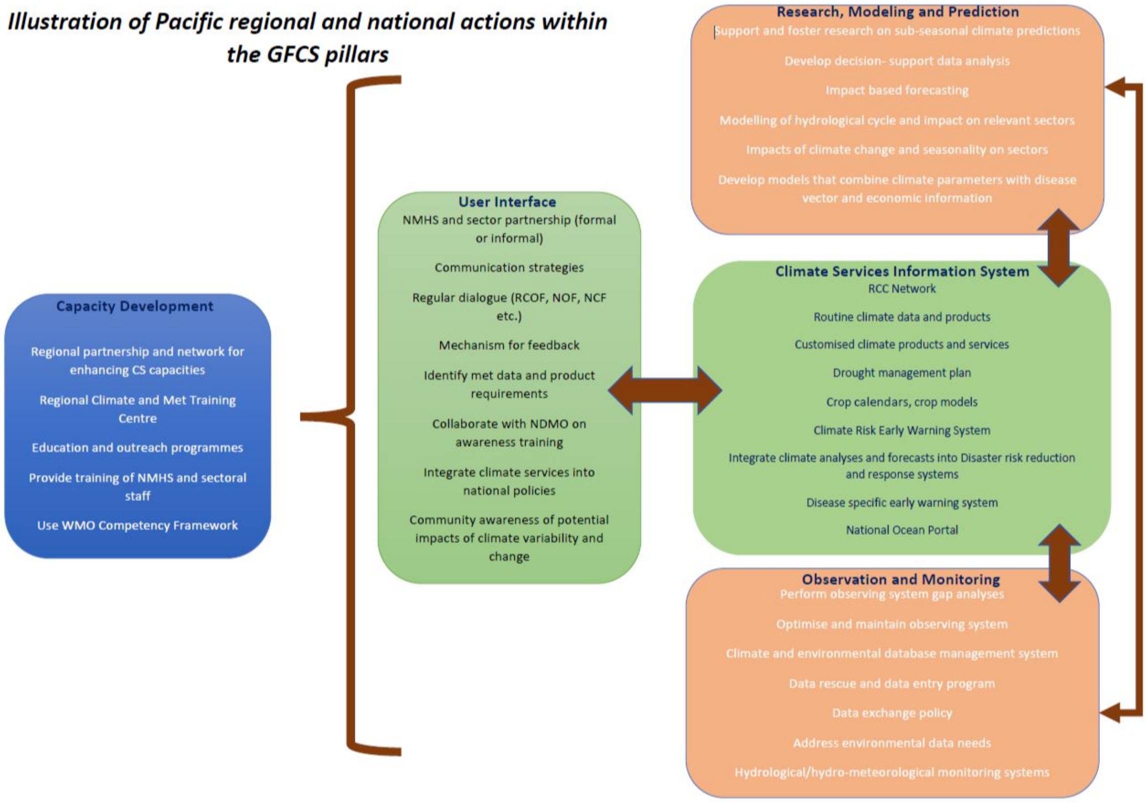

Figure 73. Pacific regional and national actions with the GFCS pillars

This Result addresses most of the actions outlined above and will also support implementation of the GFCS's recommended infrastructural capacity building.[353] Emphasis has been put on ensuring that equipment to be installed under this Programme can be operated and maintained by the NMHSs in the long-term. This will be supported be targeted technical training under Sub-activity 4.1.2. Particularly in remote locations such as the five Pacific SIDS, Numerical Weather Prediction (NWP) outputs provides the first line of warnings, with satellite data becoming increasingly useful at shorter ranges. The Programme therefore prioritises feeding the global NWP systems with enhanced local observations and developing in-country capacity to use the output. Developing capabilities to exploit satellite data is the second priority.

Hence the main focus of this Component is on ***transforming the five NMHSs from WMO's Basic–Category 1 level to WMO's Essential-Category 2 level.*** Generally, Category 1 NMHSs can provide basic weather and climate services to their countries through delivering a basic range of climate data and products, participating in regional climate forums and engaging in limited interactions with end-users. At Category 2 level, the NMHSs will be able to:

- Deliver a basic range of climate services and products;
- Provide climate predictions;
- Participate in climate forums;
- Interact with end-users from different sectors;
- Gather feedback on the information that end-users provide;

[353] Kolli, R. WMO, 2016. Presentation called "National Perspectives of the Implementation of the Global Framework for Climate Services"

- Have well-established protocols for emergencies, backup of data and some off-site facilities;
- Have climate observers and meteorologists trained to WMO standards;
- Have 24/7 operation (where possible);
- Have a well-established Quality Management System (QMS); and
- Have access to most Numerical Weather Prediction (NWP) data/products from other centres.

Thus, whilst Category 1 NMHSs engage in basic climatology (related to the pillars focused on the technical aspects of climate science), the Level 2 and higher incorporate capacity that spans all five GFCS pillars.[354]

Activity 2.1 Infrastructure and technical support for observations and monitoring

Under this Activity, the Programme will strengthen infrastructure and in-country technical capacity to enhance observations and monitoring networks in all five countries. This will be achieved through the installation of new and upgraded infrastructure and equipment to extend the geographical coverage of climate and weather observations; training and support for observations, monitoring and maintenance; and establishment of robust Quality Management Systems (QMSs).

2.1.1 Enhance national observations and monitoring networks to GBON standards and establish QMSs

All five countries propose to extend the geographical coverage of their climate and weather observations through enhancement of infrastructure and local technical capacity in alignment with the draft provisions of the WMO Global Basic Observing Network (GBON).

Based on the GBON concept adopted by the World Meteorological Congress, the detailed GBON regulatory material is currently under development, and it will be submitted to the Extraordinary World Meteorological Congress in June 2021 for approval. While the final GBON regulatory material is thus yet to be approved, for the purpose of this Programme, the draft regulatory material which served as the basis for the Congress approval of the GBON concept is used. This approach for the design of the observations-related activities, as discussed with the five countries and the AE, and agreed upon with WMO,[355] will help ensure that the activities proposed represent suitable, feasible and optimal solutions for the national basic observing networks and their contributions to the global public good provided by the NWP systems, regardless of any potential further refinements of the GBON requirements.

The proposed locations for new observing equipment in Cook Islands, Niue, Palau, RMI and Tuvalu are provided in the country sections of this Feasibility Study; and details of the operation and maintenance (O&M) arrangements are provided in Annex 21. Each country has either allocated publicly owned land for the weather stations or gained formal permission in writing from traditional landowners to use the sites.

[354] Mahon, R. Climate Services, 2019. Fit for purpose? Transforming National Meteorological and Hydrological Services into National Climate Service Centers

[355] As formally confirmed by the WMO Director, Infrastructure Department in his message to the AE dated 7 July 2020: "Through this initiative, WMO, in collaboration with the AE and the countries involved has undertaken the review of individual countries' observational gaps based on draft GBON regulatory provisions and current capacity and reporting practice. The resulting proposed activities correspond to an optimal, suitable, and feasible national basic observing network design that responds to country priorities and needs while ensuring consistency with the proposed concept and draft regulatory material for the GBON…".

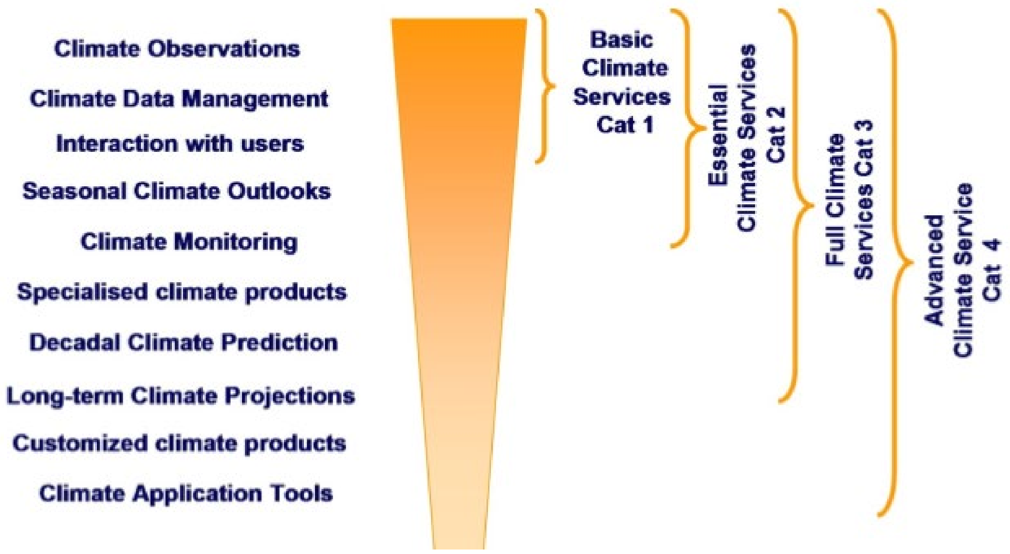

Figure 74. Types of climate products and services by NMHS category (Source: WMO)

The following interventions will contribute to the achievement of WMO Category 2 (Essential) status for climates in the five countries:

Strengthen the network of land-based observation stations and improve observation station density in compliance with Global Basic Observing Network (GBON) requirements

The Programme will procure equipment to expand and upgrade the network of land-based observation stations measuring atmospheric pressure, temperature, humidity, horizontal wind and precipitation in compliance with GBON requirements and obligations. The Programme will install new/upgraded climate monitoring stations (AWS and AWOS) in all five countries that will feed data into GBON for use in global Numerical Weather Prediction (NWP). In addition, Cook Islands will procure upper air land-based consumables and a DigiCORA receiver to ensure that CIMS can collect, contribute and use data from its existing network. Further country-specific details are provided in the individual country sections, and in Annex 21 (Operations and Maintenance Plan).

Especially in remote locations such as the five Pacific SIDS, NWP output provides the first line of warnings and satellite data become increasingly useful at shorter ranges. The Programme therefore prioritizes feeding the global NWP systems with enhanced local observations and developing the capability to use the output, and to develop the capability to exploit satellite data as the second priority. Emphasis has been put on ensuring that equipment to be installed under this Programme can be operated and maintained by the NMHSs in the long-term.

Install dual-polarization X-band Doppler radar systems

Weather radar is a critical component of meteorological observation networks and associated weather forecast and warning systems around the world. Radar technology provides real-time, high spatio-temporal resolution visualised weather data, which can be vital to informing reliable and accurate early warning systems. The potential functionality of weather radar systems in the Pacific region could include:

- Provision of improved and more accurate weather monitoring and forecasts;
- Tracking of local extreme events (e.g. afternoon convection and hailstorms);

- Better determination of rainfall rate and intensity, which is important for determining the potential for extreme rainfall and flash flooding and enabling hazard warnings to be issued more accurately and in a more timely fashion;
- Validation of NWP model forecasts.[356, 357]

The requirements for successful operation and maintenance of weather radar systems by NMHSs have been summarised by the Fiji Meteorological Service – one of the leading NMHSs in the region – as follows:

- Mechanical – Monthly maintenance capacity of the gears and motors;
- ICT – Robust communication platform with adequate server, software output and storage;
- Electrical – Monthly power bill with robust power surge and uninterruptible power supply (UPS) to hold till generators come online;
- Instrumentation – Monthly calibration test of the radar to ensure data integrity and repairs when necessary;
- Infrastructure – Building with good water proofing and regular clearing of the radome; and
- Financial – Budget required for O&M.

The Programme will install a dual-polarization X-band Doppler radar in each of the five countries. Dual-polarization radars obtain information on both the horizontal and vertical dimensions of precipitation particles, which gives meteorologists a better understanding of the size and shape of particles. The advantages of dual polarization include:

- Improved accuracy of precipitation estimates, leading to better flash flood determination;
- Ability to differentiate between differentiate between different types of precipitation;
- Improved detection of non-meteorological echoes (e.g. tornado debris, birds, etc.);
- Detection of aircraft icing conditions.[358]

A Doppler radar is capable of measuring the velocity of precipitation particles (and thus, the wind). This enables Doppler radars to identify the detailed wind structure within severe thunderstorms.

The choice of an X-band system is on account of its low cost – in comparison to S or C band systems – and its small size, with potential for portable options. This is particularly important for the Pacific SIDS, which may have complex topography that limits accessibility for larger systems.

In addition to infrastructure, the Programme will provide technical training (Sub-activity 4.1.2) to build in-country capacity for radar operations, maintenance and data applications for weather and climate monitoring and analyses.

Compliance with the WMO Integrated Global Observing System (WIGOS)

[356] Vanuatu Meteorological and Geo-Hazards Department and SPREP, 2017. Radar, Automatic Weather Stations and Other Equipment: Technical Specifications, Operations and Maintenance
[357] Gabella, M. et al. 2012. A Network of Portable, Low-Cost, X-Band Radars. DOI: 10.5772/38997
[358] National Weather Service. Dual Polarization Radar. Available at: https://www.weather.gov/bmx/radar_dualpol

The five countries will improve the continuity of operation and availability of observations in accordance with WMO Technical Regulations (WMO-No. 49)[359] and in the Manual on the WMO Integrated Global Observing System (WMO-No. 1160).[360] This will facilitate the provision of timely, quality-assured, quality-controlled and well-documented compatible long-term observations in compliance with WIGOS. In particular, Cook Islands, RMI and Tuvalu will strengthen their maintenance schedules, procure spare parts and calibration equipment, and undertake iterative training in calibration and maintenance with development partners. Niue will source in-country IT expertise to ensure that all equipment is maintained and operational.

Niue and Tuvalu have prioritised staff training to support their proposed extended observation networks. Providers such as the Fiji Meteorological Service, the Fiji National University and others will deliver Basic Information Package Meteorological Training (BIP-MT) to new meteorological service technicians to enable them to take observations correctly, record them correctly and save the data securely. New observers will also be trained to calibrate and maintain the NMHSs' in situ observational equipment. This is fundamental to cost effective and consistent data collection and is a WMO requirement. Ensuring data continuity and quality is critical for climate change related studies and monitoring. Existing staff will be able to take the course as a refresher in maintenance and calibration. The course consists of foundation topics in maths and physics, physical and dynamical meteorology, basic synoptic and mesoscale meteorology, basic climatology, meteorological instruments and methods of observation.

Climate data management

The five countries will enhance data and data management to ensure that historical as well as real-time atmospheric, oceanic and terrestrial observations of the Essential Climate Variables (ECVs) prepared by the Global Climate Observing System (GCOS) and partners for climate purposes are exchanged freely for use in Regional Climate Centres (RCCs) for at least one Global Surface Network site per country. Fifty-four ECVs have been identified for GCOS; and are required to support the work of the United Nations Framework Convention on Climate Change (UNFCCC) and the Inter-governmental Panel on Climate Change (IPCC).[361] Furthermore, the Programme will support the five NMHSs to adopt a well-documented strategy including vision and operating manual to ensure security, integrity, retention policy and technology migration for data archival processes and systems. Enhanced data management interventions will be implemented under Activity 2.3.

Generic monitoring products

The Programme will build on the CREWS Pacific SIDS Project[362] to enhance Climate Risk Early Warning Systems (CREWS) and Early Action Rainfall Watch (EAR Watch) in Niue, Palau and Tuvalu.

Compute sector-specific Climate Indices

To be delivered under Sub-activity 2.2.2.

Value-added products

To be delivered under Sub-Activity 2.2.2.

Quality Management Systems (QMS)

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[359] WMO, 2019. WMO-No. 49. Technical Regulations. Basic Documents No. 2. Volume 1 – General Meteorological Standards and Recommended Practices

[360] WMO, 2019. WMO-No. 1160. Manual on the WMO Integrated Global Observing System. Annex VIII to the WMO Technical Regulations

[361] WMO, 2019. WMO-No. 1160. Manual on the WMO Integrated Global Observing System. Annex VIII to the WMO Technical Regulations

[362] CREWS, 2020. Pacific: Strengthening Hydro-Meteorological and Early Warning Services. Available at: https://www.crews-initiative.org/en/projects/pacific-strengthening-hydro-meteorological-and-early-warning-services

WMO has stated that the "benefits of implementing a QMS and achieving certification of compliance with ISO 9001 are significant. It can be demonstrated that the benefits to WMO Member NMHSs and other relevant agencies will far outweigh the initial effort and resources required to develop and implement a QMS. There is sufficient evidence that a QMS can help to enhance the quality of NMHS activities including streamlining and optimizing the processes and procedures applied and the products and services provided."[363]

The Programme will support the five NMHSs to establish a Quality Management System (QMS) to help enhance the quality of NMHS activities, including streamlining and optimising the processes and procedures applied and the products and services provided. Each NMHS will aim to obtain certification of compliance with ISO9001:2015. The Programme will facilitate that NMHS staff engage with experts from the WMO network and participate in training and an annual QMS Workshop. Cook Islands has a close relationship with New Zealand's NMS and RMI and Palau with NOAA, and these partners will be fully engaged in the QMS process.

Enhance forecasting systems

To be delivered under Sub-activity 2.2.2.

In respect of each of the five Programme countries, UNEP will ensure compatibility of observation equipment with WMO standards for meeting the GBON requirements. To this end, UNEP will work with relevant Regional Technical Partners to provide technical support for the assembly, calibration, installation, operation and/or maintenance of observations equipment – upon country request. UNEP will also undertake procurement of equipment directly upon request from countries. National Executing Entities (EEs) will ensure that observation equipment is suited to the national context through coordination with the NMHSs and technical partners. National EEs will also be responsible for country-specific interventions requiring localised solutions such as the hiring of local consultants, convening national workshops and procurement of certain items required nationally.

Activity 2.2 Ocean and climate modelling and impact-based forecasting

Under this Activity, the Programme will establish end-to-end ocean services and strengthened climate information and early warning systems in all five countries. The Programme will develop a new ocean modelling framework, along with web-based portals for climate and oceans data. Furthermore, the Programme will enhance NMHS capacity to use the data to develop tailored, location-specific climate services and products relevant to climate-sensitive sectors from government agencies to community level, including through the establishment of in-house impact-based forecasting capacity.

The diagram below represents the proposed development of ocean services in the five Pacific SIDS, aligned with the GFCS pillars.

[363] WMO, 2017. WMO-No. 1100. Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers

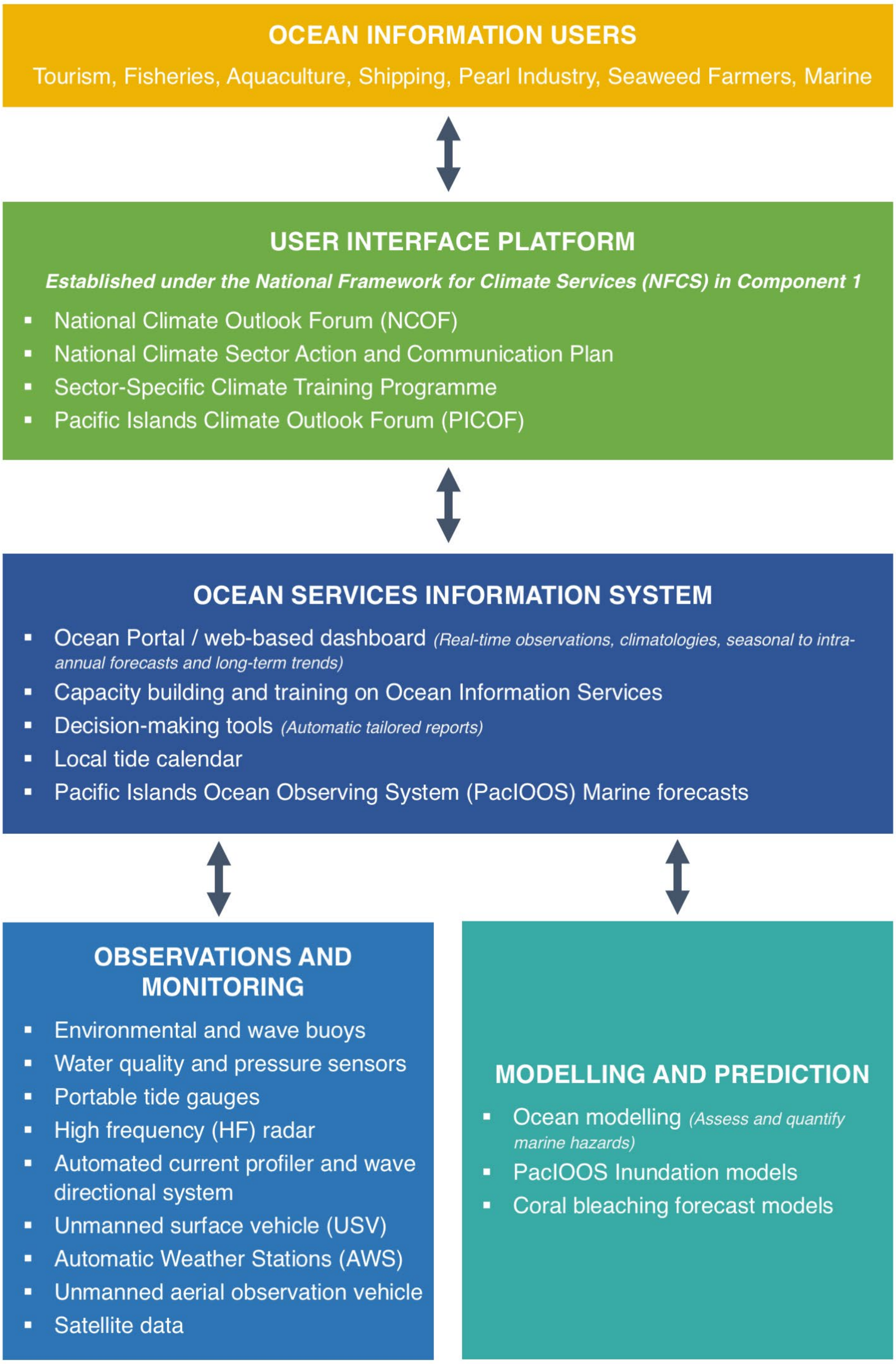

Figure 75. Alignment of the proposed Ocean Services Information System with the GFCS pillars

2.2.1 Establish ocean information services

This Sub-activity will develop end-to-end ocean services in all five Programme countries through the establishment of ocean observations and monitoring, strengthened ocean modelling and prediction, and tailored decision-making tools and ocean data portals to enable optimised use of climate and ocean information. This will enable the NMHSs to engage with the marine sector within their respective countries and provide information vital for safe and effective industry operation. The Programme will facilitate that NMHSs have access to relevant ocean data that is frequently updated, low bandwidth, tailored for priority applications within their EEZs, and accompanied by targeted training and capacity building. It is essential that guidance is provided to NMHSs and relevant stakeholders on how to access and interpret ocean and climate data, which can then inform relevant decision-making.[364]

The following interventions will contribute to the achievement of WMO standards for marine and oceanographic services in the five Programme countries:

Establish ocean observations and monitoring

The Programme will establish ocean observations and monitoring through the installation and maintenance of surface wave and environmental buoys for in-situ measurements of a wide range of physical and environmental oceanic variables (e.g. real-time temperature, salinity, dissolved oxygen, waves, pH, etc.); multi-parameter water quality and/or pressure sensors for systematic ocean monitoring; establishment of high frequency (HF) radar[365] to provide real-time 2D current and wave data (Niue); precision sensor water temperature loggers to expand in-situ ocean temperature observations (RMI); deployment of a near-breaking-zone current profiler and wave directional system (Palau) and unmanned deep ocean observing vehicle (Cook Islands); installation of automatic weather stations (AWSs) on four inter-island shipping vessels to measure atmospheric pressure, wind speed and direction, air temperature, sea surface temperature and wave height (Cook Islands); and routine deployment of an unmanned aerial vehicle to quantify 3D shoreline change and erosion (Cook Islands and Tuvalu). The Programme will also enhance capacity for remote sensing derived coastal observations such as water quality mapping (e.g. turbidity, chlorophyll, coloured dissolved oxygen matter – CDOM, etc.), marine habitat mapping and shoreline change analysis. In addition, NMHS staff will be supported to integrate site monitoring data to calibrate satellite-derived ocean observations to improve understanding of local impacts and establish proxy relationships between ocean drivers and coastal impacts.

Strengthen ocean modelling and prediction

With the support of regional technical partners, the Programme will build in-country capacities for statistical and dynamic downscaling of localised ocean information and multivariate forecast modelling based on individual country needs and priorities. In Cook Islands, Niue and Tuvalu, the Programme will develop an ocean modelling framework utilising a three-step methodology: i) analysis of long-term large-scale ocean and atmospheric data to map spatial and temporal variabilities and identify annual, monthly and daily predictors that drive localised ocean conditions and impacts; ii) development of downscaled wave, circulation and inundation models at country, island and lagoon scales; and iii) establishment of a long-term integrated ocean and coastal impact monitoring program combining remote sensing and in-situ ocean and coastal impact data. The framework will enable NMHS staff to assess and predict short and long-term lagoon health-related hazards and risks; and will

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[364] Powers M, Begg Z, Smith G and Miles E (2019) Lessons from the Pacific Ocean Portal: Building Pacific Island Capacity to Interpret, Apply, and Communicate Ocean Information. *Front. Mar. Sci.* 6:476. doi: 10.3389/fmars.2019.00476

[365] HF radar will be installed in-land to increase sustainability of the ocean monitoring station (i.e. reduced risk inherent to cyclone hazard, vandalism, etc.)

be tailored to specific sites to identify large and small spatio-temporal scale drivers that can play a significant role in modulating lagoon health. The Programme will establish and develop in-house capacity and capabilities for ocean modelling and prediction – for example, understanding the contribution of various drivers to forecast marine health from days/weeks to seasonal scale – through technical training and workshops, including the use of satellite (e.g. COPERNICUS) and HF radar. Engagement of the Copernicus Marine Service[366] will support lagoon health monitoring through a combination of remote sensing, in-situ environmental sampling and dynamic modelling. In Palau, the Programme will build capacity for ocean modelling through the Pacific Islands Ocean Observing System (PacIOOS) to include: i) near-term wave, circulation and inundation forecast models; and ii) long-term future climate scenarios to ascertain the most at-risk coastlines and advise vested parties on response efforts. PacIOOS provides coastal and ocean information, tools and services to empower ocean users and stakeholders in the U.S.-affiliated Pacific Islands, including Palau and RMI. The Programme interventions in Palau will build on and complement existing efforts in the region, including development of wave run-up forecast tools that are already being used by RMI to predict high sea levels and wave inundation. In RMI, the Programme will focus on ocean modelling and prediction to improve the accuracy of coral bleaching forecasts and inform fisheries planning and decision-making. Forecasters will be supported to integrate multi-parameter (temperature, conductivity, dissolved oxygen, pH and turbidity) in-situ data with satellite-derived information and high-definition photogrammetry to refine models and enhance predicting skills. The Programme will organise a national stakeholder workshop and a regional workshop involving all five participating countries to facilitate knowledge transfer on improved coral bleaching model forecasting and outlooks.

Establish ocean information services

The Programme will establish ocean information services through the development of tailored decision-making tools and integration of quality-controlled data into local databases and regional interfaces (e.g. the Pacific Ocean Portal – the region's centralised platform for ocean data visualisation) to facilitate optimised use of location-specific ocean and climate information. This will include the integration of satellite-derived data (e.g. from the EU COPERNICUS Programme and NOAA) to complement and enhance information from in-situ observations. In Cook Islands, Niue and Tuvalu, the Programme will facilitate the conversion of ocean observation and monitoring data into actionable information via decision-making tools tailored to fulfil ocean stakeholder needs. This will include a graphical user interface with capacity to generate automated reports; impact-based ocean outlook and multi-variate forecasting tool; state-of-the-art satellite and HF radar data-derived products tailored to provide optimised benefit to stakeholders; and high-resolution circulation models and particle tracking to support decision-making on search and rescue, pollution management, navigational safety and marine protection areas (MPAs). In particular, the Copernicus Marine Service will support the use of Sentinel-2 satellite-derived lagoon health parameters / proxies to be calibrated using in-situ data (from buoys and data loggers) for specific sites in Cook Islands, Niue and Tuvalu. A user-friendly tool will be developed and deployed in each country to deliver a free Sentinel-2 derived lagoon health monitoring product. In Palau and RMI, the Programme will develop web-based national "dashboards" including (where available) real-time observations, climatologies, seasonal to inter-annual forecasts and long-term trends. The dashboards will draw existing data from and be integrated into a regional dashboard, which will support the development of the WMO's Regional Area 5 (RA-V; Asia Pacific region) Pacific Islands Regional Climate Centre, as well as many ongoing facilities and

[366] Copernicus Marine Service, 2020. Available at: https://marine.copernicus.eu/

programmes for ocean information services and early warning systems. The dashboards will integrate data from the global tide gauge network (sea level), drifting floats and observing system arrays (SST) and meteorological stations (precipitation); as well as satellite measurements from AVISO (sea level), Pathfinder (SST) and PERSIANN (precipitation). A training exercise whereby the dashboards are presented, and users trained on how to make best use of the information, will be held at the annual Pacific Islands Climate Outlook Forum. This will also provide a mechanism for wider exposure of the interventions.

2.2.2 Enhance climate information and impact-based forecasting

The Programme will enhance NMHS capacity for the provision of tailored, location-specific climate services and products relevant to climate-sensitive sectors from government agencies to community level. This will be achieved through the following sub-activities:

Enhance in-house forecasting capacity and systems

The five countries do not currently undertake forecasting in-country but use forecasts provided by other national meteorological organisations such as the Regional Specialised Meteorological Centre – a section of the Fiji Meteorological Service – and the Pacific National Weather Services – a department of the US National Ocean and Atmospheric Administration (NOAA). To enhance in-house forecasting capacity and the utilisation of high quality climate information for developing monthly, seasonal and longer-scale climate predictions, the Programme will conduct training on forecasting; use of data and information in preparing for the tropical cyclone season and for climate extremes (e.g. drought and floods); dynamical seasonal prediction (ACCESS-S); and hybrid multi-model ensemble prediction (PICASO). The use of MME systems will improve the ability of NMHSs to utilise all of the already existing high-quality climate information available to them, which is limited in the common use of single-model forecasts. MME systems have been proven to be a valuable method to overcome model biases that can hinder prediction skill in individual dynamical models, which may have systematic errors and biases.[367] The Programme will also enhance forecasting systems by creating value-added products, such as graphics, maps and reports to explain climate forecasts and climate model information (for example, Niue and Tuvalu will develop user-friendly forecast information products customised to specific user needs); and enhance the use of satellite data (e.g. from Himawari and COPERNICUS) through developing skills in image analysis and assimilation of observations in the NWPs. NMHSs mostly rely on global products to provide their stakeholders with ocean prediction services. Global ocean products are often too coarse to provide reliable information in Pacific island countries. Under this Programme, high-resolution ocean forecast systems will be development (Cook Islands, Niue and Tuvalu), which will significantly improve wave, current and inundation prediction products. The new ocean forecast systems will be based on meta-models, providing a lightweight solution tailored to the resources available at the NMHS. Through this approach, the ocean forecast system will be hosted by the NMHS, thereby increasing country ownership of the Programme's outputs.

Introduce impact-based forecasting

Impact-based forecasting considers the vulnerability of people, livelihoods and assets as well as consideration of the hydrometeorological hazard. It focuses on translating meteorological and hydrological hazards into sector- and location-specific impacts and the development of responses to mitigate those impacts. An accurate and timely hydrometeorological warning does not guarantee

[367] Kim, G. et al. Global and regional skill of the seasonal predictions by WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble

safety of life or prevent major socio-economic losses; WMO has highlighted the need for countries need to transition from focusing only on the accuracy of hazard-based forecasting to also emphasising the potential impacts of a forecast – i.e. an evolution from "what the weather will be" (phenomenon-based warning) to "what the weather will do" (impact-based warning).[368]

The Programme will support NMHS staff in building their capacity to understand the relationships between the spatial and temporal variations in vulnerability and exposure as they relate to various hazards; and strengthen their partnerships with Disaster Management Officers and other partner agencies and user communities. Building on the ocean framework developed under Sub-activity 2.2.1, the Programme will facilitate NMHSs to generate impact-based ocean outlooks and impact-based forecasts. This will be complemented by training on the use of monitoring data to inform the continuous improvement of impact-based forecasts; and on communicating forecasts, warnings and local-scale impact-based advice – to be further supported under Sub-activity 4.1.2. Furthermore, the Programme will develop health and drought early warning systems in Palau and RMI to generate more useable climate information to inform focused and timely interventions that maximise population health and wellbeing.

Establish climate science and analysis capacity

To support the enhancement of in-house forecasting capacity, the Programme will build a strong scientific and analytical foundation for NMHSs through training and mentoring attachments covering climatology and oceanography. Early-career scientists from NMHSs will be selected to undertake in-depth technical capacity building through a customised Young Scientist Support Program (supported by APCC), including highly in-depth training for 2-3 months exploring various climate prediction and analysis techniques such as downscaling predictions, generating sub-seasonal-to-seasonal forecasts, analysing large-scale patterns, and tropical cyclones, etc. This will equip participants, particularly those with less experience, with both the basic knowledge needed to perform their duties as climate officers, as well as more advanced knowledge that can help them develop downscaled or impact-based forecasts.

Facilitate stakeholder uptake of impact-based forecasts and information

This will be achieved through the development of tailored products and services for climate-sensitive sectors. This will include the health and drought early warning systems in Palau and RMI; Climate Risk Early Warning System (CREWS) and Early Action Rainfall Watch (EAR Watch) in Niue, Palau and Tuvalu; and harmonisation of climate and sector data between the NMHS, Ministry of Health and Fisheries Department in the context of developing data and information products that will be useful to those sectors in Tuvalu. Each country will engage a Programme-hired local climate expert who will facilitate provision of the much-expanded climate information services and will focus on climate science and data analysis for new functions. The climate experts will also be responsible for sector and inter-ministry coordination; and the development of new products and services in response to sector demand.

Introduce customised climate information and early warning generation

The Programme will enhance existing climate prediction systems to generate local station-based temperature outlooks, provide monthly forecast data, and be equipped with the ability to generate flexible sector-tailored climate information and variables upon request – and based on sector needs identified in stakeholder workshops (Sub-activity 1.1.2). The Programme will also facilitate the tailored

[368] WMO, 2018. Bulletin no.: Vol 67 (2) – 2018. Impact-based Forecasting and Warning: Weather Ready Nations

and iterative development of products generated by the existing climate data management system (CDMS). NMHS staff in Niue and Tuvalu will be supported to undertake real-time analysis of climate and other environmental data and develop customised products, reports and advisories for early warnings. This will enhance capacity for the communication of up-to-date climate risk information to key stakeholders and facilitate risk-informed early action decision making. In Tuvalu, the Programme will facilitate all historical climate observation records on paper to be digitised and ingested into the CDMS; and climate records held in NIWA's database to be made compatible with existing data management software. The availability of a decades-long reliable dataset from a specific location will make it possible to discover long-term trends and to make projections of future changes.

Activity 2.3 Harmonised climate data and information management

Under this Activity, the Programme will integrate climate data and information into decision-making and planning in climate-sensitive sectors through the development and implementation of climate data and information strategies in Cook Islands, Niue, Palau and RMI.

2.3.1 Establish and implement national climate data and information strategies

Each country will develop a National Data and Information Strategic Action Plan for improved climate-related data management, governance and enhanced inter-sectoral communication. With support from SPREP and building on the GEF-funded "Inform" project, a dedicated National Coordinator will collate national data, research and information relevant to climate change into previously established Environmental Data Portals. This will be implemented in close cooperation with National Statistics Offices and other data custodians. SPREP will support the National Coordinators in analysing and publicising the existence and value of their portals' contents, and in helping countries to use them. Two immediate benefits will be greater availability of essential data for planning climate change interventions and infrastructure investments, and improved tracking and reporting of progress against the UNFCCC and other climate-related multi-lateral environmental agreements and conventions. As usable data from climate-sensitive sectors becomes available (for some sectors and countries directly through this Programme's inputs), the potential will be created for overlay of datasets such as climate and disease incidence in such a way that risks can be predicted.

National Statistics Offices (NSOs) are fully engaged with and leading the implementation of the "Inform" project through i) setting up national data management and governance networks; ii) design and use of cloud-based national environmental databases and reporting tools; iii) facilitating the collection and management of national environmental statistics; and iv) design and validation of national State of Environment reporting templates. Lessons learnt from the "Inform" project will be utilised when working with NSOs and other data custodians as part of the Programme.

National Climate Data Consultant

The Programme will support the recruitment and training of National Climate Data Consultants (NCDCs) who will work in key ministries to publicise each country's Environmental Data Portal, to extend its user base and to help the users of its data to maximise their skills.

In the Cook Islands, the NCDC will work in the National Environment Service Ministry; in Niue in the Ministry of Natural Resources; in Palau in the Office of Climate Change; and in RMI in the Office of Environment Planning and Policy Coordination.

The NCDCs will build capacity among key government staff to collate and validate data as well as share and promote it with their primary audiences. They will serve as national administrators for the data portals assigning access and ensuring users are making full use of the capacity of the system. To open lines of communication and data effectively between the various national providers the NCDC will facilitate regular meetings with the national data community, communicate regularly with national and regional partners, and track the use and application of the national portal and its products. The NCDC will serve as the Programme focal point for the regional environment data manager at SPREP.

The NCDCs will participate in training in on-line cloud hosting skills and knowledge, and in sub-regional exchanges and South–South learning. In Cook Islands, with SPREP's support, the NCDC will be a member of the technical committee that drafts the National Data and Information Strategic Action Plan and will lead the development and implementation of the Plan. For Niue, the Inform project manager in SPREP will focus on helping the NCDC to locate data and to develop workflows enabling the Ministry for Natural Resources to access and use climate impact data. RMI's NCDC will be a member of the technical committee that drafts the National Data and Information Strategic Action Plan and will lead the development and implementation of the Plan.

The NCDCs' work on harmonising the way data is recorded and stored will make it possible to use UNEP's Country Level Impacts of Climate Change (CLICC) principles, using consistent formats for data records so that CIMS's climate data can be presented with national data from other sources, coherently and transparently. This has potential to reduce significantly the burden for each country of reporting its performance against MEAs and to improve the quality of its reports. This in turn has benefits for the Governments' understanding of climate change impacts and their capacity to plan effective adaptation and to advocate in international forums.

National Data and Information Strategic Action Plan

Each country's NMHS proposes to develop a strategy in an area of particular concern—data management or for maximising the effectiveness of communication with sectors. The Plans will stipulate that future climate-related data collection is sex- and age-disaggregated, where possible and/or relevant.

Cook Islands will convene a technical committee to draft a **National Data and Information Strategic Action Plan** (NDISAP). The NDISAP will include climate data and information, which the Cook Islands Government plans to use in concert with data from other sectors in order to mainstream climate considerations into the work of those sectors. The Government also wants to be able to put data from various sector sources with climate data as it reports to the international community on its implementation of multilateral environmental agreements (MEAs). Much better information about terrestrial systems and the impacts of warming can be derived from a database that can bring these sources together and harmonise them sufficiently for the data to be used in planning and reporting. The Data Strategy will use high-level quarterly meetings to monitor progress towards the robust management of climate data, the locating of related data sources and their harmonisation.

In Niue, an international and a local consultant will support a technical committee in drafting a **Data Strategy for the Ministry of Natural Resources** (MNR), which includes the NMHS. The Data Strategy and its action plan will be developed through a national 3-day workshop with stakeholders—senior and junior MNR staff, other agencies and individuals who hold or need to use climate and environment data—and will form part of the Ministry's overall Strategic Plan.

Climate data is usually collected and kept at a significantly higher standard than other national data: good quality data is collected systematically, recorded and stored digitally, backed-up reliably and readily retrieved for use in information products, and usually a country has reliable data dating back many decades. This is rarely the case for health data, environmental data or information on other sectors.

In order to mainstream climate considerations into the work of sectors, the Niue Government needs to be able to use climate data and information in concert with data from those sectors. This is particularly important for the very climate-sensitive sectors of agriculture, fisheries, infrastructure and health already being affected by atmospheric and ocean warming. Like the Cook Islands, the Government of Niue also wants to be able to combine data from various sector sources with climate data as it prepares reports to the international community on its implementation of multilateral climate-related agreements.

In RMI, a local consultant will support a technical committee in drafting a **Data Strategy for the Office of Environment Planning and Policy Coordination** (OEPPC). The Data Strategy and its action plan will be developed through a national 3-day workshop with stakeholders—OEPPC and WSO staff, other agencies and individuals who hold or need to use climate and environment data.

The Cook Islands', Niue's and RMI's Data Strategies will benefit from SPREP's Inform project, which has already set up an Environmental Data Portal for each of the five Programme countries (and 9 other SPREP member countries) and an over-arching regional portal. All five Programme countries have national environment data portals, hosted on-line by SPREP, and networked together at the regional level in the Pacific Environment Portal (https://Pacific-data.sprep.org). Each government has endorsed its national portal and the regional environment portal (also managed by SPREP) as the formal repository for national environment-related datasets and knowledge products. All the portals are protected by having their data stored and retrieved from multiple machines on the cloud: if one of the servers crashes unexpectedly, the data portal won't go down. The Portal allows data to have different access levels, so a country can ensure its formal permission is required for access to specific datasets or information.

This Programme will enable the Inform project to add a dataset specifically focused on Climate and Oceans knowledge and information to each of the five countries' Environmental Data Portals.

This national Environmental Data Portal "provides an easy way to find, access and reuse national data."[369] Its "main purpose is to provide easy access and safe storage for Environmental datasets to be used for monitoring, evaluating and analysing environmental conditions and trends to support environmental planning, forecasting and reporting requirements at all levels."[370]

The Environmental Data Portal enables government agencies to report against the Sustainable Development Goals and the multi-lateral environmental agreements (MEAs) to which the Programme countries are parties. It also allows the Government to archive reliably and relatively cheaply national environment-related reports and policy documents. The addition of a climate and oceans subset will extend this capacity to NMHSs, holding their data securely but encouraging its much broader use in monitoring changes, planning national adaptation initiatives and reporting on MEAs.

RESULT 3 – IMPROVED COMMUNITY PREPAREDNESS, RESPONSE CAPABILITIES AND RESILIENCE TO CLIMATE RISKS

Vast ocean areas and widely dispersed islands mean that isolated communities are under considerable threat from climate-related hazards and increasingly frequent extreme climate events. Making climate information accessible and actionable to populations in very remote locations, so that vulnerable communities can enhance their preparedness and response capabilities, represents a significant challenge. Therefore, Programme Result 3 will focus on enhancing warning dissemination and

[369] SPREP, Environmental Information for Decision Making, available at <www.cookislands-data.sprep.org> [August 2019].
[370] SPREP, Environmental Information for Decision Making, Available at <www.cookislands-data.sprep.org> [August 2019].

communication mechanisms, coordinating and integrating sustainable disaster risk management actions, and building local capacity to improve community preparedness and disaster risk reduction for multiple climate-related hazards.

Australia's Climate and Ocean Support Program in the Pacific (COSPPac) has helped participating countries to introduce key concepts to climate-sensitive sectors, and the Finnish-Pacific project (FINPAC, implemented by SPREP) has managed successful pilot climate awareness activities with communities in the five Programme countries, among others and lessons will be drawn from these and other projects. Post-hoc evaluation by FINPAC shows that although people in remote communities may listen to NMHS forecasts, most rely only on traditional climate knowledge (TK) when they make decisions, or at best on TK in combination with official forecasts.[371] WMO recommends that TK be recognised, valued and used to explain climate science—the long-term benefit of recognising TK will be that broadcasted advice will be accepted and acted upon, so that communities are better prepared to respond to climate extremes, leading to reduced socio-economic disruption and fewer morbidities and deaths. The importance of integrating TK into climate-related decision-making was also highlighted in the IPCC Special Report on Global Warming of 1.5°C, which noted the cultural resilience of Pacific island inhabitants and how their knowledge can underpin the development of adaptation strategies.[372]

Programme Result 3 contributes to the attainment of the overall Goal of the Sendai Framework for Disaster Risk Reduction: "*The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries".* In particular, the Programme will contribute to the Framework's Global Target (g) "*Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030*".

The Programme will also contribute to the outcomes of the 2019 UN Climate Action Summit, in particular targets 3 and 4 of the Risk-informed Early Action Partnership (REAP) on investment in "*early warning system infrastructure and institutions to target early action in 'last/first mile' communities*" and "*more people are covered by new or improved early warning systems…*".

The Result will significantly enhance social resilience to climate change and build national response capability to multiple climate-related hazards—both the existing droughts, floods and cyclones and the long term changes of rising temperatures and sea levels and ocean acidification.

Its Activities are more country-specific than the first two components and there are fewer opportunities for combined multi-country activities. However, during the process of discussing "last mile" issues, some novel approaches being used by NMHSs were shared and will be adopted by other members of the group. The Programme Management Unit (PMU) will facilitate sharing of successes and lessons throughout the implementation of the Programme.

Furthermore, this Result will introduce Forecast-based Financing (FbF) in the five countries as an innovative mechanism whereby early actions at community and government level are pre-planned based on credible forecasts, and are funded and implemented before a climate shock to minimise losses and damages caused by climate-related hazards and reduce the need for humanitarian assistance in their aftermath.

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[371] Lefale, P., 2009, Ua 'afa le Aso Stormy weather today: traditional ecological knowledge of weather and climate, the Samoa Experience. Climate Change. doi:10.1007/s10584-009-9722-z.
[372] IPCC, 2018. Special Report on Global Warming of 1.5°C.

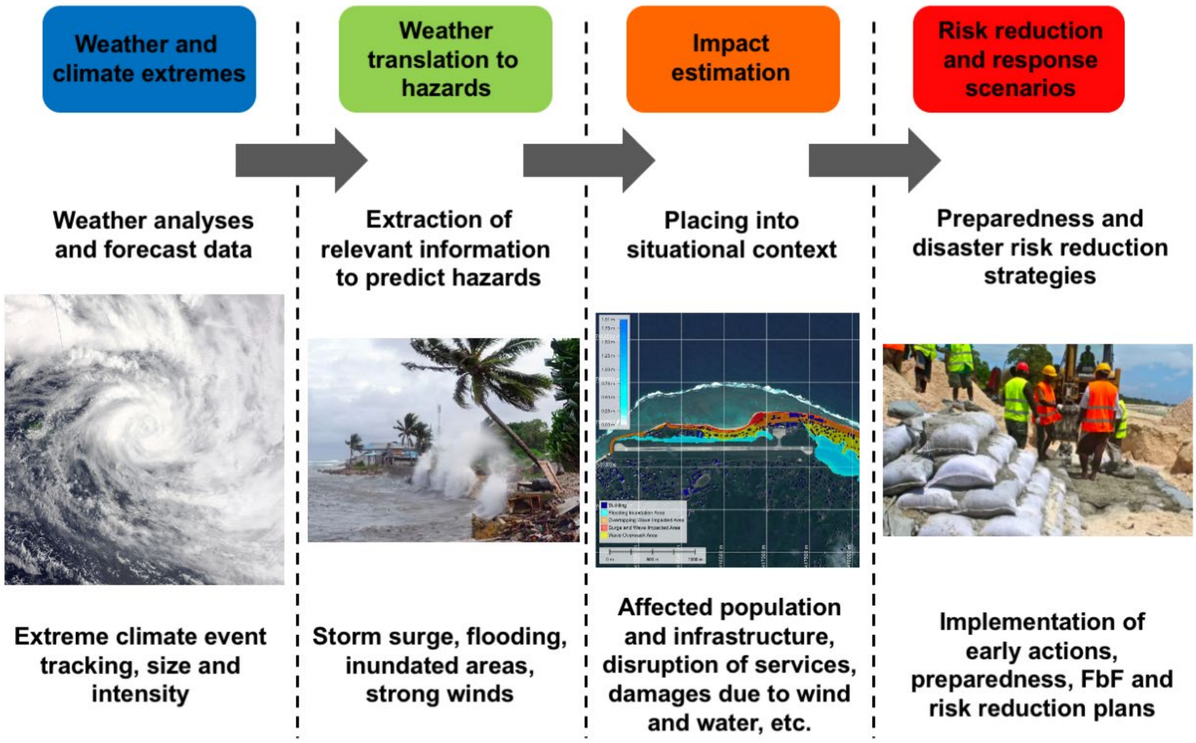

Figure 76. Translating weather forecasts into impact-relevant information for community preparedness and disaster risk reduction

Under this Result, the Programme will not only secure the delivery of climate information and early warnings to end-users but work with them to co-design and co-produce information products, drawing on their specialised knowledge of their environment to create warnings that are actionable and effective. Temporary jobs will be created for island populations, including women, by engaging them in on-the-ground activities related to the community-based MHEWSs. Gender mainstreaming will be a key element of the Programme and special attention will be paid to the inclusion of vulnerable groups and women to ensure that gender issues are considered, as well as the unique climate information needs of the elderly, people living with disabilities and the most geographically and/or socially vulnerable communities. Climate information and early warning centres will be established in selected communities in the five countries as part of community-based early warning schemes that will help secure the lives, assets and livelihoods of remote island communities.

Selection criteria

Specific island communities / beneficiaries will be identified based on the following general eligibility criteria:

- **Exposure and vulnerability to hydrometeorological hazards:** Measured based on historical trends in disaster loss databases (e.g. EM-DAT, DesInventar, Pacific Catastrophe Risk Assessment and Financing Initiative – PCRAFI, Pacific Damage and Loss information system – PDaLo), secondary data analysis (e.g. existing hazard, vulnerability and exposure maps) and consultation with national disaster management agencies. Geographical targeting is the first level of beneficiary selection and will coordinate with development of the Monitoring and Evaluation (M&E) framework for the Programme and will be validated by national stakeholders in the Programme Steering Committee (PSC).

- **Dependency of livelihoods in climate-sensitive sectors:** Measured based on the proportion[373] of households in a community for which the main source of income generation is in one of the priority sectors identified in the Pacific Roadmap for Strengthened Climate Services – i.e. agriculture and food security, disaster risk management, energy, health, water, fisheries and tourism.[374] This analysis will be conducted through consultation with government agencies, sector representatives and local government.
- **Potential to support increased livelihood opportunities:** The Programme will prioritise the inclusion of beneficiaries that satisfy at least one of the following criteria –
    - Woman / Single parent / Elderly / Youth / Disabled head of household;
    - Not receiving external assistance (i.e. from international organisations, NGOs, community groups, etc.);
    - High levels of debt / no access to credit / no formal savings that could be used to (re)start livelihood;
    - Previous loss of production assets or labour opportunities due to a natural disaster.
- **Willingness to participate in Programme activities**.

At the inception phase, the Programme Management Unit (PMU) will further elaborate and refine transparent and just selection criteria in consultation with the Programme Steering Committee (PSC). Selection criteria will be made available to all and will be disseminated to affected populations and shared with local government authorities and community-based organisations for endorsement. A beneficiary feedback mechanism will be established through the National Coordination Committees (NCCs) to monitor that selection criteria continue to be appropriate through Programme implementation and the most vulnerable people are being reached.

Sub-activity	Target Beneficiaries and Selection Criteria
3.1.1 – Strengthen EWS organisational and decision-making processes	**Early Warning System (EWS) stakeholders:** "EWS stakeholders" should include the disaster management authorities at the national, regional and local levels, agencies responsible for issuing hazard warnings and advisories (e.g. NMHSs), humanitarian and relief organisations (e.g. Red Cross Red Crescent national societies) and public and private communication entities. Other stakeholders include agencies responsible for various sectors, such as agriculture, energy, health, water resource management, fisheries, transport, telecommunications and education.[375] Local stakeholders include representatives of communities, women's groups and local government. Selection of "EWS stakeholders" for participation in Programme activities will be made on the basis of: i) Maximising representation of the groups outlined above; ii) Maximising geographical coverage; iii) Aiming for 50:50 gender disaggregation in participants.

[373] Exact percentile thresholds will be established in the Programme inception phase.
[374] SPREP, 2016. Pacific Roadmap for Strengthened Climate Services 2017 - 2026
[375] WMO, 2018. Multi-hazard Early Warning Systems: A Checklist

	Women: defined on the basis of self-identification as female. The Programme will also prioritise the selection of women from women-headed households.
3.1.2 – Strengthen communication systems to reach the last-mile	**Last-mile communities:** Communities at "the last mile" will be selected on the basis of: i) Geographic isolation; ii) Lack of critical infrastructure (e.g. water supply, public health, transportation, communications); iii) Lack of access to climate hazard and disaster risk information.
3.1.3 – Communicate early warnings to island communities	**EWS stakeholders** will be selected as per the criteria outlined above. **Community-based organisations:** Partnerships with civil society organisations and local women's groups for the implementation of specific interventions will be prioritised on the basis of: i) Potential for synergies and complementarities with existing projects and initiatives and avoidance of overlaps and doubling of efforts; ii) Level of organisation and ability based on the expectation that ownership of and investment of time and resources in activities is key to ensure sustainability.
3.2.1 – Enhance disaster preparedness and response measures	**Women** beneficiaries and **Community-based organisations** will be selected as per the criteria outlined above. **Youth:** defined as persons under 18 years of age.
3.2.2 – Conduct public awareness and education campaigns on climate hazards and risks	**Women** beneficiaries, **Youth** and **Community-based organisations** will be selected as per the criteria outlined above. **Elder / Elderly:** defined as persons over 60 years of age.
3.2.3 – Integrate traditional knowledge into early warning systems	**Elderly** beneficiaries will be selected as per the criteria outlined above.
3.3.1 – Develop FbF Roadmaps defining thresholds and triggers	**Forecast-based Financing (FbF) stakeholders** will be selected as per the criteria for "EWS stakeholders" outlined above.
3.3.2 – Build capacity for FbF	**FbF stakeholders** will be selected as per the criteria for "EWS stakeholders" outlined above. **Community-based organisations** will be selected as per the criteria outlined above. **Professional staff:** Professional staff who will benefit from training and capacity building under the Programme include island councillors, NGO staff and government workers. These beneficiaries will be selected according to the following process: i) Organisations have and/or will be identified based on alignment between the proposed activities and the organisation's mandate, expertise and/or services delivered; ii) Identified organisations will be invited to nominate staff to participate in the activities based on alignment between the propose outcomes of the

	intervention (e.g. technical focus of the training) and the respective individual's responsibilities and expertise within the organisation; The Programme will review the list of nominated participants and select participants based on assessment of alignment between the intervention and the participants' responsibilities and expertise; whilst also aiming for 50:50 gender disaggregation in participants.
3.3.3 – Support development of Early Action Protocols (EAPs)	**FbF stakeholders** will be selected as per the criteria for "EWS stakeholders" outlined above. **Professional staff and community-based organisations** will be selected as per the criteria outlined above.

Table 27. Preliminary selection criteria for beneficiary groups

Activity 3.1 Warning dissemination and communication

Under this Activity, the Programme will enhance the dissemination and communication of climate risk information and early warnings based on the enhanced data generated under Programme Result 2. The Programme will particularly focus on strengthening last-mile communication systems to ensure that people and communities in remote locations receive warnings in advance of impending hazard events. NMHSs will be supported to develop a range of communications products tailored to end-users at the community level. National Disaster Management Authorities, Red Cross Red Crescent National Societies and community-based organisations will play a key role in enhancing preparedness and response capabilities.

3.1.1 Strengthen EWS organisational and decision-making processes

This Sub-activity will ensure the effective and coordinated delivery of early warning services through strengthened organisational and decision-making processes of NMHSs, disaster management agencies, civil society organisations and other key actors.

An annual workshop will be conducted in each of the five countries to define the functions, roles and responsibilities of key EWS actors; develop warning communication strategies; and develop, trial and refine Standard Operating Procedures (SOPs). The workshops will be attended by various EWS stakeholders, disaster management authorities and NMHS representatives. The warning communication strategies to be developed will facilitate coordination between NMHSs – as warning issuers – and with downstream dissemination channels, such as island community volunteer networks. The strategies will include the development of community feedback mechanisms to verify that warnings have been received and to alert NMHSs to potential gaps in communication networks. At the start of Programme implementation, an in-country deep dive study on gender and community stakeholders will be conducted to facilitate that the design of EWS organisational and decision-making processes is gender-responsive and that such processes proactively consider and address the specific needs, concerns and capabilities of different gender groups. Knowledge gained and outputs from the workshops will be leveraged in development of the Forecast-based Financing mechanisms (Activity 3.3).

3.1.2 Strengthen communication systems to reach the last-mile

This Sub-activity will enhance connectivity and communication systems to facilitate that climate information and early warnings reach communities at the last-mile, including on remote outer islands; and that communication channels are resilient to the impacts of extreme climate events. This will be achieved through the following interventions:

- **Develop last-mile communication strategies** based on understanding of last-mile connectivity (which population groups can be reached by different communication channels) and tailored to the differential needs of specific groups (including women and men, elderly people and children, people with disabilities, and remote island populations at large). This will include agreement on a glossary of climate and weather terms in local languages, and the routine use of the terms in television weather reports, which will enhance understanding between NMHSs and communities.
- **Upgrade last-mile communications infrastructure** through equipment maintenance and upgrade; establishment of backup systems and processes; and the development of additional communication channels to improve coverage and resilience to impacts on infrastructure. For example, Niue and Tuvalu will install village "compass" posts with pointers to known locations, and signposts to show people which way to go during different extreme events. This will enable communities to appropriately action local climate and early warning information. In addition, backup systems using Pactor modems and HF radio will be established in eight outer islands of Tuvalu to improve two-way communications with isolated communities during a disaster. In Palau, a maritime safety information network will be established in accordance with the International Hydrographic Organization's Safety of Life at Sea (SOLAS) convention.
- **Enhance communication channels and early warning systems** through the development of multiple-channel climate and ocean information products (e.g. for social media, mobile, radio, television and website applications). For example, Niue, Palau and Tuvalu will each develop an ocean and climate mobile application, which will provide immediate access to detailed, up-to-date information on local terrestrial and ocean climate conditions. NMHS websites will also be upgraded with a user-friendly interface to enable easy access to climate and ocean information. Niue will increase their reach into communities with additional radio and newspaper coverage. In RMI, development of a web-based dashboard linked to the regional portal will improve accessibility and understanding of RMI's ocean data and early warnings as they relate to coral reefs.
- **Develop and implement localised mobile climate information communication systems with early warning to reach last-mile populations.** Through mobile-cellular communication channels, this system will provide predicted risks and alerts utilising geostationary satellite nowcast and local/regional forecast information. The system could also integrate information on locations of first-aid stations and nearby medical facilities, and status reports. For example, at-risk populations could receive information on their mobile device detailing nearby hospitals and shelters. The system will be designed to handle potential and existing risks on a 24/7 basis and will be customisable for any population group size – from small communities to larger central governments. For short-term disasters, the system will utilise satellite imagery analysis based on 2 km, 10-minute resolution (e.g. Chollian 2A) for nowcasting of wind, wave height and convective initiation of rapidly developing thunderstorms two hours in advance, which is not possible with Numerical Weather Prediction. Localised communication systems will support disaster risk management on various timescales from short-term disasters (e.g. torrential rainfall, coastal flooding, etc.) to long-term disasters (e.g. droughts). The possibility

to integrate a two-way communication channel between end-users and information providers would allow for continued enhancements to the system based on user feedback.[376]

- **Identify opportunities to utilise private sector resources to disseminate warnings**, such as mobile-cellular, television, radio broadcasting and social media. The identification of appropriate private sector partners could be facilitated by the market assessment that will be undertaken under Sub-activity 1.1.2.

3.1.3 Communicate early warnings to island communities

This Sub-activity will use tailored approaches to improve the content and communication of NMHS forecasts to ensure the effective dissemination of impact-based early warnings and enable communities to take advantage of all available forecast information. In doing so, the Programme will utilise the improved forecasts and warnings of severe weather as a result of, amongst others, the WMO Severe Weather Forecasting and DRR Demonstration Project (SWFDDP) in South Pacific, in which Cook Islands, Niue and Tuvalu participated. This will be achieved through the following interventions:

- **Improve warning messages to provide clear guidance for triggering response actions.** The Programme will work with NMHSs, National Disaster Management Authorities and local communities to co-design and co-produce information products, drawing on their specialised knowledge of their environment to create warnings that are actionable and effective.
- **Ensure that the public and other stakeholders are aware of which authorities issue the warnings and trust their messages:** engagement with island communities and other stakeholders will improve community awareness of which authorities issue warnings, build trust between stakeholders and improve acceptance of science-based information products.
- **Include the different risks and needs of subpopulations in early warnings:** the particular climate information needs of the elderly, people living with disabilities and geographically and/or socially vulnerable communities (e.g. on remote outer islands) will be taken into account, as well as ensuring that warnings are gender responsive. For example, the Disability Coordination Office at the Ministry of Culture and Internal Affairs in RMI will partner with the Disabled Persons Organization to ensure effective communication on disability-inclusive programming for early warning. Additionally, the delivery of disability-inclusive climate change and disaster preparedness activities and educational products will be expanded. This will include production of an educational video using a Sign Language Interpreter on climate change early warnings in Marshallese with English captions. In Tuvalu, a National Coordination Team will be established to engage with and address the priorities of vulnerable groups.

Activity 3.2 Preparedness and response capabilities

Under this Activity, the Programme will engage with communities at the last mile to enhance preparedness and response actions at the local level. This will be facilitated by the development of community-based disaster risk reduction and disaster risk management plans, community level

[376] This will be delivered by the APEC Climate Center in collaboration with the Ewha Womans University, utilising a proven method that is currently being implemented in Cambodia, with the endorsement of the Cambodia Ministry of Water Resources and Meteorology, Asian Disaster Preparedness Center (ADPC) and the Preah Vihear National Authority

vulnerability assessments, and training and awareness workshops to enhance awareness of climate hazards and risks.

3.2.1 Enhance disaster preparedness and response measures

This Sub-activity will use community-based approaches to enhance risk ownership at the local level and help establish collaborative community networks for coordinated action for preparedness and response to climate-induced hazards. This will include the following interventions:

- **Community-based disaster preparedness plans** including co-development of community-based sustainable climate adaption plans for climate resilience, using integrated scientific information and traditional climate knowledge (see Sub-activity 3.2.3) in Niue; and development of community-based disaster risk reduction plans and a Drought Monitoring Plan for each inhabited island in Tuvalu.

- **Multi-hazard risk and vulnerability assessments** utilised to develop disaster risk reduction strategies and products. For example, Cook Islands will utilise community-based vulnerability assessments to develop hazard maps, damage assessment tools and a National Emergency Operation Centre (NEOC); and Niue will update their vulnerability and adaptation assessment tool.

- **Capacity building for disaster response**, including women's training programmes in Palau to enhance capacity to prepare for and respond to climate disasters and emergencies; and the establishment and training of 70 outer island Emergency Response Teams (ERTs) in RMI.

- **Assessment of community-level communications and response actions** to test and optimise the effectiveness of early warning dissemination processes, preparedness and response actions. For example, Tuvalu will conduct annual disaster warning drills previously developed by island communities.

3.2.2 Conduct public awareness and education campaigns on climate hazards and risks

The Programme will conduct public awareness and education campaigns to enhance community knowledge and understanding of climate hazards and the potential impacts on lives and livelihoods of local populations. Communities will be educated on how warnings will be disseminated; which sources are reliable and how to respond. The Programme will ensure the use of targeted approaches to improve awareness of climate hazards and risks tailored to the specific needs of vulnerable groups (e.g. women, children, older people and people with disabilities). The interventions will include the delivery of school and community-based activities for climate change awareness, and training and capacity building workshops on climate hazards and disaster risk reduction. Niue will undertake several community and youth climate initiatives, such as climate change awareness days, Talanoa sessions on climate-related stories with elders, and climate and health wellness programs. Palau, RMI and Tuvalu will undertake public awareness and education campaigns on climate in both their capitals and outer islands. In the Cook Islands, the Women's committee (Au Vaine Kumiti) will work with island communities, specifically through training by technically qualified women to educate children and elders on how to use technology to access early warning information and to contribute to local scale vulnerability assessment.

3.2.3 Integrate traditional knowledge into early warning systems

The body of climate knowledge Pacific communities have acquired and codified over many hundreds of years of careful and deliberate observation has great cultural value in itself. Memorised and transmitted over generations, it is used by subsistence fishers, farmers and gardeners, and in the collection of wild resources. It holds information that can potentially contribute to a greater understanding of regional climate change for regions without long historic climate data observations.[377] Traditional knowledge has carried populations through periods of extreme weather and climate variability and it can contribute to their resilience to the changes in the natural environment that they are seeing now.

"World Bank Group President Robert Zoellick acknowledged [2010] that Indigenous people carry a 'disproportionate share of the burden of climate change effects' and must be included in international climate change discussions. Translating this largely theoretical recognition into practice remains a major challenge, in large part because of the perceived inferiority of local Indigenous knowledge compared to the conventional western scientific mode of inquiry….While this perception dominates public and policy discourse, the acknowledgement of the value of Indigenous peoples' observations of environmental, particularly weather and climate-related changes, is gradually increasing in the western scientific peer reviewed literature….[P]apers broadly reinforce the value for western scientists of engaging with Indigenous people to gain weather and environmental change observations for geographic regions with a paucity of scientific data. In a similar way, the large-scale climate projections developed by western scientists could likewise be of value for local Indigenous communities as they seek ways of adapting to and planning for environmental change." [378]

Remote Pacific communities often rely on traditional (or indigenous) methods for forecasting and responding to climate extremes and geohazards. Failure to acknowledge this can reduce the effectiveness and reach of contemporary forecasts and warnings. However, international research, including that of the COSPPac Traditional Knowledge Project, has shown that traditional knowledge can be incorporated into NMHS products and services and this greatly increases community acceptance of NMHS materials. Recognising the value of traditional climate knowledge improves communication and understanding between communities and NMHSs.

In the Programme countries, weather and seasonal climate forecasts are available through national meteorological and hydrological services, but uptake of NMHS forecasts in remote Pacific communities is often limited. To address this, NMHSs need a clearer understanding of the types of information local communities currently use and how this information is received, to enable them to modify their products and their delivery to meet community preferences.

COSPPac Phase I included, at partner countries' request, a pilot program to collect and store traditional climate knowledge (TK). With advice from BoM's Indigenous TK expert, NMHS staff developed questionnaires and data entry forms, and interviewed community elders on their use of traditional indicators—these can include changes in plant and animal behaviour, cloud formation, and conditions conducive to the formation and onset of severe weather systems and seasonal changes in climate.[379]

The interviews revealed that remote communities mainly relied on weather and climate forecasts based on TK alone or in combination with contemporary forecasts. "Many who had access to both forecast systems indicated that they only sourced contemporary forecasts in the lead up to and during extreme events, particularly cyclones, to assist their decision-making. Recent extreme events in the

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[377] D. Green (B) Climate Change Research Centre, University of New South Wales, Sydney 2052, Australia e-mail: donna.green@unsw.edu.au G. Raygorodetsky, 2010, Global Biocultural Initiative, The Christensen Fund, Palo Alto, CA 94301, USA 240 Climatic Change 100:239–242.
[378] Chambers L and others, 2019, Traditional or contemporary weather and climate forecasts: reaching Pacific communities, Regional Environmental Change.
[379] Lefale P, 2009, Ua 'afa le Aso Stormy weather today: traditional ecological knowledge of weather and climate, the Samoa Experience. Clim Change. doi:10.1007/s10584-009-9722-z.

Pacific have shown that self-reliant communities, with knowledge of traditional ways of forecasting, and responding to climate extremes, experience several benefits including reduced social-economic disruption and lower than expected death rates, particularly when combined with contemporary warnings. Therefore, there is a need to better understand the role of local traditional knowledge-based forecasts and for NMHSs to work towards improving the content and communication of their forecasts to enable communities to take advantage of all available forecast information. For effective risk reduction, warnings and responses should therefore complement contemporary forecasts, rather than replace TK-based forecasts." [380]

The populations of the participating countries have extensive traditional knowledge concerning adaptation to climate variability; application of this knowledge to decision-making informed by science will enhance adaption to long-term changes. While remote Pacific island communities may listen to NMHS forecasts, most rely only on traditional climate knowledge (TK) when they make decisions, or at best on TK in combination with official forecasts.[381] WMO recommends that TK be recognised, valued and used to explain climate science—the long-term benefit of recognising TK will be that broadcasted advice will be accepted and acted upon so that communities are better prepared to respond to climate extremes, leading to reduced socio-economic disruption and fewer morbidities and deaths. The importance of integrating TK into climate-related decision-making was also highlighted in the IPCC Special Report on Global Warming of 1.5°C, which noted the cultural resilience of Pacific island inhabitants and how their knowledge can underpin the development of adaptation strategies.[382]

Therefore, this Sub-activity will incorporate TK into NMHS products to significantly improve forecast communication while expanding the spatial and temporal relevance of the forecasts[383] and increasing community acceptance of NMHS materials. The Programme will facilitate engagement with community elders to discuss the types of information that local communities use, their traditional methods of forecasting and how TK can be applied to and complement scientific forecasts. Such discussions are envisaged to generate local acceptance of technically derived climate forecasts, so that communities trust NMHS's information and act on their advice to improve their climate risk preparedness and response capacity.

Support for TK under this Programme builds upon previous work undertaken through the Climate and Oceans Support Program in the Pacific (COSPPac), which included Niue in its TK interventions. Under COSPPac, the Niue Meteorological Service (NMS) worked with community elders to collect and digitise TK indicators in a TK database. The Programme will build on this to collate and verify traditional climate and weather indicators documented under the COSPPac project. Beyond this stage, the Programme will develop seasonal calendars and utilise traditional terminology in translating seasonal forecasts and extreme weather warnings in Vagahau Niue. Moreover, the Programme will upscale the TK work to other countries – notably Palau and RMI – using the methodology that proved successful in COSPPac. Niue, Palau and RMI will recruit a local TK consultant who will be responsible for all Programme work relating to TK, including the establishment of a national workplan; engagement with relevant stakeholders; provision of community education and awareness activities; collection and archiving of climate TK information. In Tuvalu, the TK intervention builds on the Community-based Early Warning System and DRR (CB-EWS/DRR) implemented under Sub-activity 3.2.1. The Programme

[380] Plotz RE and Chambers LE, 2017, The Best of Both Worlds: A Decision-making Framework for Combining Traditional and Contemporary Forecast Systems, Journal of Applied Meteorology and Climatology, Vol 56, Issue 8, pp2377-2392.
[381] Lefale, P., 2009, Ua 'afa le Aso Stormy weather today: traditional ecological knowledge of weather and climate, the Samoa Experience. Climate Change. doi:10.1007/s10584-009-9722-z.
[382] IPCC, 2018. Special Report on Global Warming of 1.5°C.
[383] SPREP, Pacific Roadmap for Strengthened Climate Services 2017–2026

will undertake consultations with communities and TK information holders; and TK indicators will be documented and stored in a TK database.

Under the COSPPac TK project, each country signs an agreement with COSPPac/SPREP that outlines that all information gathered in the country remains the property of said country and is only stored in the TK database in-country. All Intellectual Property (IP) rights and sharing issues belong solely to the country. The project teams normally work with the communities that are willing to share their TK information. The IP agreement can be signed with the NMHS or another government agency, such as the Ministry of Culture, etc., who will act as the custodian of the TK data on behalf of the country's government. A lower level agreement can also be with the community leaders, NMHS or another government agency.

Note that Cook Islands did not express a desire to undertake the TK project under this Programme as it is already being progressed through other activities.

Activity 3.3 Forecast-based Financing (FbF)

Under this Activity, the Programme will introduce Forecast-based Financing (FbF) in Cook Islands, Niue,[384] Palau, RMI and Tuvalu. FbF is an innovative mechanism whereby early actions are pre-planned based on in-depth forecasts and risk analysis, and are funded and implemented before a climate shock to minimise losses and damages caused by climate-related hazards and reduce the need for humanitarian assistance in their aftermath.[385] A key element of FbF is that the allocation of financial resources is agreed in advance, along with the specific forecast threshold that triggers the release of funding to implement planned early actions. The roles and responsibilities of actors involved in implementing these actions are defined in an Early Action Protocol (EAP).[386] The conceptual framework for FbF is shown in the figure below.

[384] There is no Red Cross Red Crescent National Society in Niue, thus potential implementation of FbF-related actions awaits verification
[385] WFP, 2019. Forecast-based Financing Factsheet
[386] IFRC, 2020. What is Forecast-based Financing? Available at: https://www.forecast-based-financing.org/about/

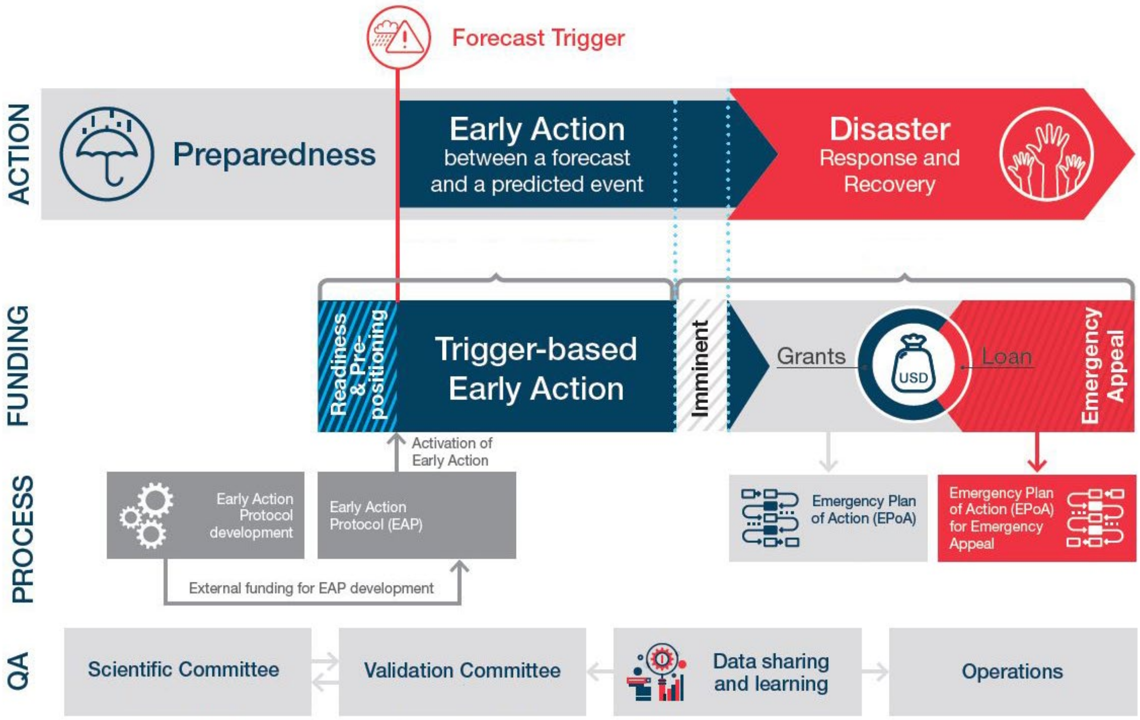

Figure 77. Forecast-based Financing conceptual framework[387]

The Red Cross and Red Crescent Movement has been working on the FbF approach since 2007, with the Red Cross Red Crescent Climate Centre taking the scientific lead. In 2016, the International Federation of Red Cross and Red Crescent Societies (IFRC) committed to expand its engagement in FbF by pledging its integration in the financing of global disaster risk management. In 2017, the IFRC finalised its Framework for Climate Action towards 2020, which identified FbF as a key priority for addressing climate change.[388] As of 2020, there are 15 pilot FbF projects at various stages of implementation by National Societies in Africa, the Americas and the Asia-Pacific region.[389]

The Programme will partner with the IFRC, individual Red Cross Red Crescent National Societies (where present) in the five countries and National Disaster Management Authorities to coordinate implementation of this Output.

3.3.1 Develop FbF Roadmaps defining thresholds and triggers

This Sub-activity will develop an FbF Roadmap for each Programme country, which will identify forecasts (magnitude, probability and lead time) that can trigger humanitarian actions.[390]

The first phase of the Roadmap will begin with a scoping study that will cover feasible hazards to target with FbF, forecasting capability, and the institutional landscape in each of the five countries. This will include consultations with national agencies such as Disaster Management, NMHSs, Agriculture and Health; regional agencies such as SPREP, SPC, WFP, UNDP and others; and partnerships with the IFRC, Red Cross Red Crescent Climate Centre and National Red Cross Red Crescent Societies. For FbF to be

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387 Adapted from: IFRC, 2020. Forecast-based Action (FbA) by the DREF. Available from: https://media.ifrc.org/ifrc/fba/

388 IFRC, 2018. Forecast-based Action by the DREF. Available at: https://www.forecast-based-financing.org/wp-content/uploads/2018/10/DRK_Broschuere_FUND_Web_ENG.pdf

389 IFRC, 2020. Forecast-based Financing Projects. Available at: https://www.forecast-based-financing.org/our-projects/

390 Lopez, Coughlan de Perez, Bazo, Suarez,Van den Hurk, Van Aalst, 2018: Bridging forecast verification and humanitarian decisions: A valuation approach for setting up action-oriented early warnings

a sustainable and effective mechanism, Early Action Protocols (EAPs) need to be embedded in national institutions, who have roles and responsibilities for taking early action. The scoping phase will identify the national and/or sub-national actors (government and civil society) in each country and enter into a dialogue with them about the potential for early action.

For the countries with a positive landscape for institutional participation in Forecast-based Financing, the second comprehensive phase of the Roadmap will be developed. This phase will consist of collaborative consultations with country institutions to delineate three key elements that would enable country-led design of an FbF mechanism:

1. Menu of Triggers – A 'trigger' is a forecast that is issued, which exceeds a pre-defined danger level and probability threshold, leading to the initiation of early actions. The menu of trigger options are developed through the following steps: i) Review and analysis of the current early warning system, risk assessments and available forecasts; ii) Danger levels defined for the selected hazards and intervention area; iii) Assessment of the accuracy of available forecasts for the intervention area; and iv) Menu of triggers designed as options for triggering early actions.
2. Forecast-based Actions – Identification of possible early actions that can be triggered by existing forecasts, which aim to avoid losses and damages if an extreme event materialises. Early action is at the acute end of disaster risk reduction – i.e. it is a last chance to reduce risk and build resilience. Clear and focused interventions can be achieved through planning early actions according to the specific risk faced by particular communities. 'Preparedness for response' actions could also be considered, such as preparation of evacuation sites, readiness of logistic teams, prepositioning of stock, registering people for cash transfers and set up of coordination mechanisms, etc.
3. Institutional Arrangements – A potential architecture of country-level technical working groups and institutional ownership for FbF, including funding mechanisms when necessary. A lead national agency/s in which to embed EAPs will be identified.

The FbF Roadmaps will provide a set of 10 recommendations per country for critical next steps to move forward with Forecast-based Financing. These next steps will be focused on filling capacity gaps that enable the design and activation of an FbF mechanism by the identified lead agency/s, and the design and testing process for EAPs. The Roadmaps will include the following components:[391]

- **Stakeholder Identification** – The Programme will identify the key stakeholders to be involved in the development and implementation of FbF in each country, including international, national, regional and local actors and lead agency/s. This will help to avoid creating parallel systems and ensure that upon reaching a trigger, no additional discussions on permissions, etc. will be required.
- **Risk Assessment** – The Assessment will include individual analysis of risk factors, key hazards, past impact, exposure and vulnerability. Based on the analysis, the priority hazards to be addressed by FbF early actions will be identified. The selection of prioritised hazards will be based on in-depth analysis of historical disaster impacts and the extent to which the hazard has produced and will produce negative impacts on lives, livelihoods, well-being and other development aspects. Furthermore, the assessment will provide an overview of the different types of early actions that could be taken to mitigate risk by the identified stakeholders, in different sectors (agriculture, health, etc).

[391] IFRC, 2018. Forecast-based Financing Early Action Protocol template

- **Impact-based Forecasting (Triggers)** – The Trigger analysis will provide an overview of all available forecasts – including lead time, skill/confidence and extreme event probability. This analysis will also offer suggestions on impact-based forecasting products or the potential for such products to be developed, which would overlay a forecast with exposure and vulnerability information. Exposure maps are useful to identify the main exposed elements that the intervention will focus on. For example, if the most frequent and biggest impact due to tropical storms is the damage of houses built from light materials, the 'exposed element' will be *houses built from light materials*. Vulnerability information will comprise of indicators than depend on the prioritised impact. If several indicators are selected, a composite vulnerability index will be established. Furthermore, the EAP will outline what data will be used to monitor the 'exposed element' and vulnerability indicators – including data sources, access to data, data quality, granularity and how often it is updated. Development of the Trigger model will require close collaboration with the executing agencies of Programme Result 2.

- **Resourcing Overview** – The Assessment will identify various options for accessing funding or necessary resources for potential early actions that are more costly or resource-intensive. This will include an overview of potential national level funds for anticipatory actions, Disaster Risk Financing options, and humanitarian funding options.

The Sub-activity will build on the scoping study commissioned by the Australian Red Cross and Red Cross Red Crescent Climate Centre[392] in 2016, which assessed the main considerations of adapting FbF to the Pacific with a focus on three larger Pacific SIDS (Fiji, Papua New Guinea and Solomon Islands), to adapt it to the context and capacities of the much smaller five Programme countries. In developing the FbF Roadmaps, the following key findings from the Red Cross scoping study will be taken into account:

- Forecast skill and possible warning lead times differ considerably from other countries, primarily because the Pacific has very small dispersed islands, short rivers, steep catchments, high El Niño–Southern Oscillation (ENSO) sensitivity, and each country experiences a broad spectrum of extreme events;
- Forecast skill and timeframes differ considerably for different hazards;
- Lack of historical hydrological data and modelling capability throughout the region;
- Some of the most difficult disturbances in the Pacific happen on much longer timescales than FbF has typically operated under;
- Concerns about false alarms and potentially creating apathy towards other forms of early warning are pervasive in the region; and
- The extent to which the populations are dispersed and remote has strong implications for FbF design and budgeting.

The scoping study also identified the flexible financing mechanisms required to implement FbF in Pacific island countries:

- "Advocacy for the establishment of a regional and/or national financing mechanism that allows government to rapidly fund anticipatory action based on imminent impact;

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[392] Australian Red Cross and Red Cross Red Crescent Climate Centre, 2016: Use of Forecast-based Financing in the Pacific: A Scoping Study

- Government investment in both the development of the Forecast-based Action system itself and the funding required to activate early action protocols when triggers are effected;
- Pursuit of national or regional level pooled funding mechanism to allow government access to anticipatory funds – in alignment with the Framework for Resilient Development in the Pacific (FDRP);
- Coordination and streamlining of anticipatory pooled funds with existing / pipeline Pacific disaster risk financing mechanisms for DRR (e.g. the Pacific Resilience Facility[393]) through to risk insurance (e.g. Pacific Catastrophe Risk Insurance Facility)."

3.3.2 Build capacity for FbF

In this Sub-activity, up to five of the 10 "next steps" that were identified for each country in their Roadmap will be developed and executed. Steps that fall within technical capacity building, research or technical advice will be supported by the Red Cross Red Crescent National Societies. Depending on the national context and the findings of the scoping study, these activities could include the following:

- Scientific collaboration with national or regional forecasters to carry out a forecast verification analysis or forecast calibration to support the development of triggers;
- Technical support to build enthusiasm for anticipatory actions and change mindsets;
- Specific links between the FbF and EWEA narrative with the principles and activities embedded in other outputs of the Programme;
- Technical support in finding ways to connect with existing regional systems, mechanisms and/or priorities to have a region-wide understanding or buy-in of FbF;
- Table-top exercise to discuss a historical extreme event and what could have been done by different actors to prevent impacts;
- Round-table discussion on financing mechanisms for critical early actions that could be part of an FbF mechanism.

3.3.3 Support development of Early Action Protocols (EAPs)

In this Sub-activity, the Red Cross Red Crescent National Societies will support the countries that have full Roadmaps and identified appropriate national institutions to spearhead FbF (Sub-activity 3.3.1) to develop Early Action Protocols (EAPs) through technical working groups for the priority impacts identified in Sub-activity 3.3.1. These EAPs will vary from country to country, depending on the results of the Roadmap and the capacity building activities. Each country will carry out a series of conversations to develop an EAP, which could range from focusing on a simple life-saving action by one actor to a more complex document with a greater variety of actions and forecast analysis.

To identify what should be in the EAP, each country lead agency/s will convene a technical working group, engaging stakeholders at all levels – including community representatives, disaster risk reduction committees, civil society organisations, local and national government departments, NGOs and private sector actors. The Climate Centre will provide technical guidance to the lead agency on the process and provide quality assurance, but delivery of the EAP will rest with the lead agency.

The following criteria will be considered when discussing possible actions: i) Consistency with government and/or other institutional contingency plans - this will ensure that FbF is adding value

[393] As of February 2020, the Pacific Resilience Facility has not yet been established. Source: https://www.abc.net.au/radio-australia/programs/pacificbeat/pac-govs-seek-funding-for-new-climate-fund-they-want-to-control/11922814

and covers gaps in the existing disaster risk management system; ii) Prevention/mitigation of impact and preparedness for response – this will include an assessment of non-direct reduction of hardship such as reduced food and nutrition insecurity, which would add further value to the investment; iii) Scale – the bigger the population protected, the more effective the system; iv) Practicality – the possibility to implement a certain action will depend on the geographical, social, political and economic context; v) Social acceptability – community engagement is essential for successful implementation; vi) Value for money – this will include assessment of non-economic benefits; vii) Relevance – this will identify the organisation with the most relevant expertise and capacity to implement the action; viii) Appropriate financing options; and ix) Efficiency – this will consider existing social protection programs and pre-identified at-risk communities, which would enhance the efficiency of FbF implementation.[394]

Determination of forecast-based actions will be based on:

1. Preparation and implementation/activation **time** and action lifetime;
2. **Capacity** to implement the proposed action;
3. Financial, material, human and technological **resources** required; and
4. **Access** issues in providing assistance.

Following identification of the most suitable forecast-based actions, the EAPs will be developed by the lead national agency/s.

The EAPs will describe which forecast will trigger which action; where to act – based on the forecast and trigger information; and assign responsibilities to specific stakeholders for implementation of each action. In the case of more complex EAPs, they can also include a proposal for a Financial Mechanism, which will outline what funds need to be made available (including readiness costs, stock pre-positioning and activation cost for trigger-based early actions) and how they will be accessed by specific stakeholders. This Sub-activity will collaborate with national climate finance policies (Sub-activity 1.1.4) to explore situations when funding for early action can be linked to government budgets.[395] Depending on local capacity, simulations can be held to carry out a “test” of the actions of the EAP.

RESULT 4 – ENHANCED REGIONAL KNOWLEDGE MANAGEMENT AND COOPERATION FOR CLIMATE SERVICES AND MHEWS

Programme Result 4 will optimise synergies among the Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu. The Programme will organise joint learning events and training; promote equipment, software and tools common to all five countries; and foster networking and mentoring among the five NMHSs. The Result will directly address the key education and training needs – such as Forecasting and Numerical Weather Prediction (NWP), Instrumentation and Observation and Climate Services – reported by Pacific NMHSs to WMO[396] and in a study conducted by the Disaster Resilience for Pacific SIDS (RESPAC) project.[397]

[394] IFRC, 2016. Prioritization of Forecast-based Actions. Available at: http://fbf.drk.de/manual.html#c30
[395] IFRC, 2018. Monitoring and Evaluation (M&E) of Forecast-based Financing (FbF). A practical reference for country-level implementation
[396] WMO, 2017. Status of Human Resources in National Meteorological and Hydrological Services
[397] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre

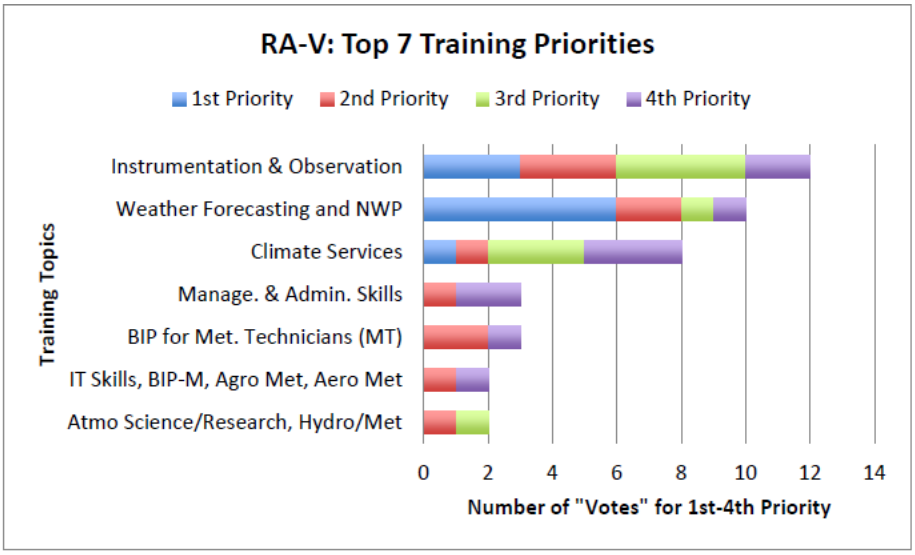

Figure 78. RA-V NMHS training priorities (Source: WMO)

In general, Pacific NMHSs are aiming to improve the quality of their services and increase the number of products in existing service areas, rather than increase the provision of broader types of services. Figure 38 indicates that there is a notable demand for professionalisation of the climate, forecasting and marine services areas (dark cyan), whereas improved observations capacity is a priority for technical staff with 2-year or lesser qualifications (light cyan).

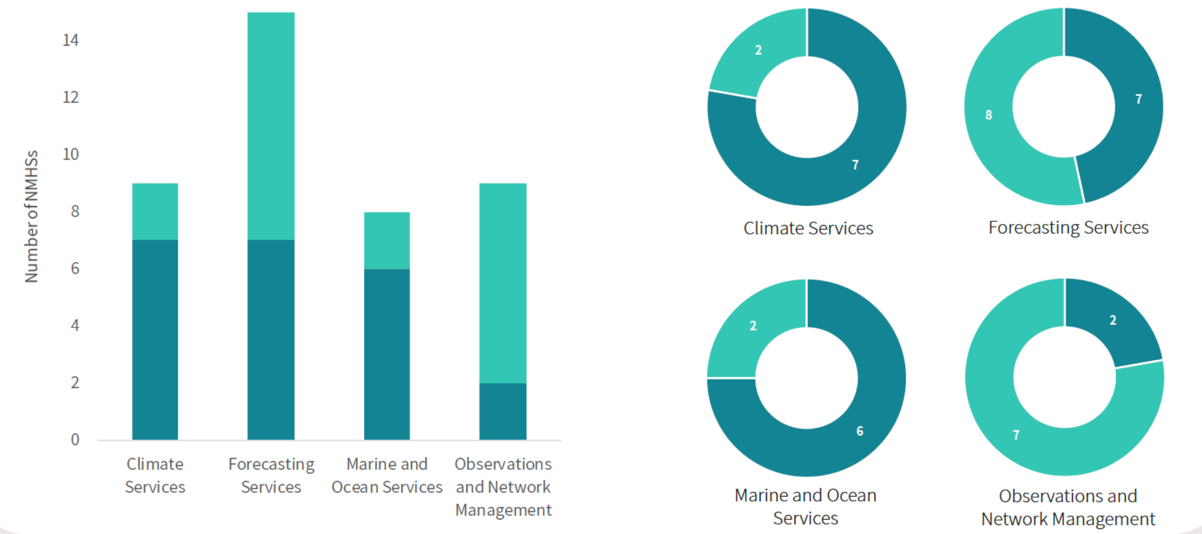

Figure 79. Pacific Islands Meteorological Strategy (PIMS) Pacific Key Outcomes (PKO) areas rated in the top three priority areas by staff type (Source: UNDP RESPAC)

This regional approach will ensure optimal knowledge management by sharing lessons learned and information on best practices. Programme Result 4 will complement and build on existing mechanisms for the entire Pacific region such as the newly established Pacific Climate Change Centre (PCCC), the Pacific Meteorological Council (PMC), the Regional Climate Outlook Forum, WMO regional meteorological centres and training and regional learning institutions such as the University of the South Pacific (USP) and its Pacific Centre for Environment and Sustainable Development (PaCE-SD). The Result will facilitate sharing of successes and lessons on the communication of climate-related information throughout the implementation of the Programme and foster South–South collaboration.

The Result takes advantage of the already established GEF-funded "Inform" project, implemented by UNEP and executed by SPREP, which is helping 14 Pacific island countries to manage and use environmental data well (discussed under Programme Result 2). Under the Programme, SPREP will further embed workflows, data validation and the interactive ICT platform into both the national processes in the five countries as well the operation of the secretariat in multiple focal areas. Building on the platform and processes that the "Inform" project has developed amongst select environment ministry staff, the Programme will expand the workflows to a wider stakeholder group and thereby increase use and demand at both the national and secretariat levels. Upon completion of the Programme, the officer position as well as associated fees including hosting will be absorbed by the SPREP CORE budget and country funding. These are already indications of increased direct national support in several Pacific island countries for data management, use and sharing; and the Programme will continue to grow this national commitment and ownership over its implementation period.

Activity 4.1 Enhance regional data, knowledge management and cooperation

Under this Activity, the Programme will enhance coordination and knowledge sharing among the five countries to improve data and knowledge management, including establishment of an interactive ICT platform and regional data centre. The organisation of joint learning, mentoring and training events through existing WMO, USP and other centres to facilitate sharing of successes and lessons learned will further strengthen climate and ocean information services across the region.

4.1.1 Establish interactive ICT platform

This sub-activity will establish an interactive ICT platform, which will serve as a data analytic centre for the management and organisation of climate data, information, experiences, case studies and other forms of knowledge from the five Programme countries in standardised, comparable formats most useful for end-users. The platform will include the establishment of a regional data centre fed by national data centres in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu. The countries will make as much as possible of their climate-related data publicly available through their national data portals and the regional Pacific Environmental Portal. The GEF-funded "Inform" project is already working with staff in Pacific environment ministries to find and harvest useful datasets and information on their countries' environment and to publicise the existence of the information. All five countries now have national data portals which can be used to develop workflows to share data seamlessly between sectors. The Programme will add a repository for climate data and bring data management and coordination into its schedule of capacity building activities. Improved data sharing and discoverability will provide a conduit for NMHSs to assess partners' sector data or knowledge products, while hosting and sharing their own on a common platform. Enhancement in data management capacity will be achieved through the following steps:

- Addition of a new category for climate data and information to each national portal;
- Training and engagement of national climate data consultants (see Sub-activity 2.3.1);
- Support for countries to prepare their national reporting for climate-related agreements (e.g. NDCs, VNRs, National Communications to UNFCCC). This is currently a major administrative burden for very small countries, but with access to good quality data, it provides an opportunity to evaluate policy and assess progress on adaptation. A two-way flow of information from NMHSs to and from relevant sectors for national and global reporting will ensure coordination in the use of climate data and information and raise the profile of NMHSs in other sectors thereby supporting demand and fostering sustainability.

- Participation of data consultants in regional forums to enhance the use of data in national planning;
- Establishment of electronic links with existing data sources and back-up in the regional portal; and
- Management of the ICT platform for the five Programme countries through support for ICT interventions across the five countries, including application of ICT in NMHSs operations and upgrading or introducing new methods and systems, such as wireless communications and Internet of Things (IoT) infrastructure for climate services.

4.1.2 Organise learning, mentoring and training

This sub-activity will comprise training, mentoring and advisory services for local consultants and staff in NMHSs in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu on strengthening climate information services; strengthening observations, monitoring, modelling and prediction; strengthening of marine weather and ocean services; establishing MHEWSs at national and community levels; and building community resilience against climate risks. This will be facilitated through partnerships with existing WMO regional training centres (e.g. China Meteorological Administration (CMA) Training Centre [398] through coordination by the Chinese Academy of Meteorological Sciences), USP and others in the organisation of:

- Joint learning events for exchanging knowledge and sharing experiences and lessons learned in strengthening climate information services and MHEWs in the five countries. This will have a major focus on the development and implementation of National Frameworks for Climate Services (NFCSs) through all components and related activities of this Programme.
- Targeted training of NMHS staff (e.g. meteorologists, ICT administrators, forecasters) in key areas that are essential for the Programme's impact and long-term sustainability. This will be undertaken through existing training centres in the WMO network, the University of the South Pacific (USP), the International Centre for Theoretical Physics (ICTP) and others. Training will be delivered through a combination of on-site workshops and remote learning courses. Topics of training could include:
    - Forecasting and Numerical Weather Prediction (NWP) by suitably qualified providers such as WMO regional training centres and other WMO-approved meteorological organisations. This could include nowcasting techniques for severe weather, and short-term climate monitoring and prediction in disaster prevention and mitigation.
    - Observation and Instrumentation, including Operation and Maintenance (O&M) of equipment for long-term sustainability.
    - Innovative and cost-saving technologies for observation, modelling and prediction with special focus on the application of ICT. Hence, these events will also be critical for regularly reviewing options for upgrading or introducing new methods and systems in NMHSs in the five countries, such as wireless communications and Internet of Things (IoT) infrastructure for climate services and disaster management.

[398] CMA propose to provide free in-person and remote training courses covering the top seven training priorities of Pacific NMHSs

- Principles of satellite remote sensing and use of meteorological satellite images in weather analysis and forecasting.
- Demonstration and training on the operation and maintenance of weather radar systems – installed under Sub-activity 2.1.1 by regional partners from the WMO network (possibly the Fiji Met Service in cooperation with USP under the new WMO Regional Training Center). The demonstrations and training will build capacity of the NMHSs for the provision of improved and more accurate weather monitoring and forecasts; tracking of local extreme events; better determination of rainfall rate/intensity, which is important for determining the potential for extreme rainfall and flash flooding enabling hazard warnings to be issued more accurately and in more timely fashion; and validating Numerical Weather Prediction (NWP) forecasts.
- Enhancing institutional effectiveness of NMHSs through Quality Management Systems (QMS), Weather Forecast Service Standard and related certification.
- Enhancing NMHS services through Impact-based forecasting and Forecast-based Financing.
- Enhancing Climate services in NMHSs, including options for ensuring long-term financing and cost-recovery such as private sector investment, public-private partnerships and the application of National Climate Funds.
- Use of alerts, information exchange and coordination in the first phase after major sudden-onset disasters, including through the Global Disaster Alert and Coordination System (GDACS).

Furthermore, the Programme will provide mentoring and technical advisory services to NMHSs in the five countries through capacity building, training and awareness raising initiatives and materials for a range of stakeholders; provide technical backstopping and capacity support to the national delivery of Programme activities; and provide expert advice to the Programme team on key climate information services and best practices, including gender-responsive implementation. In order to enhance synergies and avoid creating parallel structures, the Programme will work closely with the WMO-SPREP Pacific Meteorological Desk Partnership (PMDP), a regional coordination mechanism that supports and coordinates meteorological activities in the Pacific, and the Pacific Meteorological Council (PMC) at large.

8 – COUNTRY-SPECIFIC INTERVENTIONS

COOK ISLANDS

BACKGROUND

The Cook Islands consists of 15 small islands scattered over almost 2 million square kilometres of the Pacific Ocean, northeast of New Zealand, between French Polynesia and American Samoa. Since its Constitution took effect on 4 August 1965, the Cook Islands has been a self-governing, parliamentary, representative democracy within a constitutional monarchy in free association with New Zealand. Under the terms of the free association, Cook Islanders hold New Zealand citizenship and have the right of free access to New Zealand. Cook Islands has a twenty-four-seat, unicameral parliament directly elected by universal suffrage from single-seat constituencies for a fixed four-year term. There is also a House of Ariki, a ceremonial upper house that provides advice to the Parliament on land use and customary issues. The Government's ministries are shared among a six-member Cabinet including the Prime Minister. Its largest island, Rarotonga has the capital, Avarua and most of the Cook Islands' population of 17,700 (2019).[399]

In common with the other Programme countries, Cook Islands' economic development is hindered by its isolation from foreign markets, the small size of domestic markets, its limited terrestrial natural resources, its periodic devastation by climate-related natural disasters, and its inadequate infrastructure. The Cook Islands Government is concerned about climate change impacts, such as coral bleaching and ocean health, the safety of local and international ships at sea, the health of coastal fisheries that support local livelihoods, and the risks and impacts of coastal inundation from storms, wave events, tsunami and sea level rise.

Lagoon circulation and health are critical concerns for tourism providers and pearl aquaculture, which are key drivers of economic growth. Tourism has brought significant revenue and development to both Rarotonga and Aitutaki—more than 120,000 tourists visited the islands each year between 2014 and 2017. Other sources of revenue are financial services, agricultural exports, fishing licences and remittances from relatives working overseas. Improved knowledge about and prediction of impacts is critical to increasing its resilience to climate change and natural disaster hazards, and to inform climate change adaptation measures.

The Cook Islands is divided into two distinct topographic groups of volcanic high islands and low-lying coral atolls. The northern group is geologically older and consists of six atolls whose elevation is one to two metres above mean sea level. The southern group is younger and includes several "high" islands, formed by volcanic action: the highest elevation point is Te Manga at 652 metres, on Rarotonga. Some of the islands are makatea, or raised atolls (like Niue), lifted by geological action. The combined land area of the 15 islands is 240 km^2 and an estimated 64% is forested.[400] The Cook Islands' exclusive economic zone of 1.976 million square kilometres was legislated in 2017 as a marine park, Marae Moana, to integrate its management and conservation, from ridge to reef and from reef to ocean.

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399 Government of Cook Islands, 2019, Vital Statistics and Population Estimates March Quarter 2019. This number includes non-permanent residents (tourists).

400 Central Intelligence Agency, available at <https://www.cia.gov/index.html> [August 2019].

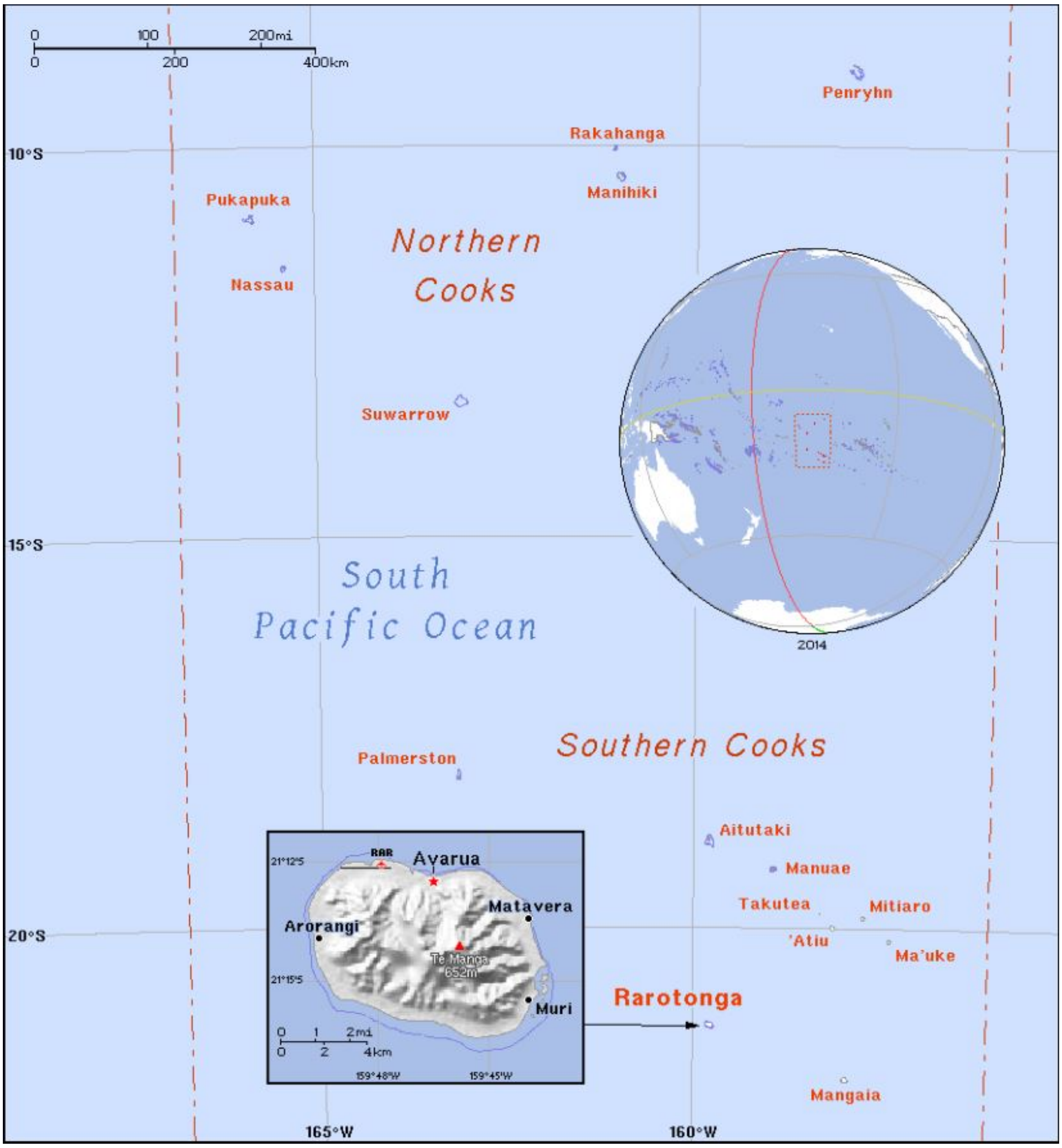

Figure 80. Map of Cook Islands (Source: Ian Macky[401])

The Cook Islands lie within the South Pacific Convergence Zone and have a tropical, mild maritime climate. The country has an average annual rainfall of 2000 mm with two thirds falling in the rainy season between November and April. The mean maximum temperature is 28°C and mean minimum 21°C, but during El Niño years the weather differs widely from the average. The Southern Cook Islands

[401] Ian Macky, 2013. Map of Cook Islands. Available at: https://ian.macky.net/pat/map/ck/ck_blu.gif

can have up to 60% less than average rainfall whereas the Northern Cook Islands can see an increase of 2300 mm (4300 mm in total).[402]

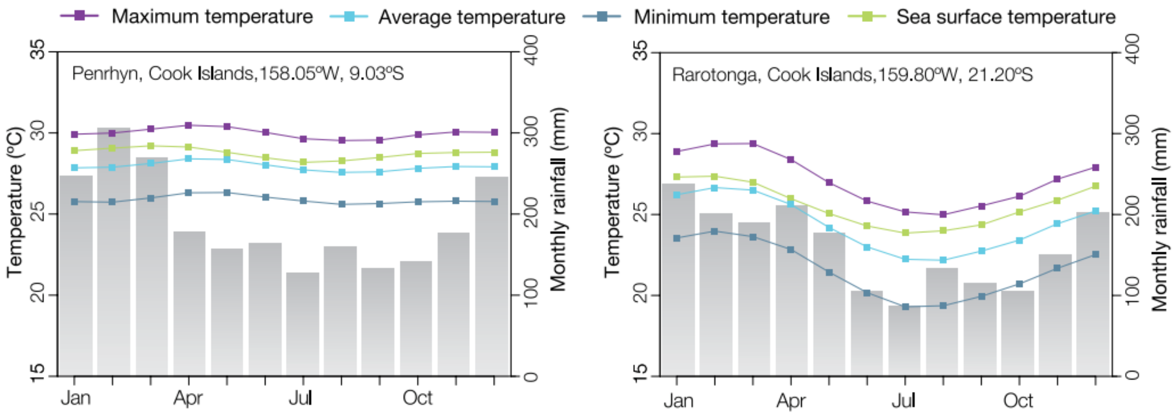

Figure 81. Seasonal rainfall and temperature at Penrhyn (in the North) and Rarotonga (in the south) (Source: PACSSAP, 2015)

Green Climate Fund

The Cook Islands was accredited to the Green Climate Fund as a Direct Access Entity (DAE) in 2018 and is able to submit projects directly to the GCF. In March 2019, the Government agreed a Country Programme with the GCF that captures the Government's prioritised strategy and approach to addressing climate change. The Country Programme "indicates NZD 203M … for projects covering a wide range of areas such as energy efficiency, renewable energy, building resilient infrastructure, coastal management and water resources, as well as boosting the involvement of the private sector."[403]

The Country Programme was developed as part of the GCF Readiness and Preparatory Support programme. It outlines the Cook Islands' priorities for achieving low emissions and climate resilient development and provides a roadmap for coherent engagement with development partners. The Country Programme aims to maximise financial opportunities and ensure that resources are directed efficiently towards national climate and development priorities.

The Country Programme builds on the Cook Islands' own climate and development strategies, including its National Sustainable Development Plan (NSDP) 2016–2020; its JNAP II–Are We Resilient? The Cook Islands 2nd Joint National Action Plan—A sectoral approach to Climate Change and Disaster Risk Management 2016–2020; the Cook Islands Renewable Energy Chart 2016–2020; the Intended Nationally Determined Contribution (INDC) 2015; the Second National Communication to the UNFCCC 2011; the Cook Islands National Infrastructure Investment Plan 2015–2025; individual Island Community Development Plans; the Cook Islands State of the Environment Report 2017; the Cook Islands National Biodiversity Strategy and Action Plan 2017–2021 and the Cook Islands Climate Change Policy 2018–28. It has been informed by the community, the public and private sectors, and nongovernment and civil society partners, through participatory approaches under the guidance of the National Designated Authority, the Climate Change Cook Islands division of the Office of the Prime Minister.[404]

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[402] Australian Government, 2015, Climate Change in the Pacific: Scientific Assessment and New Research Volume 2.
[403] Green Climate Fund, 2019, Cook Islands launches its first GCF country programme, available at <https://www.greenclimate.fund/news/cook-islands-launches-its-first-gcf-country-programme> [August 2019].
[404] Cook Islands, 2018, Cook Islands Climate Change Country Programme.

Current provision of climate services: strengths, priorities and barriers

The Cook Islands Meteorological Service (CIMS) is a division of the Ministry of Transport. It provides weather updates, forecasts and warnings in accordance with the requirements of the Meteorology Act 1995–96 and its obligations as a member of the World Meteorological Organization. CIMS issues a daily weather bulletin and a seven-day weather forecast (both provided by the Fiji Meteorological Service in its role as the Regional Specialised Meteorological Centre), a climate outlook for the next three months and tide charts.[405] Based upon local observations, climatology and local experience, CIMS staff provide additional interpretative details of the FMS weather bulletin and forecast to tourist operators, disaster management and other government agencies, and marine operators.[406]

CIMS has 11 established positions, nine of which are currently filled:

- Director – Arona Ngari;
- Senior Observers – Bates Manea, Nathan Tisam, Manea Maretapu;
- Observers – Mike, Piri, Tehira, Tino;
- IT/Engineering – Sam.

Types of climate products and services by national climate service provider	List in detail the activities being undertaken to fulfil	Requirements to improve your services
Number of Staff involved in climate Services 9	Synoptic and hourly reports, monthly climate summaries and seasonal and rainfall outlooks.	Back-ups and regular updates. Need to see products in graphical forms
Climate Observations 9	Reporting at 1800Z including outer island stations. Rainfall stations are also included.	Updating the network in the Cook Islands.
Climate Data Management 4	QMS and IT for maintaining the Database	Addressing some bugs in the current software
Interaction with Users 9	News media via newspaper, TV and social media	Newsletters and regular reports
Seasonal Climate Outlooks 2	Monthly regional discussions, tailor-made products for clients and media release on status of climate	Updates and translation to local language
Climate Monitoring 4	Temperature, Rainfall, SOI, Sea Level Rise, Drought, and seasonal normal.	Graphical products need to be derived and promoted.
Specialised climate products (Sectors) 2	Julian Oscillation, PDO, ENSO	Become part of the media promotion
Decadal Climate Prediction 2	PDO and Julian Oscillation	Linkages to national and regional issues
Long-term Climate Predictions 2	SLR	Proactive in the UNFCCC
Customised climate products 4	ENSO, SOI, Return periods	More tailor-made products. Some return periods derivation
Climate Application Tools 4	SCOPIC, ICU, POAMA, APEC CC	Sharing with national and regional users.

405 Government of Cook Islands, Cook Islands Meteorological Service, available at <www.met.gov.ck> [August 2019].
406 UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre

Table 28. Current capabilities and climate services provided by and requirements to improve climate services in Cook Islands (Source: PSS in-country consultations)

The CIMS Office is located close to the airport (Rarotonga International Airport). In the area of aviation, there is one staff member whose primary role is quality assurance of observational services to civil aviation. A competency assessment of the observers has been conducted but the Quality Management System (QMS) has not been formally completed. Aviation forecast products (up to 10 Terminal Aerodrome Forecasts – TAFs) are provided by Fiji Meteorological Service.[407]

Since 2018/19, with RESPAC funding, NIWA is enabling staff to produce prototype and operational data analysis products such as time series and maps (http://docs.niwa.co.nz/eco/CK/m/index.html). This work is a robust foundation on which improved climate products and services can be developed.

CIMS staff have advanced in their capacity to interpret and use meteorological data, largely through training provided by Australia's Pacific Islands Climate Prediction Project (PICPP) and Climate and Oceans Support Program in the Pacific (COSPPac). These two projects installed purpose-built software that enables meteorological service staff in all five countries (and nine others) to generate forecasts of the local climate 3 to 9 months ahead. The software—Seasonal Climate Outlook for Pacific Island Countries (SCOPIC)—uses each country's local data to generate a forecast statistically, focussing on expected rainfall and scalable down to the level of the weather station recording the data, if necessary. The data used in SCOPIC is drawn from a climate data management system called CliDE (Climate Data for the Environment) which ingests and archives digitised climate data and makes it available for manipulation and use in information products. The collection of local data allows the CIMS to monitor and report on Rarotonga's climate at local scale.

Over the ten years from 2009, PICPP and then COSPPac have mentored CIMS' climate officers in the use of SCOPIC to produce a monthly report on upcoming climate conditions and to evaluate the accuracy of their previous climate forecasts. During this time, the officers' confidence and accuracy has improved. This mentoring continues, now by the Pacific Regional Environment Programme (SPREP) climate officer, who manages a monthly conference call with up to 11 Pacific climate officers and the Australian Bureau of Meteorology (BOM). The CIMS climate officer discusses the calculation of his current climate forecast with the SPREP climate officer one to one ahead of the roundtable phone call. The group discussion then considers the forecasts across the region for the next few months and compares each country's previous predictions with the recorded data for those months. Confidence and accuracy continue to improve, and Australia continues to provide support to SPREP for the maintenance and further development of the software.

The Australian Government continues to support the monitoring of sea level rise and other climate data at the Port of Avatiu wharf. SPC maintains and provides access to the Pacific Ocean Portal originally developed by BOM through COSPPac: the Portal allows a user with limited internet access to select a location and a sector such as tourism, fisheries, and shipping, ask for ocean parameters such as sea temperature, wave heights, coral bleaching, currents, salinity and chlorophyll, and receive the information visualised as maps and diagrams. CIMS' data contributes to the Portal, which is one of the tools CIMS demonstrates to national stakeholders.

The Director of CIMS is working to strengthen its professional (i.e. university degree-educated) staffing. In 2017, CIMS had only one professional staff member, working in administration and management. The priority is to enhance research capability so that Cook Islands can benefit from collaboration with regional partners and the wider scientific community. The Director has expressed interest in recruiting two new staff, who would contribute to climate services, climate policy

[407] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre

development and review, development of in-house skill sets and strengthened coordination with clients on operational products from Fiji. Ideally, the staff would have master's degrees in meteorology and/or climate change. However, some of the roles could be carried out by Senior Meteorological Technicians to reduce impact on salary caps. At present, new technical recruits are trained on-the-job and participate in courses from FMS and others as they arise.[408]

CIMS experiences barriers to its effective delivery of essential services common to all five very small island countries, some of which this Programme will address collectively, adding to existing networking among the countries and achieving economies of scale, and some in a tailored country programme. Its vast ocean areas, the changing climatic conditions, the great dispersion of its islands—the distance between Rarotonga in the southern Cooks and Penrhyn in the northern group is nearly 1400km—and capacity constraints make it difficult for CIMS to put in place comprehensive and sustained climate information services. The economic value of climate information and its importance to human safety is not fully reflected in its national budget and there is limited potential for cost recovery for agrarian advice, infrastructure planning advice, public health early warnings or even essential aviation and maritime services.

Specialised services requiring highly trained staff are difficult for CIMS to sustain—qualified meteorologists are in demand in developed Pacific rim countries, which can offer higher pay, better professional development and other opportunities. Ageing and obsolete equipment and unreliable internet access add to CIMS' challenges.

CIMS has identified the following priorities: [409]

- Strengthened capacity of CIMS to collect and manage data and information on weather and climate variability—especially severe weather and natural hazard events and impacts;
- Capacity building and training;
- Developing GIS capabilities;
- Collecting information, data and traditional knowledge relevant to adaptive fishing and farming;
- Enhancing/extending the current observational network;
- Enhanced dissemination of products (local language, graphical products, newsletters, reports);
- Development of sector-specific information products.

With regards to capacity building and training, at the technical level the needs focus on improving sustainability and quality of existing services; maintenance and repair of equipment; and observations and network management. At the professional level, the needs focus on improving the capacity of staff to contribute to wider research projects; and improving climate services. At both levels, there is a need to strengthen knowledge and skills in communication and computing.[410]

CIMS also notes its need for information on its surrounding ocean. "As a natural regulator of the Earth's climate and cornerstone of the global climate system, the importance of the ocean can no longer be underestimated. From greater risk to coastal areas due to rising sea levels, strong winds, storms and cyclones, to food insecurity among island populations linked to declining marine resources,

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[408] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre

[409] UNDP, 2017. Identified in the UNDP proposal: Increasing the resilience of the Cook Islands through a comprehensive approach to climate information services and early warning systems.

[410] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre

an unhealthy ocean in a changing climate can yield great environmental, economic and social imbalances."[411]

The Cook Islands Meteorological Act 1995–96 refers to climatology but not to climate change and it does not include disaster management legislation—this is managed by Emergency Management Cook Islands (EMCI) within the Ministry of the Office of the Prime Minister, under the Disaster Risk Management Act 2007.[412]

In the Cook Islands, as elsewhere, climate change first emerged primarily as an environmental issue. The National Environmental Service (NES) was mandated as the lead institution in government, and its Director as the Operational Focal Point for the UNFCCC. NES is the lead agency for the implementation of regional and international treaties on the environment to which the Cook Islands is a party. The NES is also the point of contact for the Pacific Regional Environment Programme (SPREP), as well as for facilitating funding access through the Global Environment Facility (GEF).

In 2014, as a part of a restructure, the Climate Change Cook Islands (CCCI) portfolio and a renewable energy unit—the Renewable Energy Development Division—were relocated to the Office of the Prime Minister (OPM), with EMCI. EMCI has oversight and coordination responsibilities for disaster risk management activities in the Cook Islands. CIMS remains in the Ministry of Transport, reflecting its importance to shipping and air transport.

In 2013, the Cook Islands Government approved the Joint National Action Plan on Climate and Disaster Compatible Development (JNAP 2013–2016). The Policy is designed to ensure that the sustainable development of the Cook Islands is actively pursued through a climate and disaster resilient approach. In 2018, with support from the GCF Readiness Programme, CCCI prepared a specific national climate change policy that aims to ensure all stakeholders take actions to address climate change in a development context, particularly with regard to reducing greenhouse gas emissions, and building resilience to climate change impacts. The Climate Policy also outlined measures for mainstreaming climate change across government agencies and ministries, and indicated mitigation targets, such as 100% renewable energy by 2020–2025, and zero net emissions by 2030.

The activities proposed for this Programme address priorities identified by CIMS, CCCI, NES and EMCI, agencies that work together to improve the communication of accessible and useful climate information to the Government and people of the Cook Islands.

Disaster risk management

Emergency Management Cook Islands (EMCI) coordinates all DRM activities and provides policy advice to the National Disaster Risk Management Council (NDRMC), which is chaired by the Prime Minister. The National Disaster Risk and Climate Change Platform was formed in 2011 and comprises government, non-government and civil society organisation representatives. The Platform stakeholders meet quarterly to share information and discuss current and future climate change and disaster management related projects and initiatives in Cook Islands.[413]

Financing for climate services and disaster risk management

[411] United States of America, U.S. Climate Resilience Toolkit Storm Surge, available at <https://toolkit.climate.gov/topics/coastal/storm-surge> [August 2019].

[412] Government of the Cook Islands, 2011, Joint National Action Plan.

[413] Cook Islands, 2016. The Cook Islands Second Joint National Action Plan 2016-2020

The estimated climate change spending for the financial period 2016/17 – 2019/20 was 16% of total appropriation within the national budget. 7% was covered by the Government of Cook Islands, 6% by development partners and 3% by borrowings (loans). Total climate change finance equates to 9% of GDP.[414] The Cook Islands Disaster Emergency Trust Fund was initiated with a transfer of NZD 200,000 from the Government Reserve Trust Fund in the 2011/12 financial year. The Fund is limited to emergency response and early recovery activities and is not intended for longer-term recovery.[415] As of November 2016, the Fund had a balance of NZD 1.5 million (approximately USD 900,000).[416]

Previous national climate services and early warning activities

The Cook Islands has several climate change related projects under way or recently completed.

As part of the preparation for its 2011 **Second National Communication** to the UN Framework Convention on Climate Change, vulnerability and risk assessments were conducted on all islands in 2009. This baseline is in the process of being updated in preparation for the completion of the Third National Communication.

The GEF-funded **Ridge to Reef (R2R)** project (2012–2017) enhanced the Cook Islands' ability to manage effectively its key environmental sectors, such as marine resources, environment protection, tourism, and agriculture. The recently endorsed Marae Moana Act 2017 sets out an integrated management approach within the Cook Islands' total EEZ of nearly 2 million square kilometres. This innovative approach enables each of the 12 inhabited islands of the country to ensure there is no commercial fishing and resource exploitation with 50km of each island, allowing a focus on community and locally based fisheries and resource use, but also enables other resource uses outside of those zones, such as continued tuna fisheries, and the recent exploration of the sea bed for deep sea minerals.

In 2011 the Cook Islands conducted a pilot study with Asian Development Bank regional technical assistance which focused on developing and pilot-testing innovative, low-cost adaptation activities. Entitled '**Protecting Island Biodiversity and Traditional Culture in the Cook Islands through Community-Based Risk Management**', the pilot study in two villages in Aitutaki and two in Rarotonga built on the methodologies used by the Cook Islands Red Cross in conducting community-based vulnerability and adaptation assessments in villages around the country since 2003.

The pilot project field-tested a participatory approach that integrated local knowledge and engaged vulnerable communities in the formulation of adaptation plans. It developed practical tools, along with information and education, to ensure that the communities could analyse climate risk and decide on climate change adaptation and disaster risk reduction strategies. Project outcomes included community risk profiles, adaptation plans, and GIS-based community vulnerability and risk atlases. Activities in Result 3 will benefit from lessons learnt from the project.

Strengthening the Resilience of our Islands and our Communities to Climate Change (SRIC-CC: A UNDP Adaptation Fund project: 2012–2018) strengthened the ability of public services and communities to make informed decisions and manage climate change driven pressures in a pro-active, integrated and strategic manner at community levels. The project helped to implement the Cook Islands' first JNAP 2012–2016. Activities in Component 3 will build upon this earlier work.

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[414] Cook Islands, 2019. GCF Country Programme

[415] Government of Cook Islands, 2011. Policy Governing the Establishment and Operation of the Cook Islands Disaster Emergency Trust Fund (CI DE-TF)

[416] ADB, 2016. Proposed Policy-Based Loan Disaster Resilience Program (Cook Islands)

The Climate Change Cook Islands office within the Office of the Prime Minister is the National Designated Authority for interaction with the Green Climate Fund and since 2015 has been involved in strengthening capacities and knowledge on the GCF's processes and procedures, enabling the Cook Islands to access GCF resources directly. Building upon approved direct access to the Adaptation Fund, the Ministry of Finance and Economic Management (MFEM) was approved as a Direct Access Entity to the GCF in 2018. In August 2018, the **Pa Enua Action for Resilient Livelihoods (PEARL)** project, was funded by the Adaptation Fund, through MFEM. PEARL builds upon SRIC-CC experience and lessons learnt.

CCCI in partnership with MFEM is now about to implement its **4th Readiness Programme**, the GCF's first Health Sector Proposal under the Simplified Approval Process (SAP), the Pacific region's first Enhanced Direct Access (EDA) programme, and larger scale project developments related to Renewable Energy, Building Resilience in Infrastructure, Coastal Protection, Waste Management, and Water Security and Sanitation. The CCCI's other primary role is to ensure the country's national obligations to the UNFCCC (National Communications) and its Paris Agreement (NDCs/BURs, etc) are undertaken, completed, and submitted to the UN Secretariat.

SPREP's **Inform project** (Building National and Regional Capacity to Implement Multilateral Environmental Agreements by Strengthening Planning and the State of Environment Assessment and Reporting in the Pacific) is helping the Cook Islands (and 13 other countries) to acquire access to its own national datasets for environmental information. It is working with the Cook Islands to develop staff capacity to locate useful datasets, assess the quality of the data, manage its ingestion to the national environment data portal, and use the data in national planning and in reporting on multilateral environmental agreements. SPREP hosts the Cook Islands' national portal and a regional portal, and provides training, mentoring and support. Inform will be the foundation for the Cook Islands' climate data strategy.

The Cook Islands State of Environment (SoE) Report 2018 was officially approved by Cabinet on 6 March 2020. The SoE reports the status and trend of 24 environmental indicators across seven themes. The report presents the first integrated account of Cook Islands' natural resources since the publication of the first SoE in 1993. Data and information that formed the report were made possible through the collective effort of national stakeholders under the lead of the National Environmental Service, in partnership with SPREP, through the ACPMEA2 and Inform projects.

Alignment with national priorities

Te Kavienga Nui is the Cook Islands' National Sustainable Development Plan (NSDP) 2016–2020. Goal 5 (of eight) "Resilient and sustainable communities" has as its goal "Strengthen resilience to combat the impacts of climate change and natural disasters." The NSDP is well aligned with the country's regional and international commitments, including the Paris Agreement, which the Cook Islands signed in 2016.

The Joint National Action Plan II (JNAP II)—Are we resilient?: a sectoral approach to climate change and disaster risk management (2016–2020)[417] is a key national mechanism for harmonising disaster risk management and climate change adaptation in the Cook Islands. It seeks to minimise overlaps between the two, to promote strong cooperation, coordination and collaboration between stakeholders and to ensure that, with the assistance of the international community, the Cook Islands will undertake the necessary activities to safeguard its future by reducing and managing risks and

[417] Government of the Cook Islands, 2016, Joint National Action Plan II.

vulnerabilities as far as is humanly possible. The vision of the Cook Islands' JNAP II is a safe, resilient and sustainable Cook Islands. It contains Strategies, Actions and Sub-Actions across four key Strategic Areas: Governance, Monitoring, Disaster Management and Risk Reduction and Climate Change Adaptation.

The Cook Islands' Second National Communication to the UNFCCC reported several climate change adaptation needs and priorities to improve planning and decision making, including:

- Need to develop a NAPA–type document based on all vulnerability and adaptation assessments undertaken so far for all islands
- High resolution modelling of coastal and other processes required, and a complete GIS information system developed
- Comprehensive climate and risk information availability through research and assessments for all islands, to improve understanding of specific vulnerabilities and current and future resilience and to provide a basis for education and awareness
- Improved understanding of the impacts of climate change on specific target groups of the population, leading to informed policy making and improved provision of services
- Need for a national body to oversee climate change activities and a full-time national coordinator—partially implemented through the Sectoral and Institutional Strengthening Programme—to ensure a coordinated and wider network of government stakeholders are involved in climate policy development and project design and implementation
- Need to mainstream and integrate climate change in and across all sectors, resulting in an improved national response; includes greater integration of climate change in all planning and implementation, including socio-economic programmes and projects
- Capacity building on implementation of renewable energy technologies for longer term operation of these energy systems over current imported fossil fuels and diesel-powered energy;
- Address funding mechanisms and financial constraints, given that activities are mostly supported by external sources; recognize that financing of climate activities will suffer budget constraints in light of other development priorities;
- Ensure proactive engagement in the international climate negotiations so that obligations under UNFCCC are not excessively burdensome for small island developing states;
- Land tenure system impedes effective implementation of adaptation – e.g. lack of zoning and physical planning; use participatory approaches to address land issues that impede sustainable development, with due consideration of traditional tenure systems at national and local levels; and
- Address the lack of enforcement of climate change-related policies and regulations, including adaptation and mitigation—is this just an enforcement issue (e.g. poor enforcement of building codes), or is there a need for climate change-related legislation and regulations?

These priorities are consistent with those of the Cook Islands' GCF Country Programme, which highlighted how the Cook Islands aims to address climate change mitigation and adaptation, through the identification of 11 thematic areas. The final outcome of the Country Programme was the identification and prioritisation of a project pipeline to the GCF for financial and technical support. The Country Programme was prepared through extensive consultations with all islands, and was endorsed by Cabinet in 2018, along with the Climate Policy. This proposal and its activities will complement the Cook Islands Country Programme.

RESULT 1 – STRENGTHENED DELIVERY MODEL FOR CLIMATE INFORMATION SERVICES AND MHEWS COVERING OCEANS AND ISLANDS

Activity 1.1 Strengthen institutional and policy frameworks and delivery models for climate services

Under this Activity, the Programme will establish comprehensive institutional and policy frameworks and delivery models for strengthened climate services in Cook Islands. This will include the development of a National Framework for Climate Services (NFCS), which will be supported by effective coordination mechanisms to mainstream climate risk knowledge into the decision making of climate-sensitive sectors. Moreover, Cook Islands will conduct a climate services market assessment and develop a policy for sustainable financing and delivery of climate services. Amongst others, engagement with the development of national budgets will enable justification of the value of climate services, strengthen existing funding for disaster relief and contribute to the identification of long-term sources of funds.

C1.1.1 Develop the Cook Islands Framework for Climate Services

The Cook Islands Meteorology Act 1996 pre-dates the wide recognition of global warming as a major issue for Pacific island countries. It requires the CIMS to collect both weather and climate data but does not provide direction on making information available for use in developing well-informed adaptation to climate variability and change. CIMS does now provide such advice and is keen to develop its capacity to communicate it more effectively and to tailor its information to the needs of its end-users.

Throughout the implementation of this Programme, CIMS proposes to conduct a series of consultative workshops with stakeholders to develop and refine a National Framework for Climate Services (NFCS). In the first half of year one, CIMS will invite representatives of government agencies responsible for key sectors including the five Global Framework for Climate Services (GFCS) sectors—water, health, renewable energy, food security and agriculture, and disaster risk reduction—to take part in a 3-day workshop facilitated by local consultants. The workshop will begin with a presentation of basic climate science, an explanation of the kinds of data CIMS collects, and a presentation of the products and services their data has been used to create. Sectors will also be asked to present on how they currently use climate information and how they could extend their use. The workshop would begin the process of agreeing with these stakeholders more specific functions, relationships and services.

The consultants will use the outcomes of the first workshop to draft the NFCS, which will inform the future climate work of CIMS. Objectives will be to agree with key sectors a suite of directly applicable information products, with a process for checking their utility regularly and revising them when needed. In year five the NFCS will be re-evaluated using feedback and learnings from each sector over the previous four years.

C1.1.2 Conduct market assessment to explore viable opportunities for climate information services in sectors and business segments

This Sub-activity will support Cook Islands to understand its existing market for climate services and potential sustainable climate services models; and utilise a value chain approach to mobilise private sector finance in climate services delivery. In the longer term, this will support establishment of a foundation for a cycle of investment, service enhancement, research and development, and re-investment, which has already created commercial markets for climate services in developed countries.[418]

The Programme will conduct a detailed market assessment, which will assess the following:

- **Involved actors in climate services** – This include providers, intermediaries and users: i) Government agency/s (including CIMS) responsible for the operation of the national meteorological infrastructure and provision of public weather and climate services; ii) Academic (university) research community; iii) Media entities; iv) Private sector and other providers; and v) Users, which consists of the general public, as the users of basic services, and the economic and social sectors and organisations as the users of specialised, tailored services.[419]
- **Regulatory environment** – Analysis of the current regulatory environment for climate information and early warning services in Cook Islands and subsequent identification of policy incentives to unlock barriers to private sector investment;
- **Supply and demand analysis** – Identification of country-relevant sector and business needs for climate services (for example, level of information, scales and access required);
- **Private sector engagement** – Building on the analysis of supply and demand, the Programme will support CIMS to engage with the private sector – including through the National Climate Outlook Forums (Sub-activity 1.1.3) – to identify private sector sponsors' interest in the generation, translation and transfer function and in purchasing climate-related information.
- **Business models** – Analysis of business models for climate services that are successful in other countries, with a focus on Small Island Developing States (SIDS). This will include case studies on private sector company provision of climate services as well as government-led initiatives.

Based on the above analysis, the Programme will support Cook Islands to identify opportunities to develop value-added climate products and services; and potential for public-private partnerships and private sector investment in climate services. Private sector engagement will improve the cost-effectiveness of CIMS and increase potential for catalysing innovation in climate information technologies. This Activity will also inform development of the national policy for financing climate services in Sub-activity 1.1.4.

C1.1.3 Mainstream climate risk knowledge into sectors

National Climate Outlook Forum

In the second half of the year, CIMS will run a National Climate Outlook Forum (NCOF) before the onset of the cyclone season (October/November for Cook Islands) and after the Pacific Islands Climate Outlook Forum (PICOF).

The participants in the earlier workshop (for government agency officers) will be better prepared to understand the Outlook and how it supports specific sectoral advice. The NCOF will be fine-tuned in response to the contributions of workshop participants, as they explain how they use CIMS's advice.

In years two, three and four, CIMS will hold similar 2-day workshops successively with the private sector, NGOs and communities to articulate what information they want from their meteorological service and the formats in which it will be most useful to them. On the second day of these workshops, CIMS will run that year's NCOF for all stakeholders. This will encourage wide communication of the

[418] SAID, 2018. Climate Information Services Market Assessment and Business Model Review
[419] WMO, 2015. WMO-No. 1153. Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services

outlook for the upcoming cyclone season and for growing conditions to all Cook Islands communities. It will provide an annual opportunity for sectors to articulate their priorities and preferences for delivery of climate information throughout the year.

In year five, the NCOF will be presented to all stakeholders as usual, after the NFCS review workshop. CIMS will explain how its data should be used in planning climate-proof infrastructure, preparing for extremes of rainfall and drought, delivering timely disaster warnings and informing the Cook Islands' advocacy in international forums.

Climate Information Services Sector Action and Communication Plan

In the first half of the second year of the Programme, CIMS will engage an international and a national consultant to facilitate a workshop with stakeholders from government agencies and community representatives to identify sector specific priorities and actions for climate information services, targeting five key climate-sensitive sectors. The workshop will further develop the ideas about the information needs of specific sectors gained from the NFCS. It will also consider, with sector representatives, how climate information and risk knowledge can be mainstreamed into their work and applied in their decision-making.

The consultants will use the outcomes of the workshop to draft a Climate Information Services Sector Action Plan and a Communication Plan for an agreed number of important sectors. The plans must address sector-specific needs for information services relating to both disaster risk reduction and management, and effective climate change adaptation.

The Plans will document an agreed process for testing the best ways of regularly communicating climate information to sectors. This will include both finding ways to make information easily accessible and exploring potential methods of improving the understanding of climate information by all workers in a sector, and by the users of that sector's own services.

This is likely to include a range of activities, such as improving CIMS's use of social media, but to begin with a program of capacity building in understanding climate and weather information for government workers. The sector communication plans will be tailored to the specific interests and needs of each sector and will cover basic climate science, an explanation of the kinds of data the CIMS collects, and a presentation of the products and services it provides. It should include support to the sector in communicating climate information within the sector, and to the sector's clients and end users.

Sector-Specific Climate Training Programme

The Climate Information Services (CIS) Sector Action Plans for Cook Islands will guide sector-specific climate training for the five sectors identified in the action plans: these may include fisheries, tourism, water, health, renewable energy, food security and agriculture, and disaster risk reduction.

CIMS will engage an international and a national consultant in the second half of the second year to develop a training programme, with guidance materials and capacity building resources, to facilitate the uptake of climate information services by the targeted sectors and their stakeholders. The training will be non-technical and directly relevant to each sector and applicable to its activities. This intervention is replicating an activity implemented by a GCF funded Climate Information Services for Resilient Development Project in Vanuatu.[420]

The consultants will conduct a CIS training needs assessment with CIMS, and based on the assessment, will use existing and new CIS information to develop a tailored training programme. The Training

[420] SPREP, 2018, Climate Information Services for Resilient Development in Vanuatu. The Project has a Bislama name, "Vanuatu Klaemet Infomesen blong Redy, Adapt mo Protekt (Van-KIRAP)".

Programme will be in line with the Cook Islands Framework for Climate Services (NFCS), the Pacific Island Meteorological Strategy (PIMS) 2017–2026 and the Pacific Roadmap for Strengthened Climate Services.

In year five the sector plans and the communication plans will be re-evaluated and updated using feedback and learnings from each sector.

Train the Trainer for Sectors

CIMS will engage an international consultant to demonstrate the use of the CIS training programme through facilitating Train the Trainer sessions for sector personnel, non-governmental organisations (NGOs) and CIMS. The training will use sector-specific case studies.

Five workshops will run in the third and fourth year, each targeting a different sector. There will be an opportunity to update the training programme after each workshop.

Climate vulnerability and risk assessment to support national infrastructure

Cook Islands is under pressure to develop effective infrastructure and associated support activities in the face of an increasingly changing climate. A combination of severe weather events, mainly intense rainfall periods, droughts and flooding, will increase the vulnerability of the country's infrastructure and associated support services. These climate challenges are recognised by the Government and articulated in the National Infrastructure Investment Plan 2015 (NIIP) as a need for "detailed assessments for those proposed priority projects most susceptible to climate change and natural hazards in order to identify potential adaptation measures (and incremental costs of them) to mitigate impacts and increase their resilience." The plan outlines a range of priority projects in climate sensitive sectors, such as water, renewable energy, ports and airports, and for social assets such as schools and hospitals.

Under the original NIIP climate change risk of each of the identified priority projects was assessed and it was assigned a high, medium, or low risk score, as part of a cursory climate impacts rating. The process of priority setting did not include the application of either climate modelling or related quantified risk assessment techniques. The probable timing of changes in the risk profile was not included—that is, whether the asset is currently at unacceptable risk, or whether its risk is likely to increase by 2030, 2050 or 2100 to unacceptable levels. Nor was staged adaptation considered as an option for increasing resilience, reducing risk and being fiscally responsible. There is a clear need for a comprehensive and detailed infrastructural climate change vulnerability assessment to update the vulnerability index of each project. This process would make a major improvement to the initial NIIP reporting.

In addition to a vulnerability assessment, the Government of Cook Islands plans to conduct a detailed economic assessment of the incremental cost of climate change with a temporal risk component, as required by lending institutions, with the help of the University of Waikato. Currently, the NIIP has only attached arbitrary economic value (costs) on the economic cost of climate change to these projects. This activity will require the estimation of current capital costs, climate proofing costs and the cost of infrastructural damage in the absence of adaptation and climate proofing. The objective of the activity is to develop a detailed risk and economic assessment of the incremental cost of climate change in Cook Islands, to inform the updating of the NIIP and to build local capacity on the methodological approaches used in the assessment.

C1.1.4 Develop national policies for financing climate services

This Sub-activity will provide the foundation for the establishment of a financially sustainable business model for climate services in Cook Islands. Based on the NFCS established under Sub-activity 1.1.1, the Programme will develop a national climate services financial policy to ensure that CIMS has the means to sustain and ensure the ongoing operation of its mandated services in order to mitigate weather-, climate-, and water-related risks.[421]

The financial policy will be carefully developed with the support of the World Meteorological Organization (WMO) to ensure that it is tailored to the context of Cook Islands. In line with World Bank guidance,[422] the financial policy will cover the following elements:

- Opportunities for greater cooperation between the public and private sectors and academia given that many economic sectors increasingly depend on meteorological information for safe and efficient operations.
- Opportunities for win-win situations that fulfil the public sector responsibility to help the economically disadvantaged while meeting the needs of enterprises for climate services. To this end, the Programme will ensure that the Government of Cook Islands is made aware of the economic value of climate information in, for instance, reducing the need for dangerous marine rescues, reducing the need for transport of drinking water to outer islands in drought, and reducing the costs of recovery from cyclone damage.
- Opportunities to coordinate and/or integrate financing for climate services and disaster risk management to strengthen existing disaster relief funds and establish reliable funding for disaster preparedness activities, which are often limited to ad-hoc donor funding. This would facilitate a more efficient and streamlined approach to implementing often overlapping actions for climate change adaptation and disaster risk management.
- Identification of elements for a sustainable financial model for CIMS based on the climate services value chain, which highlights the different roles of NMHSs in providing basic forecasts and warnings to protect society from the adverse effects of severe weather (a public good typically supported by governments) but also in providing specialised value-added services to government agencies and individual businesses (which may offer opportunities for cost-recovery from governmental and non-governmental sources).
- Potential to establish a National Climate Fund (NCF) as a mechanism to support Cook Islands' engagement with climate finance by facilitating the collection, blending, coordination of, and accounting for climate finance directed towards climate services.[423] According to UNDP guidance,[424] these funds could have the following goals:
  - Collect sources of funds and direct them toward climate change activities that promote national priorities;
  - Blend finance from public, private, multilateral and bilateral sources to maximise a country's ability to advance national climate priorities;
  - Coordinate country-wide climate change activities to ensure that climate change priorities are effectively implemented; and
  - Strengthen capacities for national ownership and management of climate finance, including for "direct access" to funds.

[421] World Bank, 2013. Weather and Climate Resilience. Effective Preparedness through National Meteorological and Hydrological Services
[422] Ibid.
[423] UNDP, 2015. Blending Climate Finance Through National Climate Funds.
[424] Ibid.

Functions of NCFs could include:

- Support goal setting and the development of programmatic strategies for climate resilience;
- Fund capitalisation;
- Management of partnerships;
- Provide project approval and support implementation;
- Supply policy assurance;
- Provide financial control;
- Manage performance measurement, including monitoring and reporting on activities and resource disbursement; and
- Provide and support knowledge and information management.

- Potential for continued support from the Systematic Observations Financing Facility (SOFF) as part of the Alliance for Hydromet Development, which was launched in December 2019 by 12 international organizations including UNEP. The SOFF is envisaged to ensure provision of basic systematic observations as a global public good by providing equitable, predictable, sustainable, and performance-based finance as well as technical assistance to developing countries for the provision of foundational observational data as per the Global Basic Observing Network (GBON) standard adopted by the WMO Congress in 2019. GBON aims to improve the global availability of the most essential surface-based data by defining the obligation for countries to implement a minimal set of surface-based observations for which international exchange of observational data will be mandatory.

RESULT 2 – STRENGTHENED OBSERVATIONS, MONITORING, MODELLING AND PREDICTION OF CLIMATE AND ITS IMPACTS ON OCEAN AREAS AND ISLANDS

Activity 2.1 Enhance infrastructure and technical support for observations and monitoring

C2.1.1 Enhance national observations and monitoring networks to GBON standards and establish QMSs

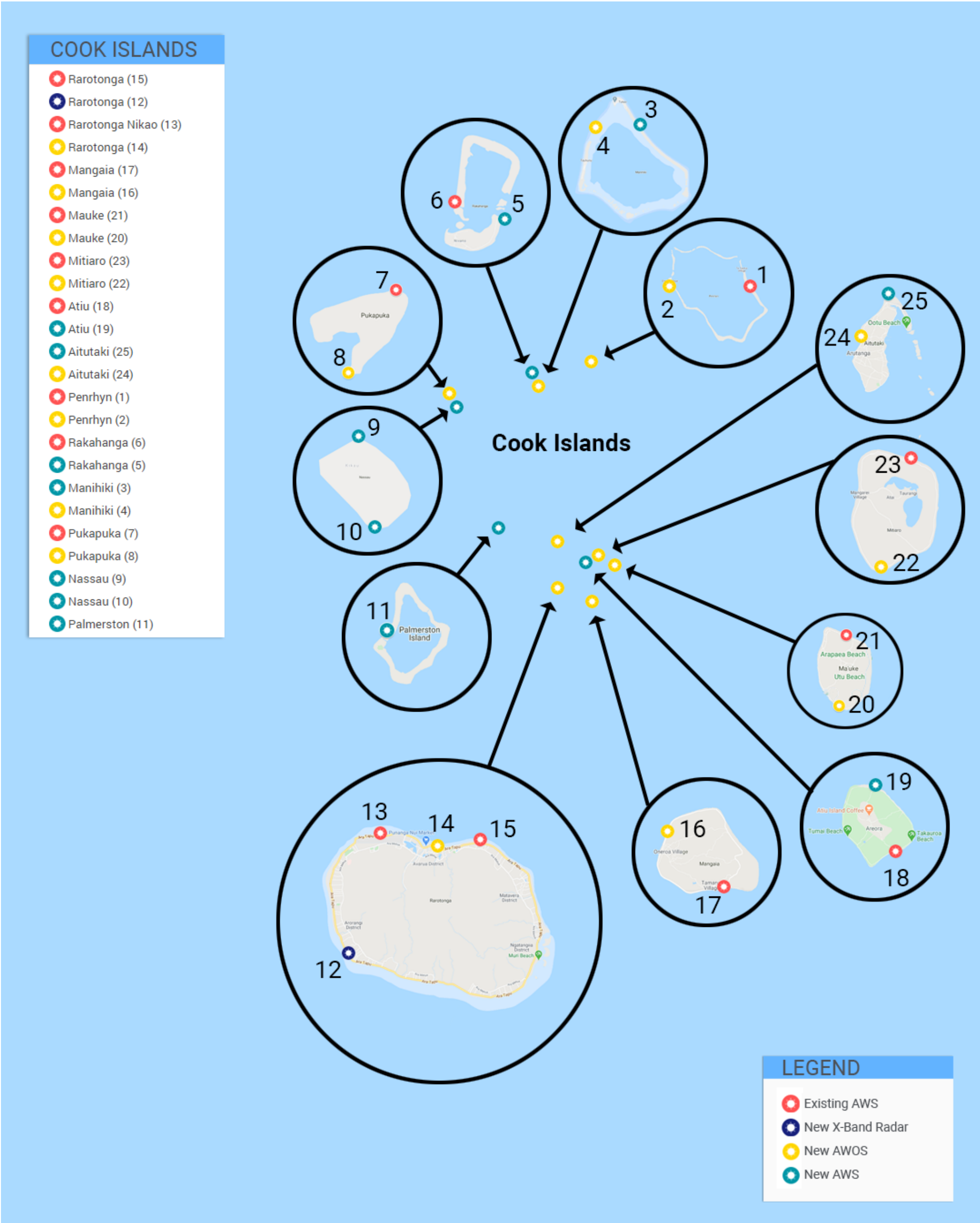
Strengthen the network of land-based observations and improve observation station density in compliance with GBON

The Programme will procure equipment to strengthen the network of land-based observation stations measuring atmospheric pressure, temperature, humidity, horizontal wind and precipitation and regular reporting of data in compliance with the provisions of the WMO Global Basic Observing Network (GBON). WMO have proposed a target number of 50 observation points across the EEZ of Cook Islands.[425] The Programme will facilitate observations through a mix of surface-based, upper air and marine observations. Critically, funding will be supplied for communications to ensure that observations can be made available via GTS to WMO, in compliance with GBON.

[425] SOFF, 2020. Systematic Observations Financing Facility. Collaborative thinking workshop. Workshop outcomes and the way ahead. February 25-26 2020, Offenbach, Germany

Installation of four AWS and nine AWOS stations

The Programme will install four new/upgraded Automatic Weather Stations (AWS), located at Atiu, Rakahanga, Nassau and Palmerston, with sensors for rainfall, air temperature, barometric pressure, wind speed and direction, soil temperature (10, 20, 30 cm) and soil moisture. The stations will contain all-parameter local Modbus Meteorological Display Consoles (MMDC) including METAR/SYNOP coded message display. In addition, nine Automated Weather Observing Systems (AWOS) will be installed/upgraded at Rarotonga, Mangaia, Mauke, Mitiaro, Aitutaki, Penrhyn, Manihiki, Pukapuka and Nassau. Each AWOS station will contain AWS sensors (as above) as well as a ceilometer and visibility meter.[426]



[426] These are the proposed sites under the current baseline and to support GBON. Given the dynamic nature of projects in the Pacific, these sites will be reconfirmed during each year of implementation and should site locations require changes, this will be done within the context of GBON and within the current budget.

Figure 82. Proposed surface land-based observations network for Cook Islands

Consumables for land-based upper air observations

Remote sensing data expands and complements conventional observations and enables observations at local and regional scales. Cook Islands uses satellite data but realises that investment in maintaining its national in-situ measurements is essential and expanding its observation network to cover its ocean areas.[427] While observing sites for both ground and upper air data have been established over the years, many are no longer functioning. The reasons include obsolescence, unavailability of trained observing staff, lack of technical and financial capacity for equipment maintenance and replacement, and the ongoing need to fund the supply of consumables.[428] Limited internet access and unreliable electrical power systems hamper communications and CIMS' ability to document the extent, rate and intensity of local climate fluctuations and overall change is compromised.[429]

The Programme will supply CIMS with upper air land-based consumables – radiosondes and balloons – to facilitate that Cook Islands can collect, contribute and use data from its network. In addition, the Programme will procure a DigiCORA® Sounding System, which simplifies daily synoptic observation by receiving, processing and forwarding meteorological information surely and securely. The system gives meteorologists comfortable control over the sounding process by integrating sounding controls, archiving the sounding data, and meteorological message creation. For routine soundings the system offers a variety of features and allows the desired balance of manual versus automatic control. In addition to the traditional alphanumeric messages, the system software produces the WMO specified Binary Universal Form for the Representation of meteorological data (BUFR) messages.[430]

In support of both global climate monitoring and Numerical Weather Prediction, and as recommended by the WMO,[431] CIMS would also like to install hydrogen proton generation and storage equipment at its Rarotonga station, which is part of the Global Climate Observing System (GCOS) Upper Air Network (GUAN) and has budgeted for staff training in operation and maintenance. The proposed DigiCORA receiver, with the supply of consumables, will enable CIMS to provide an effective horizontal resolution for global weather and climate models. The proposed tools, equipment and spares will enable CIMS staff to manage on-going maintenance.

Refurbishment of the CIMS Office

The proposed refurbishment of the CIMS office in Rarotonga will install UK Met Office Weather Package software; and updated hardware such as computers capable of running software that will make climate information more accessible to non-scientifically trained audiences. The building's electrical wiring will be replaced, and the office's essential outputs will be safeguarded by renewable emergency installation through the addition of solar panels. Solar panels will facilitate a more reliable power supply and reduce dependence on imported diesel.

The proposed items are: solar panel installation; furniture including desks, chairs, tables, filing cabinets, and air conditioners; UK Met Office Weather Package software; hardware including a printer, TV monitors and computers; and protective clothing.

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[427] WMO, 2017, Enhancing Early Warning Systems to build greater resilience to hydrometeorological hazards in Pacific Small Island Developing States: Draft Feasibility Study.

[428] Consumables are disposable or non-recoverable items used routinely in observing programs, and typically include such items as balloons and radiosondes.

[429] WMO, 2017, Enhancing Early Warning Systems to build greater resilience to hydrometeorological hazards in Pacific Small Island Developing States: Draft Feasibility Study.

[430] WMO, 1991, a Guide to the Code from FM-94 BUFR.

[431] WMO categorises the Cook Islands as a remote and data sparse region, making its contribution particularly valuable.

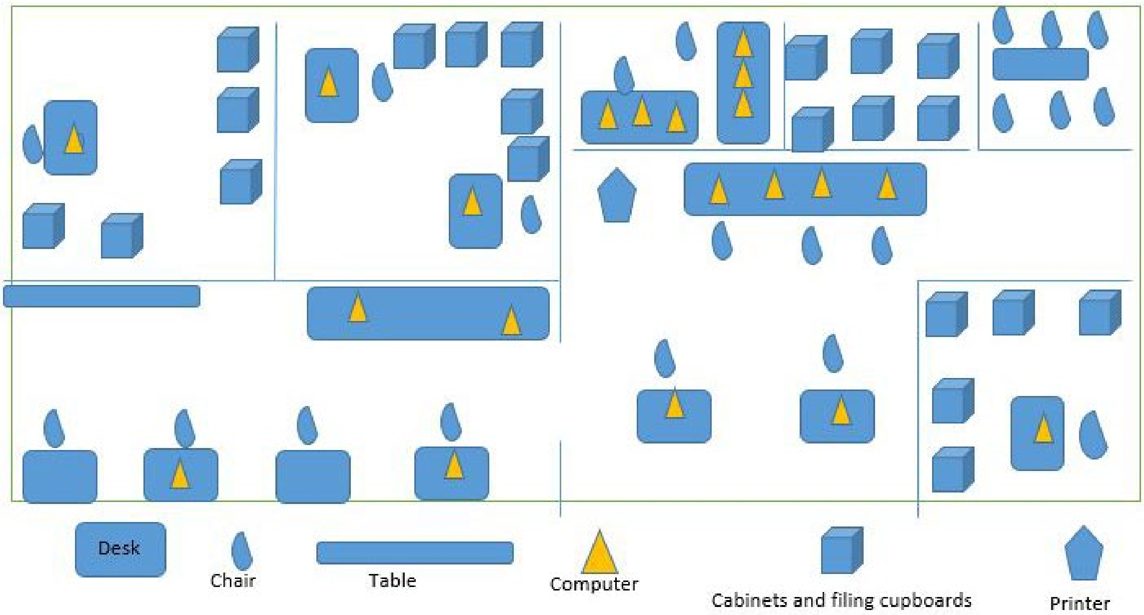

Figure 83. Cook Islands Refurbishment Plan (Source: Cook Islands Meteorological Services)

Installation of a dual-polarization X-band Doppler radar

The Programme will install a dual-polarization X-band Doppler radar at Rarotonga. Dual-polarization radars obtain information on both the horizontal and vertical dimensions of precipitation particles, which gives meteorologists a better understanding of the size and shape of particles. The advantages of dual polarization include:

- Improved accuracy of precipitation estimates, leading to better flash flood determination;
- Ability to differentiate between differentiate between different types of precipitation;
- Improved detection of non-meteorological echoes (e.g. tornado debris, birds, etc.);
- Detection of aircraft icing conditions.[432]

A Doppler radar is capable of measuring the velocity of precipitation particles (and thus, the wind). This enables Doppler radars to identify the detailed wind structure within severe thunderstorms.

The choice of an X-band system is on account of its low cost – in comparison to S or C band systems – and its small size, with potential for portable options. This is particularly important for the Pacific SIDS, which may have complex topography that limits accessibility for larger systems.

In addition to infrastructure, the Programme will provide technical training (Sub-activity 4.1.2) to build in-country capacity for radar operations, maintenance and data applications for weather and climate monitoring and analyses.

Compliance with the WMO Integrated Global Observing System (WIGOS)

Local technical consultants to maintain Automatic Weather Stations (AWSs)

Over the last year, CIMS has increased its deployment of automatic weather stations (AWSs) from one to 11, with the support of the Global Environment Facility, the Russian Government through the

[432] National Weather Service. Dual Polarization Radar. Available at: https://www.weather.gov/bmx/radar_dualpol

Disaster Resilience for Pacific SIDS project and in collaboration with the United Nations Development Programme (UNDP) and New Zealand's National Institute for Water and Atmosphere (NIWA). There is only one trained technician to implement the demanding schedule of regular calibration and maintenance the AWSs require and the technician has no backup. CIMS proposes to recruit and train two additional local technical consultants who will conduct yearly maintenance of the AWSs in the northern and southern Cook Islands.

Support for observation equipment operations and maintenance

NIWA has developed and supplied AWS equipment to many Pacific island countries over the past 2 – 3 decades, gaining significant experience in the design, durability, and maintenance of climate monitoring and data management systems deployed in tropical marine environments with limited technical backup. NIWA provides a low-cost backup of all AWS data, a real time visualisation service, training, and coaching support for NMHS staff.

NIWA has installed 11 AWSs in Cook Islands for different projects but no spares were provided. Through this Programme, NIWA will supply eight complete sets of climate sensors, measuring:

- Wind speed and direction, relative humidity, air temperature, barometric pressure;
- Hydrological services rain gauge;
- LiCor solar radiation;
- Unidata grass and earth temperature;
- Acclima soil moisture; and
- Decagon leaf wetness.

NIWA will also provide a complete maintenance kit for field site inspection of Cook Islands' existing automated weather stations and a bench-top instrument calibration kit. It will work with CIMS to develop a maintenance plan for its in-situ equipment and agreements for sustaining the equipment beyond the term of this Programme.

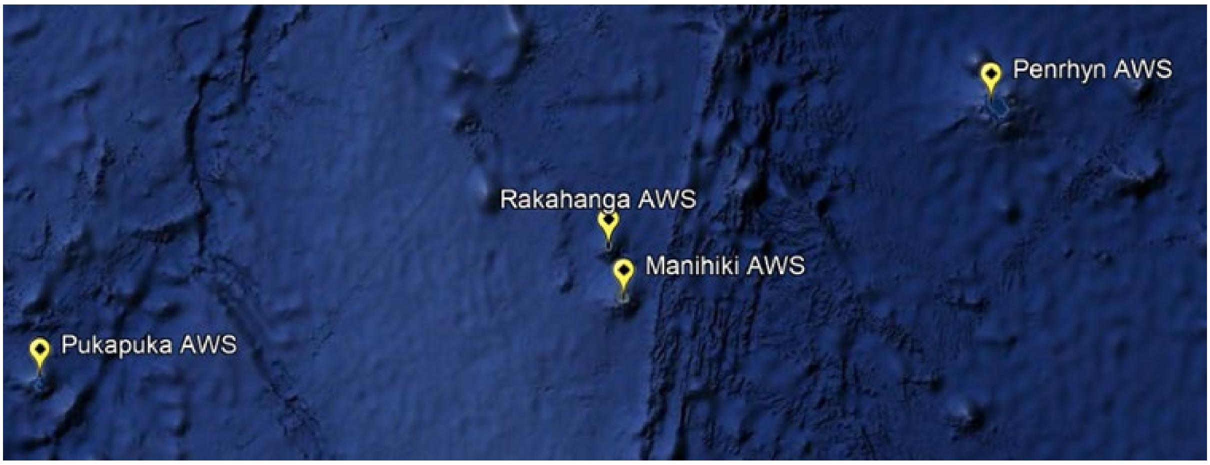

Figure 84. AWSs in Northern Cook Islands

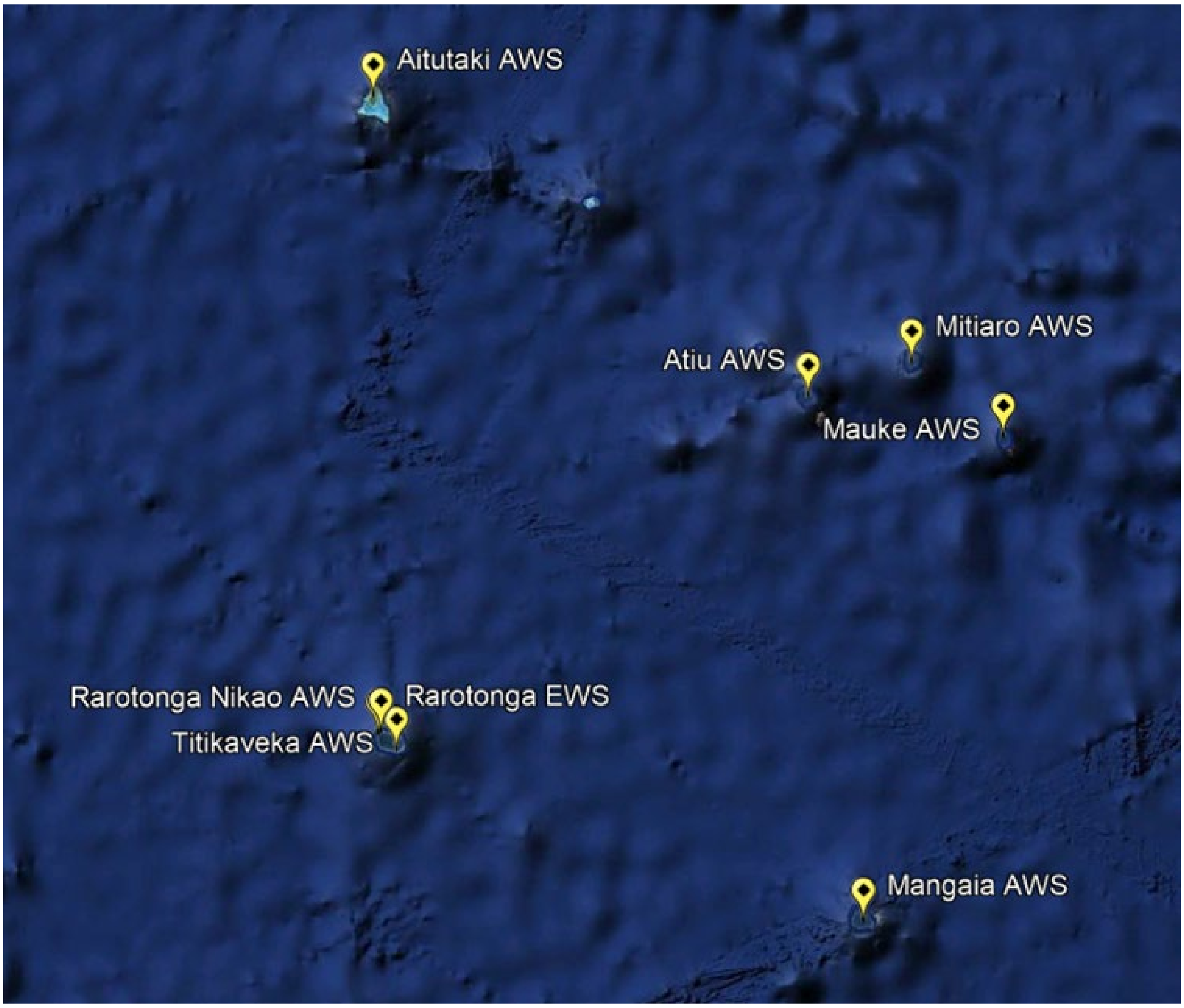

Figure 85. AWSs in Southern Cook Islands

Quality Management System (QMS)

The CIMS will establish a QMS to help to enhance the quality of its activities, including streamlining and optimising the processes and procedures applied and the products and services provided. CIMS will aim to obtain certification of compliance with relevant ISO standards.[433] Cook Islands has a close relationship with New Zealand's NMS, who will be fully engaged in the QMS process. CIMS staff will engage with experts from the WMO network and participate in training and an annual QMS workshop.

Activity 2.2 Strengthen ocean and climate modelling and impact-based forecasting

C2.2.1 Establish ocean information services

The Pacific Community (SPC) is the principal scientific and technical organisation in the Pacific region, supporting development since 1947. One of the key objectives of its Geoscience, Energy and Maritime (GEM) Division is to strengthen ocean and coastal monitoring and prediction services in Pacific island countries and territories.

[433] https://library.wmo.int/doc_num.php?explnum_id=4141.

SPC is currently implementing several projects and methodologies relevant to this proposal. The GEM team has conducted related studies in recent years and maintains high technical capabilities that will support delivery of proposed activities. In the Cook Islands, SPC has recently worked with the Marine Resources Department to develop circulation models for Muri Lagoon and Aitutaki to support decision-making on the potential effects of dredging, widening of a channel, and coastal development.

SPC is a key implementing partner in the Australian-funded Climate and Oceans Support Program in the Pacific managed by the Bureau of Meteorology, and specifically serves as host to the region's oceanographic capacity building and technical training hub, home to the Pacific Ocean Portal and several marine meteorology training tools. Since 2016, SPC staff have conducted training in the Cook Islands on introductory ocean science, ocean monitoring, and the application of ocean data and forecasts for improved decision-making. SPC has supported stakeholder engagement workshops to facilitate feedback to CIMS from potential users in fisheries, tourism, environment, national disaster management, maritime police, shipping companies, and others. The lessons learned from these workshops inform future engagement with key ocean stakeholders and communities.

Ocean observations and monitoring

Unmanned surface vehicle (USV)

Cook Islands' EEZ of 1.975 million square kilometres is a multiple-use marine park – the Marae Moana. The establishment of Marae Moana is the result of many years of planning and consultation with Cook Islanders to ensure that all residents feel ownership over the decisions made in the marine park. The Government of Cook Islands plans to map Marae Moana thoroughly, and once a baseline of data has been established, to divide the park into zones with designated uses including fishing, seabed exploration, pearl farming and other industry uses in addition to marine protected zones. The plan takes a holistic approach, providing a broad framework for the sustainable use and conservation of the Cook Islands' marine resources.

Climate Change Cook Islands (CCCI) proposes that an unmanned surface vehicle (USV) be used to provide baseline measurements to inform the integrated management plan for Marae Moana. CCCI would determine the area to be surveyed and would purchase the data from the survey, not the USV itself. The deployment will gather ocean data relevant to climate and weather forecasting, long term climate observation, bathymetry, fisheries and transport. This proposal covers the first year pilot mission, which would serve as the first step in the establishment of a long-term ecosystem monitoring programme.

The 7 metre USV's movement is powered by wind and its instruments by solar power. USVs have acquired invaluable information on the behaviour of the Southern Oscillation in the equatorial Pacific.[434] USVs are augmenting data available from the grid of buoys installed by NOAA in the 1980s—the Tropical Atmosphere Ocean (TAO) array—which have become very difficult to maintain. The buoys, anchored to the ocean floor, accrete marine growths, so they act as fish aggregation devices and they are frequently damaged as fishermen move them to reach the fish.

The pilot mission would take consistent and real-time measurements of the physical, biological, chemical and landscape variables of the Cook Islands' aquatic ecosystems, enabling scientists and ocean managers to quantify ecosystem integrity, bio-diversity impact and changes in marine ecosystems over time. It would create an expanded meteorological, oceanographic and acoustic dataset that complements and adds value to any existing regional and local surveying and monitoring.

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[434] NOAA, Ocean Climate Stations, available at <https://www.pmel.noaa.gov/ocs/saildrone> [August 2019].

The USV's capacity to collect carbon saturation, current / circulation and bathymetric data is of particular interest to CIMS's work on climate resilience. Its ability to contribute to satellite calibration is a bonus. The USV would deliver high resolution data in real time and raw data after the mission. CIMS would require the data to be delivered in a form that can be ingested to the Cook Islands Climate Data Portal (hosted by SPREP). The Portal allows different levels of access and CIMS would be able to provide access to regional organisations or donors to help create products from the data. SPC's Pacific Ocean Portal would be able to draw upon the dataset—this has potential to greatly extend the area for which visualised information can be created by the Portal, showing ocean climate and conditions across the Marae Moana. This in turn would make it possible to improve the prediction of extreme climate events arising from ocean processes.

Observation equipment on inter-island ships

NIWA will install automated weather stations on four inter-island shipping vessels so they can report regularly on the weather in open waters. The equipment will include data logging and transmission. The additional data will improve the forecasting of weather events for Rarotonga and the Southern Cook Islands. The equipment will be compatible with the international Voluntary Observing Ship Scheme (VOS) and the international Convention on Safety of Life at Sea (SOLAS). It will measure atmospheric pressure, wind speed and direction, air temperature, sea surface temperature and wave height. The equipment budget includes provision for spares.

All the shipboard observations will be transmitted to the Global Telecommunication System (GTS)/ WMO Information System (WIS) through authorised channels and the data will be integrated with satellite communications and operational initialisation and monitoring.

NIWA technical staff will support equipment maintenance for four years and training for both the on-board crew and CIMS technical staff on operations and maintenance. The first training will be for at least two weeks and for at least one trainee per vessel. It will include technical and training documentation. NIWA will provide a one-week refresher training course in Years 3, 4 and 5. The training is designed to ensure CIMS technical staff can support Vessel AWS maintenance beyond the Programme.

Environmental and wave buoys

SPC will support the establishment of medium to long term in-situ ocean observation environmental buoys and wave buoys providing data on currents, waves and water quality directly to CIMS. These will make possible routine ocean monitoring and in-situ coral mapping. Baseline monitoring via regular (and post-disaster) drone surveys will allow shoreline changes and erosion to be recorded and analysed.

Once monitoring sites are established, SPC will link this data to calibrate satellite derived ocean observations, improving understanding of local impacts and establishing proxy relationships between ocean drivers and coastal impacts for algal blooms and other monitoring priorities. This monitoring equipment will improve downscaled ocean forecast models for all the Cook Islands.

Ocean information services

Development of an ocean modelling framework to inform risk-based planning and early warning

Coastal ocean processes are driven by large-scale oceanic and atmospheric conditions, such as atmospheric pressure and sea surface temperature. With support from SPC, the Programme will develop an ocean modelling framework, which will link these large-scale regional drivers to local (island to lagoon scale) impacts. The framework will provide Cook Islands with state-of-the-art coastal oceanography and hazard data. This will inform improved local risk-knowledge and impact-based early warning (e.g. annual, monthly, and intra-daily).

The development of this framework requires a three-step methodology:

1. Analysis of long-term large-scale ocean and atmospheric data to map their spatial and temporal variabilities and identify annual, monthly and daily predictors that drive localised ocean conditions and their impacts.
2. Statistical and dynamic downscaling of localised ocean information based on individual country needs and priorities. For example, the Programme will develop downscaled wave, circulation and inundation models at country, island and lagoon scales.
3. Establishment of a long term integrated ocean and coastal impact monitoring program combining remote sensing and in-situ ocean and coastal impact data collection and analysis. The monitoring program will be tailored around the local impacts either directly or via a proxy indicator (for example, turbidity, chlorophyll, inundation, erosion information). The monitoring information will be used to refine downscaled solutions.

The following table provides further details on proposed downscaled ocean products, their various coverage and resolutions as well as proposed monitoring sites, equipment and techniques.

Downscaled Models (resolution)	Observation / Monitoring	Proposed Target Sites
Country scale (kilometres) • Wave • Circulation ***Island scale (100s metres)*** • Wave • Circulation ***Lagoon / coastal scale (metres)*** • Wave • Circulation • Inundation (country-scale coverage)	***In-situ observation*** • Surface wave and environmental buoys (modular system that can measure a wide range of physical and environmental oceanic variables – e.g. real-time temperature, salinity, dissolved oxygen, waves, pH, etc.) • Various temporary physical and environmental oceanography loggers • Drone survey for shoreline change and post-disaster impact survey ***Remote sensing derived coastal observation*** • Water quality mapping (e.g. turbidity, chlorophyll, coloured dissolved oxygen matter) • Marine habitat mapping – including in-situ sample data collection • Shoreline change analysis • Post-disaster impact mapping	***Cook Islands lagoon downscaling and monitoring sites:*** • Muri Lagoon • Aitutaki • Manihiki

Table 29. Proposed downscaled products, monitoring sites, equipment and techniques (Source: SPC)

Provision of ocean services, data management systems and visualisation via the Pacific Ocean Portal

The data collected and produced through the ocean modelling framework will be integrated into a data management system and converted into actionable information through decision making tools tailored to fulfil ocean stakeholder needs. Due to the limited internet bandwidth in the region, all downscaled ocean products and monitoring information will be easily accessible via local servers to ensure optimised use of the information. Furthermore, the data will be integrated into the Pacific Ocean Portal – the region's centralised platform for ocean data visualisation.

Capacity building to strengthen local ocean monitoring programs and oceanographic capability

To facilitate a sustainable local monitoring program, SPC will provide training and capacity building for technical, ocean monitoring focal points at CIMS, such as the Programme-hired National Ocean Expert (see intervention below). Focal points will be trained at SPC and in-country on maintenance of monitoring equipment and undertaking of coastal impact surveys. Over the five years of the Programme, focal points will receive on-going oceanographic capacity building through various regional and international trainings including certified trainings those offered through the International Oceanographic Data and Information Exchange (IODE). In addition, 2 – 3 key climate and forecasting staff identified at CIMS will undertake attachment training at SPC on applications of the ocean data and forecasts made available through the Programme.

SPC will work with CIMS to develop information products and ocean services and carry out at least one in-country stakeholder engagement workshop in each country to socialise users to these new services and incorporate feedback to enhance their usability (see intervention below).

In addition, through this Programme and in coordination with complementary disaster management initiatives, SPC will work closely with Emergency Management Cook Islands (EMCI) to capitalise on the improved hazard and risk information to inform planning and investment. Through this proposal SPC will work closely with WMO to support Cook Islands to fulfil its requirements under the WMO Marine Meteorology competency framework.

Engagement of a National Ocean Expert

The Programme-hired local consultant will strengthen Cook Islands' local ocean monitoring programmes and oceanographic capability. Monitoring the local ocean climate directly helps people—inter-island shipping, subsistence fishermen and tourists—to avoid unnecessary risks and will contribute invaluable data to the scientific community. The National Ocean Expert will extend CIMS's capacity to give practical advice to seafarers, subsistence fishers, tourists and pearl farmers. The consultant will monitor threats to reefs—warming and bleaching—so that harm can be minimised. When coral is stressed by atypical heat, if the reef is protected temporarily from human activity, it will recover more quickly; if people are warned of an elevated risk of ciguatera poisoning, they can avoid eating reef fish species during the warming episode. An ocean outlook, presented as a bulletin or via other media, can be made very useful to users in sectors affected by ocean conditions.

SPC will support the National Ocean Expert and CIMS to conduct ocean data stakeholder engagement workshops, including outer islands, twice yearly in Years 2 – 5 of the Programme. The emphasis will be on communicating the impact of hazards, rather than simply conveying technical information from the forecasting system.

The capacity of CIMS to communicate impact-based forecasting and warnings, and the ability of other agencies and communities to understand the warnings and take effective action, will be improved through this more frequent interaction. The National Ocean Expert will establish feedback mechanisms to make sure that delivery of information is effective and is modified if needed. CIMS will use existing in-country early warning systems and compatible software to deliver ocean information to ensure its accessibility to all users.

Expected results

The expected results and key deliverables of the Ocean Information Services intervention in Cook Islands are outlined below:

1. **Improved hazard risk knowledge**
    a. Analysis of inundation hazard and risk for all islands;
    b. Localised impacts to coral reefs and vulnerable bleaching areas;
    c. Water quality and lagoon residence time in Manihiki, Aitutaki, and Muri Lagoon

    Through the development of an ocean modelling framework, this component will assess and quantify the multiple marine hazards and physical vulnerabilities that contribute to coastal inundation, decreased lagoon health and marine life (coral and fish) in coastal waters. Via the development of decision-making tools (e.g. graphical user interface with capacity to generate automated reports tailored to stakeholder needs), the risk knowledge generated will inform response planning, coastal adaptation solutions and investment. This component will also commence a comprehensive approach for capacity building to meet the WMO competency framework requirements for marine meteorology and oceanographic services.

2. **Detection and monitoring procedures established**
    a. Establishment of medium to long term in-situ ocean observation environmental buoys and wave buoys providing data on currents, waves, water quality etc. directly to CIMS;
    b. Strengthening routine ocean monitoring efforts using medium to long-term water quality sensors, and in-situ coral mapping;
    c. Baseline monitoring via regular (and post disaster) drone survey quantifying 3D shoreline change and erosion;
    d. Once monitoring sites are established, SPC will link this data to calibrate satellite derived ocean observations, improving understanding of local impacts and establishing proxy relationships between ocean drivers and coastal impacts for algal blooms and other monitoring priorities.

    This component will improve downscaled ocean forecast models for all the islands in Cook Islands. This includes installing observation systems and procedures such as real-time ocean data from surface buoys and, developing tailored remote sensing solution for lagoon water quality monitoring and conducting post-event assessments to collect sound impact data. During the implementation phase, SPC will investigate the availability of affordable, light-weight and easily maintained environmental buoys. Depending on the robustness of emerging systems, SPC might be able to deploy a maximum of three environmental buoy (Manihiki, Aitutaki and Muri lagoon). If no affordable solution is deemed of reasonable quality standard, SPC proposes to prioritise deployment in Manihiki due to its remoteness and economical sensitivity to water quality (i.e. pearl farming). An emphasis will be placed on training on the use and maintenance of in-situ and remote sensing observation data and equipment as well as conducting tailored impact surveys. Throughout the Programme lifetime, SPC in partnership with Cook Islands will develop the foundation of ocean-driven impact-based forecasts based on an open source and affordable monitoring solution. The success of this ambitious system relies on a long-term impact monitoring effort, as the monitoring data will inform the continuous improvement of impact-based forecasting.

3. **Enhanced ocean services, impact forecasting, and data accessibility**
    a. Inundation early warning system for all islands;
    b. High-resolution circulation model and particle tracking forecast and hindcast models;

c. Accessibility of near real-time ocean data for decision making via local and regional portals.

The ocean framework developed will provide an impact-based ocean outlook as well as impact-based forecasts. The warning system will be tailored to local conditions and circumstances, including capacity in its use and maintenance. The system will comprise a multivariate forecasting tool to obtain fast and accurate estimates of potential site-specific impact. Meanwhile, the high-resolution circulation model and particle tracking forecasts will support decision making on search and rescue, pollution management control, navigational safety, and establishment of temporary MPAs to protect turtle hatchlings, coral and fish larvae. This quality-controlled data will be directly available to CIMS via local servers in near real-time, but will also be integrated into existing local databases and regional interfaces including the Pacific Ocean Portal, thus facilitating public access, understanding and application.

4. **Strengthened local oceanographic capacity, communications and ocean data stakeholder engagement**
    a. National Ocean Expert position established;
    b. Twice annual ocean data stakeholder engagement workshops, including outer islands.

This component places an emphasis on communicating the impact of the hazard, rather than simply conveying technical information from the forecasting system. The capacity of CIMS to communicate impact-based forecasting and warnings, as well as the improved ability of other agencies and communities to understand the warnings and take effective action, will be improved via more frequent interaction and collaborative establishment of feedback mechanisms. The products will be disseminated within standards and institutional mechanisms that are compatible with existing in-country EWS communication platforms.

C2.2.2 Enhance climate information and impact-based forecasting

Young Scientist Support Program

To support the enhancement of in-house forecasting capacity, the Programme will build a strong scientific and analytical foundation for NMHSs through training and mentoring attachments covering climatology and oceanography. Early-career scientists from NMHSs will be selected to undertake in-depth technical capacity building through a customised Young Scientist Support Program (supported by APCC), including highly in-depth training for 2-3 months exploring various climate prediction and analysis techniques such as downscaling predictions, generating sub-seasonal-to-seasonal forecasts, analysing large-scale patterns, and tropical cyclones, etc. This will equip participants, particularly those with less experience, with both the basic knowledge needed to perform their duties as climate officers, as well as more advanced knowledge that can help them develop downscaled or impact-based forecasts.

Engagement of a National Climate Expert

To support the provision of the much expanded climate information services, CIMS proposes to engage a Programme-hired local consultant, at science graduate level, for the five year term of the Programme. Previous experience indicates the position is likely to be made permanent thereafter, as the value of the extra services made possible is demonstrated. The consultant will focus on climate science and data analysis for new functions, and will take day to day responsibility for sector coordination, working with the Ministries of Tourism, Transport, Infrastructure, Health, Agriculture, Environment Services and others. The consultant will develop new information products in response to demand from the sectors.

Training attachments and mentoring

The Australian Bureau of Meteorology (BoM) will arrange regular training and mentoring for the National Climate Expert through attachments and regional meetings and by supporting their attendance at key conferences throughout the term of the Programme. BoM will also provide similar training on ocean and tide information, and mentoring to the new consultant using seasonal forecasting products from ACCESS-S.

Activity 2.3 Harmonise climate data and information management

C2.3.1 Establish and implement national climate data and information strategies

National Climate Data Consultant

The Programme will support the recruitment and training of a National Climate Data Consultant (NCDC) who will work within the National Environment Service Ministry. The NCDC's role is to publicise the Cook Islands Environmental Data Portal, particularly the climate data subset, to extend its user base and to help the users of its data to maximise their skills.

The NCDC will build capacity among key government staff to collate and validate data as well as to share and promote it with their primary audiences. S/he will serve as national administrator for the data portal, assigning access and ensuring staff are making full use of the capacity of the system. To open lines of communication and data effectively between the various national providers the NCDC will facilitate regular meetings with the national data community; communicate regularly with national and regional partners; and track the use and application of the national portal and its products. The NCDC will serve as the Programme focal point for the regional environment data manager at SPREP.

The NCDC will participate in training with the NCDCs of the other four countries in online cloud hosting skills and knowledge, and in sub-regional exchanges and South–South learning. With SPREP's support, the NCDC will be a member of the technical committee that drafts the National Data and Information Strategic Action Plan and will lead the development and implementation of the Plan.

The NCDC's work on harmonising the way data is recorded and stored will make it possible to use UNEP's Country Level Impacts of Climate Change (CLICC) principles, using consistent formats for data records so that CIMS's climate data can be presented with national data from other sources, coherently and transparently. This has potential to reduce significantly the burden of reporting the Cook Islands' performance against multilateral environmental agreements (MEAs) and to improve the quality of its reports. This in turn has benefits for the Government's understanding of climate change impacts and its capacity to plan effective adaptation and to advocate in international forums.

National Data and Information Strategic Action Plan

The Programme-hired National Climate Data Consultant will be engaged to support a technical committee in drafting a National Data and Information Strategic Action Plan (NDISAP) for the Cook Islands. Climate data is usually collected and kept at a significantly higher standard than other national data: good quality data is collected systematically, recorded and stored digitally, backed-up reliably and readily retrieved for use in information products. This is rarely the case for health data, environmental data or information on other sectors.

The Government of Cook Islands plans to use climate data and information in concert with data from other sectors in order to mainstream climate considerations into the work of those sectors. The Government also needs to be able to put data from various sector sources with climate data as it reports to the international community on its implementation of MEAs. Much improved information about terrestrial systems and the impacts of warming can be derived from a database that can bring these sources together and harmonise them sufficiently for the data to be used in planning and reporting. The Data Strategy will use high-level quarterly meetings to monitor progress towards the robust management of climate data, the locating of related data sources and their harmonisation.

The Data Strategy will benefit from SPREP's INFORM project, which has already set up an Environmental Data Portal for each of the five Programme countries and an over-arching regional portal. Cook Islands already has a national environment data portal, hosted on-line by SPREP, and networked together at the regional level in the Pacific Environment Portal (also managed by SPREP). The Cook Islands Government has endorsed its national portal and the regional environment portal as the formal repository for national environment-related datasets and knowledge products. The portals are protected by having their data stored and retrieved from multiple machines on the cloud: if one of the servers crashes unexpectedly, the data portal won't go down.

This Programme will add a dataset specifically focused on Climate and Oceans knowledge and information to the Cook Islands Environmental Data Portal. The national Environmental Data Portal "provides an easy way to find, access and reuse national data."[435] Its "main purpose is to provide easy access and safe storage for Environmental datasets to be used for monitoring, evaluating and analysing environmental conditions and trends to support environmental planning, forecasting and reporting requirements at all levels."[436] The Cook Islands portal enables government agencies to report against the Sustainable Development Goals and the MEAs to which the Cook Islands is a party. It also allows the Government to archive reliably and relatively cheaply national environment-related reports and policy documents.

The data that Emergency Management Cook Islands (EMCI) proposes to collect with the support of this Programme (Programme Result 3) will be stored in the ArcGIS GeoPortal. The products generated from the data—vulnerability assessments, hazard maps, climate risk hotspots, etc.—will be ingested to the Cook Islands Environmental Data Portal, and will be available in-country to CIMS for matching populations and assets against climate risks to identify hotspots, for instance. Both databases—ArcGIS and the Environmental Data Portal—allow for different levels of access to avoid beach of privacy.

RESULT 3 – IMPROVED COMMUNITY PREPAREDNESS, RESPONSE CAPABILITIES AND RESILIENCE TO CLIMATE RISKS

Activity 3.1 Improve warning dissemination and communication

Under this Activity, the Programme will enhance the dissemination and communication of climate risk information and early warnings based on the enhanced data generated under Programme Result 2. The Programme will particularly focus on strengthening last-mile communication systems to ensure that people and communities in remote locations receive warnings in advance of impending hazard events. CIMS will be supported to develop a range of communications products tailored to end-users at the community level. Emergency Management Cook Islands (EMCI), Cook Islands Red Cross Society

[435] Government of Cook Islands, Environmental Information for Decision Making, available at <www.cookislands-data.sprep.org> [August 2019].
[436] ibid

and community-based organisations will play a key role in enhancing preparedness and response capabilities.

C3.1.1 Strengthen EWS organisational and decision-making processes

This Sub-activity will ensure the effective and coordinated delivery of early warning services through strengthened organisational and decision-making processes of CIMS, EMCI, civil society organisations and other key actors.

An annual workshop will be conducted to define the functions, roles and responsibilities of key EWS actors; develop warning communication strategies; and develop, trial and refine Standard Operating Procedures (SOPs). The workshops will be attended by various EWS stakeholders, EMCI and CIMS representatives. The warning communication strategies to be developed will facilitate coordination between CIMS – as warning issuers – and with downstream dissemination channels, such as island community volunteer networks. The strategies will include the development of community feedback mechanisms to verify that warnings have been received and to alert CIMS to potential gaps in communication networks. At the start of Programme implementation, an in-country deep dive study on gender and community stakeholders will be conducted to facilitate that the design of EWS organisational and decision-making processes is gender-responsive and that such processes proactively consider and address the specific needs, concerns and capabilities of different gender groups. Knowledge gained and outputs from the workshops will be leveraged in development of the Forecast-based Financing mechanism (Activity 3.3).

C3.1.2 Strengthen communication systems to reach the last-mile

This Sub-activity will enhance connectivity and communication systems to facilitate that climate information and early warnings reach communities at the last-mile, including on remote outer islands (Pa Enua); and that communication channels are resilient to the impacts of extreme climate events. This will be achieved through the following interventions:

Training and capacity building for communications at the 'last-mile'

The Department of Climate Change (Climate Change Cook Islands – CCCI) will provide a program of training and capacity building to understand climate and weather information for island councillors, NGOs and government workers including teachers in the Pa Enua (outer islands). The program will enhance the awareness of community members to climate change issues, including school children who may choose this as a career path. All materials will be delivered in Cook Islands Maori and will provide information enabling communities to initiate their own adaptation measures, which will enhance local ownership for climate resilience and facilitate continuity and sustainability.

Trained communicators will conduct the capacity building in all 12 inhabited islands, including Rarotonga. The communication of climate change information and the assistance with developing adaptation activities will advance the priorities of the Cook Islands National Sustainable Development Plan, the Cook Islands Climate Change Policy and the second Joint National Action Plan.

Train the trainers workshop

In Year 1 of the Programme, Climate Change Cook Islands (CCCI) will utilise a training of trainers (ToT) approach to enable trainers to teach others to transform and simplify weather information for the public to use.

Localised mobile climate information communication system

The Programme will develop and implement localised mobile climate information communication systems with early warning to reach last-mile populations. Through mobile-cellular communication channels, this system will provide predicted risks and alerts utilising geostationary satellite nowcast and local/regional forecast information. The system will be designed to handle potential and existing risks on a 24/7 basis and will be customisable for any population group size – from small communities to larger central governments. For short-term disasters, the system will utilise satellite imagery analysis based on 2 km, 10-minute resolution (e.g. Chollian 2A) for nowcasting of wind, wave height and convective initiation of rapidly developing thunderstorms two hours in advance, which is not possible with Numerical Weather Prediction. Localised communication systems will support disaster risk management on various timescales from short-term disasters (e.g. torrential rainfall, coastal flooding, etc.) to long-term disasters (e.g. droughts). The possibility to integrate a two-way communication channel between end-users and information providers would allow for continued enhancements to the system based on user feedback.[437]

C3.1.3 Communicate early warnings to island communities

The Programme will conduct annual multi-stakeholder workshops focused on the co-design and co-production of early warning information products to improve early warning messaging to island communities and provide clear guidance for triggering response actions. Participants will include various EWS stakeholders, community representatives, Emergency Management Cook Islands (EMCI) and CIMS. A local consultant will support delivery of the workshops and will draw on the specialised knowledge of stakeholders and communities to create impact-based early warning messages that are actionable and effective. The workshops will provide an opportunity for engagement between warning issuers and warning 'users' to facilitate that the public and other stakeholders are aware of which authorities issue the warnings, and build trust and acceptance of information disseminated. Furthermore, the Programme will seek to engage a wide variety of community representatives to ensure that warnings are targeted to the different risks and needs of vulnerable subpopulations.

Activity 3.2 Enhanced preparedness and response capabilities

C3.2.1 Enhance disaster preparedness and response measures

Vulnerability assessments and hazard mapping at community level

The Government of Cook Islands wishes to strengthen its understanding of its communities' vulnerabilities to climate risks and their information needs by mapping populations and assets and matching them with climate risk data.

Emergency Management Cook Islands (EMCI) is responsible for the management of disaster risks. It currently uses census data and GIS information to assemble hazard maps and to determine the vulnerability of villages and the people who live there. These data sources are not adequate for sound preparation and response planning.

EMCI proposes to undertake detailed surveys of households on the islands of Rarotonga and Aitutaki, where most of the population lives, recording individual vulnerabilities. The surveys will assess building structures, water supplies, sanitation infrastructure, telecommunication systems and food security, all of which have been sources of heightened risk exposure in previous disasters.

[437] This will be delivered by the APEC Climate Center in collaboration with the Ewha Womans University, utilising a proven method that is currently being implemented in Cambodia, with the endorsement of the Cambodia Ministry of Water Resources and Meteorology, Asian Disaster Preparedness Center (ADPC) and the Preah Vihear National Authority

A technical team will use GIS and GeoDatabase software to collate the data with existing information from national statistics, public works authorities, health and education ministries, and with data from the CIMS weather stations on both islands. The team will filter and analyse the baseline data collected and generate disaster risk reduction products—hazard maps, damage assessment tools and a National Emergency Operation Centre (NEOC) dashboard. This integrated approach is designed to further reduce exposure and vulnerability and to prevent the creation of new disaster risks.

Apps and early warning systems (triggers) will be developed that will support the implementation, response and recovery plans that communities already have in place. A public EMCI Portal will be set up and users in the Pa Enua (outer islands) will be trained in its use. The Trigger Apps will reduce disaster risk and ensure responses are well-informed, coordinated, consistent and effectively managed. An information feedback system will ensure continuous review of the plans and tools, so that lessons learnt from their use are applied effectively.

The technical team will also conduct spatial analyses and create maps that can be included in periodic reports EMCI makes to the Government. This will contribute effective tracking of progress to EMCI's monitoring and reporting and will strengthen the scientific foundation of EMCI's learning and knowledge management. Sensitive information will be protected in accordance with EMCI's code of conduct and the Cook Islands GIS Taskforce's regulatory body.

Vulnerability assessment and hazard mapping will help strengthen disaster risk governance and enhance disaster preparedness for effective response and recovery, rehabilitation and reconstruction. This request builds on the Pa Enua Action for Resilience Livelihoods (PEARL) project, currently being implemented in the outer islands. EMCI also manages an Emergency Management GeoPortal using ArcGIS and open source software to develop a baseline of data. This is a functional and comprehensive repository of disaster risk management (DRM) data and information. The database consists mainly of shape files, feature classes, database tables and raster layers with associated documentation such as outer islands' DRM plans.

The EMCI GeoPortal is a project initiated by EMCI for the purpose of creating a disaster risk management baseline of data for the Cook Islands which includes the Pa Enua. One of the key lessons learnt during the Cyclone Pat response that devastated the island of Aitutaki in 2010 was that the lack of centralised baseline data for Aitutaki (and the other islands including Rarotonga) hindered the progress of the response and caused unnecessary delays to the response and early recovery work.

The methodology used to capture and record field data is a combination of a Global Positioning System (GPS), an Unmanned Aircraft System (UAS), digitisation and ground truthing by carrying out household disaster risk surveys using mobile apps. A GIS tracking tool will be used to capture the adaptation activities and report on learning and knowledge management. Carrying out household surveys using GIS mobile apps technology will enable surveyors to capture DRM data in the field. A data dictionary has been created to facilitate capturing of data on the locations of vulnerable households and vulnerable citizens.

This data dictionary will be uploaded to the Cook Islands ArcGIS portal from offline mobile devices containing ArcGIS Maps. Geospatial data, analysis and information will be accessible on the EMCI GeoPortal. Before the field surveys, the DRM surveyors will be trained in the use of the GIS mobile devices and conduct mock mapping exercises. Training has already begun, with several household surveyors using paper-based material to enable spatial mapping of the household surveys. However, the survey and analysis will be much more efficient using the offline mobile apps, which contain GIS applications providing users with data input and updates of the existing GIS DRM database.

The surveyors will also be collecting qualitative information on households. This will include issues or concerns in relation to DRM and climate change not captured by the quantitative questions. This information will be transferred and stored in an online database (accessible only by DRM managers). Each entry in the database will have a unique reference code linked to the mobile app devices. The GIS will allow for the entries in the feature class to be linked to the online database, transferring all relevant data to the GIS. Analysis and querying of the data will then be trialled.

EMCI is the primary agency for disaster risk management and its main role is the development of plans and sub-plans for disaster risk reduction and management. The plans cannot be developed without data and currently use existing information such as census and GIS data, with the existing sector planning tools. GCF resources will support a centralised integrated information system with oversight from the GIS Taskforce. An EMCI GeoPortal Information Flowchart has been adopted as the foundation, to ensure that data collected by the various sector surveyors, including the water and agriculture sectors, either using apps or manually, are fed into one central data system.

This includes the information from the CIMS weather stations, funded under the "Strengthening the Resilience of the Cook Islands to Climate Change" Programme (SRIC-CC) on each of the islands. The data and information will be filtered and management tools, apps and early warning systems (Triggers) will be developed that will support the implementation, response and recovery plans already in place. Training Pa Enua communities in the use of the public EMCI Portal will be essential. The Trigger apps will reduce disaster risks and ensure response is coordinated, consistent and effectively managed. The feedback system will ensure continuous review of the plans and further improvements of the information system as recommended by the GIS Taskforce.

This intervention will give EMCI the ability to conduct spatial analysis and create maps that can be included in periodic reports. This will contribute to monitoring and reporting by tracking progress and will strengthen the scientific foundation of EMCI's knowledge management. Sensitive information will be protected as determined by the GIS Taskforce.

This intervention has an integrated approach and builds on and heightens the SRIC-CC. It is designed to further reduce exposure and vulnerability, preventing the creation of new disaster risks. Disasters, many of which are exacerbated by climate change and which are increasing in frequency and intensity, significantly impede progress towards sustainable development. Evidence indicates that exposure of people and assets in all countries has increased faster than vulnerability has decreased, generating new risks and a steady rise in disaster related losses, with significant economic, social, health, cultural and environmental impacts, especially at the local and community levels. Recurring small-scale disasters and slow onset disasters particularly affect communities like those in the Pa Enua of the Cook Islands. Households and the few and small Pa Enua enterprises constitute a high percentage of all losses. It is urgent and critical for the Cook Islands to anticipate, plan for and reduce disaster risk in order to protect people, communities, livelihoods, health, cultural heritage, socio-economic assets and ecosystems, and thus strengthen their resilience.

This intervention will advance the EMCI's capacity to implement the Cook Islands' Joint National Action Plan II for Disaster Risk Management, its National Disaster Risk Management Plan, its Strategic Roadmap for Emergency Management and its National Sustainable Development Plan 2016–2020. It builds on the *Akamatutu'anga no te tuatau manakokore ia e te taui'anga reva* – SRIC-CC.

C3.2.2 Conduct public awareness and education campaigns on climate hazards and risks

NGO community awareness programme

Au Vaine Kumiti (Women's Committee) is an established indigenous civil society organisation working with island communities on disaster risk management and climate change activities. It raises funds for risk management activities such as the refurbishment of the Tupapa village community centre into an emergency operation centre and the refurbishment of three buildings in Rarotonga, with EU funding. Au Vaine was selected by Emergency Management Cook Islands for community work targeting women, youth, elderly people and children because of its strong track record.

Au Vaine takes Tropical Cyclone warning information to communities and shows them how to access specific information and updates from CIMS's Facebook page. Members show grandchildren how to help their grandmothers to use the technology, using tablets they can take home to practise. They teach children, many of whom have mobile phones, to take photographs of climate impacts—damage to buildings, water tanks, beaches and gardens—and to upload them as impact data to the GeoPortal. Training children to teach adults is a shift in paradigm and will contribute to long term sustainability of Programme outcomes by introducing youngsters to key concepts at an early age.

Au Vaine trains young women IT specialists to help with the training, encouraging other young women to go into IT careers. Au Vaine has been running these projects since 2016 but it lacks funds to extend its work to communities in the outer islands.

Community work enables them to engage with subsistence farmers and gardeners and with community water managers and to make links between these sectors and CIMS. Previously Au Vaine was able to use funds from the Strengthening the Resilience of our Islands and our Communities to Climate Change (SRIC-CC) project for work with young farmers and they would like to keep doing this work and to strengthen home gardens and export enterprises. This makes life in the outer islands more attractive to young people, who can make their living in organic farming or smart agriculture, building their own economic resilience and staying in their own homes.

Activity 3.3 Establish Forecast-based Financing (FbF)

Under this Activity, the Programme will establish Forecast-based Financing (FbF) in Cook Islands, in partnership and coordination with the International Federation of Red Cross and Red Crescent Societies (IFRC), Cook Islands Red Cross Society and Emergency Management Cook Islands (EMCI).

C3.3.1 Develop FbF Roadmaps defining thresholds and triggers

This Sub-activity will develop a Forecast-based Financing (FbF) Roadmap for Cook Islands, which will identify forecasts (magnitude, probability and lead time) that can trigger humanitarian actions.[438]

The first phase of the Roadmap will begin with a scoping study that will cover feasible hazards to target with FbF, forecasting capability, and the institutional landscape in Cook Islands. This will include consultations with national agencies such as EMCI, CIMS, the Ministry of Agriculture and Te Marae Ora (Ministry of Health); regional agencies such as SPREP, SPC, WFP, UNDP and others; and partnerships with the IFRC, Red Cross Red Crescent Climate Centre and Cook Islands Red Cross Society. For FbF to be a sustainable and effective mechanism, Early Action Protocols (EAPs) need to be embedded in national institutions, who have roles and responsibilities for taking early action. The scoping phase will identify the national and/or sub-national actors (government and civil society) in Cook Islands and enter into a dialogue with them about the potential for early action.

The second phase of FbF Roadmap development will consist of collaborative consultations with country institutions to delineate three key elements that would enable country-led design of an FbF mechanism:

[438] Lopez, Coughlan de Perez, Bazo, Suarez,Van den Hurk, Van Aalst, 2018: Bridging forecast verification and humanitarian decisions: A valuation approach for setting up action-oriented early warnings

1. Menu of Triggers – A 'trigger' is a forecast that is issued, which exceeds a pre-defined danger level and probability threshold, leading to the initiation of early actions.
2. Forecast-based Actions – Identification of possible early actions that can be triggered by existing forecasts, which aim to avoid losses and damages if an extreme event materialises.
3. Institutional Arrangements – A potential architecture of country-level technical working groups and institutional ownership for FbF, including funding mechanisms when necessary.

The FbF Roadmaps will provide a set of 10 recommendations for critical next steps to move forward with Forecast-based Financing. These next steps will be focused on filling capacity gaps that enable the design and activation of an FbF mechanism by the identified lead agency/s, and the design and testing process for EAPs. The Roadmaps will include the following components:[439]

- **Stakeholder Identification** – The Programme will identify the key stakeholders to be involved in the development and implementation of FbF, including international, national, regional and local actors and lead agency/s.
- **Risk Assessment** – The Assessment will include individual analysis of risk factors, key hazards, past impact, exposure and vulnerability. Based on the analysis, the priority hazards to be addressed by FbF early actions will be identified. The assessment will also provide an overview of the different types of early actions that could be taken to mitigate risk by the identified stakeholders, in different sectors (agriculture, health, etc).
- **Impact-based Forecasting (Triggers)** – The Trigger analysis will provide an overview of all available forecasts – including lead time, skill/confidence and extreme event probability.
- **Resourcing Overview** – The Assessment will identify various options for accessing funding or necessary resources for potential early actions that are more costly or resource-intensive.

C3.3.2 Build capacity for FbF

In this Sub-activity, up to five of the 10 "next steps" that were identified in the Roadmap will be developed and executed. Steps that fall within technical capacity building, research or technical advice will be supported by Cook Islands Red Cross Society. Depending on the national context and the findings of the scoping study, these activities could include the following:

- Scientific collaboration with national or regional forecasters to carry out a forecast verification analysis or forecast calibration to support the development of triggers;
- Technical support to build enthusiasm for anticipatory actions and change mindsets;
- Specific links between the FbF and EWEA narrative with the principles and activities embedded in other outputs of the Programme;
- Technical support in finding ways to connect with existing regional systems, mechanisms and/or priorities to have a region-wide understanding or buy-in of FbF;
- Table-top exercise to discuss a historical extreme event and what could have been done by different actors to prevent impacts;
- Round-table discussion on financing mechanisms for critical early actions that could be part of an FbF mechanism.

[439] IFRC, 2018. Forecast-based Financing Early Action Protocol template

C3.3.3 Support development of Early Action Protocols (EAPs)

Cook Islands Red Cross Society will support the development of Early Action Protocols (EAPs) through technical working groups for the priority impacts identified in Sub-activity 3.3.1. A series of conversations will be initiated to develop an EAP, which could range from focusing on a simple life-saving action by one actor to a more complex document with a greater variety of actions and forecast analysis.

To identify what should be in the EAP, the identified FbF lead agency/s will convene a technical working group, engaging stakeholders at all levels – including community representatives, disaster risk reduction committees, civil society organisations, local and national government departments, NGOs and private sector actors. The Red Cross Red Crescent Climate Centre will provide technical guidance to the lead agency on the process and provide quality assurance, but delivery of the EAP will rest with the lead agency.

Following identification of the most suitable forecast-based actions, the EAPs will be developed by the lead national agency/s. The EAPs will describe which forecast will trigger which action; where to act – based on the forecast and trigger information; and assign responsibilities to specific stakeholders for implementation of each action. In the case of more complex EAPs, they can also include a proposal for a Financial Mechanism, which will outline what funds need to be made available (including readiness costs, stock pre-positioning and activation cost for trigger-based early actions) and how they will be accessed by specific stakeholders. This Activity will collaborate with national climate finance policies (Sub-activity 1.1.4) to explore situations when funding for early action can be linked to government budgets.[440] Depending on local capacity, simulations can be held to carry out a "test" of the actions of the EAP.

RESULT 4 – ENHANCED REGIONAL KNOWLEDGE MANAGEMENT AND COOPERATION FOR CLIMATE SERVICES AND MHEWS

Activity 4.1 Enhance regional data, knowledge management and cooperation

Under this Activity, the Programme will enhance coordination and knowledge sharing among the five countries to improve data and knowledge management, including establishment of an interactive ICT platform and regional data centre. The organisation of joint learning, mentoring and training events through existing WMO, USP and other centres to facilitate sharing of successes and lessons learned will further strengthen climate and ocean information services across the region.

C4.1.1 Establish interactive ICT platform

This sub-activity will establish an interactive ICT platform, which will serve as a data analytic centre for the management and organisation of climate data, information, experiences, case studies and other forms of knowledge from the five Programme countries in standardised, comparable formats most useful for end-users. The platform will include the establishment of a regional data centre fed by national data centres in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu. The countries will make as much as possible of their climate-related data publicly available through their national data portals and the regional Pacific Environmental Portal.

This Activity takes advantage of the already established GEF-funded "Inform" project, which is being implemented by UNEP and executed by SPREP. Inform is already working with staff in Pacific

[440] IFRC, 2018. Monitoring and Evaluation (M&E) of Forecast-based Financing (FbF). A practical reference for country-level implementation

environment ministries to find and harvest useful datasets and information on their countries' environment and to publicise the existence of the information. The five Programme countries now have national data portals, which can be used to develop workflows to share data seamlessly between sectors. The Programme will add a new category for climate data and information in the Cook Islands' national portal – existing categories include health, fisheries, tourism and disaster management as they relate to the environment – and bring the bring data management and coordination into its schedule of capacity building activities. The National Climate Data Consultant (Sub-activity 2.3.1) will take part in technical workshops and training at SPREP and implement a comprehensive data strategy in-country with SPREP's support. Improved data sharing and discoverability will provide a conduit for CIMS to assess partners' sector data or knowledge products, while hosting and sharing its own on a common platform. Enhancement in data management capacity will be achieved through the following steps:

- Addition of a new category for climate data and information to each national portal;
- Training and engagement of national climate data consultants (see Sub-activity 2.3.1);
- Support for countries to prepare their national reporting for climate-related agreements (e.g. NDCs, VNRs, National Communications to UNFCCC). This is currently a major administrative burden for very small countries, but with access to good quality data, it provides an opportunity to evaluate policy and assess progress on adaptation. A two-way flow of information from NMHSs to and from relevant sectors for national and global reporting will ensure coordination in the use of climate data and information and raise the profile of NMHSs in other sectors thereby supporting demand and fostering sustainability.
- Participation of data consultants in regional forums to enhance the use of data in national planning;
- Establishment of electronic links with existing data sources and back-up in the regional portal; and
- Management of the ICT platform for the five Programme countries through support for ICT interventions across the five countries, including application of ICT in NMHSs operations and upgrading or introducing new methods and systems, such as wireless communications and Internet of Things (IoT) infrastructure for climate services.

SPREP usually provides significant support to countries preparing their reporting against the many MEAs and climate-related agreements to which they are party. This regular process includes updating each country's State of the Environment report, clearly documenting and illustrating climate impacts. This process will give SPREP an entry point for discussing the data strategy with senior Cook Islands officials. Better access to more data will make it easier to identify meaningful indicators for indicator based reporting, and the project will help non-specialists understand the analysis and interpretation of data.

Improved data is only useful to decision makers, development partners and other user groups if there is wide knowledge of its existence, location, purpose and openness. As this Programme progresses, reporting for international climate agreements will be much improved by the countries' ability to draw upon a longer and more extensive body of high quality data—officers will know what data exists, how it can be sourced and how to use it well. The participation of data consultants in regional forums will build capacity to advocate for effective use in national planning and development of useful data products.

The Inform team estimates there is valuable climate change material held in more than 24 active and legacy systems among the five countries; and in many cases the obsolete hardware needed to read it is still functioning. SPREP will establish electronic links with existing data sources so they can be translated and will back them up on the regional portal. There are multiple datasets held by researchers or by individual departmental officers in danger of being lost, and SPREP will help the Cook Islands to locate and salvage them.

C4.1.2 Organise learning, mentoring and training

This sub-activity will comprise training, mentoring and advisory services for local consultants and staff in NMHSs in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu on strengthening climate information services; strengthening observations, monitoring, modelling and prediction; strengthening of marine weather and ocean services; establishing MHEWSs at national and community levels; and building community resilience against climate risks. This will be facilitated through partnerships with existing WMO regional training centres (e.g. China Meteorological Administration (CMA) Training Centre [441] through coordination by the Chinese Academy of Meteorological Sciences), USP and others in the organisation of:

- Joint learning events for exchanging knowledge and sharing experiences and lessons learned in strengthening climate information services and MHEWs in the five countries. This will have a major focus on the development and implementation of National Frameworks for Climate Services (NFCSs) through all components and related activities of this Programme.
- Targeted training of NMHS staff (e.g. meteorologists, ICT administrators, forecasters) in key areas that are essential for the Programme's impact and long-term sustainability. This will be undertaken through existing training centres in the WMO network, the University of the South Pacific (USP), the International Centre for Theoretical Physics (ICTP) and others. Training will be delivered through a combination of on-site workshops and remote learning courses. Topics of training could include:
    - Forecasting and Numerical Weather Prediction (NWP) by suitably qualified providers such as WMO regional training centres and other WMO-approved meteorological organisations. This could include nowcasting techniques for severe weather, and short-term climate monitoring and prediction in disaster prevention and mitigation.
    - Observation and Instrumentation, including Operation and Maintenance (O&M) of equipment for long-term sustainability.
    - Innovative and cost-saving technologies for observation, modelling and prediction with special focus on the application of ICT. Hence, these events will also be critical for regularly reviewing options for upgrading or introducing new methods and systems in NMHSs in the five countries, such as wireless communications and Internet of Things (IoT) infrastructure for climate services and disaster management.
    - Principles of satellite remote sensing and use of meteorological satellite images in weather analysis and forecasting.
    - Demonstration and training on the operation and maintenance of weather radar systems – installed under Sub-activity 2.1.1 by regional partners from the WMO network (possibly the Fiji Met Service in cooperation with USP under the new WMO

[441] CMA propose to provide free in-person and remote training courses covering the top seven training priorities of Pacific NMHSs

Regional Training Center). The demonstrations and training will build capacity of the NMHSs for the provision of improved and more accurate weather monitoring and forecasts; tracking of local extreme events; better determination of rainfall rate/intensity, which is important for determining the potential for extreme rainfall and flash flooding enabling hazard warnings to be issued more accurately and in more timely fashion; and validating Numerical Weather Prediction (NWP) forecasts.

- Enhancing institutional effectiveness of NMHSs through Quality Management Systems (QMS), Weather Forecast Service Standard and related certification.
- Enhancing NMHS services through Impact-based forecasting and Forecast-based Financing.
- Enhancing Climate services in NMHSs, including options for ensuring long-term financing and cost-recovery such as private sector investment, public-private partnerships and the application of National Climate Funds.
- Use of alerts, information exchange and coordination in the first phase after major sudden-onset disasters, including through the Global Disaster Alert and Coordination System (GDACS).

Furthermore, the Programme will provide mentoring and technical advisory services to NMHSs in the five countries through capacity building, training and awareness raising initiatives and materials for a range of stakeholders; provide technical backstopping and capacity support to the national delivery of Programme activities; and provide expert advice to the Programme team on key climate information services and best practices, including gender-responsive implementation. In order to enhance synergies and avoid creating parallel structures, the Programme will work closely with the WMO-SPREP Pacific Meteorological Desk Partnership (PMDP), a regional coordination mechanism that supports and coordinates meteorological activities in the Pacific, and the Pacific Meteorological Council (PMC) at large.

NIUE

BACKGROUND

Niue is one of the largest raised coral atolls in the world, with no mountains or rivers, little arable land and limited natural fresh water supplies. It is a single island, with two distinct levels: a plateau in the centre of the island reaches about 60m above sea level and is surrounded by limestone cliffs. An estimated 70% of the plateau is covered by forest.[442] The lower level is a coastal terrace about half a kilometre wide and about 25m high, sloping down to meet the sea at small cliffs with many limestone caves. Its surrounding reef has a single navigable break near the capital, Alofi.

Niue has a land area of 259 km2 and is situated in the southwest Pacific Ocean (19˚S, 169˚W) about 2,400km northeast of New Zealand. Within its exclusive economic zone of 39,000 km2, Niue has two reef atolls, Antiope and Beveridge, visible only at low tide, from which commercial fishing is banned. Its marine region hosts several seamounts renowned for their high value fisheries productivity.[443]

Niue's lack of fresh water and its remoteness mean its resilience to natural disasters is very low. In a 1998–2009 study conducted by the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and the United Nations Office for Disaster Risk Reduction (UNISDR) (2010) Niue was listed as the second most vulnerable country in the Asia-Pacific region, based on relative physical exposure to storms and impacts on its population, and third top in the potential loss to its GDP.

Its population of approximately 1618 (July 2017 estimate)[444] is spread across 14 villages. Large scale outward migration, usually from younger age groups, has occurred since 1971, predominantly to New Zealand for education, employment opportunities and family ties, as well as perceived higher standards of living abroad. About 24,000 people of Niuean ancestry live in New Zealand.[445] More than 20% of these are Niue-born which means that there are about 15 times as many people who identify as Niuean living in New Zealand as in Niue.[446] Many Niueans travel home frequently and own land in Niue, and it is becoming more common for younger Niueans to migrate back home.[447]

The economy is heavily dependent on support from New Zealand, which has a statutory obligation to provide economic and administrative assistance to Niue. Aid accounts for 70% of Niue's GDP. Other financial resources include agricultural exports, taxation, fishing licences, international lease of Niue's unique four-digit phone numbers, remittances from Niueans working abroad and additional support from development partners. Its low population, scarcity of natural resources, isolation and high costs of transportation mean that Niue's economy is not yet self-sufficient.

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[442] United States of America, Central Intelligence Agency, available at <www.cia.gov> [August 2019].
[443] Government of Niue, 2013, Niue National Climate Change Policy.
[444] United States of America, Central Intelligence Agency, available at <https://www.cia.gov/library/publications/the-world-factbook/geos/ne.html> [August 2019].
[445] Government of Australia, Niue, available at <https://dfat.gov.au/geo/niue> [August 2019].
[446] United States of America, Central Intelligence Agency, available at <https://www.cia.gov/library/publications/the-world-factbook/geos/ne.html> [August 2019].
[447] Meeting with NMHS Director

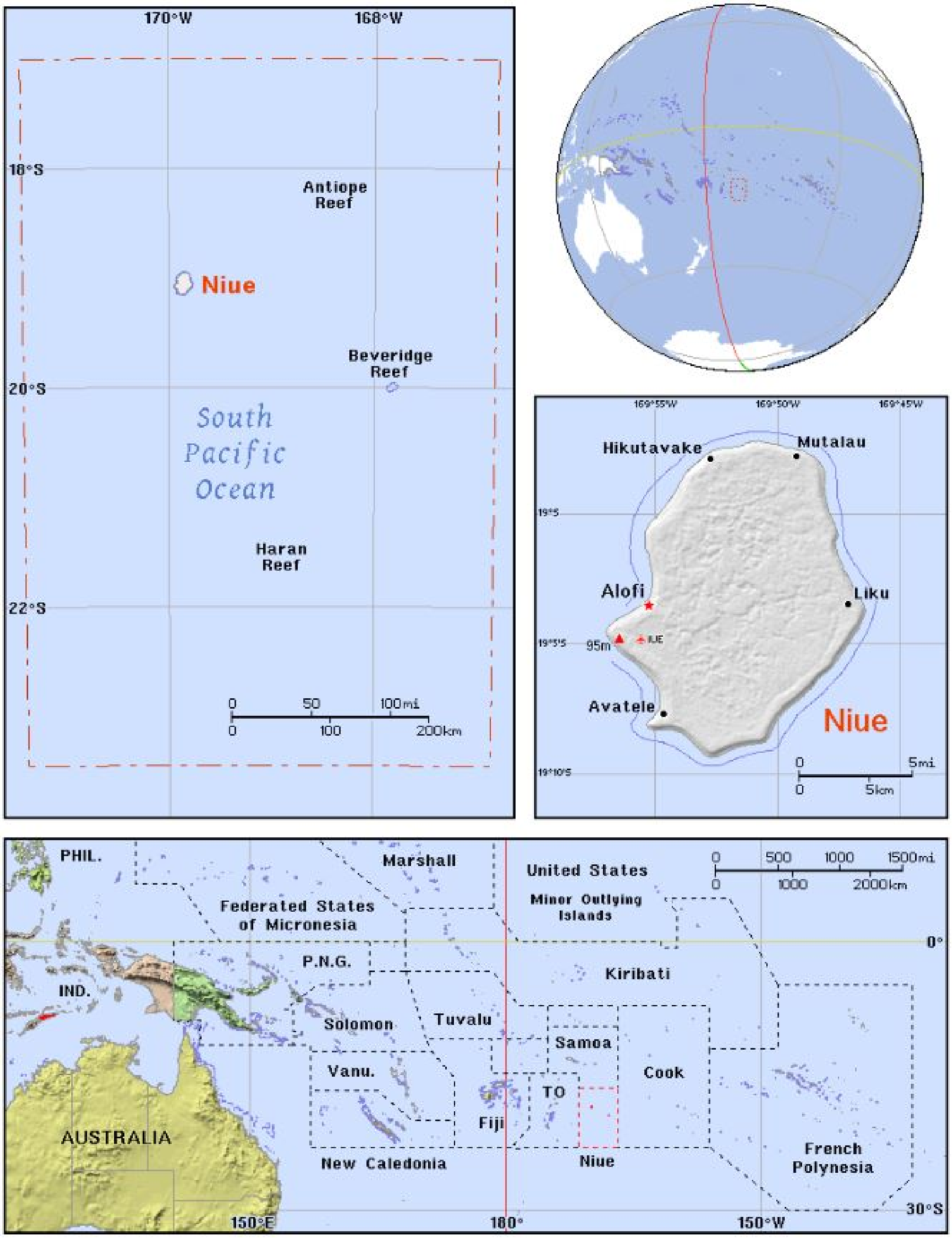

Figure 86. Map of Niue - (Source: https://ian.macky.net/pat/map/nu/nu.html), Copyright 2013 by Ian Macky)

Current provision of climate services: strengths, priorities and barriers

The Niue Meteorological Service (NMS) is a department of the Ministry of Natural Resources. The service consists of eight officers, as shown in the organogram below.

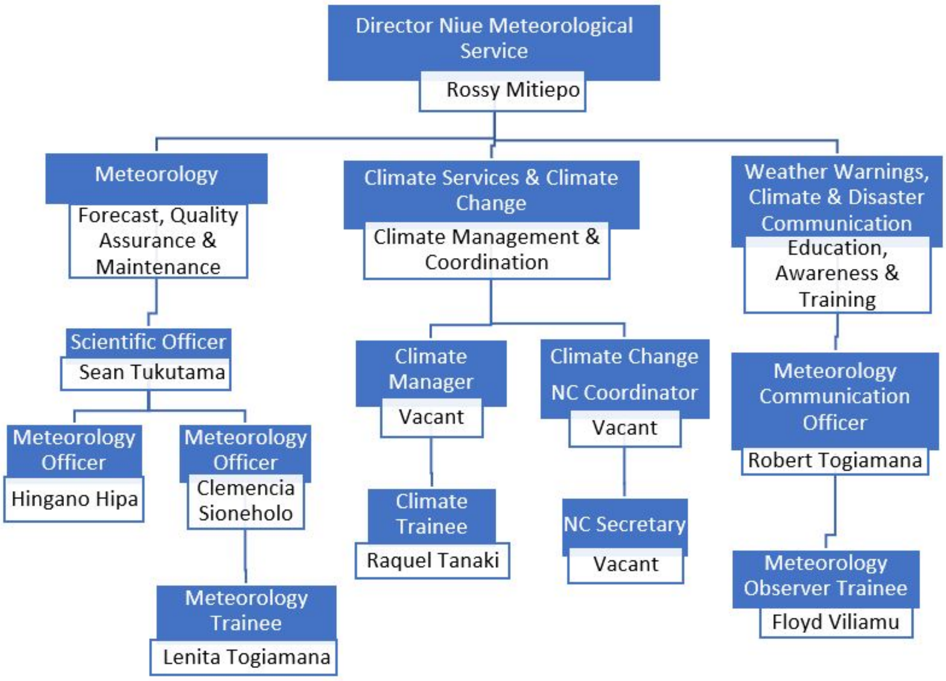

Figure 87. Niue Meteorological Service Organisational Chart (Source: Niue Meteorological Service)

NMS provides synoptic and climate observations to the international meteorological community, and disseminates general, marine, aviation and Tropical Cyclone forecasts to the population of Niue.[448] These functions are required as per the Niue Meteorological Services Act of 2013 and Niue's membership of the World Meteorological Organization (WMO). Manual synoptic observations (3-hourly) and METAR reports (hourly) are carried out during normal working hours from 8am to 4pm on Monday to Friday. Weekend coverage is limited to two hours in the mornings. Synoptic observations carried out outside these working hours are transmitted through an automated system, the Synoptic Automatic Weather Station. These observations are passed by email to MetService New Zealand, which uploads them to the GTS. A rainfall station (Liku) is located on the eastern side of Niue and is operated by the former Director of NMS. A second observing site was located at the agricultural research farm, but the site is not operational due to inability of staff to routinely record observations.

Niue relies on general forecasts (24-hour duration issued three times per day) from Fiji Regional Specialised Meteorological Centre (RSMC). NMS officers elaborate on these forecasts based on local knowledge and web-based analysis and diagnosis from FMS and other sources to provide openly accessible 24-hour forecast products covering public weather and marine forecasts for vessels immediately offshore. The forecasts are disseminated via email, Facebook, TV and radio to the public in English and Niuean. A 3-day elaborated forecast is provided at a fee to subscribers. In addition, TV weather graphics are provided to the Broadcasting Corporation of Niue (BCN) four days per week. No forecasts are provided for aviation. The Niue Climate Outlook is issued on a monthly basis, which

[448] Government of Niue, Niue Meteorological Service, available at < http://informet.net/niuemet/> [August 2019].

focuses on rainfall (likelihood of above or below average rainfall) with a 3-month outlook and ENSO status, as well as items of general interest regarding weather and climate matters. NMS staff participate in the Pacific Climate Outlook Forum prior to issuing the Niue Climate Outlook.

NMS has started to work on implementing a Quality Management System (QMS) as required by WMO and the International Civil Aviation Authority (ICAO) but it has not been completed due to staff movement and workload.

Staff are recruited at NMS with secondary school qualifications, as trainees under the Niue Public Service classification. Trainees undertake on-the-job training with more senior observers and are formally assessed to demonstrate that they have reached a competent level for observations. Staff are encouraged to undertake regional observation training as it becomes available.

All officers – except the Director – are rostered for observational duties. In addition to observing roles, one officer is responsible for IT and equipment maintenance and repair and forecasting; another is responsible for media and public communications; and a third is responsible for climate data entry, monitoring and forecasting. Senior staff are required to multi-task in these areas.[449]

NMS plays an important role in times of climate-related disasters, providing weather warning advice to the Niue Disaster Council (NDC), an executive council led by the Chairperson, Secretary of Government (SoG) who takes the lead for the Government of Niue in issuing action alerts. These agencies coordinate with the Directors General of government ministries and with BCN. NMS hosts Niue's Emergency Operations Centre when a disaster is imminent. The NDC consists of the SoG, the Chief of Police, the National Disaster Management Officer and the Director of the NMS. The Police Chief and the NDMO coordinate disaster responses through engaging the Utilities and Transport sectors.

NMS staff have achieved great advances in their capacity to interpret and use meteorological data, largely through training provided by Australia's Pacific Islands Climate Prediction Project (PICPP) and Climate and Oceans Support Program in the Pacific (COSPPac). These two projects installed purpose-built software that enables NMHS staff in all five countries (and nine others) to generate forecasts of the local climate 3 to 9 months ahead. The software—Seasonal Climate Outlook for Pacific Island Countries (SCOPIC)—uses Niue's local data to generate a forecast statistically, focussing on expected rainfall and scalable down to the level of the weather station recording the data, if necessary. The data used in SCOPIC is drawn from a climate data management system called CliDE (Climate Data for the Environment) which ingests and archives digitised climate data and makes it available for manipulation and use in information products. The collection of local data allows the NMS to monitor and report on Niue's climate at local scale.

Over the ten years from 2009, PICPP and then COSPPac has mentored climate officers in Niue in the use of SCOPIC to produce a monthly report on upcoming climate conditions and to evaluate the accuracy of their previous climate forecasts. During this time, the officers' confidence and accuracy has improved markedly, and they contribute to group support for new climate officers to achieve the same competence. This mentoring continues, now by SPREP's climate officer, who manages a monthly conference call with up to 11 Pacific climate officers and the Australian Bureau of Meteorology (BOM). The Niue climate officer discusses the calculation of his or her current climate forecast with the SPREP climate officer one-to-one ahead of the roundtable phone call. The group discussion then considers the forecasts across the region for the next few months and compares each country's previous predictions with the recorded data for those months.

[449] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre

The Australian Government continues to support the monitoring of sea level rise and other climate data at Niue's Alofi wharf. SPC maintains and provides access to the Pacific Ocean Portal originally developed by BOM through COSPPac: the Portal allows a user with limited internet access to select a location and a sector such as tourism, fisheries, and shipping, ask for ocean parameters such as sea temperature, wave heights, coral bleaching, currents, salinity and chlorophyll, and receive the information visualised as maps and diagrams. The Portal is one of the tools Niue MS demonstrates to stakeholders.

The Niue Meteorological Service was an early entrant to the traditional climate knowledge (TK) project begun by COSPPac and now managed by SPREP. NMS was engaged in the design of survey forms and of the national database that allows differentiated access to the digitised information, according to age, sex and other categories. The intensive data collection process, conducted by NMS staff and interns with community elders, created opportunities to discuss the services the NMS provides, how they are generated and how they compare. The contribution of traditional climate knowledge has been shown to improve the accuracy of scientifically derived long-range forecasts and add valuable specific impact information for sectors.[450]

This Programme will work with BOM to advance further Niue's traditional climate knowledge activities with communities. The work will include both contributions to the technical challenges of storing and using TK and input to discussions with elders about the application of their knowledge to seasonal forecasting. Over time, these discussions aim to generate acceptance of the technically derived climate forecasts made by the NMS—one of the immediate benefits is that communities are more likely to take notice of extreme weather warnings. As the climate becomes more chaotic, scientifically derived climate forecasts are expected to have greater predictive power than traditional climate indicators. Acceptance of Niue MS's warnings and advice will advantage communities and let them prepare effectively.

Types of climate products and services by national climate service provider	List in detail the activities being undertaken to fulfil national requirements	Requirements to improve your services
Number of Staff involved in climate Services	4 staff Communication Climate data observations Climate data recording Climate data archiving Climate data entry into hard copy MET 301 Climate data entry – Excel, CliDE Climate data basic analysis	- Need to develop national framework providing strategic and operational guidance for coordination amongst key stakeholders of climate services - Need to support ocean science attachment training, and national climate training - Need to establish Ocean Services
Climate Observations	9am climate data observations - Rain, temperature, relative humidity, evaporation, sunshine hours, wind direction, visibility, pressure, dew point and soil thermometer	Expand real-time marine and ocean observations
Climate Data Management	- Climate data entry into CliDE	Basic or refresher training for new staff on CliDE

[450] https://ccafs.cgiar.org/news/indigenous-knowledge-weather-forecasting-lessons-build-climate-resilience-east-africa-0#.XQIpuIgzbIU

	- Climate interpretation and analysis for monthly outlook	
Interaction with Users	- Information sent out via TV weather, Email to government all staff and non-government email list, monthly Niue Climate Outlook.	- Need to communicate climate forecasts to sectors, facilitate access, and train sector agencies to understand the climate information - Establish annual National Climate Outlook Forum or workshop led by the Met Service - Need for more community outreach programmes and visual awareness products including TV awareness programme - Need for community training on climate change and oceans information - Need to increase frequency of climate and weather forecasts over the radio
Seasonal Climate Outlooks	Niue Climate Outlook sent to stakeholders monthly.	Training on climate analysis and interpretation.
Climate Monitoring	Use SCOPIC to monitor drought and rainfall	- Refresher training on SCOPIC - Need for monitoring of traditional knowledge indicators, and referencing as baseline knowledge
Specialised climate products (Sector)	Nil	Need to develop agency and sector-specific products and services
Decadal Climate Prediction	Nil	
Long-term Climate Predictions	Nil	
Customized climate products	Nil	- Need for localized climate information - Information to be translated, made relevant and presented in a form that is useful to local community e.g. farmers and fishermen
Climate Application Tools	SCOPIC	

Table 30. Current capabilities and climate services provided by and requirements to improve climate services in Niue (Source: In-country consultations)

Niue Meteorological Service experiences barriers to effective delivery of essential services common to all five very small island countries, many of which this Programme will address collectively, adding to existing networking among the countries and achieving economies of scale.

The following constraints affect the NMS's work:[451]

- Limited collection of climate and weather data. At present, there is only one automatic weather station on the island, which collects data on only limited variables. As such, the country does not collect data on variables such as visibility, cloud height and wave height, all of which are critical for informing citizens, tourists and airline officials about conditions that could be of concern. Furthermore, the lack of multiple weather stations limits the relevance of the data collected for other parts of the island and might paint a skewed picture, over time, of the weather and climate in Niue. Finally, weather and climate data are collected only during work hours. This means that any meteorological phenomena that occur outside normal working hours (8am to 4pm, Monday to Thursday) do not necessarily get registered in the country's data collection system.
- Limited telecommunication capacity of NMS. While Niue can access satellite data to monitor tropical cyclones and other low-pressure systems, and can receive forecasting information from the RMSC,[452] the telecommunications capabilities of the NMS are so limited that real time monitoring of such systems is often a challenge. The telecommunication constraints extend to also limit the ability of the NMS and other agencies engaged in disaster preparedness and response (police, fire, NDMO, BCN, paramedics) to effectively communicate with communities in parts of the island other than Alofi, the capital.
- Lack of an adequate physical space to house the NMS. The current space cannot support the number of staff and type of equipment necessary for Niue to collect, analyse and use weather and climate data. In addition, the NMS is located in a building that cannot withstand a cyclone of a high magnitude, putting Niue's ability to manage during natural disasters into question.
- Lack of sufficient staff capacity in the NMS, both in terms of number of staff and in terms of education and training. Weather data is collected only during normal work hours because of limited staff availability. In addition, current staff need training to be able to adequately analyse collected data and produce climate information products of use to end-users.
- Inability of line ministries to use weather and climate data collected to inform policies, plans and activities. While the Government has committed to mainstreaming climate risk consideration across its functions, government staff from line ministries are unclear about how climate information could be used to improve their policies, plans and activities related to key development sectors—agriculture, fisheries, tourism, infrastructure and health.
- Inability of private sector and communities to use climate information to make climate-smart decisions related to food security, water security, fire risk, tourism development, etc. There is little engagement by the Government with communities in relation to addressing climate risks, and as a result, communities and individuals have limited awareness of climate change vulnerabilities and resilience practices.[453] Considerable thought and planning has been invested in how NMS climate staff can engage communities and particularly young people.[454]

The priority area for professional training and education is climate services and climate change. The priorities for technical training of NMS staff are: ICT; equipment maintenance and repair; refresher courses covering forecasting, climate and general meteorology; initial training for observers; and

[451] Niue UNDP, 2017, Identified in the UNDP proposal: Increasing the resilience of Niue through a comprehensive approach to climate information services and early warning systems.
[452] Fiji Meteorological Service is a WMO Regional Specialised Meteorological Centre
[453] UNDP, 2017. Increasing the resilience of Niue through a comprehensive approach to climate information services and early warning systems.
[454] R Mitiepo, pers comm, 2019

capacity building for staff to work with donor agencies (i.e. writing proposals and reports, and project management).[455]

Disaster risk management

The National Disaster Council (NDC) is responsible for day-to-day coordination for hazards, with the Police undertaking much of the required work – including risk reduction and awareness raising. In times of disaster, the Chief of Police provides leadership in overall response, relief and initial recovery.[456]

Financing for climate services and disaster risk management

There is no national budget allocation for climate change programming in Niue. Through the GCF Readiness and Preparatory Support programme, SPREP is building the capacity of Niue to manage and streamline climate finance.[457] Disaster risk management is not budgeted for explicitly and Niue does not have national or sectoral contingency funds for disaster response (except for Niue Power Board, which has funds for emergency responses).[458] The JNAP estimates that the total cost for implementation is NZD 2,117,255 (approximately USD 1.3 million), with NZD 268,037 (approximately USD 160,000) coming from in-kind contributions made by the Government of Niue and partners (such as SPC/SOPAC and SPREP).[459]

Previous national climate services and early warning activities

Niue has several climate change related projects under way or recently completed.

A **traditional climate knowledge project** supported by the Climate and Oceans Support Program in the Pacific (NZD20,000) funded surveys conducted with village elders and the development of a glossary of climate terms in Vagahau Niue (VN), the Niuean language. Data is stored in a national database which allows different culturally determined levels of access. The development of the VN glossary will make well-understood climate information much more achievable.

UNFCCC contributed NZD50,000 to the NMS as part of its support to Niue's **Second National Communication**, for technical assistance and public education activities.

The GEF-funded **Ridge to Reef** (R2R) project focused on the expansion of Niue's protected estate on land and on its marine areas through a combination of community conservation areas and government-led protected areas. It introduced legal and regulatory frameworks and policies to ensure the conservation, sustainable use, and access and benefit sharing of natural resources and ecosystems.[460]

The Niue Meteorological Service used an allocation of flexible funds from the **Climate and Oceans Support Program in the Pacific** (NZD24,000) to upgrade equipment, conduct workshops with public and private sector users of its information and publicise its services.

[455] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre
[456] Niue, 2012. Joint National Action Plan for Disaster Risk Management and Climate Change
[457] SPREP, 2017. Readiness Proposal - Niue
[458] Niue Police Force, 2012. National progress report on the implementation of the Hyogo Framework for Action (2011-2013) - Interim
[459] Niue, 2012. Niue's Joint National Action Plan for Disaster Risk Management and Climate Change
[460] UNDP, 2018, Pacific R2R Project Progress Report

The **Pacific Adaptation to Climate Change** (PACC) project (2008–2013: USD500,000: partners GEF, UNDP, SPREP) helped to provide an adequate back up system to Niue's existing groundwater supply infrastructure by increasing rainwater harvesting and the water storage capacity of individual households within village communities. It supported capacity building, training, climate scenarios, modelling and the application of socio-economic, vulnerability and adaptation assessments to current water resource management. Further funding from the Australian Government and the EU will ensure all the inhabited households (477 households in 14 villages) in Niue have a rainwater capture and storage system.

A UNDP–GCF Project helped to develop goals and objectives subsequently advanced in the 2014–2019 **Niue National Strategic Plan** (NNSP), which presents a vision for mainstreaming climate change considerations within sectoral lines. It identified key sectors for climate mainstreaming—water resources, food security, public health and infrastructure and contributed to the Forest Policy, the Niue National Energy Policy, and the Ecosystems Approach to Fisheries Management.

The **USP-EU Global Climate Change Alliance** (GCCA) Support through Capacity Building, Community Engagement and Applied Research project was implemented on Niue from 2012-2016. The GCCA, launched in 2007 by the EU to assist Least Developed Countries (LCD) and Small Island Developing States (SIDS) is based on two pillars: improved political dialogue on climate change and concrete financial support for adaptation to the negative effects of climate change. It has supported five communities in Niue to develop climate adaptation plans and to use these plans to attract more funding to implement their activities.

SPREP's **Inform Project** (Building National and Regional Capacity to Implement Multilateral Environmental Agreements by Strengthening Planning and the State of Environmental Assessment and Reporting in the Pacific) is helping Niue (and 13 other countries) to acquire access to its own national datasets for environmental information. It is working with Niue to develop staff capacity to locate useful datasets, assess the quality of the data, manage its ingestion to the national environment data portal, and use the data in national planning and in reporting on multilateral environmental agreements. SPREP hosts Niue's national portal and a regional portal, and provides training, mentoring and support. Inform will be the foundation of Niue's climate data strategy.

As of May 2020, the Niue State of Environment (SoE) Report 2019 was completed, endorsed and ready to be officially launched. The report was commissioned with the purpose of providing the government, community leaders and key decision makers with key information on the state and trend of the environment in Niue. It also includes an assessment of the effectiveness of management actions taken and deficiencies that need to be addressed to improve the state of the environment for future Niueans. The report by developed by Niue's Department of Environment with SPREP's assistance and includes content contributions by various representatives from government departments, universities and non-governmental organisations.

Alignment with national priorities

In its most recent report (2017) to the Pacific Meteorological Council (PMC), Niue's NMHS identified its priorities:

- Increasing capacity of human resource development through capacity building and training to enhance and strengthen weather and climate services;
- Providing sector-specific climate information for fisheries, agriculture, health and tourism;
- Outreach on weather, climate and hazards for village communities;
- Implementation of Climate Early Warning Systems (CLEWS); and

- Providing actionable climate information in local language for communities and schools.[461]

The following national policies reinforce Niue's priorities for strengthening its climate information and knowledge services.

Niue's **National Climate Change Policy 2013** identifies the following objectives:

- Awareness raising—to promote public awareness and improve stakeholder understanding of the causes and effects of climate change and climate variability as well as vulnerability, adaptation and mitigation responses; and
- Data collection, storage, sharing, and application—to improve and strengthen the collection, storage, management and application of climate data, including greenhouse gases and emissions, to monitor climate change patterns and its effects.[462]

Niue's **Joint National Action Plan** (2012) has five priority areas:

- Strong and effective institutional basis for disaster risk reduction / climate change adaptation;
- Strong public awareness and improved understanding of the causes and effects of climate change, climate variability and disasters;
- Strengthened livelihoods, community resilience, natural resources and assets;
- Strengthened capacity to adopt renewable energy technologies and improve energy efficiency; and
- Strengthened disaster preparedness for effective response.[463]

The Niue **National Strategic Plan** requires its Meteorological Service to:

- Provide reliable, timely and quality meteorological and climate services to all residents (Pillar 3); and
- Ensure the adverse effects of climate change and natural hazards are mitigated and appropriate adaptation programmes are implemented to strengthen Niue's resilience (Pillar 5).[464]

RESULT 1 – STRENGTHENED DELIVERY MODEL FOR CLIMATE INFORMATION SERVICES AND MHEWS COVERING OCEANS AND ISLANDS

Activity 1.1 Strengthen institutional and policy frameworks and delivery models for climate services

Under this Activity, the Programme will establish comprehensive institutional and policy frameworks and delivery models for strengthened climate services in Niue. This will include the development of a National Framework for Climate Services (NFCS), which will be supported by effective coordination mechanisms to mainstream climate risk knowledge into the decision making of climate-sensitive sectors. Moreover, Niue will conduct a climate services market assessment and develop a policy for sustainable financing and delivery of climate services. Amongst others, engagement with the

[461] Reporting on National Priority Actions of the Pacific Islands Meteorological Strategy (PIMS) 2012-2021.
[462] Government of Niue, 2013, Niue National Climate Change Policy.
[463] Government of Niue, 2012, Niue Joint National Action Plan.
[464] Government of Niue, 2014, Report to PIMS.

development of national budgets will enable justification of the value of climate services, strengthen existing funding for disaster relief and contribute to the identification of long-term sources of funds.

N1.1.1 Develop the Niue National Framework for Climate Services

Niue has a comparatively recent Meteorology Services Act (2013), drafted in collaboration with WMO and SPREP, which sets out its responsibilities, obligations and rights in relation to the provision of weather and climate information. The Act gives the NMS authority to issue warnings directly to the public and requires it to provide any advice needed by the Disaster Management Council, particularly during cyclone season. In practice, extreme weather warnings are issued by the Council. The Act allows the NMS to charge fees for advice but is not specific about which services can incur fees or from whom, nor about budget appropriations for NMS costs. In practice, the NMS will need to make significant further progress towards a structured programme of services which in time will build support for fees for services.

Throughout the implementation of this Programme, the NMS proposes to conduct a series of consultative workshops with stakeholders to develop and refine a National Framework for Climate Services (NFCS). In the first half of year one, the NMS will invite representatives of government agencies responsible for key sectors including the five Global Framework for Climate Services (GFCS) sectors—water, health, renewable energy, food security and agriculture, and disaster risk reduction—to take part in a 3-day workshop facilitated by an international consultant and a local consultant. The workshop will begin with a presentation of basic climate science, an explanation of the kinds of data the NMS collects, and a presentation of the products and services their data has been used to create. Sectors will also be asked to present on how they use climate information and how they would like to work with the NMS. The workshop would begin the process of agreeing with these stakeholders more specific functions, relationships and services.

The two consultants will use the outcomes of the first workshop to draft the NFCS, which will inform the future work of the NMS. Objectives will be to agree with key sectors a suite of directly applicable information products, with a process for checking their utility regularly and revising them when needed. In year five the NFCS will be re-evaluated using feedback and learnings from each sector over the previous four years. The Meteorological Services Act requires the NMS to contribute climate-related advice for infrastructure planning, disaster response preparation and international advocacy—these inputs should be agreed with the relevant departments.

N1.1.2 Conduct market assessment to explore viable opportunities for climate information services in sectors and business segments

This Sub-activity will support Niue to understand its existing market for climate services and potential sustainable climate services models; and utilise a value chain approach to mobilise private sector finance in climate services delivery. In the longer term, this will support establishment of a foundation for a cycle of investment, service enhancement, research and development, and re-investment, which has already created commercial markets for climate services in developed countries.[465]

The Programme will conduct a detailed market assessment, which will assess the following:

- **Involved actors in climate services** – This include providers, intermediaries and users: i) Government agency/s (including NMS) responsible for the operation of the national meteorological infrastructure and provision of public weather and climate services; ii) Academic (university) research community; iii) Media entities; iv) Private sector and other

[465] SAID, 2018. Climate Information Services Market Assessment and Business Model Review

providers; and v) Users, which consists of the general public, as the users of basic services, and the economic and social sectors and organisations as the users of specialised, tailored services.[466]

- **Regulatory environment** – Analysis of the current regulatory environment for climate information and early warning services in Niue and subsequent identification of policy incentives to unlock barriers to private sector investment;
- **Supply and demand analysis** – Identification of country-relevant sector and business needs for climate services (for example, level of information, scales and access required);
- **Private sector engagement** – Building on the analysis of supply and demand, the Programme will support NMS to engage with the private sector – including through the National Climate Outlook Forums (Sub-activity 1.1.3) – to identify private sector sponsors' interest in the generation, translation and transfer function and in purchasing climate-related information.
- **Business models** – Analysis of business models for climate services that are successful in other countries, with a focus on Small Island Developing States (SIDS). This will include case studies on private sector company provision of climate services as well as government-led initiatives.

Based on the above analysis, the Programme will support Niue to identify opportunities to develop value-added climate products and services; and potential for public-private partnerships and private sector investment in climate services. Private sector engagement will improve the cost-effectiveness of NMS and increase potential for catalysing innovation in climate information technologies. This Activity will also inform development of the national policy for financing climate services in Sub-activity 1.1.4.

N1.1.3 Mainstream climate risk knowledge into sectors

National Climate Outlook Forum

In the second half of the year the NMS will deliver a National Climate Outlook Forum (NCOF), before the onset of the cyclone season (October/November for Niue) and after the Pacific Islands Climate Outlook Forum (PICOF).

The participants in the earlier workshop (for government officials) will be better prepared to understand the Outlook and how it supports specific sectoral advice. The NCOF will be fine-tuned in response to the contributions of workshop participants, explaining how they use the NMS' advice.

In years two, three and four, NMS will hold similar 2-day workshops successively with the private sector, NGOs and communities to articulate what information they want from NMS and the formats in which it will be most useful to them. On the second day of these workshops, NMS will present that year's NCOF for all stakeholders. The NCOF will be presented to all stakeholders as usual in year five after the NFCS review workshop.

Ministers' climate briefing

The process of developing the NFCS will be reinforced by an annual formal briefing in October/ November to the Parliamentary Ministers, based on the NCOF and combining information about the climate, how it is changing and what the implications are for Niue, with a presentation on the products and analyses the NMS can generate. NMS will explain the use of its data in planning climate-proof

[466] WMO, 2015. WMO-No. 1153. Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services

infrastructure, preparing for extremes of rainfall and drought, delivering timely disaster warnings and informing Niue's advocacy in international forums.

Climate Information Services Sector Action and Communication Plan

In the first half of the second year of the Programme, the NMS will engage an international and a national consultant to facilitate a workshop with stakeholders from government agencies and communities to identify sector specific priorities and actions for climate information services, targeting five sectors. The workshop will further develop the ideas about the information needs of specific sectors gained from the NFCS. It will also consider, with sector representatives, how climate information can be mainstreamed into their work and applied in their decision-making.

The consultants will use the outcomes of the workshop to draft a Climate Information Services Sector Action Plan and a Communication Plan for an agreed number of important sectors. The plans will address sector-specific needs for information services relating to both disaster risk reduction and management, and effective climate change adaptation.

The Plans will document an agreed process for testing the best ways of regularly communicating climate information to sectors. This will include both finding ways to make information easily accessible and exploring potential methods of improving the understanding of climate information by all workers in a sector, and by the users of that sector's own services.

This is likely to include a range of activities, such as improving the NMS's use of social media, but to begin with a programme of capacity building in understanding climate and weather information for government workers. The sector communication plans will be tailored to the specific interests and needs of each sector and will cover basic climate science, an explanation of the kinds of data the NMS collects, and a presentation of the products and services it provides. It should include support to the sector in communicating climate information within the sector, and to the sector's clients and end users.

Sector-Specific Climate Training Programme

The Climate Information Services (CIS) Sector Action Plans for Niue will guide sector-specific climate training for the five sectors identified in the action plans: these may include fisheries, tourism, water, health, renewable energy, food security and agriculture, and disaster risk reduction.

NMS will engage an international and a national consultant in the second half of the second year to develop a training programme, with guidance materials and capacity building resources, to facilitate the uptake of climate information services by the targeted sectors and their stakeholders. The training will be non-technical and directly relevant to each sector and applicable to its activities. This intervention is replicating an activity implemented by a GCF funded Climate Information Services for Resilient Development Project in Vanuatu.[467]

The consultants will conduct a CIS training needs assessment with NMS, and based on the assessment, will use existing and new CIS information to develop a tailored training programme. The Training Programme will be in line with the Niue Framework for Climate Services (NFCS), the Pacific Island Meteorological Strategy (PIMS) 2017–2026 and the Pacific Roadmap for Strengthened Climate Services.

In year five the sector plans and the communication plans will be re-evaluated and updated using feedback and learnings from each sector.

[467] SPREP, 2018, Climate Information Services for Resilient Development in Vanuatu. The Project has a Bislama name, "Vanuatu Klaemet Infomesen blong Redy, Adapt mo Protekt (Van-KIRAP)".

Train the Trainer for Sectors

The NMS will engage an international consultant to demonstrate the use of the CIS training programme through facilitating Train the Trainer sessions for sector personnel, non-governmental organisations (NGOs) and NMS. The training will use sector-specific case studies.

Five workshops will run in the third and fourth year, each targeting a different sector. There will be an opportunity to update the training programme after each workshop.

N1.1.4 Develop national policies for financing climate services

This Sub-activity will provide the foundation for the establishment of a financially sustainable business model for climate services in Niue. Based on the NFCS established under Sub-activity 1.1.1, the Programme will develop a national climate services financial policy to ensure that NMS has the means to sustain and ensure the ongoing operation of its mandated services in order to mitigate weather-, climate-, and water-related risks.[468]

The financial policy will be carefully developed with the support of the World Meteorological Organization (WMO) to ensure that it is tailored to the context of Niue. In line with World Bank guidance,[469] the financial policy will cover the following elements:

- Opportunities for greater cooperation between the public and private sectors and academia given that many economic sectors increasingly depend on meteorological information for safe and efficient operations.
- Opportunities for win-win situations that fulfil the public sector responsibility to help the economically disadvantaged while meeting the needs of enterprises for climate services. To this end, the Programme will ensure that the Government of Niue is made aware of the economic value of climate information in, for instance, reducing the need for dangerous marine rescues, reducing the need for transport of drinking water to outer islands in drought, and reducing the costs of recovery from cyclone damage.
- Opportunities to coordinate and/or integrate financing for climate services and disaster risk management to strengthen existing disaster relief funds and establish reliable funding for disaster preparedness activities, which are often limited to ad-hoc donor funding. This would facilitate a more efficient and streamlined approach to implementing often overlapping actions for climate change adaptation and disaster risk management.
- Identification of elements for a sustainable financial model for NMS based on the climate services value chain, which highlights the different roles of NMHSs in providing basic forecasts and warnings to protect society from the adverse effects of severe weather (a public good typically supported by governments) but also in providing specialised value-added services to government agencies and individual businesses (which may offer opportunities for cost-recovery from governmental and non-governmental sources).
- Potential to establish a National Climate Fund (NCF) as a mechanism to support Niue's engagement with climate finance by facilitating the collection, blending, coordination of, and accounting for climate finance directed towards climate services.[470] According to UNDP guidance,[471] these funds could have the following goals:

[468] World Bank, 2013. Weather and Climate Resilience. Effective Preparedness through National Meteorological and Hydrological Services
[469] Ibid.
[470] UNDP, 2015. Blending Climate Finance Through National Climate Funds.
[471] Ibid.

- Collect sources of funds and direct them toward climate change activities that promote national priorities;
- Blend finance from public, private, multilateral and bilateral sources to maximise a country's ability to advance national climate priorities;
- Coordinate country-wide climate change activities to ensure that climate change priorities are effectively implemented; and
- Strengthen capacities for national ownership and management of climate finance, including for "direct access" to funds.

Functions of NCFs could include:

- Support goal setting and the development of programmatic strategies for climate resilience;
- Fund capitalisation;
- Management of partnerships;
- Provide project approval and support implementation;
- Supply policy assurance;
- Provide financial control;
- Manage performance measurement, including monitoring and reporting on activities and resource disbursement; and
- Provide and support knowledge and information management.

- Potential for continued support from the Systematic Observations Financing Facility (SOFF) as part of the Alliance for Hydromet Development, which was launched in December 2019 by 12 international organizations including UNEP. The SOFF is envisaged to ensure provision of basic systematic observations as a global public good by providing equitable, predictable, sustainable, and performance-based finance as well as technical assistance to developing countries for the provision of foundational observational data as per the Global Basic Observing Network (GBON) standard adopted by the WMO Congress in 2019. GBON aims to improve the global availability of the most essential surface-based data by defining the obligation for countries to implement a minimal set of surface-based observations for which international exchange of observational data will be mandatory.

RESULT 2 – STRENGTHENED OBSERVATIONS, MONITORING, MODELLING AND PREDICTION OF CLIMATE AND ITS IMPACTS ON OCEAN AREAS AND ISLANDS

Activity 2.1 Enhance infrastructure and technical support for observations and monitoring

N2.1.1 Enhance national observations and monitoring networks to GBON standards and establish QMSs

Strengthen the network of land-based observations and improve observation station density in compliance with GBON

The Programme will procure equipment to strengthen the network of land-based observation stations measuring atmospheric pressure, temperature, humidity, horizontal wind and precipitation and regular reporting of data in compliance with the provisions of the WMO Global Basic Observing Network (GBON). WMO have proposed a target number of eight observation points across the EEZ of Niue.[472] The Programme will facilitate observations through a mix of surface-based, upper air and marine observations. Critically, funding will be supplied for communications to ensure that observations can be made available via GTS to WMO, in compliance with GBON.

Installation of two AWS and one AWOS station

The Programme will install two new/upgraded Automatic Weather Stations (AWS), located at Liku and Tuapa, with sensors for rainfall, air temperature, barometric pressure, wind speed and direction, soil temperature (10, 20, 30 cm) and soil moisture. The stations will contain all-parameter local Modbus Meteorological Display Consoles (MMDC) including METAR/SYNOP coded message display. In addition, one new/upgraded Automated Weather Observing System (AWOS) will be installed at Hanan Airport. The AWOS station will contain AWS sensors (as above) as well as a ceilometer and visibility meter. [473]

Niue will also procure one set of AWS spares and a bench-top instrument calibration kit.

[472] SOFF, 2020. Systematic Observations Financing Facility. Collaborative thinking workshop. Workshop outcomes and the way ahead. February 25-26 2020, Offenbach, Germany

[473] These are the proposed sites under the current baseline and to support GBON. Given the dynamic nature of projects in the Pacific, these sites will be reconfirmed during each year of implementation and should site locations require changes, this will be done within the context of GBON and within the current budget.

Figure 88. Proposed land-based observation network in Niue

Installation of a dual-polarization X-band Doppler radar

The Programme will install a dual-polarization X-band Doppler radar in Alofi. Dual-polarization radars obtain information on both the horizontal and vertical dimensions of precipitation particles, which gives meteorologists a better understanding of the size and shape of particles. The advantages of dual polarization include:

- Improved accuracy of precipitation estimates, leading to better flash flood determination;
- Ability to differentiate between differentiate between different types of precipitation;
- Improved detection of non-meteorological echoes (e.g. tornado debris, birds, etc.);
- Detection of aircraft icing conditions.[474]

A Doppler radar is capable of measuring the velocity of precipitation particles (and thus, the wind). This enables Doppler radars to identify the detailed wind structure within severe thunderstorms.

[474] National Weather Service. Dual Polarization Radar. Available at: https://www.weather.gov/bmx/radar_dualpol

The choice of an X-band system is on account of its low cost – in comparison to S or C band systems – and its small size, with potential for portable options. This is particularly important for the Pacific SIDS, which may have complex topography that limits accessibility for larger systems.

In addition to infrastructure, the Programme will provide technical training (Sub-activity 4.1.2) to build in-country capacity for radar operations, maintenance and data applications for weather and climate monitoring and analyses.

Compliance with the WMO Integrated Global Observing System (WIGOS)

Basic Information Package Meteorological Training

Providers such the Fiji Meteorological Service, the Fiji National University and others will deliver Basic Information Package Meteorological Training (BIP-MT) to new NMS technicians to enable them to take observations correctly, record them correctly and save the data securely. New observers will also be trained to calibrate and maintain the NMS's in situ observational equipment. This is fundamental to cost effective and consistent data collection and is a WMO requirement. Ensuring data continuity and quality is critical for climate change related studies and monitoring. Existing staff will be able to take the course as a refresher in maintenance and calibration. The course consists of foundation topics in maths and physics, physical and dynamical meteorology, basic synoptic and mesoscale meteorology, basic climatology, meteorological instruments and methods of observation.

Local Information and Communications Technology (ICT) support and services

NMS have a wide-ranging requirement for ICT support for both their observational and IT equipment which support the collection, analysis and dissemination of climate, ocean and weather information. Much of the hardware and software used by the NMS (e.g. CliDE, CliDEsc, Traditional Knowledge (TK) server, real-time sea level data display) requires on call support and maintenance.

This sub-activity will fund a local ICT company to provide support to the NMS as well as to support wider community communication coverage, maritime safety and disaster warnings.

Quality Management System (QMS)

QMS training for NMS staff will be conducted by an international consultant in Years 1, 3 and 5 in Niue, training nearly all staff on the maintenance and calibration of in-situ instrumentation.

The proposed training will enable NMS staff to gain certification at WMO standard for quality management. NMS's objective is to become compliant with ISO9001:2015.

Activity 2.2 Strengthen ocean and climate modelling and impact-based forecasting

N2.2.1 Establish ocean information services

SPC is the principal scientific and technical organisation in the Pacific region, supporting development since 1947. One of the key objectives of the Geoscience, Energy and Maritime (GEM) Division of SPC is to strengthen ocean and coastal monitoring and prediction services in Pacific island countries.

SPC is currently implementing several projects and methodologies relevant to this proposal. It is a key implementing partner in the Australian-funded Climate and Oceans Support Program in the Pacific managed by BOM and hosts the region's oceanographic capacity building and technical training hub, home to the Pacific Ocean Portal and several marine meteorology training tools. Since 2016, SPC staff have conducted training in Niue on introductory ocean science, ocean monitoring, and the application of ocean data and forecasts for improved decision-making. SPC has supported stakeholder engagement workshops to facilitate feedback to the NMS from potential users in fisheries, tourism, environment, national disaster management, maritime police, shipping companies and other sectors. The lessons learned from these workshops will inform future engagement with key ocean stakeholders and communities.

Ocean observations and monitoring

SPC will support the establishment of medium to long term in-situ ocean observation environmental buoys and wave buoys providing data on currents, waves and water quality directly to the NMS.

These will make possible routine ocean monitoring efforts using medium to long-term water quality sensors, and in-situ coral mapping. Baseline monitoring via regular (and post-disaster) drone surveys will allow shoreline changes and erosion to be recorded and analysed.

Once monitoring sites are established, SPC will link this data to calibrate satellite derived ocean observations, improving understanding of local impacts and establishing proxy relationships between ocean drivers and coastal impacts for algal blooms and other monitoring priorities. This monitoring equipment will improve downscaled ocean forecast models for Niue.

Ocean information services

Development of an ocean modelling framework to inform risk-based planning and early warning

Coastal ocean processes are driven by large-scale oceanic and atmospheric conditions, such as atmospheric pressure and sea surface temperature. With support from SPC, the Programme will develop an ocean modelling framework, which will link these large-scale regional drivers to local (island to lagoon scale) impacts. The framework will provide Niue with state-of-the-art coastal oceanography and hazard data. This will inform improved local risk-knowledge and impact-based early warning (e.g. annual, monthly, and intra-daily).

The development of this framework requires a three-step methodology:

1. Analysis of long-term large-scale ocean and atmospheric data to map their spatial and temporal variabilities and identify annual, monthly and daily predictors that drive localised ocean conditions and their impacts.
2. Statistical and dynamic downscaling of localised ocean information based on individual country needs and priorities. For example, the Programme will develop downscaled wave, circulation and inundation models at country, island and lagoon scales.
3. Establishment of a long term integrated ocean and coastal impact monitoring program combining remote sensing and in-situ ocean and coastal impact data collection and analysis. The monitoring program will be tailored around the local impacts either directly or via a proxy indicator (for example, turbidity, chlorophyll, inundation, erosion information). The monitoring information will be used to refine downscaled solutions.

The following table provides further details on proposed downscaled ocean products, their various coverage and resolutions as well as proposed monitoring sites, equipment and techniques.

Downscaled Models (resolution)	Observation / Monitoring	Proposed Target Sites
Country scale (kilometres) • Wave • Circulation	***In-situ observation*** • High Frequency (HF) radar (real-time 2D current and wave) • Surface wave and environmental buoy (modular system that can measure a wide range of physical	***Niue monitoring sites:*** • Off Alofi • Off Niue's eastern coast (site to be determined)

	and environmental oceanic variables – e.g. real-time temperature, salinity, dissolved oxygen, waves, pH, etc.) • Various temporary physical and environmental oceanography loggers • Drone survey for shoreline change and post-disaster impact survey ***Remote sensing derived coastal observation*** • Water quality mapping (e.g. turbidity, chlorophyll, coloured dissolved oxygen matter) • Marine habitat mapping – including in-situ sample data collection • Shoreline change analysis • Post-disaster impact mapping	

Table 31. Proposed downscaled products, monitoring sites, equipment and techniques (Source: SPC)

Provision of ocean services, data management systems and visualisation via the Pacific Ocean Portal

The data collected and produced through the ocean modelling framework will be integrated into a data management system and converted into actionable information through decision making tools tailored to fulfil ocean stakeholder needs. Due to the limited internet bandwidth in the region, all downscaled ocean products and monitoring information will be easily accessible via local servers to ensure optimised use of the information. Furthermore, the data will be integrated into the Pacific Ocean Portal – the region's centralised platform for ocean data visualisation.

Capacity building to strengthen local ocean monitoring programs and oceanographic capability

To facilitate a sustainable local monitoring program, SPC will provide training and capacity building for technical, ocean monitoring focal points at NMS, such as the Programme-hired National Ocean Expert (see intervention below). Focal points will be trained at SPC and in-country on maintenance of monitoring equipment and undertaking of coastal impact surveys. Over the five years of the Programme, focal points will receive on-going oceanographic capacity building through various regional and international trainings including certified trainings those offered through the International Oceanographic Data and Information Exchange (IODE). In addition, 2 – 3 key climate and forecasting staff identified at NMS will undertake attachment training at SPC on applications of the ocean data and forecasts made available through the Programme.

SPC will work with NMS to develop information products and ocean services and carry out at least one in-country stakeholder engagement workshop in each country to socialise users to these new services and incorporate feedback to enhance their usability (see intervention below).

In addition, through this Programme and in coordination with complementary disaster management initiatives, SPC will work closely with the National Disaster Management Office (NDMO) to capitalise on the improved hazard and risk information to inform planning and investment. Through this proposal SPC will work closely with WMO to support Niue to fulfil its requirements under the WMO Marine Meteorology competency framework.

Engagement of a National Ocean Expert

The Programme-hired local consultant will strengthen Niue's local ocean monitoring programs and oceanographic capability. The benefits of monitoring the local ocean climate directly help people—subsistence fishermen and tourists—to avoid unnecessary risks and will contribute invaluable data to the scientific community. The National Ocean Expert will monitor threats to Niue's hard coral reefs—warming and bleaching—so that harm can be minimised. When coral is stressed by heat, if the reef is protected temporarily from human activity, it will recover more quickly; if people are warned of an elevated risk of ciguatera poisoning, they can avoid eating reef fish species during the warming episode.

SPC will support the National Ocean Expert and NMS to conduct ocean data stakeholder engagement workshops twice yearly in Years 2 – 5 of the Programme. The emphasis will be on communicating the impact of hazards, rather than simply conveying technical information from the forecasting system.

The capacity of NMS to communicate impact-based forecasting and warnings, and the ability of other agencies and communities to understand the warnings and take effective action, will be improved through this more frequent interaction. The National Ocean Expert will establish feedback mechanisms to ensure that delivery of information is effective and is modified if needed. NMS will use existing in-country early warning systems and compatible software to deliver ocean information to ensure its accessibility to all users. An ocean outlook, presented as a bulletin or via other media, can be made very useful to users in sectors affected by ocean conditions.

Expected results

The expected results and key deliverables of the Ocean Information Services intervention in Niue are outlined below:

1. **Improved hazard risk knowledge**
    a. Analysis of inundation hazard and risk;
    b. Localised impacts to coral reefs and vulnerable bleaching areas.

    Through the development of an ocean modelling framework, this component will assess and quantify the multiple marine hazards and physical vulnerabilities that contribute to coastal inundation, decreased lagoon health and marine life (coral and fish) in coastal waters. Via the development of decision-making tools (e.g. graphical user interface with capacity to generate automated reports tailored to stakeholder needs), the risk knowledge generated will inform response planning, coastal adaptation solutions and investment. This component will also commence a comprehensive approach for capacity building to meet the WMO competency framework requirements for marine meteorology and oceanographic services.

2. **Detection and monitoring procedures established**
    a. Establishment of medium to long term in-situ ocean observation HF radar and wave buoys providing real time data on currents and waves directly to NMS;
    b. Strengthening routine ocean monitoring efforts using medium to long-term water quality sensors, and in-situ coral mapping;
    c. Once monitoring sites are established, SPC will link this data to calibrate satellite derived ocean observations, improving understanding of local impacts and establishing proxy relationships between ocean drivers and coastal impacts for algal blooms and other monitoring priorities.

    This component will improve downscaled ocean forecast models for Niue. This includes installing observation systems and procedures such as real-time ocean data from surface buoys and radar systems, developing tailored remote sensing solution for water quality monitoring and conducting post-event assessments to collect sound impact data. An emphasis will be placed on training on the use and maintenance of in-situ and remote sensing observation data and equipment as well as conducting tailored impact surveys. Throughout the Programme lifetime, SPC in partnership with Niue will develop the foundation of an ocean-driven impact- based forecasts based on an open source and affordable monitoring solution. The success of this ambitious system relies on a long-term impact monitoring effort, as the monitoring data will inform the continuous improvement of the impact-based forecast.

3. **Enhanced ocean services, impact forecasting, and data accessibility**
    a. Inundation early warning system;
    b. High-resolution circulation model and particle tracking forecast and hindcast models;
    c. Accessibility of near real-time ocean data for decision making via local and regional portals.

The ocean framework developed will provide annual, and monthly impact-based ocean outlook as well as impact-based forecasts. The warning system will be tailored to local conditions and circumstances, including capacity in its use and maintenance. The system will comprise a multivariate forecasting tool to obtain fast and accurate estimates of potential site-specific impact. Meanwhile, the high-resolution circulation model and particle tracking forecasts will support decision making on search and rescue, pollution management control, navigational safety, and establishment of temporary MPAs to protect turtle hatchlings, coral and fish larvae. This quality-controlled data will be directly available to NMS via local servers in near real-time but will also be integrated into existing local databases and regional interfaces including the Pacific Ocean Portal, thus facilitating public access, understanding and application.

4. **Strengthened local oceanographic capacity, communications and ocean data stakeholder engagement**
    a. National Ocean Expert position established;
    b. Twice annual ocean data stakeholder engagement workshops.

This component places an emphasis on communicating the impact of the hazard, rather than simply conveying technical information from the forecasting system. The capacity of NMS to communicate impact-based forecasting and warnings, as well as the improved ability of other agencies and communities to understand the warnings and take effective action, will be improved via more frequent interaction and collaborative establishment of feedback mechanisms. The products will be disseminated within standards and institutional mechanisms that are compatible with existing in-country EWS communication platform.

N2.2.2 Enhance climate information and impact-based forecasting

Young Scientist Support Program

To support the enhancement of in-house forecasting capacity, the Programme will build a strong scientific and analytical foundation for NMHSs through training and mentoring attachments covering climatology and oceanography. Early-career scientists from NMHSs will be selected to undertake in-depth technical capacity building through a customised Young Scientist Support Program (supported by APCC), including highly in-depth training for 2-3 months exploring various climate prediction and analysis techniques such as downscaling predictions, generating sub-seasonal-to-seasonal forecasts, analysing large-scale patterns, and tropical cyclones, etc. This will equip participants, particularly those with less experience, with both the basic knowledge needed to perform their duties as climate officers, as well as more advanced knowledge that can help them develop downscaled or impact-based forecasts.

Engagement of a National Climate Expert

To support the provision of the much-expanded climate information services, Niue proposes to engage a Programme-hired local consultant, at science graduate level, for the five-year term of the Programme. The National Climate Expert will focus on climate science and data analysis for new functions and will take day to day responsibility for sector coordination, working with the National Disaster Committee, the Ministries of Infrastructure (Transport and Utilities including energy), Social Services (Health, Education, Justice, Lands, Survey and Community Affairs) and the NMS' Ministry of Natural Resources, which covers Environment, Agriculture, Forestry and Fisheries. The consultant will develop new products in response to demand from the sectors.

Training attachments and mentoring

The Australian Bureau of Meteorology (BoM) is a long term partner of Pacific island meteorological services, delivering the Pacific Sea Level Monitoring project since 1991 and supporting the development of seasonal climate forecasting capacity since 2003. Since 2012, BoM has collaborated with Niue MS and other NMHSs in the Climate and Oceans Support Program in the Pacific (COSPPac), supporting the achievement of NMHSs' priorities for delivery of reliable and accessible climate information services. NMS proposes to organise staff attachments for training and mentoring with BoM, specifically to improve climate and ocean monitoring and prediction skills. Familiarity with the range of different climate models used in large meteorological services will give NMS climate officers a stronger understanding of climate and ocean processes.

BoM will provide training attachments focusing on seasonal prediction using ACCESS-S software and on the use of information in preparing for the tropical cyclone season and for climate extremes such as droughts and floods. NMS staff will learn the use of ACCESS-S for seasonal forecasting of ocean conditions. NMS's budget allows for a total of 12 weeks' attachments for the National Climate Expert over the term of the Programme and 12 weeks for the National Ocean Expert.

BoM will help NMS staff on attachment to prepare scientific material for publication and provide opportunities for them to present papers and posters at climate conferences.

Early Warning Systems (CREWS, EAR Watch and Impact Forecasts)

The larger Pacific meteorological services are generating products and developing services in response to demand from climate-sensitive sectors in their countries, and BoM's training inputs will benefit from their experience in facilitating this work over the last ten years. NMS staff are ready to use the seasonal forecasts they now generate every month to create tailored products for specific sectors, with support from BoM in establishing the format of products and the technical process of generating the information. This sub-activity will build on early work undertaken through COSPPac and COSPPac 2.

BoM will conduct workshops in partnership with the NMS to build the scientific understanding of staff and their capacity to explain to their clients the application of climate monitoring and prediction products to their sectors. It will conduct three Climate Risk Early Warning System (CREWS) and Early Action Rainfall Watch (EAR Watch) workshops over the term of the Programme. It will provide seasonal prediction training and training in the use of information for preparing impact-based forecasts, which give specific practical advice to government and communities on preparation for extreme events.

Through this sub-activity BoM will contribute to the NMS's knowledge sharing by supporting an officer to publish scientific material and to attend a relevant conference.

Basic climate training at the local university

Recruitment from within Niue means new NMS staff typically have secondary school science backgrounds. It is not realistic to require tertiary qualifications in meteorology or climatology—these must be acquired outside Niue, where there are also attractive employment opportunities. However, the basic physics education needed by an entry level weather and climate observations officer is available at the Alofi campus of the University of the South Pacific. The NMS proposes to have two officers each year begin the two-year foundation course: over the term of the Programme, eight officers will complete the course of study, enhancing the capacity of the NMS to understand and clearly communicate complex physical processes to non-scientists.

Inclusion of water sector data in CliDE

BoM has worked with the NMS since 2009 on a robust open source climate data management system (CDMS) common to all 14 Pacific NMHSs, the Climate Data for the Environment (CliDE) software package. CliDE has replaced the multitude of CDMSs used in the past in Pacific countries, now all obsolete and unsupported. The software has gone through a continuous process of improvement and is now used in all the partner countries to ingest data, store it securely with backup, and make it available for manipulation for information products. CliDE is used as the basis for donor-provided add-on software such as NIWA's CliDEsc and for tools developed by BOM such as a drought monitoring tool.

In this sub-activity, BOM will replace the ageing CliDE server in NMS, update user and administrator manuals and provide refresher user and administrator training on CliDE and its new products. It will enhance CliDE's ability to monitor Niue's water sector data in several steps:

- develop a key entry form for monthly water sector data
- build and upgrade the analysis of sector data in CliDE
- develop training modules—this could potentially be delivered as an accredited tertiary course through the Pacific Climate Change Centre at the SPREP campus in Apia.

BOM will host two training attachments for NMS staff and BOM staff will make four trips to Niue for installation and in-country training in the use of the software. The improvement of CliDE's capacity to monitor monthly water data will allow NMS to advise Niue's water sector on the impacts of climate change.

Customised climate information and early warnings

CliDEsc is a product generator platform managed by NIWA that enables real time analysis of climate and other environmental data from the CliDE database and other sources of data.

CliDEsc products, reports and advisories can be customised for early warning reporting. TMS climate officers can use CliDEsc products to get up-to-date information to key risk managers, helping to inform their decisions and so make early action and responses possible. CliDEsc is currently used in eight Pacific countries, but has yet to be installed in Niue. The basic software platform is soon to be installed in Niue under Australia's COSPPac program. This Programme will enable consultation to be undertaken with climate and environmental risk managers in Niue to determine their information needs, and to customise information derived from climate observations.

NIWA will support the design, customisation and production of CliDEsc early warning products. This work builds on earlier climate early warning system (CLEWS) projects that NIWA has implemented in the Pacific region, funded by the GEF, World Bank, and through NIWA's capital development program. Examples under the GEF include the "*Solomon Islands Water Sector Adaptation Project* (SIWSAP)", the *Integration of Climate Change Risk and Resilience into Forestry Management in Samoa* (ICCRIFS), and the Cook Islands project "*Strengthening the resilience of our islands and our communities to climate change (SRIC-CC)*". These were implemented in collaboration with UNDP and the partner countries' ministries. The World Bank project "*A Drought Risk Visualisation Tool Kit for Pacific Island Countries"* was funded under the GFDRR Challenge Fund. The products developed using the combined CliDE/CliDEsc data management and product generator platform are transferrable between Pacific countries where CliDEsc is installed, currently numbering eight countries in all. Installation of the basic CliDEsc package in a further six countries, including Niue, will be funded under COSPPac.

Activity 2.3 Harmonise climate data and information management

N2.3.1 Establish and implement national climate data and information strategies

National Climate Data Consultant

The Programme will support the recruitment and training of a National Climate Data Consultant (NCDC) who will work within the Ministry of Natural Resources, with support from the manager of SPREP's Inform data management project. The NCDC's role is to publicise the Niue Environmental Data Portal, to extend its user base and to help the users of its data to maximise their skills.

The NCDC will build capacity among key government staff to validate data as well as to share and promote their data with their primary audiences. The NCDC will serve as national administrator for the data portal, assigning access and ensuring users are making full use of the capacity of the system. To open lines of communication among the various national owners of data, the NCDC will host regular meetings with the national data community, communicate regularly with national and regional partners, and track the use and application of the national portal and its products. The NCDC will serve as the project focal point for the regional environment Data Manager at SPREP.

The NCDC will participate in training with the NCDCs of the other four countries in online cloud hosting skills and knowledge, and in sub-regional exchanges and South–South learning. The Inform project manager in SPREP will focus on helping the NCDC to locate data and to develop workflows enabling the Ministry for Natural Resources to access and use climate impact data. With SPREP's support, s/he will lead the development of the National Data Strategy and implement its Action Plan. The NCDC's work on harmonising the way data is recorded will make it possible to use UNEP's Country Level Impacts of Climate Change (CLICC) principles, using consistent formats for data records so that the NMS's climate data can be presented with national data from other sources, coherently and transparently. This has potential to reduce significantly the burden of reporting Niue's performance against multilateral environmental agreements and to improve the quality of its reports. This in turn has benefits for the Government's understanding of climate change impacts and its capacity to plan effective adaptation.

Ministry of Natural Resources Data Strategy and Action Plan

Climate data is usually collected and kept at a significantly higher standard than other national data: good quality data is collected systematically, recorded and stored digitally, backed-up reliably and readily retrieved for use in information products, and usually a country has reliable data dating back many decades. This is rarely the case for health data, environmental data or information on other sectors. Most impact data for sectors and even most reports are held off-line by a small group of national officers, consultants and researchers. In this context, impact includes data and reports on trends in a variety of subjects such as forest cover, coral cover, agricultural productivity, impact of cyclones, water availability and seasonality, all highly relevant to climate change. As a result, decisions are made based on sub-optimal evidence. The coordination of data related to climate science is very undeveloped and there is potential for much better information about terrestrial systems and the impacts of warming to be derived from bringing data sources together.

In order to mainstream climate considerations into the work of sectors, the Government of Niue plans to use climate data and information in concert with data from those sectors. This is particularly important for the very climate-sensitive sectors of agriculture, fisheries and health already being affected by atmospheric and ocean warming. The Government also needs to be able to combine data from various sector sources with climate data as it prepares reports to the international community on its implementation of multilateral climate-related agreements.

A consultancy—an international consultant and the National Climate Data Consultant—will support a technical committee in drafting a Data Strategy for the Ministry of Natural Resources (MNR), which includes the NMS. The Data Strategy and its Action Plan will be developed through a national 3-day workshop with stakeholders—senior and junior MNR staff, other agencies and individuals who hold or need to use climate and environment data—and will form part of the Ministry's overall Strategic Plan.

The National Data Strategy activity is very much helped by an established UNEP project executed by SPREP, the Inform project (GEF-funded: USD4.3M: 2017–2021). Inform has already set up an Environmental Data Portal for each of the five Programme countries (and 10 other SPREP member countries) and an over-arching regional portal. SPREP and SPC recently agreed to host all information in a shared "data ecosystem". The data portals are hosted on-line by SPREP, and networked together at the regional level in the Pacific Environment Portal (https://Pacific-data.sprep.org). All the portals are protected by having their data stored and retrieved from multiple machines on the cloud: if one of the servers crashes unexpectedly, the Data Portal won't go down. The Government of Niue has endorsed its national portal and the regional environment portal as the formal repository for national datasets and knowledge products.

This Programme will add a dataset focusing on climate and oceans knowledge, information and data to the Niue Environment Data Portal. The Portal "provides an easy way to find, access and reuse national data."[475] Its "main purpose is to provide easy access and safe storage for Environmental datasets to be used for monitoring, evaluating and analysing environmental conditions and trends to support environmental planning, forecasting and reporting requirements at all levels."[476] The Portal allows data to have different access levels, so Niue can ensure its formal permission is required for access to specific datasets or information.

The Data Portal already helps government agencies to prepare better reports against the Sustainable Development Goals and the multilateral environment agreements (MEAs) to which Niue is a party. It also allows the Government to archive reliably and relatively cheaply national environment-related reports and policy documents. The addition of a climate and oceans subset will extend this capacity to the Niue Meteorological Service, holding its data securely but encouraging its much broader use in monitoring changes, planning national adaptation initiatives and reporting on MEAs.

Quarterly one-day meetings will monitor progress towards the robust management of climate data, the locating of related data sources and their harmonisation. An early win could be the harmonisation

[475] SPREP, NEDP Environmental Information for Decision Making, available at < https://niue-data.sprep.org/> [August 2019]
[476] Ibid

of NMS's data with the outputs of the UNDP-Niue Government Ridge to Reef project, which is working towards an Environmental Information Management System, and is keen to collaborate.

RESULT 3 – IMPROVED COMMUNITY PREPAREDNESS, RESPONSE CAPABILITIES AND RESILIENCE TO CLIMATE RISKS

Activity 3.1 Improve warning dissemination and communication

Under this Activity, the Programme will enhance the dissemination and communication of climate risk information and early warnings based on the enhanced data generated under Programme Result 2. The Programme will particularly focus on strengthening last-mile communication systems to ensure that people and communities in remote locations receive warnings in advance of impending hazard events. NMS will be supported to develop a range of communications products tailored to end-users at the community level.

N3.1.1 Strengthen EWS organisational and decision-making processes

This sub-activity will ensure the effective and coordinated delivery of early warning services through strengthened organisational and decision-making processes of NMS, the National Disaster Council (NDC), civil society organisations and other key actors.

An annual workshop will be conducted to define the functions, roles and responsibilities of key EWS actors; develop warning communication strategies; and develop, trial and refine Standard Operating Procedures (SOPs). The workshops will be attended by various EWS stakeholders, NDC and NMS representatives. The warning communication strategies to be developed will facilitate coordination between NMS – as warning issuers – and with downstream dissemination channels, such as island community volunteer networks. The strategies will include the development of community feedback mechanisms to verify that warnings have been received and to alert NMS to potential gaps in communication networks. At the start of Programme implementation, an in-country deep dive study on gender and community stakeholders will be conducted to facilitate that the design of EWS organisational and decision-making processes is gender-responsive and that such processes proactively consider and address the specific needs, concerns and capabilities of different gender groups. Knowledge gained and outputs from the workshops will be leveraged in development of the Forecast-based Financing mechanism (Activity 3.3).

N3.1.2 Strengthen communication systems to reach the last-mile

This sub-activity will enhance connectivity and communication systems to facilitate that climate information and early warnings reach communities at the last-mile; and that communication channels are resilient to the impacts of extreme climate events. This will be achieved through the following sub-activities:

Upgrade last-mile communications infrastructure

Climate billboards

NMS will use billboards to extend the reach of climate forecasts for slow onset events such as droughts or anticipated heavy rainfall, drawing on the monthly on-line climate forecast (OCOF) reports the NMS climate officer develops with support from SPREP. The billboards will give information relevant for maritime safety and food gardening in Vagahau Niue. This information will also benefit from work on the translation of climate terms and the ongoing collection of traditional climate knowledge, to make it both more readily understood and more acceptable as an authoritative source. Experience from previous activities collecting traditional knowledge has enabled the NMS to refine its approaches to community elders, farmers—which means most women living in villages—and artisanal fishers, focusing on activities that attract the most interest and participation.

Compass posts

NMS proposes to use an idea developed by the Tuvalu Meteorological Service: installing "compass" posts in each village. The compass posts use the fact that people name wind directions by naming an island, village or country in that direction rather than north, south, etc. The compass post has pointers to known places. Climate information can be delivered in a format such as "a severe cyclone is approaching from the direction of Liku", with confidence that the warning will be understood.

This (hypothetical) warning will be further improved by being given in Vagahau Niue and with impact information, such as "prepare for very strong winds before this afternoon, by bringing loose items indoors and covering windows securely, and don't let children play outdoors".

Community collection of weather and climate information

NMS will provide communities with hard drives to store climate and ocean images, so they can document changes, particularly to coastal areas but also the impacts of both extreme events and slow onset climate extremes. NMS staff and/or the Programme-hired National Climate Expert will regularly visit the communities to download the images from the hard drives and upload them to the Niue Environmental Data Portal.

Enhance communication channels and early warning systems

Dissemination via radio and TV

The contribution of critical equipment to BCN will enhance the clarity and impact of radio and television broadcasts to Niue's population—information from the NMS will be transmitted accurately and in formats agreed with communities and with end users in specific sectors. The laptop purchase proposed for the BCN presenters will enable the broadcaster to present climate and weather data in graphical formats that make the information much more accessible to non-technical users. Increasing the climate radio talk show from fortnightly to weekly will further integrate climate change information and disaster preparation issues into the news media. Buying a fortnightly space in the national newspaper (Niue Star) will expand the reach of the climate outlooks that NMS develops, and its advice on the implications of that forecast for important sectors.

NMS ocean and climate website

NMS currently hosts a website which will need to add products and services from climate and ocean services. NMS will engage a web developer to develop a user-friendly interface to enable easy access their climate and ocean information.

Social media

At present, NMS only has access to the Internet through the Government's network, which prevents the use of social media. Purchasing additional access to the internet, with access to social media, will give the NMS many more options for interesting and entertaining delivery of its information, as well as immediate communication in times of extreme weather and disasters. NMS uses its Facebook page to disseminate daily weather forecast and other updates.

NMS ocean and climate mobile application

NMS will engage an expert developer to create an application for mobile devices such as mobile phones and tables which will provide immediate access to detailed, up to date information on local terrestrial and ocean climate conditions. IT expertise will be engaged to update and improve the NMS website with a user-friendly interface to enable easy access to climate and ocean information. This will require an overhaul in consultation with sector contacts familiar with their constituents' preferences, and a sample of users with limited technical skills to ensure its utility.

Translation of NMS products

NMS will hire local translators for 3 to 4 months to translate into Vagahau Niue workbooks for schools, the Niue Weather and Climate Glossary, legends about the weather, resource books on the history of Niue's weather and climate, students' perspectives of cyclones, village plans and other documents that need to be accessible in people's first language.

Localised mobile climate information communication system

The Programme will develop and implement localised mobile climate information communication systems with early warning to reach last-mile populations. Through mobile-cellular communication channels, this system will provide predicted risks and alerts utilising geostationary satellite nowcast and local/regional forecast information. The system will be designed to handle potential and existing risks on a 24/7 basis and will be customisable for any population group size – from small communities to larger central governments. For short-term disasters, the system will utilise satellite imagery analysis based on 2 km, 10-minute resolution (e.g. Chollian 2A) for nowcasting of wind, wave height and convective initiation of rapidly developing thunderstorms two hours in advance, which is not possible with Numerical Weather Prediction. Localised communication systems will support disaster risk management on various timescales from short-term disasters (e.g. torrential rainfall, coastal flooding, etc.) to long-term disasters (e.g. droughts). The possibility to integrate a two-way communication channel between end-users and information providers would allow for continued enhancements to the system based on user feedback.[477]

N3.1.3 Communicate early warnings to island communities

The Programme will conduct annual multi-stakeholder workshops focused on the co-design and co-production of early warning information products to improve early warning messaging to island communities and provide clear guidance for triggering response actions. Participants will include various EWS stakeholders, community representatives, the National Disaster Council (NDC) and NMS. A local consultant will support delivery of the workshops and will draw on the specialised knowledge of stakeholders and communities to create impact-based early warning messages that are actionable and effective. The workshops will provide an opportunity for engagement between warning issuers and warning 'users' to facilitate that the public and other stakeholders are aware of which authorities issue the warnings, and build trust and acceptance of information disseminated. Furthermore, the Programme will seek to engage a wide variety of community representatives to ensure that warnings are targeted to the different risks and needs of vulnerable subpopulations.

Activity 3.2 Enhance preparedness and response capabilities

N3.2.1 Enhance disaster preparedness and response measures

[477] This will be delivered by the APEC Climate Center in collaboration with the Ewha Womans University, utilising a proven method that is currently being implemented in Cambodia, with the endorsement of the Cambodia Ministry of Water Resources and Meteorology, Asian Disaster Preparedness Center (ADPC) and the Preah Vihear National Authority

This Sub-activity will use community-based approaches to enhance risk ownership at the local level and help establish collaborative community networks for coordinated action for preparedness and response to climate-induced hazards. This will include the following interventions:

Community preparation of Climate Adaptation Plans and multi-hazard risk and vulnerability assessments

The University of the South Pacific–EU Global Climate Change Alliance (GCCA) Support through Capacity Building, Community Engagement and Applied Research project was implemented in Niue between 2012 and 2016. The project worked with five Niuean communities to develop climate adaptation plans and to use the plans to attract funding for implementation. Two other communities had already developed plans with support from UNDP's Community-Centred Sustainable Development Plans project in 2010–2013.

The GCCA's objective was to enable the EU to help those developing countries most vulnerable to climate change, in particular Least Developed Countries (LDCs) and Small Island Developing States (SIDS). These countries are hardest hit by the adverse effects of climate disruption and they have the least capacity to respond and adapt to its impacts. The Alliance has two pillars: improved political dialogue on climate change; and concrete financial support for adaptation to its negative effects.

The project supported the implementation of the joint EU-Pacific Islands Forum's Niue Declaration on Climate Change in 2008 and of the Pacific Islands Framework for Action on Climate Change (PIFACC). It also supported the Joint Initiative on Climate Change of the European Commission and the Pacific Islands Forum Secretariat, which aims to strengthen the political dialogue and to mobilise and facilitate the disbursement of climate change funding from the international community to ensure that Pacific countries receive their fair share in an efficient and coordinated manner.

Niue would like to extend the activity to the other seven communities, enabling them to develop sustainable development plans using NMS climate and ocean information to ensure the plans take account of long-term climate change. Each community will draw on its own traditions, documenting its cultural and ecological knowledge to strengthen community adaptability and resilience. The project will provide equal recognition for men, women and youth, and opportunities to contribute. Participation in the development of community-based plans will encourage community members to consider how their current livelihood practices can be adapted to enhance their climate resilience, which will serve as an essential primary step for communities to adopt new climate-resilient livelihoods.

The extended project will update the vulnerability and adaptation Assessment Guide developed by the original project. The USP EU GCCA Project's trained team of assessors will undertake vulnerability and adaptation assessments for the seven remaining villages. The information will be collated to form the basis of Niue's Climate Change Adaptation and Resilience Plan. All fourteen individual plans will be confirmed with village communities and translated into Vagahau Niue. Plans will be printed, and each household will have a copy. The activities agreed in the Plans will improve communities' climate resilience.

N3.2.2 Conduct public awareness and education campaigns on climate hazards and risks

Climate Information Centers

Two Climate Information Centers will be established (one in the North and one in the South) to raise awareness on climate hazards and risks among communities and youth in Niue. Working with community-based and youth organisations, the Centers will conduct awareness raising activities in different villages and schools, organise the Climate Awareness Day in October, and undertake educational campaigns on emergency responses such as evacuation procedures. The activities will deliver information on climate hazards and risks that is relevant to local livelihoods and promotes awareness of how the information can be used to enhance climate resilience.

Disaster management and climate awareness workshops

Disaster preparation training in each village will make such instructions more practical and specific to the circumstances of each village, as determined by communities themselves. The NMS will work with partners such as women's networks, the Red Cross Society, the Boys' and Girls' Brigades and the Disaster Management Council to develop early warning communication protocols.

Workbooks for Niue Weather and Climate

NMS will work with the Department of Education on developing curriculum on climate and weather for the schools (Niue Primary and Niue High School), including graded workbooks for the Niue Weather and Climate Glossaries, legends about the weather, the history of Niue's weather and climate, resource books, students' perspectives of cyclones etc.

Raising awareness through community activities

The lessons of previous projects are also being used in activities with primary school age children and teenagers—two very different target groups. Younger children will be engaged through games and outdoor activities, stories about climate in Vagahau Niue, competitions, drawing and colouring books about climate, making posters and videos, and family-focused activities.

Older youngsters, most of whom belong to the Boys' and Girls' Brigades, will be offered both outdoor activities such as camping trips and disaster preparation training, and active participation in the collection of information from elders, the development of climate messages and the creation of innovative information materials. Preparations for a Youth Council Climate Conference will be designed by young people, with inputs from the ministries of education and health and the NMS will continue its intern programme, recruiting students interested in a possible career in climatology and meteorology.

NMS will work with the Department of Health to run wellness programme targeting communities and schools. The Programme will support the NMS to participate in Talanoa sessions (a local talk show) on climate related stories with elders.

NMS will develop brochures, posters, and factsheets about climate change and adaptation which they will distribute during their training or awareness events on climate and ocean services.

N3.2.3 Integrate traditional knowledge into early warning services

Niue Meteorological Service is strongly committed to engagement with its community. It was an early proponent of cultural ecological knowledge and traditional climate knowledge projects, and despite its small size, has been recruiting interested high school students as interns for some years. Its proposed activities build on previous activities and use carefully planned inputs with other agencies such as the Niue Star, Niue Youth Council and church groups to maximise the visibility of its messages.

The body of climate knowledge Niuean communities have acquired and codified over many hundreds of years of careful and deliberate observation has great cultural value in itself. It is used by subsistence fishers, farmers and gardeners, and in the collection of wild resources. It can also contribute to their resilience to the changes in the natural environment that they are seeing now. The Niue Meteorological Service has been engaged for several years in a traditional climate knowledge (TK) project, instigated by COSPPac and now managed by SPREP, which aims to record and apply traditional science to adaptation to change.

NMS was engaged in the design of survey forms and of the national database that allows differentiated access to the digitised information, according to age, sex and cultural categories. The intensive data collection process, conducted by NMS staff and interns with community elders, created opportunities to discuss the services the NMS provides, how information is generated and how NMS' forecasts compare with predictive systems still widely used in Niue. For instance, a discussion about the observable climate events and seasonal phenomena—flowering times, insect hatching, bird behaviour—that presage a good growing season for mangoes can lead into an explanation of the scientifically measurable factors the NMHS uses to make the same prediction—the measurable movement of warm and cold air, high and low pressure, and so on.

This Programme will work with SPREP to advance further Niue's traditional climate knowledge activities with communities. The work will include both contributions to the technical challenges of storing and using TK and input to discussions with elders about the application of their knowledge to seasonal forecasting. Over time, these discussions generate acceptance of the technically derived climate forecasts made by the NMS—one of the immediate benefits is that communities are more likely to take notice of extreme weather warnings. As the climate becomes more chaotic, scientifically derived climate forecasts are expected to have greater predictive power than traditional climate indicators. It will be beneficial if Niuean communities learn to trust NMS' information and to act upon their advice on likely impacts and on effective preparation and response.

NMS with SPREP's support plans to progress its systematic collection of traditional climate knowledge and to begin a formal process of using TK as a valuable adjunct to NMS' information, or even of integrating it with the NMS' climate forecasting.

Collation and verification of traditional climate and weather indicators

The NMS will select a TK Committee of elders, who will be asked to verify the relevance and accuracy of all gathered information, including data collected at previous meetings and workshops. The NMS will collate and report on all TK weather and climate information obtained from previous workshops, government meetings, panels and other TK related projects in Niue. The NMS will contact and collaborate with any organisations that may hold TK and seek permission to store any historical weather and climate knowledge they hold. The TK survey and interview format developed by BOM in COSPPac with input from NMS recognises intellectual property rights and is used in Vagahau Niue. The survey was used to interview participants at three formal stakeholder and committee meeting workshops and whenever informal opportunities to collect and verify indicator data occur.

Management of collected TK information

Niue owns a secure purpose-built national electronic database designed by BOM to hold its collated traditional climate information, installed at the NMS's head office in Alofi. The TK officer will manage the regular input of TK into the database with help from NMS staff and will report on progress every six months to the Programme Coordinator.

SPREP will further support this initiative by facilitating a Niuean TK animation. The animation will come with a resource took kit to help facilitators link information in the animation with smart decision making and action on the ground. It will be based on and similar to the Australian Government Pacific Climate Change Science Climate Crab.[478]

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[478] Government of Australia, Pacific climate change science, Available at < https://www.pacificclimatechangescience.org/> [August 2019]

Beyond this stage, NMS plans to develop seasonal calendars and to consider the use of traditional terms in translating its own seasonal forecasts and extreme weather warnings into Vagahau Niue, and to collaborate with SPREP on publications and presentations on traditional knowledge.

To support and advance this activity the NMS has requested a TK Officer. The officer will initially work on the monitoring phase and then move on to verification and validation of the collected data with elders. S/he will be responsible to the Director of the NMS and will work with relevant government stakeholders and communities to coordinate all project work relating to traditional climate knowledge. S/he will also provide education and awareness for local communities, collect, record and archive TK information, data and images, and set out the national workplan and program for the TK Project.

Activity 3.3 Establish Forecast-based Financing (FbF)

Under this Activity, the Programme will introduce Forecast-based Financing (FbF) in Niue, in partnership and coordination with the International Federation of Red Cross and Red Crescent Societies (IFRC) and the National Disaster Council (NDC).

N3.3.1 Develop FbF Roadmaps defining thresholds and triggers

This Sub-activity will develop a Forecast-based Financing (FbF) Roadmap for Niue, which will identify forecasts (magnitude, probability and lead time) that can trigger humanitarian actions.[479]

The first phase of the Roadmap will begin with a scoping study that will cover feasible hazards to target with FbF, forecasting capability, and the institutional landscape in Niue. This will include consultations with national agencies such as NDC, NMS, the Department of Agriculture, Forestry and Fisheries, and the Department of Health; regional agencies such as SPREP, SPC, WFP, UNDP and others; and partnerships with the IFRC and the Red Cross Red Crescent Climate Centre. For FbF to be a sustainable and effective mechanism, Early Action Protocols (EAPs) need to be embedded in national institutions, who have roles and responsibilities for taking early action. The scoping phase will identify the national and/or sub-national actors (government and civil society) in Niue and enter into a dialogue with them about the potential for early action.

The second phase of FbF Roadmap development will consist of collaborative consultations with country institutions to delineate three key elements that would enable country-led design of an FbF mechanism:

1. Menu of Triggers – A 'trigger' is a forecast that is issued, which exceeds a pre-defined danger level and probability threshold, leading to the initiation of early actions.
2. Forecast-based Actions – Identification of possible early actions that can be triggered by existing forecasts, which aim to avoid losses and damages if an extreme event materialises.
3. Institutional Arrangements – A potential architecture of country-level technical working groups and institutional ownership for FbF, including funding mechanisms when necessary.

The FbF Roadmaps will provide a set of 10 recommendations for critical next steps to move forward with Forecast-based Financing. These next steps will be focused on filling capacity gaps that enable

[479] Lopez, Coughlan de Perez, Bazo, Suarez,Van den Hurk, Van Aalst, 2018: Bridging forecast verification and humanitarian decisions: A valuation approach for setting up action-oriented early warnings

the design and activation of an FbF mechanism by the identified lead agency/s, and the design and testing process for EAPs. The Roadmaps will include the following components:[480]

- **Stakeholder Identification** – The Programme will identify the key stakeholders to be involved in the development and implementation of FbF, including international, national, regional and local actors and lead agency/s.
- **Risk Assessment** – The Assessment will include individual analysis of risk factors, key hazards, past impact, exposure and vulnerability. Based on the analysis, the priority hazards to be addressed by FbF early actions will be identified. The assessment will also provide an overview of the different types of early actions that could be taken to mitigate risk by the identified stakeholders, in different sectors (agriculture, health, etc).
- **Impact-based Forecasting (Triggers)** – The Trigger analysis will provide an overview of all available forecasts – including lead time, skill/confidence and extreme event probability.
- **Resourcing Overview** – The Assessment will identify various options for accessing funding or necessary resources for potential early actions that are more costly or resource-intensive.

N3.3.2 Build capacity for FbF

In this Sub-activity, up to five of the 10 “next steps” that were identified in the Roadmap will be developed and executed. Depending on the national context and the findings of the scoping study, these activities could include the following:

- Scientific collaboration with national or regional forecasters to carry out a forecast verification analysis or forecast calibration to support the development of triggers;
- Technical support to build enthusiasm for anticipatory actions and change mindsets;
- Specific links between the FbF and EWEA narrative with the principles and activities embedded in other outputs of the Programme;
- Technical support in finding ways to connect with existing regional systems, mechanisms and/or priorities to have a region-wide understanding or buy-in of FbF;
- Table-top exercise to discuss a historical extreme event and what could have been done by different actors to prevent impacts;
- Round-table discussion on financing mechanisms for critical early actions that could be part of an FbF mechanism.

N3.3.3 Support development of Early Action Protocols (EAPs)

The IFRC will support Niue to develop Early Action Protocols (EAPs) through technical working groups for the priority impacts identified in Sub-activity 3.3.1. A series of conversations will be initiated to develop an EAP, which could range from focusing on a simple life-saving action by one actor to a more complex document with a greater variety of actions and forecast analysis.

To identify what should be in the EAP, the identified FbF lead agency/s will convene a technical working group, engaging stakeholders at all levels – including community representatives, disaster risk reduction committees, civil society organisations, local and national government departments, NGOs

[480] IFRC, 2018. Forecast-based Financing Early Action Protocol template

and private sector actors. The IFRC Climate Centre will provide technical guidance to the lead agency on the process and provide quality assurance, but delivery of the EAP will rest with the lead agency.

Following identification of the most suitable forecast-based actions, the EAPs will be developed by the lead national agency/s. The EAPs will describe which forecast will trigger which action; where to act – based on the forecast and trigger information; and assign responsibilities to specific stakeholders for implementation of each action. In the case of more complex EAPs, they can also include a proposal for a Financial Mechanism, which will outline what funds need to be made available (including readiness costs, stock pre-positioning and activation cost for trigger-based early actions) and how they will be accessed by specific stakeholders. This Sub-activity will collaborate with national climate finance policies (Sub-activity 1.1.4) to explore situations when funding for early action can be linked to government budgets.[481] Depending on local capacity, simulations can be held to carry out a "test" of the actions of the EAP.

RESULT 4 – ENHANCED REGIONAL KNOWLEDGE MANAGEMENT AND COOPERATION FOR CLIMATE SERVICES AND MHEWS

Activity 4.1 Enhance regional data, knowledge management and cooperation

Under this Activity, the Programme will enhance coordination and knowledge sharing among the five countries to improve data and knowledge management, including establishment of an interactive ICT platform and regional data centre. The organisation of joint learning, mentoring and training events through existing WMO, USP and other centres to facilitate sharing of successes and lessons learned will further strengthen climate and ocean information services across the region.

N4.1.1 Establish interactive ICT platform

This sub-activity will establish an interactive ICT platform, which will serve as a data analytic centre for the management and organisation of climate data, information, experiences, case studies and other forms of knowledge from the five Programme countries in standardised, comparable formats most useful for end-users. The platform will include the establishment of a regional data centre fed by national data centres in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu. The countries will make as much as possible of their climate-related data publicly available through their national data portals and the regional Pacific Environmental Portal.

This Activity takes advantage of the already established GEF-funded "Inform" project, which is being implemented by UNEP and executed by SPREP. Inform is already working with staff in Pacific environment ministries to find and harvest useful datasets and information on their countries' environment and to publicise the existence of the information. The five Programme countries now have national data portals, which can be used to develop workflows to share data seamlessly between sectors. Niue has endorsed the national data portal that SPREP hosts as the principal home for its environmental impact data and contextual information. Niue has also endorsed the regional Pacific Environment Portal hosted by SPREP as the repository and access point for regional data and information. SPC and SPREP have agreed to host all the information they hold in a shared ecosystem and the five countries are encouraged to make as much as possible of their data publicly available.

The Programme will add a new category for climate data and information in Niue's national portal – existing categories include health, fisheries, tourism and disaster management as they relate to the

[481] IFRC, 2018. Monitoring and Evaluation (M&E) of Forecast-based Financing (FbF). A practical reference for country-level implementation

environment – and bring the bring data management and coordination into its schedule of capacity building activities. The National Climate Data Consultant (Sub-activity 2.3.1) will take part in technical workshops and training at SPREP and implement a comprehensive data strategy in-country with SPREP's support. Improved data sharing and discoverability will provide a conduit for NMS to assess partners' sector data or knowledge products, while hosting and sharing its own on a common platform. Enhancement in data management capacity will be achieved through the following steps:

- Addition of a new category for climate data and information to each national portal;
- Training and engagement of national climate data consultants (see Sub-activity 2.3.1);
- Support for countries to prepare their national reporting for climate-related agreements (e.g. NDCs, VNRs, National Communications to UNFCCC). This is currently a major administrative burden for very small countries, but with access to good quality data, it provides an opportunity to evaluate policy and assess progress on adaptation. A two-way flow of information from NMHSs to and from relevant sectors for national and global reporting will ensure coordination in the use of climate data and information and raise the profile of NMHSs in other sectors thereby supporting demand and fostering sustainability.
- Participation of data consultants in regional forums to enhance the use of data in national planning;
- Establishment of electronic links with existing data sources and back-up in the regional portal; and
- Management of the ICT platform for the five Programme countries through support for ICT interventions across the five countries, including application of ICT in NMHSs operations and upgrading or introducing new methods and systems, such as wireless communications and Internet of Things (IoT) infrastructure for climate services.

SPREP usually provides significant support to countries preparing their reporting against the many MEAs and climate-related agreements to which they are party. This regular process includes updating each country's State of the Environment report, clearly documenting and illustrating climate impacts. This process will give SPREP an entry point for discussing the data strategy with Niue's senior officials. Better access to more data will make it easier to identify meaningful indicators for indicator based reporting, and the project will help non-specialists understand the analysis and interpretation of data.

Improved data is only useful to decision makers, development partners and other user groups if there is wide knowledge of its existence, location, purpose and openness. As this Programme progresses, reporting for international climate agreements will be much improved by the countries' ability to draw upon a longer and more extensive body of high quality data—officers will know what data exists, how it can be sourced and how to use it well. The participation of data consultants in regional forums will build capacity to advocate for effective use in national planning and development of useful data products.

The Inform team estimates there is valuable climate change material held in more than 24 active and legacy systems among the five countries; and in many cases the obsolete hardware needed to read it is still functioning. SPREP will establish electronic links with existing data sources so they can be translated and will back them up on the regional portal. There are multiple datasets held by researchers or by individual departmental officers in danger of being lost, and SPREP will help Niue to locate and salvage them.

N4.1.2 Organise learning, mentoring and training

This sub-activity will comprise training, mentoring and advisory services for local consultants and staff in NMHSs in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu on strengthening climate information services; strengthening observations, monitoring, modelling and prediction; strengthening of marine weather and ocean services; establishing MHEWSs at national and community levels; and building community resilience against climate risks. This will be facilitated through partnerships with existing WMO regional training centres (e.g. China Meteorological Administration (CMA) Training Centre [482] through coordination by the Chinese Academy of Meteorological Sciences), USP and others in the organisation of:

- Joint learning events for exchanging knowledge and sharing experiences and lessons learned in strengthening climate information services and MHEWs in the five countries. This will have a major focus on the development and implementation of National Frameworks for Climate Services (NFCSs) through all components and related activities of this Programme.
- Targeted training of NMHS staff (e.g. meteorologists, ICT administrators, forecasters) in key areas that are essential for the Programme's impact and long-term sustainability. This will be undertaken through existing training centres in the WMO network, the University of the South Pacific (USP), the International Centre for Theoretical Physics (ICTP) and others. Training will be delivered through a combination of on-site workshops and remote learning courses. Topics of training could include:
  - Forecasting and Numerical Weather Prediction (NWP) by suitably qualified providers such as WMO regional training centres and other WMO-approved meteorological organisations. This could include nowcasting techniques for severe weather, and short-term climate monitoring and prediction in disaster prevention and mitigation.
  - Observation and Instrumentation, including Operation and Maintenance (O&M) of equipment for long-term sustainability.
  - Innovative and cost-saving technologies for observation, modelling and prediction with special focus on the application of ICT. Hence, these events will also be critical for regularly reviewing options for upgrading or introducing new methods and systems in NMHSs in the five countries, such as wireless communications and Internet of Things (IoT) infrastructure for climate services and disaster management.
  - Principles of satellite remote sensing and use of meteorological satellite images in weather analysis and forecasting.
  - Demonstration and training on the operation and maintenance of weather radar systems – installed under Sub-activity 2.1.1 by regional partners from the WMO network (possibly the Fiji Met Service in cooperation with USP under the new WMO Regional Training Center). The demonstrations and training will build capacity of the NMHSs for the provision of improved and more accurate weather monitoring and forecasts; tracking of local extreme events; better determination of rainfall rate/intensity, which is important for determining the potential for extreme rainfall and flash flooding enabling hazard warnings to be issued more accurately and in more timely fashion; and validating Numerical Weather Prediction (NWP) forecasts.

[482] CMA propose to provide free in-person and remote training courses covering the top seven training priorities of Pacific NMHSs

- Enhancing institutional effectiveness of NMHSs through Quality Management Systems (QMS), Weather Forecast Service Standard and related certification.
- Enhancing NMHS services through Impact-based forecasting and Forecast-based Financing.
- Enhancing Climate services in NMHSs, including options for ensuring long-term financing and cost-recovery such as private sector investment, public-private partnerships and the application of National Climate Funds.
- Use of alerts, information exchange and coordination in the first phase after major sudden-onset disasters, including through the Global Disaster Alert and Coordination System (GDACS).

Furthermore, the Programme will provide mentoring and technical advisory services to NMHSs in the five countries through capacity building, training and awareness raising initiatives and materials for a range of stakeholders; provide technical backstopping and capacity support to the national delivery of Programme activities; and provide expert advice to the Programme team on key climate information services and best practices, including gender-responsive implementation. In order to enhance synergies and avoid creating parallel structures, the Programme will work closely with the WMO-SPREP Pacific Meteorological Desk Partnership (PMDP), a regional coordination mechanism that supports and coordinates meteorological activities in the Pacific, and the Pacific Meteorological Council (PMC) at large.

GREEN CLIMATE FUND

UN environment programme

PALAU

BACKGROUND

The Palau archipelago is made up of about 340 islands, most of which are remnants of a tectonically uplifted coral reef, covering 466 square kilometres of ocean. The curved island chain runs for 150 km from north to south and is 25km across at its widest point. Palau sits on the Philippine Sea tectonic plate only 20 km west of the 8km-deep Palau Trench, the western boundary of the up-thrusting Pacific Plate. Despite its close proximity to this subduction zone, Palau rarely experiences earthquake activity.[483] It shares maritime boundaries with the Philippines, Indonesia, and the Federated States of Micronesia.

All but six of Palau's islands lie within an expansive lagoon, enclosed by the barrier reef, that stretches northeast to southwest for almost 115 km. Babelthuap, the largest island (396 square km), is volcanic, bounded by thick mangrove forests broken occasionally by sandy beaches on the east coast. Its highest point, Ngerchelchuus, in the northwest, is 242 metres high. Babelthuap is a rolling upland, part grassland and part jungle, incised by stream action to form three rivers. With about 3,800 mm of rain annually, considerable erosion has taken place on Babelthuap, in spite of the stability provided by laterite soils, clays, and vegetation. Large hillside terraces, numerous stone ruins, and megaliths on Babelthuap give evidence of a vital culture before contact with European explorers.[484]

Twelve of Palau's islands are permanently inhabited. About eighty percent of the population (estimated at 21,500 in 2018[485]) lives on Koror Island, the centre for commerce. The capital is in the state of Melekeok, centrally located on the island of Babelthuap.[486]

A steel bridge connects the islands of Babelthuap and Koror. Koror in turn is linked by causeway to Malakal Island, the site of Palau's deep-water port, and to Arakabesan Island. The combined area of the three smaller linked islands, all of volcanic origin, is 18 square km. However, 'beginning adjacent to southern Babelthuap and eastern Koror and filling the huge lagoon for 45 km south to Peleliu are more than 300 verdant "rock islands." These are uplifted reef structures of coralline limestone, each deeply undercut at sea level. Some of the rock islands are large, towering some 180 metres; these can have interior brackish lakes, containing unique organisms, that are connected to the lagoon by subterranean channels. Plant growth is thick on the rock islands and, together with the chemical action of heavy rains, has sculpted and broken their surfaces, producing razor-sharp edges and points and broken rubble. The limestone islands have rich deposits of phosphate, and the more accessible ones have been mined.'[487]

The inhabited coral islands outside Palau's reef-lagoon-island system sit on volcanic substructures and consist of the Kayangel Islands, 40 km north of Babelthuap, and Angaur, 10 km south of Peleliu. Sonsorol, Pulo Anna, and Tobi, all with areas of less than 2.6 km^2, are 290 km southwest of the Palau archipelago. All are flat platform structures with fringing reefs.

Palau's islands were settled about 3,000 years ago by people from South East Asia. Palauan society is matrilineal: Palauan women have always been endowed with land, titles and money, and clan lands

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483 Government of Palau, 2016, Palau Disaster Management Reference Handbook.

484 Encyclopedia Britannica, Palau, available at <https://www.britannica.com/place/Palau> [August 2019]

485 Central Intelligence Agency, Palau, available at <https://www.cia.gov/library/publications/the-world-factbook/geos/print_ps.html> [August 2019]

486 GCCA, 2013, European Union and SPC; Climate Change Profile – Republic of Palau Version 2.

487 Ibid

continue to be passed through titled women and eldest daughters. Palauan villages are organized around 10 clans that are determined matrilineally. A council of chiefs from the ranking 10 clans governs the villages, and a parallel council of female counterparts plays a significant advisory role in the control and division of land and money, but there are no women in Palau's current legislature.[488]

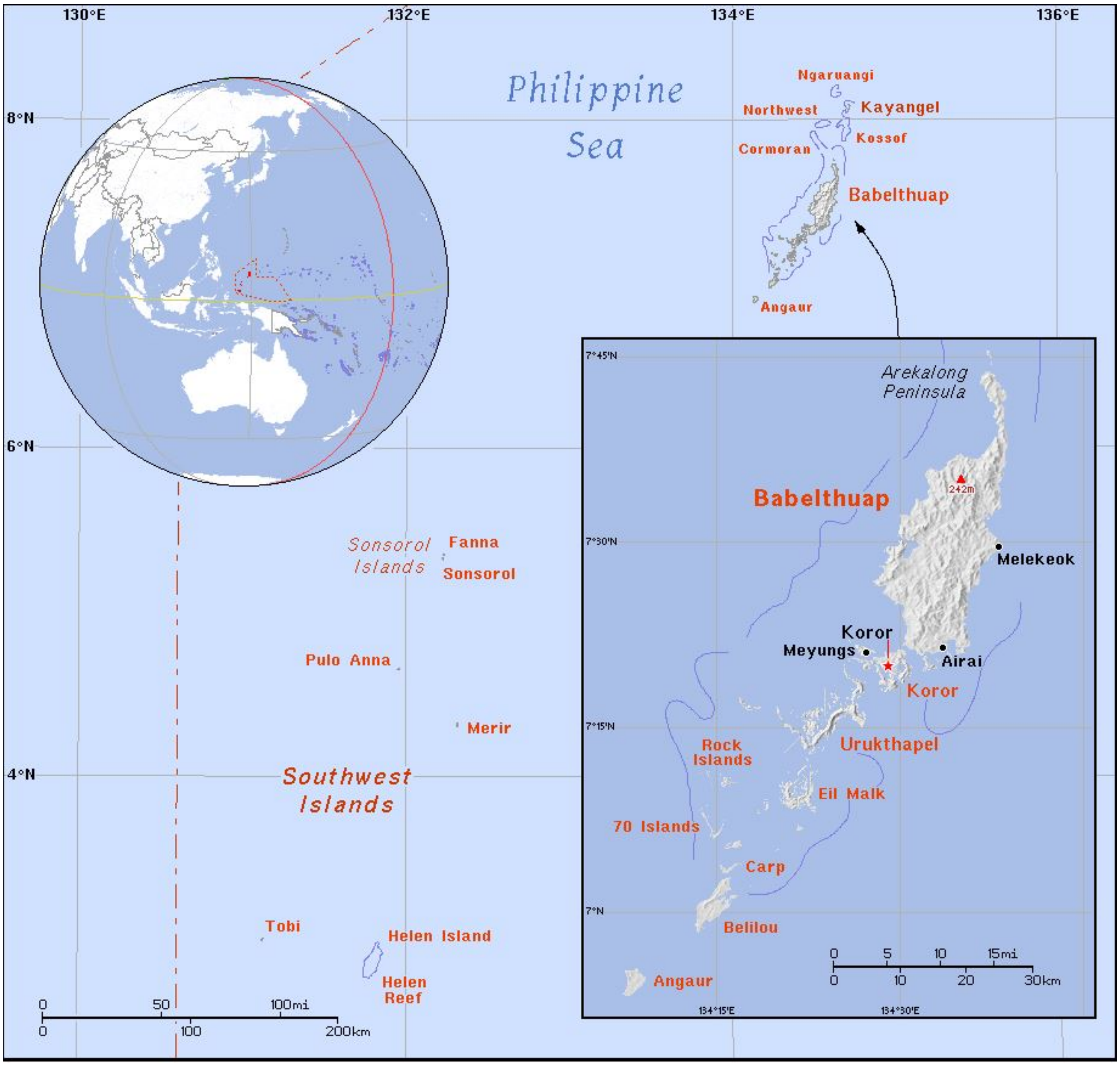

Figure 89. Map of Palau (Source: Ian Mackay)

The islands (and other Micronesian island groups) were claimed variously by Spain, Germany and Japan from the 16th century, and Palau was made a part of the United States-governed Trust Territory of the Pacific Islands in 1947. Palau first agreed a Compact of Free Association with the United States in 1986 but the Compact was not brought into effect until 1996: it envisaged a 50-year term, with reviews set for 15, 30 and 40 years.

Politically, Palau is now a presidential republic in free association with the United States, which assumes responsibility for Palau's defence and security, and provides access to social services.[489]

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[488] Government of Palau, 2016, Disaster Management Reference Handbook.
[489] Government of Australia, Palau country brief, available at <https://dfat.gov.au/geo/palau/Pages/palau-country-brief.aspx> [August 2019]

Under the Compact, and in exchange for exclusive military operating rights, the US provides Palau with economic assistance (including sector grants and trust fund contributions), access to federal services and programs (for instance postal and meteorological services) and permission for citizens to enter, work, study and reside in US states and territories. Legislative power is concentrated in the bicameral Palau National Congress.

Palau's economy is based mainly on tourism, subsistence agriculture and fishing, with a significant portion of gross national product derived from foreign aid. The country uses the United States dollar as its currency. The country's two official languages are Palauan (a member of the Austronesian language family) and English, with Japanese, Sonsorolese, and Tobian recognised as regional languages.

Since the end of World War II, the major employer in Palau has been government—first the U.S. Navy, then the Trust Territory of the Pacific Islands, and finally the Government of Palau. In the rural areas outside Koror the subsistence economy is active: taro, sweet potato and cassava are cultivated, and nearshore reef fishing is important. Offshore tuna fishing by foreign vessels provides a small amount of government revenue through the sale of licenses. There are no major exportable crops; tuna and clothing are the country's main exports.

Tourism contributes 45–55 percent of Palau's gross domestic product and is reliant on the great natural beauty and biological diversity of its islands, lagoons and reefs. Frequent natural hazards (mainly typhoons, droughts, and tidal surges), can disrupt economic activity, including tourism, and lead to loss of livelihoods, diversion of fiscal resources, and disruption of development priorities.

Current provision of climate services: strengths, priorities and barriers

"The Palau Weather Service Office (PWSO) is a component of the National Oceanic and Atmospheric Administration (NOAA). It is responsible for issuing advisories, warnings, statements, and short-term forecasts for the whole island of Palau, including the media, emergency management, aviation community, and other customers 24 hours per day, 365 days per year to keep the public safe from weather hazards. Our office monitors weather observations and provide public service to our customers. We also collect and disseminate rainfall data, launch balloons to gather upper-air weather data, administer the Cooperative Weather Observer Programme, and prepare local climatological data summaries and reports.

PWSO's new office facility is located in Airai State right across from the National Emergency Management Office (NEMO) and right next door to the Airport Rescue Fire Fighters (ARFF). They have a staff of 13 employees:

- 1 Meteorologist-In-Charge;
- 1 Administrative Assistant;
- 1 Staff Meteorologist;
- 1 Supervisor Weather Service Specialist (Met Observer);
- 5 Weather Service Specialists (Met Observer);
- 3 Electronics Programme Specialists;
- 1 Maintenance Coordinator.

PWSO's mission is to provide weather, hydrological, climate forecasts and warnings for the Republic of Palau for the protection of life and property and the enhancement of the national economy. PWSO data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the community." [490]

In addition to the six Met Observers listed above, there are six additional contracted observers located at Ngara, Melekeok and Kayangel (surf observations) and Ameliik, Koror Airport and Peleliu (synoptic observations).[491]

The Palau Weather Service Office (PWSO) provides on-ground weather observation data to NOAA Hawaii and receives from NOAA a range of data and information products on both weather and climate. The current network is as follows:

1. Melekeok State (Surf only)
2. Angaur State (Surf and 24-hour Rainfall)
3. Nekken, Aimeliik State (24-hour Rainfall and Temperature (Max-Min)
4. Peleliu State (24-hour Rainfall and Temperature (Max-Min)
5. WSO Palau main office (24-hour Rainfall and Temperature (Max-Min)

PWSO's principal client is the National Emergency Management Organisation (NEMO), which needs up to date local scale information on rainfall likely to cause flooding, approaching drought conditions that may require relief operations to be mounted, and expected extreme ocean events and typhoons. This relationship is clearly set out in Palau's National Climate Change Policy (2015), which highlights disaster risk management as a strategic priority and recognises the role of the PWSO and its tracking systems.

Palau is able to respond to sudden disasters, but it is not well prepared for the long-term changes to its climate already affecting it or likely soon to do so—sea level rise, ocean acidification, more extreme rainfall events and more severe cyclones. All these changes will elevate risks to both subsistence livelihoods and commerce, particularly tourism.

Consultation with stakeholders in Palau showed that few of the public and private sector agencies and NGOs who could benefit from climate information know what is available. Those that do, mostly do not know how to access the information or understand it. The information is often presented in scientific terminology inexplicable to non-scientists and, other than the Meteorologist in Charge (MIC), the PWSO is not yet equipped to explain climate processes in layperson's language.

The MIC of Palau WSO expressed that it would be desirable to provide a greater range of meteorological services to the community, but that further training would be required for some staff through BIP-M courses to sustain meteorological services. At present, in-service training is provided by the two degree-qualified meteorologists rather than resources from Guam (NOAA). Palau WSO has no contact with WMO RA-V training centres in Indonesia and the Philippines; and the MIC noted that regional training programs "at times appeared to neglect the needs of the countries in the North Pacific).[492]

Palau WSO has potential audiences for detailed local information on the expected progress of climate change impacts—which areas are likely to be affected first and how, what no-regrets activities could mitigate the disruption, how communities can maximise their resilience and more. Local scale information would be invaluable as well to Palau's development partners working to support climate resilience.

[490] PSS Consultations provided by Director, Palau National Weather Service, 2019.
[491] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre
[492] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre

This Programme gives the PWSO the opportunity to effect a paradigm shift to evidence-informed climate adaptation in Palau. The PWSO proposes to extend its observing capabilities and build its capacity in climate science and climate forecasting. With the support of partners, it will develop the capacity to provide climate information services to the people of Palau, to make the information easily accessible, and to deliver information in ways that make it understandable and usable. Other very small Pacific island countries have begun to acquire these capacities and are creating markets for their information, initially with public and private sector agencies, allowing them to make climate-informed decisions on infrastructure planning, water management, agricultural advice, public health, disaster preparedness and other issues. PWSO intends to establish a well-resourced climate and ocean service addressing national stakeholders' needs.

Concurrently, the PWSO proposes to expand its outreach to urban and rural communities, with meaningful information on climate processes, climate change and weather extremes, in people's first languages. The multi-country element of the Programme will give Palau's climate staff occasion to learn from the experience of other Pacific SIDSs' work on creating glossaries of indigenous terms for climate and weather phenomena.

The PWSO has identified the following priorities for skills development:

Types of climate products and services by national climate service provider	List in detail the activities being undertaken to fulfil	Requirements to improve your services
Number of Staff involved in climate Services	5 Observers, 1 Climate Focal Point, 1 Staff Meteorologist, 1 Meteorologist-In-Charge	
Climate Observations	Daily observations archived to NCDC and CliDE	
Climate Data Management	Region – NCDC, Local - CliDE	
Interaction with Users	Outreach and Awareness Programmes	Outreach equipment
Seasonal Climate Outlooks	Provided by PEAC and COSPPac	More hands-on training
Climate Monitoring	Tools provided by PEAC and COSPPac	More hands-on training
Specialised climate products (Sector	PEAC	More hands-on training
Decadal Climate Prediction	Using tools provided by PEAC and COSPPac	More training on these tools
Long-term Climate Predictions	PEAC and COSPPac	More hands-on training
Customized climate products	PEAC	More hands-on training
Climate Application Tools	PEAC and COSPPac	More hands-on training

Table 32. Status and priorities for climate services in Palau (Source: SPREP)

The PWSO provides weather, hydrological and climate forecasts (from NOAA) and warnings. Its data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the community. Palau's national Climate Change Policy (2015) identifies priority actions to be addressed:

- The assessment of climate change and disaster vulnerability and risk at multiple levels;

- Emergency communication;
- Integration of climate change and disaster risk reduction into school curricula;
- Other disaster preparedness and risk reduction measures."[493]

PWSO staff have begun to develop the capacity to interpret and use climate data, largely through training provided by Australia's Climate and Ocean Support Program in the Pacific (COSPPac). This project has installed purpose-built software that enables meteorological service staff in all five Programme countries (and nine others) to generate forecasts of their local climate 3 to 9 months ahead. The software—Seasonal Climate Outlook for Pacific Island Countries (SCOPIC)—uses each country's local observation data to generate a forecast statistically, focussing on expected rainfall and scalable down to the level of the weather station recording the data, if necessary. The data used in SCOPIC is drawn from a climate data management system called CliDE (Climate Data for the Environment, used in all 14 Pacific island countries) which ingests and archives digitised climate data and makes it available for manipulation and use in information products. The collection of local observation data allows the PWSO to monitor and report on Palau's climate at local scale.

PWSO notes the need for information on Palau's surrounding ocean—an integral part of its environment as well as the major influence on its climate. "As a natural regulator of the Earth's climate and cornerstone of the global climate system, the importance of the ocean can no longer be underestimated. From greater risk to coastal areas due to rising sea levels, strong winds, storms and cyclones, to food insecurity among island populations linked to declining marine resources, an unhealthy ocean in a changing climate can yield great environmental, economic and social imbalances."[494] Development of capacity to observe and monitor Palau's surrounding ocean is a principal component of this Programme.

In Palau, as elsewhere, climate change first emerged primarily as an environmental issue. The Office of Climate Change and the Office of Project Management are both in the Ministry of Finance, and its Director is the Operational Focal Point for the UNFCCC. The Office of Climate Change is the lead agency for the implementation of regional and international treaties on the environment to which Palau is a party and is also the main point of contact for the Pacific Regional Environment Programme (SPREP), as well as for facilitating funding access through the Global Environment Facility (GEF). NEMO is in the Vice President's Ministry.

The activities proposed for this Programme address priorities identified by Palau PWSO, NEMO and NGOs, agencies that work together to improve the communication of accessible and useful climate information to the Government and people of Palau.

Disaster Risk Management

The National Emergency Management Office (NEMO) is responsible for the coordination and implementation of preparedness, response and immediate relief actions. NEMO is also responsible for day-to-day disaster risk management activities and stakeholder engagement. The National Disaster Coordinator (NDC) is the coordinator of NEMO and assumes overall control and coordination responsibilities of the National Emergency Committee (NEC). The NEC operates from the National Emergency Operations Center (NEOC) as required in times of disaster.[495]

[493] Government of Palau, 2015, Palau Climate Change Policy
[494] Government of United States of America, U.S. Climate Resilience Toolkit Storm Surge, available at <https://toolkit.climate.gov/topics/coastal/storm-surge > [August 2019]
[495] Center for Excellence in Disaster Management and Humanitarian Assistance, 2020. Palau Disaster Management Reference Handbook

Financing for climate services and disaster risk management

There is no national budget allocation for climate change programming in Palau. There is also no dedicated budget to finance post-disaster needs, resulting in reallocation of funds from development priorities for disaster relief efforts. The Palau Climate Change Policy 2015 estimates that the cost to implement the first 5-year Action Plan across government and sectors is around USD 500 million. This includes USD 393 million for climate change adaptation measures and USD 40.8 million for disaster risk management. The Action Plan includes establishment of a USD 25 million disaster contingency fund and a USD 11 million National Disaster Recovery Fund and Insurance Program, neither of which is in place.[496, 497]

Previous national climate services and early warning activities

Palau has several climate change related projects under way or recently completed.

The **Palau Disaster Resilience Programme**: ADB loan: USD15M: 2019–2021[498]

The Asian Development Bank's Board of Directors has approved a $15M policy-based loan to help strengthen Palau's resilience to disasters by providing a predictable and quick-disbursing source of financing for early response, recovery, and reconstruction activities in the country. The fund will fill a financing gap experienced by the Government in responding to recent major disasters, including tropical cyclones and droughts. The funds will be available to be drawn upon as needed if the President of Palau declares a state of emergency due to a natural disaster.

The **Climate and Oceans Support Program in the Pacific** (COSPPac) Phase 2[499] is being implemented in 14 Pacific countries, strengthening analysis and interpretation of climate, oceans and tidal data to generate critical services to inform adaptation to climate change. It aims to enable national meteorological services to understand and use climate, ocean and sea level information to develop and disseminate useful products and services to Pacific Island governments and communities building resilience to the impact of climate change, climate variability and disasters. The program includes the Pacific Sea Level and Geodetic Monitoring Project (phase 5), the Climate Data for the Environment Project (CliDE), the Seasonal Climate Prediction Project and a program support unit.

The Climate and Ocean Support Program in the Pacific Phase 1[500] was supported by the Australian Government (2012–2018) and implemented across 14 Pacific countries including Palau by the Bureau of Meteorology with SPREP and SPC. It aimed to enhance the capacity of Pacific Islands to manage and mitigate the impacts of climate variability and change. COSPPac included a tailored training program for Pacific meteorological service staff, an Online Climate Outlook forum which mentored Pacific climate officers in developing their seasonal forecasting skills using SCOPIC, and the long-running sea level monitoring project. Meteorological services began work on the effective communication of climate information to their climate sensitive sectors and in several countries, on the collection and use of traditional climate knowledge.

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[496] ADB, 2018. Proposed Policy-Based Loan Republic of Palau: Disaster Resilience Program

[497] Palau, 2015. Palau Climate Change Policy

[498] ABD, Palau: Disaster Resilience Program, available at <https://www.adb.org/projects/52018-001/main> [August 2019]

[499] Government of Australia, Climate and Oceans Support Program: Phase 2, available at <https://www.pacificmet.net/project/climate-and-oceans-support-program-pacific-phase-2> [August 2019]

[500] Government of Australia, Climate and Ocean Support Program in the Pacific, available at < https://www.pacificmet.net/project/climate-and-ocean-support-program-pacific-cosppac> [August 2019]

The **Finland-Pacific (FINPAC) Project**: climate and disaster ready communities through improved national meteorological services[501] was a four-year project implemented by SPREP in 14 countries including Palau. It aimed "to improve livelihoods of Pacific island communities by delivering effective weather, climate and early warning services." Its two key components were providing National Meteorological Services (NMHS) with the capacity and tools to deliver and communicate timely weather and climate services to support communities; and working with communities to strengthen their ability to use and apply meteorological data and information and to develop appropriate plans to address climate change and disasters.

Inform: Environmental Information for Decision Making 2017–2021[502] is being implemented by UNEP and executed by SPREP in 14 Pacific countries, including Palau. It is establishing a network of national and regional data repositories and reporting tools to support the monitoring, evaluation, and analysis of environmental information, to support environmental planning, forecasting, and reporting requirements. Inform addresses three problems and vulnerabilities common to Pacific SIDS:

- Need for historical and current evidence of the status and trends of various environmental resources and drivers of environmental change;
- Challenges with information management, including the need for standard procedures for collecting and aggregating relevant environmental data; and
- Lack of timely access to available information by those who need it, including technical staff, governments, or communities and citizens, for national and international reporting and planning, and most importantly, for sound and informed decision making.

SPREP hosts Palau's national environment portal, which has datasets for biodiversity, coastal and marine data, atmosphere and climate, land, built environment, culture and heritage. The Government of Palau has endorsed its national portal and the regional environment portal as the formal repository for national datasets and knowledge products. The project is working with Palau to develop staff capacity to locate useful datasets, assess the quality of the data, manage its ingestion to the national environment data portal, and use the data in national planning and in reporting on multilateral environmental agreements. SPREP hosts Palau's national portal and a regional portal, and provides training, mentoring and support.

The **Pacific Adaptation to Climate Change** (PACC)[503] project aimed to reduce vulnerability and increase adaptive capacity to the adverse effects of climate change in key development sectors: coastal zone management, food security and water resource management. [504]

The **Pacific Climate Change Science Programme** 2009–2011[505] conducted a comprehensive climate change science research programme aimed at providing in-depth information about past, present and future climate in 15 partner countries including Palau.

The **Pacific-Australia Climate Change Science and Adaptation Planning Programme** (PACCSAP) 2011–2015[506] helped 14 Pacific countries, including Palau, to build resilience to current and future climate risks through improved science and data, increased awareness of climate change and its impacts, and better adaptation planning. It produced very detailed reports on scientific modelling of climate change impacts on each country under three different emissions projections.

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501 Pacific Meteorological Desk & Partnership, available at <https://www.pacificmet.net/project/finland-pacific-finpac> [August 2019]
502 SPREP, 2017, Inform Environmental Information for Decision Making.
503 SPREP, 2009, Pacific Adaption to Climate Change (PACC).
504 SPREP, 2014, Vulnerability and adaption (V&A) assessment for the water sector in Majuro, Republic of the Marshall Islands.
505 SPREP, 2009, Pacific Climate Change Science Program (PCCSP).
506 SPREP, 2011, The Pacific – Australia Climate Change Science and Adaption Planning Program (PACCSAP).

The **Programme for implementing the Global Framework for Climate Services** (GFCS) at Regional and National Scales 2015[507] was funded by Environment and Climate Change Canada (ECCC) through WMO and implemented by SPREP and the Pacific Meteorological Council. The goal of the Programme was to enhance the resilience of social, economic and environmental systems to climate variability and climate change through the development of effective and sustainable Regional and National Climate Services under the GFCS in selected regions and countries.

The **Republic of Korea-Pacific Islands Climate Prediction Services Project**[508] is implemented by the APEC Climate Centre and SPREP. It provides nationally tailored seasonal climate prediction information and builds the prediction capacity of Pacific meteorological services. Its objective is to strengthen the adaptive capacity of vulnerable communities to climate risks at seasonal timescales. The project has developed region-specific downscaling methodologies and established an online climate prediction system. Its on-line climate prediction system CLIKP, or Climate Information Toolkit for the Pacific, is available to Pacific Island National Meteorological Services at http://clikp.sprep.org/.

The **Global Climate Change Alliance**: Pacific Small Islands States and the Building Safety and Resilience in Pacific Islands Countries Project are both implemented by the Secretariat of the Pacific Community and funded by the European Union from 2016.

The **Coping with Climate Change in the Pacific Islands Region** program is funded by the German Agency for International Cooperation and the United States Agency for International Development.

PACC Palau: 'Land-to-Sea' Approach to Climate Change Adaptation: the PACC project focuses on the agricultural sector. PACC Palau is providing alternative solutions to current problems faced by farmers, including saltwater inundation, the negative impacts of increase in sea surface temperature, and changes in ocean salinity in the Ngatpang State. The objective of the PACC Palau project is to test and introduce saltwater tolerant taro varieties in order to reduce the impacts of climate change.

The **Ridge to Reef project**: GEF funding supports Palau's two linked national efforts to protect biodiversity and sustainably use natural resources: the Protected Areas Network (PAN) and the Sustainable Land Management (SLM) Initiative. The PAN focuses on locally managed marine and terrestrial protected areas. The SLM addresses land uses and both direct and indirect impacts outside of protected areas. When coordinated, the PAN and SLM will provide Palau with a powerful framework to manage resources sustainably from the local to the national levels.

Alignment with national priorities

The Programme and its proposed activities are consistent with international agreements to which Palau is a party and support the recommendations of climate-related national policies and frameworks.

International

- Sustainable Development Goals (SDGs) of the UN Development Programme
- Sendai Framework on Disaster Risk Reduction
- Paris Agreement on Climate Change.

Regional

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507 Pacific Meteorological Desk & Partnership, 2015, Program for implementing the Global Framework for Climate Services (GFCS) at Regional and National Scales.
508 SPREP, The Republic of Korea-Pacific Islands Climate Prediction.

- Framework for Resilient Development in the Pacific (FRDP) 2017–2030
- SAMOA Pathway[509]
- Pacific Island Meteorological Strategy (PIMS) 2017–2026[510]
- Pacific Roadmap for Strengthened Climate Services (PRSCS) 2017–2026[511]
- 2017 Honiara Ministerial Statement on Sustainable Weather, Climate, Oceans and Water Services for a Resilient Pacific
- 2015 Nuku'alofa Ministerial Declaration on Sustainable Weather and Climate Services for a Resilient Pacific.

National

Palau's Climate Change Policy 2015 documents the already measurable effects of climate change and calls on developed countries to prevent further harm.

http://ccprojects.gsd.spc.int/wp-content/uploads/2016/07/2.-Palau-Climate-Change-Policy.pdf

Palau's Intended Nationally Determined Contribution to the Paris Agreement records its undertakings in both mitigation of and adaptation to climate change to 2025.

https://palau-data.sprep.org/system/files/Palau_INDC.Final%20Copy.pdf

The 2017 State of the Environment Report is the National Environment Protection Council's independent scientific report on threats to fisheries and the terrestrial environment, noting the success of marine protected areas.

https://palau-data.sprep.org/system/files/2017%20SOE%20Palau.pdf

Palau 2020 National Master Development Plan (PNMDP) was developed in 1996 and approved by the Palau National Congress the following year as the Republic's long-term developmental planning document.

https://sustainabledevelopment.un.org/content/documents/3163palau.pdf

The Palau National Disaster Risk Management Framework 2010 provides for the strengthening of national disaster risk management structures and mechanisms to support improved disaster/emergency preparedness, response and recovery as well as the more effective integration of disaster risk considerations into the national development planning, including budgetary allocation processes.

The Palau Disaster Management Reference Handbook is a guide for disaster response agencies.

https://reliefweb.int/report/palau/palau-disaster-management-reference-handbook-2016

The Palau Climate Change Policy Framework addresses climate change adaptation; management of greenhouse gas emissions, including carbon sinks; and disaster risk management. It involves government, the private sector, civil society, and Palauan communities and individuals. Work on the framework, including the preparation of a community engagement strategy and 2013 gaps and needs analysis, began in 2012 with the support of the EU and GIZ.

The First National Communication to the Conference of the Parties (CoP) of the UN Framework Convention on Climate Change—the Republic of Palau has reported on: (a) an inventory of greenhouse gases following the guidelines adopted by the CoP; (b) an assessment of potential impacts of climate

[509] UN, 2014, Small Island Developing States Accelerated Modalities of Action (Samoa Pathway).
[510] SPREP, 2017, Pacific Islands Meteorological Strategy 2017-2026.
[511] SPREP, 2016, Pacific Roadmap for Strengthened Climate Services.

change in the Republic of Palau; (c) an analysis of potential measures to abate the increase in greenhouse gas emissions in the Republic of Palau and to adapt to climate change; (d) preparation of a national action plan to address climate change and its adverse impacts; and (e) preparation of the first national communication of the Republic of Palau to the COP. Besides the preparation of the national communication, the report is expected to enhance general awareness and knowledge on climate change related issues in the Republic of Palau, and to strengthen the dialogue, information exchange and cooperation among all the relevant stakeholders including governmental, non-governmental, academic and private sectors.

RESULT 1 – STRENGTHENED DELIVERY MODEL FOR CLIMATE INFORMATION SERVICES AND MHEWS COVERING OCEANS AND ISLANDS

Activity 1.1 Strengthen Institutional and policy frameworks and delivery models for climate services

Under this Activity, the Programme will establish comprehensive institutional and policy frameworks and delivery models for strengthened climate services in Palau. This will include the development of a National Framework for Climate Services (NFCS), which will be supported by effective coordination mechanisms to mainstream climate risk knowledge into the decision making of climate-sensitive sectors. Moreover, Palau will conduct a climate services market assessment and develop a policy for sustainable financing and delivery of climate services. Amongst others, engagement with the development of national budgets will enable justification of the value of climate services, strengthen existing funding for disaster relief and contribute to the identification of long-term sources of funds.

P1.1.1 Develop the Palau Framework for Climate Services

National Framework for Climate Services (NFCS)

Throughout the implementation of this Programme, Palau WSO proposes to conduct a series of consultative workshops with stakeholders to develop and refine a National Framework for Climate Services (NFCS). In the first half of year one, PWSO will invite representatives of government agencies responsible for key sectors including the five Global Framework for Climate Services (GFCS) sectors—water, health, renewable energy, food security and agriculture, and disaster risk reduction—to take part in a 3-day workshop facilitated by an international and a local consultant. The workshop will begin with a presentation of basic climate science, an explanation of the kinds of data PWSO collects, and a presentation of the products and services their data has been used to create. PWSO will explain the use of its data in planning climate-proof infrastructure, preparing for extremes of rainfall and drought, delivering timely disaster warnings and informing Palau's advocacy in international forums. Sectors will also be asked to present on how they use climate information and how they would best like to work with PWSO. The workshop would begin the process of agreeing with these stakeholders more specific functions, relationships and services.

The two consultants will use the outcomes of the first workshop to draft the NFCS, which will inform the future work of PWSO. Objectives will be to agree with key sectors a suite of directly applicable information products, with a process for checking their utility regularly and revising them when needed. In year five the NFCS will be re-evaluated using feedback and learnings from each sector over the previous four years.

Meteorological Strategy

Palau WSO will engage an international consultant, supported by a local consultant, to draft a National Meteorological Strategy, which will document the process by which PWSO will put the Pacific Islands Meteorological Strategy and the Pacific Roadmap for Strengthened Climate Services into operation. The consultants will undertake two principal tasks:

Review stage

- Review sectors' use of weather and climate information services, including use and demand within the public and private sectors, and by communities.
- Review Palau's existing sector policies and institutional and governance arrangements as they relate to climate variability and change and consider how the National Meteorological Strategy can promote better use of climate information.
- Review previous consultations, investigations and analyses of the mainstreaming of climate information into sectors' decision-making processes, focusing on the five GFCS primary sectors— Agriculture, Tourism, Water, Fisheries and Infrastructure—and on the use of weather and climate information services in early warning systems.

Drafting stage

- Conduct preparatory work with each government agency to ensure their interests are taken into account in the Strategy.
- Conduct workshops with the private sector, NGOs and community representatives to ensure their input to the Strategy.
- Facilitate a public workshop to validate and finalise the draft.

Palau WSO will put the National Meteorological Strategy into effect through the Climate Information Services Sector Action Plans (P1.1.3).

P1.1.2 Conduct market assessment to explore viable opportunities for climate information services in sectors and business segments

This Sub-activity will support Palau to understand its existing market for climate services and potential sustainable climate services models; and utilise a value chain approach to mobilise private sector finance in climate services delivery. In the longer term, this will support establishment of a foundation for a cycle of investment, service enhancement, research and development, and re-investment, which has already created commercial markets for climate services in developed countries.[512]

The Programme will conduct a detailed market assessment, which will assess the following:

- **Involved actors in climate services** – This include providers, intermediaries and users: i) Government agency/s (including PWSO) responsible for the operation of the national meteorological infrastructure and provision of public weather and climate services; ii) Academic (university) research community; iii) Media entities; iv) Private sector and other providers; and v) Users, which consists of the general public, as the users of basic services, and the economic and social sectors and organisations as the users of specialised, tailored services.[513]

[512] SAID, 2018. Climate Information Services Market Assessment and Business Model Review
[513] WMO, 2015. WMO-No. 1153. Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services

- **Regulatory environment** – Analysis of the current regulatory environment for climate information and early warning services in Palau and subsequent identification of policy incentives to unlock barriers to private sector investment;
- **Supply and demand analysis** – Identification of country-relevant sector and business needs for climate services (for example, level of information, scales and access required);
- **Private sector engagement** – Building on the analysis of supply and demand, the Programme will support PWSO to engage with the private sector – including through the National Climate Outlook Forums (Sub-activity 1.1.3) – to identify private sector sponsors' interest in the generation, translation and transfer function and in purchasing climate-related information.
- **Business models** – Analysis of business models for climate services that are successful in other countries, with a focus on Small Island Developing States (SIDS). This will include case studies on private sector company provision of climate services as well as government-led initiatives.

Based on the above analysis, the Programme will support Palau to identify opportunities to develop value-added climate products and services; and potential for public-private partnerships and private sector investment in climate services. Private sector engagement will improve the cost-effectiveness of PWSO and increase potential for catalysing innovation in climate information technologies. This Activity will also inform development of the national policy for financing climate services in Sub-activity 1.1.4.

P1.1.3 Mainstream climate risk knowledge into sectors

National Climate Outlook Forum

In the second half of the year, Palau WSO will conduct a National Climate Outlook Forum (NCOF), before the onset of the cyclone season (April for Palau) and after the Pacific Islands Climate Outlook Forum (PICOF).

The participants in the earlier workshop (for government officials) will be better prepared to understand the Outlook and how it supports specific sectoral advice. The NCOF will be refined in response to the contributions of workshop participants, explaining how they use PWSO's advice.

In years two, three and four, PWSO will hold similar 2-day workshops successively with the private sector, with NGOs and with communities combining information about the climate, how it is changing and what the implications are for Palau, with a presentation on the products and analyses the WSO can generate. The workshops will be used also to help the private sector, NGOs and communities to articulate what information they want from PWSO and the formats in which it will be most useful to them.

The overarching objectives of the NCOFs will be to:

- "Identify the specific climatic factors affecting user outcomes (e.g. streamflow, soil moisture, frost, rainfall deficiency, heatwaves, exceedance of key thresholds, etc.)
- Co-design tailored products to address identified decision-making needs
- Ensure that climate information products, including their uncertainties and limitations, are regularly communicated, interpreted and understood by users
- Discuss user views and obtain feedback for improvement of products and their access
- Provide an institutional platform for understanding the risks and opportunities of past, current and future climate; and for inter-agency coordination of policies, sectoral plans and programmes linked to potential impacts of hydro-meteorological hazards

- Evolve a culture of working together through joint climate information interpretation sessions for managing risks in various climate-sensitive sectors, like agriculture, irrigation, disaster risk reduction and health."[514]

Climate Information Services Sector Action and Communication Plan

In the first half of the second year of the Programme, Palau WSO will engage an international and a national consultant to facilitate a workshop with stakeholders from government agencies and communities and from outer islands (community representatives) to identify sector specific priorities and actions for climate information services, targeting five sectors. The workshop will further develop the ideas about the information needs of specific sectors gained from the NFCS. It will also consider, with sector representatives, how climate information can be mainstreamed into their work and applied in their decision-making.

The consultants will use the outcomes of the workshop to draft a Climate Information Services Sector Action Plan and a Communication Plan for an agreed number of important sectors. The plans will address sector-specific needs for information services relating to both disaster risk reduction and management, and effective climate change adaptation.

The Plans will document an agreed process for testing the best ways of regularly communicating climate information to sectors. This will include both finding ways to make information easily accessible and exploring potential methods of improving the understanding of climate information by all workers in a sector, and by the users of that sector's own services.

This is likely to include a range of activities, such as improving PWSO's use of social media, but to begin with a programme of capacity building in understanding climate and weather information for government workers. The sector communication plans will be tailored to the specific interests and needs of each sector and will cover basic climate science, an explanation of the kinds of data the WSO collects, and a presentation of the products and services it provides. It should include support to the sector in communicating climate information within the sector, and to the sector's clients and end users.

Sector-Specific Climate Training Programme

The Climate Information Services (CIS) Sector Action Plans for Palau will guide sector-specific climate training for the five sectors identified in the action plans: these may include fisheries, tourism, water, health, renewable energy, food security and agriculture, and disaster risk reduction.

Palau WSO will engage an international and a national consultant in the second half of the second year to develop a training programme, with guidance materials and capacity building resources, to facilitate the uptake of climate information services by the targeted sectors and their stakeholders. The training will be non-technical and directly relevant to each sector and applicable to its activities. This intervention is replicating an activity implemented by a GCF funded Climate Information Services for Resilient Development Project in Vanuatu.[515]

The consultants will conduct a CIS training needs assessment with PWSO, and based on the assessment, will use existing and new CIS information to develop a tailored training programme. The Training Programme will be in line with the Palau Framework for Climate Services (NFCS), Palau

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[514] WMO, 2018, National Climate Outlook Forums and National Climate Forums: Concept Note, World Meteorological Organization.

[515] SPREP, 2018, Climate Information Services for Resilient Development in Vanuatu. The Project has a Bislama name, "Vanuatu Klaemet Infomesen blong Redy, Adapt mo Protekt (Van-KIRAP)".

Meteorological Strategic Plan (P1.1.1), the Pacific Island Meteorological Strategy (PIMS) 2017–2026 and the Pacific Roadmap for Strengthened Climate Services.

In year five the sector plans and the communication plans will be re-evaluated and updated using feedback and learnings from each sector.

Train the Trainer for Sectors

The WSO will engage an international consultant to demonstrate the use of the CIS training programme through facilitating Train the Trainer sessions for sector personnel, non-governmental organisations (NGOs) and the WSO. The training will use sector-specific case studies.

Five workshops will run in the third and fourth year, each targeting a different sector. There will be an opportunity to update the training programme after each workshop.

P1.1.4 Develop national policies for financing climate services

This Sub-activity will provide the foundation for the establishment of a financially sustainable business model for climate services in Palau. Based on the NFCS established under Sub-activity 1.1.1, the Programme will develop a national climate services financial policy to ensure that PWSO has the means to sustain and ensure the ongoing operation of its mandated services in order to mitigate weather-, climate-, and water-related risks.[516]

The financial policy will be carefully developed with the support of the World Meteorological Organization (WMO) to ensure that it is tailored to the context of Palau. In line with World Bank guidance,[517] the financial policy will cover the following elements:

- Opportunities for greater cooperation between the public and private sectors and academia given that many economic sectors increasingly depend on meteorological information for safe and efficient operations.
- Opportunities for win-win situations that fulfil the public sector responsibility to help the economically disadvantaged while meeting the needs of enterprises for climate services. To this end, the Programme will ensure that the Government of Palau is made aware of the economic value of climate information in, for instance, reducing the need for dangerous marine rescues, reducing the need for transport of drinking water to outer islands in drought, and reducing the costs of recovery from cyclone damage.
- Opportunities to coordinate and/or integrate financing for climate services and disaster risk management to strengthen existing disaster relief funds and establish reliable funding for disaster preparedness activities, which are often limited to ad-hoc donor funding. This would facilitate a more efficient and streamlined approach to implementing often overlapping actions for climate change adaptation and disaster risk management.
- Identification of elements for a sustainable financial model for PWSO based on the climate services value chain, which highlights the different roles of NMHSs in providing basic forecasts and warnings to protect society from the adverse effects of severe weather (a public good typically supported by governments) but also in providing specialised value-added services to government agencies and individual businesses (which may offer opportunities for cost-recovery from governmental and non-governmental sources).

[516] World Bank, 2013. Weather and Climate Resilience. Effective Preparedness through National Meteorological and Hydrological Services
[517] Ibid.

- Potential to establish a National Climate Fund (NCF) as a mechanism to support Palau's engagement with climate finance by facilitating the collection, blending, coordination of, and accounting for climate finance directed towards climate services.[518] According to UNDP guidance,[519] these funds could have the following goals:
    - Collect sources of funds and direct them toward climate change activities that promote national priorities;
    - Blend finance from public, private, multilateral and bilateral sources to maximise a country's ability to advance national climate priorities;
    - Coordinate country-wide climate change activities to ensure that climate change priorities are effectively implemented; and
    - Strengthen capacities for national ownership and management of climate finance, including for "direct access" to funds.

  Functions of NCFs could include:
    - Support goal setting and the development of programmatic strategies for climate resilience;
    - Fund capitalisation;
    - Management of partnerships;
    - Provide project approval and support implementation;
    - Supply policy assurance;
    - Provide financial control;
    - Manage performance measurement, including monitoring and reporting on activities and resource disbursement; and
    - Provide and support knowledge and information management.
- Potential for continued support from the Systematic Observations Financing Facility (SOFF) as part of the Alliance for Hydromet Development, which was launched in December 2019 by 12 international organizations including UNEP. The SOFF is envisaged to ensure provision of basic systematic observations as a global public good by providing equitable, predictable, sustainable, and performance-based finance as well as technical assistance to developing countries for the provision of foundational observational data as per the Global Basic Observing Network (GBON) standard adopted by the WMO Congress in 2019. GBON aims to improve the global availability of the most essential surface-based data by defining the obligation for countries to implement a minimal set of surface-based observations for which international exchange of observational data will be mandatory.

[518] UNDP, 2015. Blending Climate Finance Through National Climate Funds.
[519] Ibid.

RESULT 2 – STRENGTHENED OBSERVATIONS, MONITORING, MODELLING AND PREDICTION OF CLIMATE AND ITS IMPACTS ON OCEAN AREAS AND ISLANDS

Activity 2.1 Enhance infrastructure and technical support for observations and monitoring

P2.1.1 Enhance national observations and monitoring networks to GBON standards and establish QMSs

Strengthen the network of land-based observations and improve observation station density in compliance with GBON

The Programme will procure equipment to strengthen the network of land-based observation stations measuring atmospheric pressure, temperature, humidity, horizontal wind and precipitation and regular reporting of data in compliance with the provisions of the WMO Global Basic Observing Network (GBON). WMO have proposed a target number of 16 observation points across the EEZ of Palau.[520] The Programme will facilitate observations through a mix of surface-based, upper air and marine observations. Critically, funding will be supplied for communications to ensure that observations can be made available via GTS to WMO, in compliance with GBON.

Installation of eight AWS and one AWOS station

The Programme will install eight new/upgraded Automatic Weather Stations (AWS), located at Aimeliik, Airai, Angaur, Ngerulmud, Ngaremlengui, Ngarchelong, Ngaraad and Kayangel, with sensors for rainfall, air temperature, barometric pressure, wind speed and direction, soil temperature (10, 20, 30 cm) and soil moisture. The stations will contain all-parameter local Modbus Meteorological Display Consoles (MMDC) including METAR/SYNOP coded message display. In addition, one new/upgraded Automated Weather Observing System (AWOS) will be installed at Koror Airport. The AWOS station will contain AWS sensors (as above) as well as a ceilometer and visibility meter.[521]

Palau will also procure three sets of AWS spares and a bench-top instrument calibration kit.

[520] SOFF, 2020. Systematic Observations Financing Facility. Collaborative thinking workshop. Workshop outcomes and the way ahead. February 25-26 2020, Offenbach, Germany

[521] These are the proposed sites under the current baseline and to support GBON. Given the dynamic nature of projects in the Pacific, these sites will be reconfirmed during each year of implementation and should site locations require changes, this will be done within the context of GBON and within the current budget.

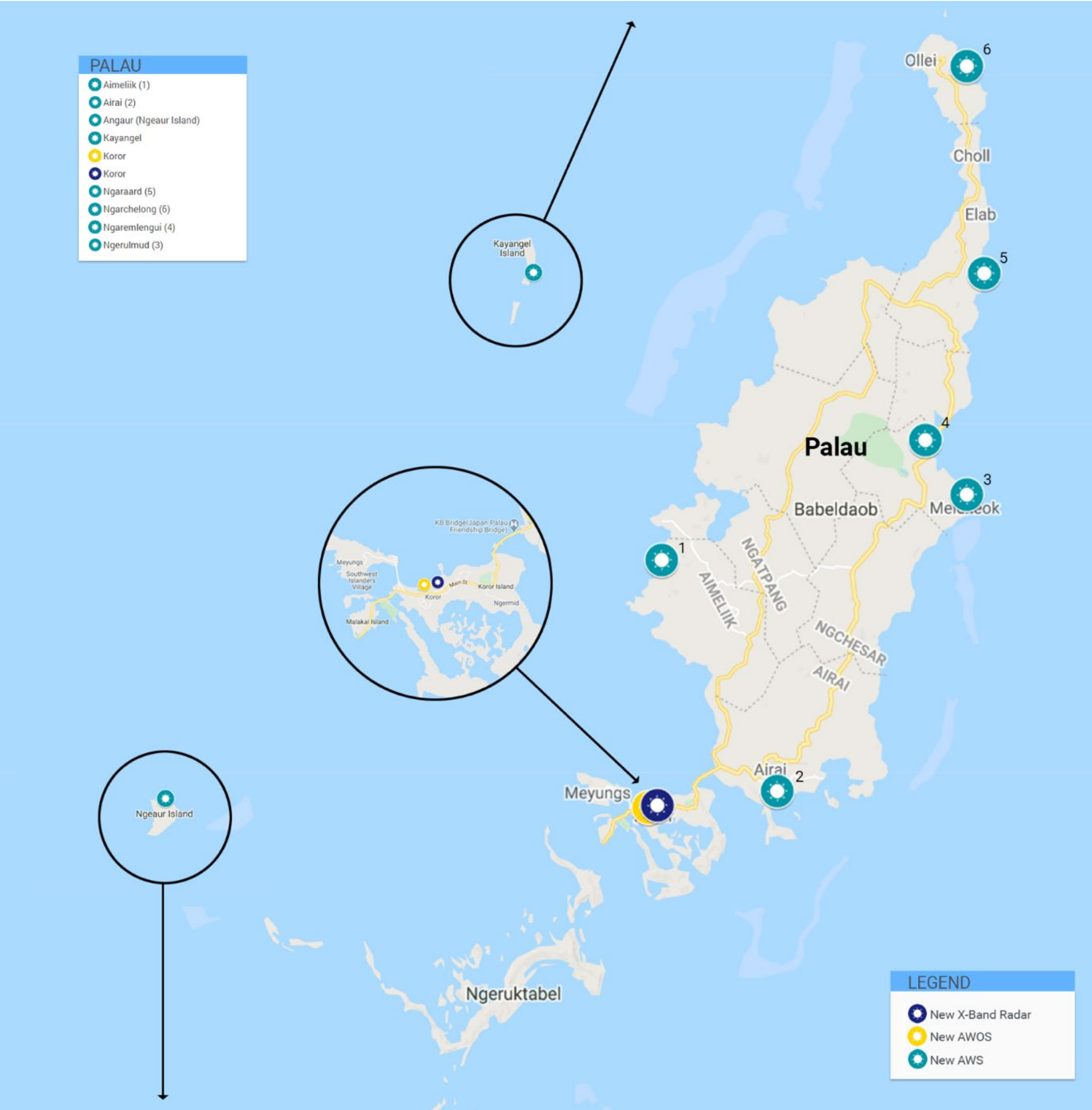

Figure 90. Proposed land-based observation network in Palau

Installation of a dual-polarization X-band Doppler radar

The Programme will install a dual-polarization X-band Doppler radaring Koror. Dual-polarization radars obtain information on both the horizontal and vertical dimensions of precipitation particles, which gives meteorologists a better understanding of the size and shape of particles. The advantages of dual polarization include:

- Improved accuracy of precipitation estimates, leading to better flash flood determination;
- Ability to differentiate between differentiate between different types of precipitation;
- Improved detection of non-meteorological echoes (e.g. tornado debris, birds, etc.);

- Detection of aircraft icing conditions.[522]

A Doppler radar is capable of measuring the velocity of precipitation particles (and thus, the wind). This enables Doppler radars to identify the detailed wind structure within severe thunderstorms.

The choice of an X-band system is on account of its low cost – in comparison to S or C band systems – and its small size, with potential for portable options. This is particularly important for the Pacific SIDS, which may have complex topography that limits accessibility for larger systems.

In addition to infrastructure, the Programme will provide technical training (Sub-activity 4.1.2) to build in-country capacity for radar operations, maintenance and data applications for weather and climate monitoring and analyses.

Quality Management System (QMS)

Palau WSO will establish a QMS to help to enhance the quality of its activities, including streamlining and optimising the processes and procedures applied and the products and services provided. The WSO will aim to obtain certification of compliance with relevant ISO standards.[523] Palau WSO staff will engage with experts from the WMO network and participate in training and an annual QMS workshop. The objective is to become compliant with ISO9001:2015. Palau has a close relationship with NOAA, who will be fully engaged in the QMS process.

Activity 2.2. Strengthen ocean and climate modelling and impact-based forecasting

P2.2.1 Establish ocean information services

Ocean modelling and prediction

Located in the western Pacific Ocean, Palau is on the edge of the Pacific Warm Pool and under the year-long influence of the inter-tropical Convergence Zone. Trade winds and monsoons bring varying precipitation, winds and waves to the islands. The monthly rainfall changes from 200 to 450 mm from the winter to the summer. The limited 4 months of wave buoy measurements at 100-m depth off the northeast coast of Babeldaob show a wide range of wave conditions with a significant wave height range of 2 to 9.3 feet and a peak period from 5 to 16 seconds. Accurate weather and wave forecasts are needed to support local communities and provide important information for commercial activities like tourism and fishing in the islands.

The daily life and commercial activities on the island can be severely impacted by typhoons from June to November every year. Two recent examples are Typhoon Bopha in 2012 and Typhoon Haiyan in 2013, passing to the south and north of the islands respectively. Both events brought severe damage to buildings and trees and caused loss of power and water supplies on the major islands. The wind speed and significant wave heights reached 155 mph and 29 feet during Typhoon Bopha and 178 mph and 25 feet during Typhoon Haiyan. In particular, the storm-induced surge and waves severely damaged the piers to the east of Melekeok during Typhoon Bopha, and inundated the causeway linking the hospital to the main island. The whole of Kayangel Island was inundated during Typhoon Haiyan. Since the intensity of the future typhoons is expected to increase in the northwest Pacific, accurate weather and wave forecasts are greatly needed for disaster preparation and mitigation.

[522] National Weather Service. Dual Polarization Radar. Available at: https://www.weather.gov/bmx/radar_dualpol
[523] WMO, 2017. WMO-No. 1100. Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers

Coastal and ocean data and information save lives and protect resources and livelihoods: this is the premise behind the Pacific Islands Ocean Observing System (PacIOOS).[524] As one of eleven Regional Associations (RAs) comprising the coastal component of the US Integrated Ocean Observing System (IOOS), PacIOOS contributes to the national provision of an "eye on our oceans, coasts and Great Lakes." PacIOOS was created to sustain coastal and ocean observations in the State of Hawaii, the territories of Guam and American Samoa, the Commonwealth of the Northern Mariana Islands (CNMI), the Republic of Palau, the Republic of the Marshall Islands, the Federated States of Micronesia, and the US Minor Outlying Islands of Howland, Baker, Johnston, Jarvis, Kingman, Midway, Palmyra and Wake. The mission of PacIOOS is to empower ocean users and stakeholders in the US-affiliated Pacific Islands by providing accurate and reliable coastal and ocean information, tools and services that are easy to access and use. Since 2007, PacIOOS has developed and served a suite of observation and forecasting products based on stakeholder needs and local capacity.

PacIOOS' four main thematic targets are: coastal hazards; marine operations; water quality and ecosystems; and living marine resources. Climate change, modelling, data management, as well as outreach and engagement cut across all these thematic areas. PacIOOS' forecasting work aims to provide near-term forecasts for response and short-term planning. Its long-term scenario-based modelling provides vital, contextualised information with which stakeholders can conduct long-range planning and design responses to changing ocean conditions due to climate change.

PacIOOS proposes a multi-component service for Palau with multiple modelled forecast products that build upon and complement each other. The components proposed for Palau are as follows:

- New 7-day high resolution atmospheric forecasts (3 km domain for all of Palau and a 1 km domain for Koror and Babeldaob);
- New 7-day high resolution wave forecast (WAVEWATCH III regional grid and SWAN island grid);
- New ocean circulation model including all of Palau;
- New 6-day inundation (wave run-up) forecast tools (one for Koror and southern Babeldaob, and one for Peleliu); and a new long-term scenario-based tool under various sea level scenarios and wave environments due to climate change.

All the components listed above will be freely available to the public via PacIOOS data services (data servers, data catalog and metadata), the PacIOOS website and via the PacIOOS online mapping platform, PacIOOS Voyager (https://www.pacioos.hawaii.edu/voyager).

The following is a brief description of activities that would lead to an operational forecast of inundation events and an understanding of future inundation threats under reasonable assumptions of long-term sea level rise and changes in storm intensity. There are three main themes to the proposed work:

A. Stakeholder Engagement

    a. A successful field program requires local technicians who will learn deployment and recovery techniques and inspect instrument sites periodically.

    b. Local knowledge will be necessary to identify the highest at-risk areas and to quantify/qualify hindcast scenarios.

[524] PacIOOS, Ocean Observing System, available at <http://www.pacioos.hawaii.edu/> [August 2019]

c. Local representatives are necessary to bridge the gap between the science team and the end users. This includes both a downstream education component and an upstream refinement of science communication.

B. Field Observations

a. Synoptic sub-surface pressure measurements (as accurate proxies for sea level measurements) will be needed for at least one full year in and around the main southern lagoon (approx. 24+ gauges).

b. The pre-breaking zone wave field (e.g., outside the fringing reef) should be observed in shallow water (~20m) for both the east and west sides of the greater lagoon region (e.g., requires two AWAC instruments or similar).

c. The post-breaking zone wave field should be observed on the west side of Koror (on and inside the reef) to determine the impact of locally generated waves during high wind regimes.

d. Nearshore pressure gauges will be needed for one full year placed in the more dynamic shoreline of Peleliu (approximately 8 gauges).

e. Datawell Waverider buoys will be needed to the east and west of the main southern lagoon region (PacIOOS will use the data from three new proposed buoys that will be purchased through the UNDP Japan project).

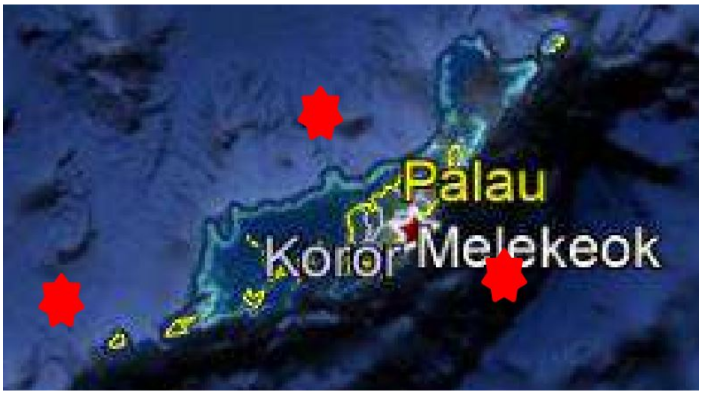

Figure 91. Location of proposed UNDP GCF Waverider Buoys

f. Access to good resolution bathymetry around Koror, the major reef system, and if available, the lagoon (PacIOOS has begun working with NOAA and PACOM partners to access such datasets).

C. Modelling Component

a. Sections of the lagoon reef zone will be modeled with BOSZ to identify cross reef energy transfer to harbor oscillations and setup, based on incoming swell direction and sea level. The model results will be validated with the observations.

b. From this, a model will be constructed for forecasting inundation up to 6 days into the future at many locations around the main Koror complex, given wave and wind inputs provided by other PacIOOS colleagues and NOAA partners.

c. As well, a separate forecast model based on BOSZ will be constructed for near term inundation forecasts around Peleliu.

d. The forecast domains developed will also be used to run longer-term future scenarios in order to ascertain the most at-risk coastlines and advise vested parties about response efforts.

National Ocean Portal

Palau will work with NOAA and the RMI WSO on the development of National Ocean Portals and a regional portal for the two North Pacific countries. The proposed work represents a collaboration between NOAA and the University of Hawaii (UH), but it will also involve the other lead agencies in WMO's Regional Area 5 (RA-V: Asia Pacific region) Pacific Islands Regional Climate Centre: these are SPC, SPREP, NIWA, BOM and Meteo-France.

Funds are requested to support the development of web-based national "dashboards" that provide location specific and relevant climate information, including (where available) real-time observations, climatologies, seasonal to interannual forecasts, and long-term trends. These "dashboards" will draw existing data and products from different data centres and national agencies, downscaling the information, tailoring it and combining it as users require. Site visits and face-to-face meetings will establish key climate indicators, stakeholders and management needs for a regional page focusing on a subset of variables. After the portals are developed, the developers will train key personnel from Palau on the use of the site, enabling the developers to get direct feedback on the site's utility, informing the development of a national dashboard into the portal for Palau.

The philosophy and technology behind the dashboard developed for the Palau could serve as a model for the wider Pacific region, and even expand to include other domain-specific indicators in support of sector-specific climate early warning systems (CLEWS).

At the core of these would be the build-out of an underlying national dashboard or site. Underlying these national sites would be the regional system that would form the backbone of the Pacific Islands Climate Monitoring Node. This backbone would be developed in the first year of the project. This activity will fall under the WMO RA-V, will be done in close collaboration with partners and will complement existing assets—COSPPac's Ocean Portal, APDRC data services and PacIOOS's coastal observations.

National portals for RMI and Palau will focus on a subset of variables, starting by focusing on three key essential variables. For example, sea level, sea surface temperature and precipitation data are of high interest, regionally relevant, and have relatively wide coverage in terms of data availability (in-situ, satellite and model). Significant effort would go into the addition of the first variable, but subsequent variables would require less effort as the mechanism for adding content becomes better understood. The new site would bring in data from the global tide gauge network (sea level), drifting floats and observing system arrays, meteorological stations, and satellite measurements from AVISO (sea level), Pathfinder (sea surface temperature) and PERSIANN (precipitation).

The new site would first be designed in terms of web-page layout, specifying what menu access (e.g. region, indicator, variable) will be provided and where. Next, the specific choices under each of these will be determined. Finally, the "results" region of the portal will need to be planned, for example, where the latitude/longitude map view will go, what and where time-series will be displayed, and where other ancillary data will go. After the regional portal is developed, key personnel from the region will work with the node developers to be trained on the use of the site and to give the developers direct feedback on the site's utility. This could be done at the annual PICOF meeting since most Pacific countries send representatives, and it will allow for a wider networking opportunity.

The proposed work will support the development of the WMO RA-V PI-RCC, established as a virtual Centre of Excellence that assists Pacific Islands' national meteorological services to deliver better climate services and products and to strengthen their capacity to meet national climate information and service delivery needs. The establishment of an ocean portal with a firm backbone based around data services and leading to region-specific sites will support many of the RA-V activities. It will also support, and leverage, many ongoing facilities and programmes such as the UH Asia-Pacific Data Research Center (APDRC; providing access to a wide array of observations and model output), the Pacific Regional Integrated Sciences and Assessments (providing sector-specific user requirements), COSPPac (specifically the ocean portal), the developing Climate Early Warning System (CLEWS) for the Pacific, the Pacific Islands Integrated Ocean Observing System (providing near-real-time observations and information in the coastal region), and more.

National Ocean Expert

One of the WSO's highest priorities—in response to user demand—is to acquire the capacity to generate ocean climate information. Palau's landmass is very small, and its surrounding ocean is an integral part of its environment as well as the major influence on its climate. The WSO proposes to engage a Programme-hired National Ocean Expert to begin developing this new capacity, with support from the University of Hawaii, NOAA and BoM.

The National Ocean Expert will strengthen the Palau's local ocean monitoring programmes and oceanographic capability. Monitoring the local ocean climate directly helps people—seafarers, subsistence fishermen and tourists—to use their natural resources sustainably and avoid unnecessary risks. It will also contribute invaluable data to the scientific community. The National Ocean Expert will extend the WSO's capacity to give practical advice to subsistence fishers and tourists: for instance, the consultant will monitor threats to reefs—warming and bleaching—so that harm can be minimised. When coral is stressed by heat, if the reef is protected temporarily from human activity, it will recover more quickly; if people are warned of an elevated risk of ciguatera poisoning, they can avoid eating reef fish species during the warming episode.

P2.2.2 Enhance climate information and impact-based forecasting

Young Scientist Support Program

To support the enhancement of in-house forecasting capacity, the Programme will build a strong scientific and analytical foundation for NMHSs through training and mentoring attachments covering climatology and oceanography. Early-career scientists from NMHSs will be selected to undertake in-depth technical capacity building through a customised Young Scientist Support Program (supported by APCC), including highly in-depth training for 2-3 months exploring various climate prediction and analysis techniques such as downscaling predictions, generating sub-seasonal-to-seasonal forecasts, analysing large-scale patterns, and tropical cyclones, etc. This will equip participants, particularly those with less experience, with both the basic knowledge needed to perform their duties as climate officers, as well as more advanced knowledge that can help them develop downscaled or impact-based forecasts.

Training attachments and mentoring

The Australian Bureau of Meteorology (BoM) is a long-term partner of Pacific island meteorological services, delivering the Pacific Sea Level Monitoring project since 1991 and supporting the development of seasonal climate forecasting capacity since 2003. Since 2012, BoM has collaborated with Palau WSO and other NMHSs in the Climate and Oceans Support Program in the Pacific (COSPPac).

BoM will provide attachments for PWSO staff focusing on seasonal prediction (ACCESS-S) training and on the use of data and information in preparing for the typhoon season, and for climate extremes such as drought or flood. It will deliver training on the use of seasonal forecasting products to generate information on the ocean and tides using ACCESS-S. Mentoring and professional development inputs will provide opportunities for PWSO climate staff to attend conferences such as AMOS and to contribute to academic papers and posters. Over the term of the Programme, BoM will provide 12 weeks training for the National Ocean Expert and 12 weeks for the National Climate Expert.

National Climate Expert

To support the provision of the much-expanded climate information services, Palau WSO proposes to engage Programme-hired National Climate Expert, at science graduate level, for the five-year term of the Programme. The National Climate Expert will focus on climate science and data analysis for new functions and will take day to day responsibility for sector coordination, working with the Ministries of Tourism, Transport, Infrastructure, Health, Agriculture, Environment Services and others. The consultant will develop new products in response to demand from the sectors.

Palau WSO's new Climate Expert will start from a lower based than the other four countries. BoM will arrange regular training and mentoring for the National Climate Expert through attachments and regional meetings and by supporting his or her attendance at key conferences throughout the term of the Programme. BoM will also provide training on ocean and tide information, and mentoring to the consultant using seasonal forecasting products from ACCESS-S.

Early Warning Systems (CREWS, EAR Watch and Impact Forecasts)

Most Pacific meteorological services are generating products and developing services in response to demand from climate-sensitive sectors in their countries, and BoM's training programs benefit from its experience in facilitating this work over the last ten years. The Programme-hired National Climate Expert will receive training from BoM in using SCOPIC to generate seasonal forecasts and to use the forecasts in early warnings, particularly for drought. The consultant will receive ongoing support from BoM in his/her preparation of in-country advice, as was received for the climate officers in each of the other thirteen COSPPac partner countries. BoM will provide seasonal prediction training and training in preparing impact-based forecasts, which give specific advice to government and communities on preparation for extreme events. This sub-activity will build on early work with the PWSO undertaken through COSPPac.

BoM will conduct workshops in partnership with PWSO to build the scientific understanding of staff and support their capacity to explain to PWSO's national partners and clients the application of climate monitoring and prediction products to their sectors. It will conduct three Climate Risk Early Warning System (CREWS) and Early Action Rainfall Watch (EAR Watch) workshops over the term of the Programme. Through this sub-activity BoM will contribute to Palau WSO's knowledge sharing by supporting an officer to publish scientific material when appropriate and to attend a relevant conference.

Health and drought early warning system

The East-West Center is currently engaged in multiple projects to produce new climate-related products and services that stakeholders in Palau have requested. In-country consultations by the East-West Center have yielded information about the impacts of and risks associated with climate change in Palau, which informed the Pacific Islands chapters of the 3rd and 4th US National Climate Assessments, and have aided the East-West Center in setting priorities for activities specific to each nation/island context.

NOAA's Pacific Regional Integrated Sciences and Assessments (RISA) programme at the East-West Center identified climate impacts on human health and the prevalence of drought and wildfire as key priorities for Palau, and is currently working with the USDA Forest Service and Palau Division of Forestry to define the climate services needs and to improve climate information delivery to the forestry sector to aid in wildfire prevention; Palau currently experiences an average of 173 wildfires per year. An upcoming (pending) project that will be led by the East-West Center will identify sector-specific requirements for drought and wildfire information systems in the US-Affiliated Pacific Islands (USAPI).

Palau is extremely vulnerable to drought events which occur regularly because of the strong influence of El Niño events. Droughts can cause drinking water shortages, severe crop damage, increased wildfire risk, power outages, and health problems such as disease outbreaks (e.g. diarrhoea, pink eye), food and water borne illnesses, and air quality-related illnesses. For example, the severe 2015–2016 drought resulted in the Government's having to declare a state of disaster, when the primary water source (the Ngerimel Reservoir) dropped to 19% capacity and the salt content of the water sharply increased. School days for children were reduced to half days, and the famous tourist attraction Jellyfish Lake was closed due to drought-related mortality of the jellyfish. There is a need for better early warning systems for drought, including improved accuracy of forecasts, better spatial distribution of automated weather stations, and improved capacity to target responses during drought.

Representatives from the Health Ministries of the Marshall Islands, Palau, and Federated States of Micronesia attended a meeting on climate change and health at the East-West Center in 2018, stating that human health in the region is particularly influenced by sub-seasonal and seasonal changes in temperature, rainfall, and extreme events, as well as the longer-term impacts of sea-level rise and ocean acidification. Storms and sea-level rise threaten the integrity of island infrastructure, such as homes, hospitals, roads, and essential health services. Drought and rising temperatures constrict freshwater supplies, while heavy rainfall events increase the risk of floods and vector-borne diseases. Food supplies are reduced by ocean acidification and impacts on reef fish populations, severe drought events resulting in crop failures, and increasing reliance on imported goods, which may exacerbate existing problems with diabetes and obesity.

A lack of resources and funding leaves the Palau health sector ill-equipped to prepare for the impacts of climate change, and better climate information is needed at timescales appropriate for planning and preparation. The Pacific RISA is currently working on a 2-year NOAA funded project to determine climate services needs in the Marshall Islands, as the Marshall Islands Ministry of Health and Human Services has asked for more useable climate information for focused and timely activities that maximise population health and well-being. Working directly with the Marshall Islands Ministry of Health and Human Services, NOAA, and the University of Hawaii Sea Level Center, the project team is currently identifying the relevant climate variables, timescales, and uncertainty associated with climate impacts, as well as gaps in the provision and accessibility of climate information for decision-making (e.g., essential infrastructure upgrades could be targeted for the areas most vulnerable to extreme events and/or sea-level rise; anticipation of coming drought conditions could improve availability of clean water).

The findings of that project will serve as the technical backstop and advice for the development of sector-specific climate early warning systems and associated monitoring infrastructure in Palau and can also be extended to the other countries in this proposed Programme. This intervention to develop health and drought early warning systems for Palau builds upon and leverages ongoing staff time and data products developed at the East-West Center and the University of Hawaii Sea Level Center.

Activity 2.3 Harmonise climate data and information management

P2.3.1 Establish and implement national climate data and information strategies

National Climate Data Consultant

The Programme will support the recruitment and training of a National Climate Data Consultant (NCDC) for climate data management, who will work within the Office of Climate Change (OCC). The NCDC will build capacity among key government staff to collate and validate data from climate-sensitive sectors and to share and promote useful data with their primary audiences. The NCDC will serve as the national administrator for Palau's data portal (described in Programme Result 4), assigning access and ensuring users are making full use of the capacity of the system. To open lines of communication and data effectively between the various national data providers, the NCDC will facilitate regular meetings with the national data community, communicate regularly with national and regional partners, and track the use and application of the national portal and its products. The NCDC will serve as the Programme focal point for the regional environment data manager at SPREP. The NCDC will organise and facilitate a yearly Inform 4-day technical workshop. The NCDC will participate in training with the NCDCs of the other four countries in online cloud hosting skills and knowledge, and in sub-regional exchanges and South–South learning.

The NCDC's work on harmonising the way data is recorded and stored will make it possible to use UNEP's Country Level Impacts of Climate Change (CLICC) principles, using consistent formats for data records so that Palau's climate data can be presented with national data from other sources, coherently and transparently. This has potential to reduce significantly the burden of reporting Palau's performance against multilateral environmental agreements and to improve the quality of its reports. This in turn has benefits for the Government's understanding of climate change impacts and its capacity to plan effective adaptation and to advocate in international forums.

RESULT 3 – IMPROVED COMMUNITY PREPAREDNESS, RESPONSE CAPABILITIES AND RESILIENCE TO CLIMATE RISKS

Activity 3.1 Warning dissemination and communication

Under this Activity, the Programme will enhance the dissemination and communication of climate risk information and early warnings based on the enhanced data generated under Result 2. The Programme will particularly focus on strengthening last-mile communication systems to ensure that people and communities in remote locations receive warnings in advance of impending hazard events. NMS will be supported to develop a range of communications products tailored to end-users at the community level.

P3.1.1 Strengthen EWS organisational and decision-making processes

This sub-activity will ensure the effective and coordinated delivery of early warning services through strengthened organisational and decision-making processes of Palau WSO, the National Emergency Management Office (NEMO), civil society organisations and other key actors.

An annual workshop will be conducted to define the functions, roles and responsibilities of key EWS actors; develop warning communication strategies; and develop, trial and refine Standard Operating Procedures (SOPs). The workshops will be attended by various EWS stakeholders, NEMO and PWSO representatives. The warning communication strategies to be developed will facilitate coordination between PWSO – as warning issuers – and with downstream dissemination channels, such as island community volunteer networks. The strategies will include the development of community feedback mechanisms to verify that warnings have been received and to alert PWSO to potential gaps in communication networks. At the start of Programme implementation, an in-country deep dive study on gender and community stakeholders will be conducted to facilitate that the design of EWS organisational and decision-making processes is gender-responsive and that such processes proactively consider and address the specific needs, concerns and capabilities of different gender groups. Knowledge gained and outputs from the workshops will be leveraged in development of the Forecast-based Financing mechanism (Activity 3.3).

P3.1.2 Strengthen communication systems to reach the last-mile

This sub-activity will enhance connectivity and communication systems to facilitate that climate information and early warnings reach communities at the last-mile, including on remote outer islands; and that communication channels are resilient to the impacts of extreme climate events. This will be achieved through the following interventions:

Upgrade last-mile communications infrastructure

Support NEMO's public awareness and training on natural disaster programme

The National Emergency Management Office (NEMO) proposes the purchase of a 38' boat and equipment for disaster and emergency relief operations. NEMO is under-equipped to deploy assessment teams to remote areas on the main island and to other islands, and to deliver humanitarian assistance. Relief deliveries of food, water and other essentials often cannot be transported by road after a disaster.

The multi-purpose boat will enable NEMO to conduct search and rescue operations as mandated by Palau's newly endorsed Mass Rescue Operations (MRO) Response and Contingency Plan and to support the outreach programmes of other agencies involved in disaster preparedness and response. PWSO and other Programme partners will also use the boat to conduct their awareness or outreach programmes, and rain gauge installation in outlying states.

NEMO also proposes to develop and print educational materials about natural hazards and climate related disasters in Palauan and English for distribution to communities and schools.

Establish maritime safety information network to fulfil SOLAS obligations

Lack of up to date meteorological data and other maritime safety information is a great risk to the safety of maritime navigation and has resulted in loss of lives and property during storms at sea, vessel groundings and collisions with floating obstructions. Search and rescue operations for foundered vessels, often including divers, increases the cost of government operations and strains limited resources. By providing adequate meteorological information and other coastal and near coastal maritime warnings, the Government can reduce the risk of loss of lives and property by ensuring vessels do not go to sea when a storm is developing or approaching and also to alert officers of the watch on vessels of any dangers in their area of operation.

The Bureau of Marine Transportation (BMT) currently uses the International Navtex (Navigational Telex) system which "is an automated medium frequency direct-printing service for the delivery of navigational and meteorological warnings and forecasts, as well as urgent maritime safety information to ships."[525] BMT are currently using transmissions from the Honolulu Navtex station and would like the Programme to procure a NAVTEX receiver, MF/HF with DSC and VHF with DSC which will be installed and operated from BMT. Initial procurement consists of two sets of each required equipment

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[525] ("Navtex", n.d.)

type for redundancy. A second procurement will occur in year 4 to replace equipment. Future equipment replacement will be funded by the BMT.

Enhance communication channels and early warning systems

Palau WSO ocean and climate mobile application

PWSO will engage an expert developer to create an application for mobile devices such as mobile phones and tablets which gives immediate access to detailed, up to date information on local terrestrial and ocean climate conditions. IT expertise will be engaged to update and improve the PWSO's website to make access more user friendly and the information more accessible. This will require an overhaul in consultation with sector contacts familiar with their constituents' preferences, and a sample of users with limited technical skills to ensure its utility.

Palau WSO ocean and climate website

PWSO currently hosts a website which will need to add products and services from climate and ocean services. PWSO will engage a web developer to develop a user-friendly interface to enable easy access to its climate and ocean information.

Localised mobile climate information communication system

The Programme will develop and implement localised mobile climate information communication systems with early warning to reach last-mile populations. Through mobile-cellular communication channels, this system will provide predicted risks and alerts utilising geostationary satellite nowcast and local/regional forecast information. The system will be designed to handle potential and existing risks on a 24/7 basis and will be customisable for any population group size – from small communities to larger central governments. For short-term disasters, the system will utilise satellite imagery analysis based on 2 km, 10-minute resolution (e.g. Chollian 2A) for nowcasting of wind, wave height and convective initiation of rapidly developing thunderstorms two hours in advance, which is not possible with Numerical Weather Prediction. Localised communication systems will support disaster risk management on various timescales from short-term disasters (e.g. torrential rainfall, coastal flooding, etc.) to long-term disasters (e.g. droughts). The possibility to integrate a two-way communication channel between end-users and information providers would allow for continued enhancements to the system based on user feedback.[526]

P3.1.3 Communicate early warnings to island communities

The Programme will conduct annual multi-stakeholder workshops focused on the co-design and co-production of early warning information products to improve early warning messaging to island communities and provide clear guidance for triggering response actions. Participants will include various EWS stakeholders, community representatives, the National Emergency Management Office (NEMO) and Palau WSO. A local consultant will support delivery of the workshops and will draw on the specialised knowledge of stakeholders and communities to create impact-based early warning messages that are actionable and effective. The workshops will provide an opportunity for engagement between warning issuers and warning 'users' to facilitate that the public and other stakeholders are aware of which authorities issue the warnings, and build trust and acceptance of information disseminated. Furthermore, the Programme will seek to engage a wide variety of

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[526] This will be delivered by the APEC Climate Center in collaboration with the Ewha Womans University, utilising a proven method that is currently being implemented in Cambodia, with the endorsement of the Cambodia Ministry of Water Resources and Meteorology, Asian Disaster Preparedness Center (ADPC) and the Preah Vihear National Authority

community representatives to ensure that warnings are targeted to the different risks and needs of vulnerable subpopulations.

Activity 3.2 Preparedness and response capabilities

P3.2.1 Enhance disaster preparedness and response measures

This sub-activity will use community-based approaches to enhance risk ownership at the local level and help establish collaborative community networks for coordinated action for preparedness and response to climate-induced hazards. This will include the following interventions:

Capacity building for disaster response

People's Empowerment Project

The Palau Red Cross Society (PRCS) and the Center for Women's Empowerment Belau (C-WEB), in cooperation with seven government and non-government agencies, will conduct training for women's organisations on community and individual needs and responses before, during, and after a disaster or single incident emergency. This training has been well-received in six of Palau's fourteen states: the Programme will enable the partners to extend it to Ngardmau, Ngaremlengui, Ngatpang, Aimeliik, Airai, Koror, Sonsorol and Hatohobei states, benefiting from the lessons learnt in the first phase.

The goal for these trainings is to enable women to gain skills for responding effectively to emergency and humanitarian crises. The partner agencies are:

- National Emergency Management Organization (NEMO);
- Palau National Weather Service;
- Emergency Health Programme, Ministry of Health;
- Behavioural Health Division, Ministry of Health;
- Bureau of Agriculture, Ministry of Natural Resources, Environment, and Tourism;
- Palau Community College – Cooperative Research and Extension;
- Environmental Quality Protection Board.

The training enables local communities to prepare efficiently for emergencies and hasten recovery afterwards. Partner agencies will ensure that knowledge gained is contextualised to the context of key sectors and how it relates to livelihood resilience. It is important for all citizens to be trained in disaster preparedness, but women's particular skills tend to be under-used and their requirements and extra responsibilities are often overlooked in planning. The activity will transfer skills in knowing when, whom and how to ask for help; remaining calm and knowing how to help family and neighbours until further help and supplies can reach them; and recognising the people in their communities who may need additional, physical, mental or emotional support after a disaster.

For this intervention, the Red Cross proposes to engage a project manager, a Communication, Monitoring, Evaluation and Improvement Coordinator and an administrative assistant for 18 months. Participants in the training programmes will receive family disaster kits.

P3.2.2 Conduct public awareness and education campaigns on climate hazards and risks

Palau WSO will conduct community-based workshops to enhance community knowledge and understanding of climate hazards and the potential impacts on the lives and livelihoods of local populations. The workshops will build capacity of participants to apply the knowledge to their individual circumstances and consider suitable options for livelihood diversification or alternative livelihoods. The workshops will be conducted annually in eight islands of Palau.

P3.2.3 Integrate traditional knowledge into early warning services

Palau has not been engaged in the COSPPac Traditional Knowledge (TK) pilot project, but will begin an intervention through this Programme, recognising the potential to engage communities in understanding climate science through discussion of traditional forecasting methods. SPREP will support Palau's traditional climate knowledge activities with communities, providing inputs from SPREP's TK expert at intervals during its progress.

The work will include both contributions to the technical challenges of storing and using TK and input to discussions with elders about the application of their knowledge to seasonal forecasting. Over time, these discussions generate acceptance of the technically derived climate forecasts made by the PWSO—one of the immediate benefits is that communities are more likely to take notice of extreme weather warnings. As the climate becomes more chaotic, scientifically derived climate forecasts are expected to have greater predictive power than traditional climate indicators. It will be beneficial if Palauan communities learn to trust PWSO's information and to act upon their advice on likely impacts and on effective preparation and response.

PWSO will engage a local TK officer to oversee the collection and storage of TK and reporting on progress. Other PWSO staff will assist with the project's development as determined by the Director of PWSO and the Programme-hired National Climate Expert. SPREP will contribute professional development and other support.

The proposed intervention consists of the following key components:

1. Understand current use of traditional climate and geohazard forecasts, warnings and responses (includes community visits and participation in the project);
2. Incorporation of traditional knowledge into PWSO products and services (including forecasts and warnings and responses);
3. Development of educational and communication products, incorporating traditional knowledge, such as climate glossaries, seasonal or crop calendars, ENSO impact and response booklets to improve communication of climate and ocean information.

This intervention will deliver:

- Training and resources for international best practice collection of traditional knowledge on weather, climate and geo-hazards (to both the PWSO and key sector partners);
- State-of-the-art customised database to store traditional knowledge related to weather, climate and geohazard (forecasts and responses);
- In-country and regional capacity to collect, store and build products and services that incorporate traditional knowledge, including Early Warning Systems;
- Educational and communication products on climate, hazards and responses (e.g. climate glossaries, seasonal or crop calendars, ENSO impact and response booklets);
- In-country workshops to build national capacity and to allow a participatory approach for sectors and community members.

The TK Officer will initially work on the data collection and monitoring phase, and then move on to verification and validation of the collected data with community elders. The TK Officer will work with relevant government stakeholders and communities to coordinate all Programme work relating to traditional climate knowledge, and will also provide education and awareness for local communities, collect, record and archive relevant TK information, data and images, and set out the national workplan and program for the TK Project. Beyond this stage, the PWSO plans to develop seasonal calendars and to collaborate with BOM and SPREP on publications and presentations on traditional knowledge.

Activity 3.3 Forecast-based Financing (FbF)

Under this Activity, the Programme will introduce Forecast-based Financing (FbF) in Palau, in partnership and coordination with the International Federation of Red Cross and Red Crescent Societies (IFRC), Palau Red Cross Society (PRCS) and the National Emergency Management Office (NEMO).

P3.3.1 Develop FbF Roadmaps defining thresholds and triggers

This sub-activity will develop a Forecast-based Financing (FbF) Roadmap for Palau, which will identify forecasts (magnitude, probability and lead time) that can trigger humanitarian actions.[527]

The first phase of the Roadmap will begin with a scoping study that will cover feasible hazards to target with FbF, forecasting capability, and the institutional landscape in Palau. This will include consultations with national agencies such as NEMO, PWSO, the Bureau of Agriculture and the Ministry of Health; regional agencies such as SPREP, SPC, WFP, UNDP and others; and partnerships with the IFRC and the Red Cross Red Crescent Climate Centre. For FbF to be a sustainable and effective mechanism, Early Action Protocols (EAPs) need to be embedded in national institutions, who have roles and responsibilities for taking early action. The scoping phase will identify the national and/or sub-national actors (government and civil society) in Palau and enter into a dialogue with them about the potential for early action.

The second phase of FbF Roadmap development will consist of collaborative consultations with country institutions to delineate three key elements that would enable country-led design of an FbF mechanism:

1. Menu of Triggers – A ‘trigger' is a forecast that is issued, which exceeds a pre-defined danger level and probability threshold, leading to the initiation of early actions.
2. Forecast-based Actions – Identification of possible early actions that can be triggered by existing forecasts, which aim to avoid losses and damages if an extreme event materialises.
3. Institutional Arrangements – A potential architecture of country-level technical working groups and institutional ownership for FbF, including funding mechanisms when necessary.

The FbF Roadmaps will provide a set of 10 recommendations for critical next steps to move forward with Forecast-based Financing. These next steps will be focused on filling capacity gaps that enable the design and activation of an FbF mechanism by the identified lead agency/s, and the design and testing process for EAPs. The Roadmaps will include the following components:[528]

- **Stakeholder Identification** – The Programme will identify the key stakeholders to be involved in the development and implementation of FbF, including international, national, regional and local actors and lead agency/s.
- **Risk Assessment** – The Assessment will include individual analysis of risk factors, key hazards, past impact, exposure and vulnerability. Based on the analysis, the priority hazards to be

[527] Lopez, Coughlan de Perez, Bazo, Suarez,Van den Hurk, Van Aalst, 2018: Bridging forecast verification and humanitarian decisions: A valuation approach for setting up action-oriented early warnings
[528] IFRC, 2018. Forecast-based Financing Early Action Protocol template

addressed by FbF early actions will be identified. The assessment will also provide an overview of the different types of early actions that could be taken to mitigate risk by the identified stakeholders, in different sectors (agriculture, health, etc).

- **Impact-based Forecasting (Triggers)** – The Trigger analysis will provide an overview of all available forecasts – including lead time, skill/confidence and extreme event probability.
- **Resourcing Overview** – The Assessment will identify various options for accessing funding or necessary resources for potential early actions that are more costly or resource-intensive.

P3.3.2 Build capacity for FbF

In this sub-activity, up to five of the 10 "next steps" that were identified in the Roadmap will be developed and executed. Depending on the national context and the findings of the scoping study, these activities could include the following:

- Scientific collaboration with national or regional forecasters to carry out a forecast verification analysis or forecast calibration to support the development of triggers;
- Technical support to build enthusiasm for anticipatory actions and change mindsets;
- Specific links between the FbF and EWEA narrative with the principles and activities embedded in other outputs of the Programme;
- Technical support in finding ways to connect with existing regional systems, mechanisms and/or priorities to have a region-wide understanding or buy-in of FbF;
- Table-top exercise to discuss a historical extreme event and what could have been done by different actors to prevent impacts;
- Round-table discussion on financing mechanisms for critical early actions that could be part of an FbF mechanism.

P3.3.3 Support development of Early Action Protocols (EAPs)

Palau Red Cross Society (PRCS) will support the development of Early Action Protocols (EAPs) through technical working groups for the priority impacts identified in Sub-activity 3.3.1. A series of conversations will be initiated to develop an EAP, which could range from focusing on a simple life-saving action by one actor to a more complex document with a greater variety of actions and forecast analysis.

To identify what should be in the EAP, the identified FbF lead agency/s will convene a technical working group, engaging stakeholders at all levels – including community representatives, disaster risk reduction committees, civil society organisations, local and national government departments, NGOs and private sector actors. PRCS will provide technical guidance to the lead agency on the process and provide quality assurance, but delivery of the EAP will rest with the lead agency.

Following identification of the most suitable forecast-based actions, the EAPs will be developed by the lead national agency/s. The EAPs will describe which forecast will trigger which action; where to act – based on the forecast and trigger information; and assign responsibilities to specific stakeholders for implementation of each action. In the case of more complex EAPs, they can also include a proposal for a Financial Mechanism, which will outline what funds need to be made available (including readiness costs, stock pre-positioning and activation cost for trigger-based early actions) and how they will be accessed by specific stakeholders. This sub-activity will collaborate with national climate finance policies (Sub-activity 1.1.4) to explore situations when funding for early action can be linked to government budgets.[529] Depending on local capacity, simulations can be held to carry out a "test" of the actions of the EAP.

RESULT 4 – ENHANCED REGIONAL KNOWLEDGE MANAGEMENT AND COOPERATION FOR CLIMATE SERVICES AND MHEWS

Activity 4.1 Enhance regional data, knowledge management and cooperation

Under this Activity, the Programme will enhance coordination and knowledge sharing among the five countries to improve data and knowledge management, including establishment of an interactive ICT platform and regional data centre. The organisation of joint learning, mentoring and training events through existing WMO, USP and other centres to facilitate sharing of successes and lessons learned will further strengthen climate and ocean information services across the region.

P4.1.1 Establish interactive ICT platform

This sub-activity will establish an interactive ICT platform, which will serve as a data analytic centre for the management and organisation of climate data, information, experiences, case studies and other forms of knowledge from the five Programme countries in standardised, comparable formats most useful for end-users. The platform will include the establishment of a regional data centre fed by national data centres in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu. The countries will make as much as possible of their climate-related data publicly available through their national data portals and the regional Pacific Environmental Portal.

This Activity takes advantage of the already established GEF-funded "Inform" project, which is being implemented by UNEP and executed by SPREP. Inform is already working with staff in Pacific environment ministries to find and harvest useful datasets and information on their countries' environment and to publicise the existence of the information. The five Programme countries now have national data portals, which can be used to develop workflows to share data seamlessly between sectors.

Palau has endorsed the national data portal that SPREP hosts for it as the principal home for its environmental impact data and contextual information. Palau has also endorsed the regional Pacific Environment Portal hosted by SPREP as the repository and access point for regional data and information. SPC and SPREP have agreed to host all the information they hold in a shared ecosystem and the five countries are encouraged to make as much as possible of their data publicly available.

The Programme will add a new category for climate data and information in Palau's national portal – existing categories include health, fisheries, tourism and disaster management as they relate to the environment – and bring the bring data management and coordination into its schedule of capacity building activities. The National Climate Data Consultant (Sub-activity 2.3.1) will take part in technical workshops and training at SPREP and implement a comprehensive data strategy in-country with SPREP's support. Improved data sharing and discoverability will provide a conduit for PWSO to assess partners' sector data or knowledge products, while hosting and sharing its own on a common platform. Enhancement in data management capacity will be achieved through the following steps:

- Addition of a new category for climate data and information to each national portal;
- Training and engagement of national climate data consultants (see Sub-activity 2.3.1);

[529] IFRC, 2018. Monitoring and Evaluation (M&E) of Forecast-based Financing (FbF). A practical reference for country-level implementation

- Support for countries to prepare their national reporting for climate-related agreements (e.g. NDCs, VNRs, National Communications to UNFCCC). This is currently a major administrative burden for very small countries, but with access to good quality data, it provides an opportunity to evaluate policy and assess progress on adaptation. A two-way flow of information from NMHSs to and from relevant sectors for national and global reporting will ensure coordination in the use of climate data and information and raise the profile of NMHSs in other sectors thereby supporting demand and fostering sustainability.
- Participation of data consultants in regional forums to enhance the use of data in national planning;
- Establishment of electronic links with existing data sources and back-up in the regional portal; and
- Management of the ICT platform for the five Programme countries through support for ICT interventions across the five countries, including application of ICT in NMHSs operations and upgrading or introducing new methods and systems, such as wireless communications and Internet of Things (IoT) infrastructure for climate services.

SPREP usually provides significant support to countries preparing their reporting against the many MEAs and climate-related agreements to which they are party. This regular process includes updating each country's State of the Environment report, clearly documenting and illustrating climate impacts. This process will give SPREP an entry point for discussing the data strategy with Palau's senior officials. Better access to more data will make it easier to identify meaningful indicators for indicator based reporting, and the project will help non-specialists understand the analysis and interpretation of data.

Improved data is only useful to decision makers, development partners and other user groups if there is wide knowledge of its existence, location, purpose and openness. As this Programme progresses, reporting for international climate agreements will be much improved by the countries' ability to draw upon a longer and more extensive body of high quality data—officers will know what data exists, how it can be sourced and how to use it well. The participation of data consultants in regional forums will build capacity to advocate for effective use in national planning and development of useful data products.

The Inform team estimates there is valuable climate change material held in more than 24 active and legacy systems among the five countries; and in many cases the obsolete hardware needed to read it is still functioning. SPREP will establish electronic links with existing data sources so they can be translated and will back them up on the regional portal. There are multiple datasets held by researchers or by individual departmental officers in danger of being lost, and SPREP will help Palau to locate and salvage them.

P4.1.2 Organise learning, mentoring and training

This sub-activity will comprise training, mentoring and advisory services for local consultants and staff in NMHSs in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu on strengthening climate information services; strengthening observations, monitoring, modelling and prediction; strengthening of marine weather and ocean services; establishing MHEWSs at national and community levels; and building community resilience against climate risks. This will be facilitated through partnerships with existing WMO regional training centres (e.g. China Meteorological

Administration (CMA) Training Centre [530] through coordination by the Chinese Academy of Meteorological Sciences), USP and others in the organisation of:

- Joint learning events for exchanging knowledge and sharing experiences and lessons learned in strengthening climate information services and MHEWs in the five countries. This will have a major focus on the development and implementation of National Frameworks for Climate Services (NFCSs) through all components and related activities of this Programme.
- Targeted training of NMHS staff (e.g. meteorologists, ICT administrators, forecasters) in key areas that are essential for the Programme's impact and long-term sustainability. This will be undertaken through existing training centres in the WMO network, the University of the South Pacific (USP), the International Centre for Theoretical Physics (ICTP) and others. Training will be delivered through a combination of on-site workshops and remote learning courses. Topics of training could include:
    - Forecasting and Numerical Weather Prediction (NWP) by suitably qualified providers such as WMO regional training centres and other WMO-approved meteorological organisations. This could include nowcasting techniques for severe weather, and short-term climate monitoring and prediction in disaster prevention and mitigation.
    - Observation and Instrumentation, including Operation and Maintenance (O&M) of equipment for long-term sustainability.
    - Innovative and cost-saving technologies for observation, modelling and prediction with special focus on the application of ICT. Hence, these events will also be critical for regularly reviewing options for upgrading or introducing new methods and systems in NMHSs in the five countries, such as wireless communications and Internet of Things (IoT) infrastructure for climate services and disaster management.
    - Principles of satellite remote sensing and use of meteorological satellite images in weather analysis and forecasting.
    - Demonstration and training on the operation and maintenance of weather radar systems – installed under Sub-activity 2.1.1 by regional partners from the WMO network (possibly the Fiji Met Service in cooperation with USP under the new WMO Regional Training Center). The demonstrations and training will build capacity of the NMHSs for the provision of improved and more accurate weather monitoring and forecasts; tracking of local extreme events; better determination of rainfall rate/intensity, which is important for determining the potential for extreme rainfall and flash flooding enabling hazard warnings to be issued more accurately and in more timely fashion; and validating Numerical Weather Prediction (NWP) forecasts.
    - Enhancing institutional effectiveness of NMHSs through Quality Management Systems (QMS), Weather Forecast Service Standard and related certification.
    - Enhancing NMHS services through Impact-based forecasting and Forecast-based Financing.

[530] CMA propose to provide free in-person and remote training courses covering the top seven training priorities of Pacific NMHSs

- Enhancing Climate services in NMHSs, including options for ensuring long-term financing and cost-recovery such as private sector investment, public-private partnerships and the application of National Climate Funds.
- Use of alerts, information exchange and coordination in the first phase after major sudden-onset disasters, including through the Global Disaster Alert and Coordination System (GDACS).

Furthermore, the Programme will provide mentoring and technical advisory services to NMHSs in the five countries through capacity building, training and awareness raising initiatives and materials for a range of stakeholders; provide technical backstopping and capacity support to the national delivery of Programme activities; and provide expert advice to the Programme team on key climate information services and best practices, including gender-responsive implementation. In order to enhance synergies and avoid creating parallel structures, the Programme will work closely with the WMO-SPREP Pacific Meteorological Desk Partnership (PMDP), a regional coordination mechanism that supports and coordinates meteorological activities in the Pacific, and the Pacific Meteorological Council (PMC) at large.

REPUBLIC OF THE MARSHALL ISLANDS

BACKGROUND

The Republic of the Marshall Islands (RMI) is a nation of islands about halfway between Hawaii and Australia, just north of the equator in the North Pacific Ocean. It is a group of 34 major islands and atolls, of which 22 are inhabited, spread out in an archipelago of two parallel chains, the eastern *Ratak* (sunrise) chain and the western *Ralik* (sunset) chain.[531] RMI shares maritime boundaries with the Federated States of Micronesia to the west, Wake Island to the north, Kiribati to the southeast and Nauru to the south. The average elevation of its islands is about two metres above sea level and the highest recorded point in the group is ten metres above sea level.[532] RMI's exclusive economic zone covers 1.9 million km^2 of ocean, though its total land area is only 181 km^2, accommodating a population of about 58,413 in 2018.[533] About 70% of the population lives either on Kwajalein in the western group or in the capital, Majuro, in the eastern group.[534]

Its islands are believed to have been settled by Micronesian people in the second millennium BCE. "[A] heavenly chain of sandy beaches and coral reefs … they are paradoxically one of the most inhospitable and challenging places to build a nation. Climate change will have numerous, complicated effects here."[535]

[531] Secretariat of the Pacific Community, 2016, Global Climate Change Alliance: Pacific Small Island States – Volume 2: Country Reports.

[532] GFDRR, the World Bank, April 2011, "Vulnerability, Risk Reduction and Adaptation to Climate Change" Climate Risk and Adaptation Country Profile.

[533] The World Bank, 2018, available at <https://data.worldbank.org/country/marshall-islands?view=chart> [August 2019].

[534] Secretariat of the Pacific Community, 2016, Global Climate Change Alliance: Pacific Small Island States – Volume 2: Country Reports.

[535] Mellgard P, 2015, available at <https://www.huffingtonpost.com.au/entry/marshall-islands-climate-change_n_56796928e4b06fa6887ea12c> [August 2019]

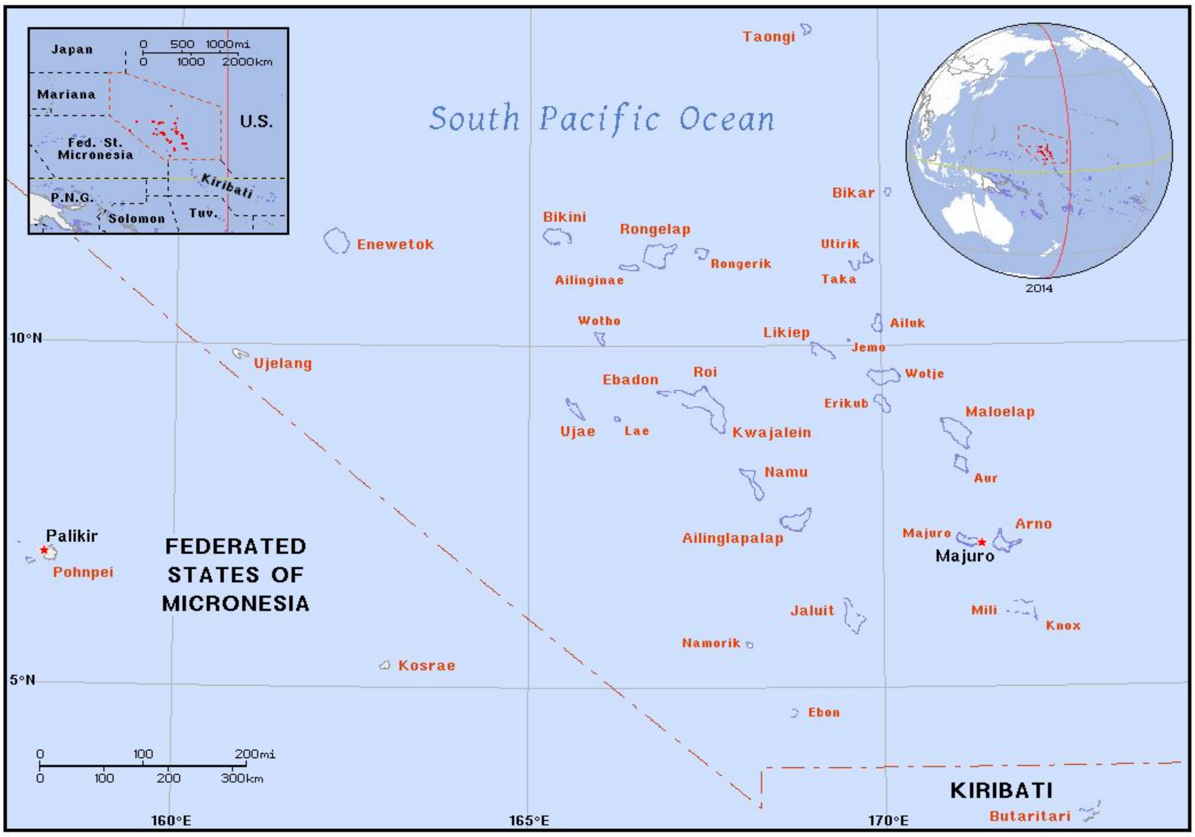

Figure 92. Map of RMI (Source: Ian Mackay)

RMI and other Micronesian islands were claimed variously by Spain, Portugal, Germany and Japan from the 16th century, but from 1946 were held by the United States of America. Nuclear tests were conducted on many of RMI's islands, most of which remain too radioactive to occupy and there is a large population still displaced by the tests. The US maintains a base on Kwajalein Island, the largest in the Kwajalein atoll.

The Marshall Islands is now a presidential republic in free association with the United States. The US provides defence, subsidies, access to some US-based agencies and the right to travel to and work in the US. With few natural resources, the country's economy relies on services, some fishing and agriculture and aid from the US, which makes up a large percentage of its GDP. Its currency is the US dollar.

RMI faces significant development pressure arising from extremely high population densities in the urban centres, high levels of poverty, a dispersed geography of atolls over a large ocean area (making communication difficult and transportation expensive), and a small island economy that is physically isolated from world markets but highly susceptible to global influences. Environmental pressures are also acute, with low elevation, fragile island ecosystems, a limited resource base and scarce freshwater resources resulting in an environment that is highly vulnerable to overuse and degradation. It is in a relatively quiet seismic area, but is surrounded by the Pacific "ring of fire" and has been struck by devastating tsunami after distant earthquakes in the past.[536]

[536] PCRAFI, 2017, Marshall Islands Country Profile.

RMI's GDP was estimated at USD211,523,642 in 2018,[537] or USD 4,740 per capita. Agricultural production is primarily at subsistence level and concentrated on small farms and home gardens. The most important commercial crops are coconuts and breadfruit and its most important industries are the processing of tuna and copra. Tourism has potential but limited infrastructure poses barriers to private sector development. The Government employs 30% of the formally employed work force.

Since its independence in 1990 when the United Nations formally dissolved US trusteeship, RMI's revenues depend largely on resources provided by the United States under the Compact of Free Association (COFA), which initially provided USD 1 billion during 1986–2001, and was renegotiated to provide $1.5 billion in direct US assistance from 2003–2024. Under the amended Compact, the US is also funding, jointly with the Marshall Islands, a Trust Fund for the people of the Marshall Islands that will provide an income stream beyond 2024 when direct Compact aid is to end.[538] The US Ronald Reagan Missile Test Site at Kwajalein Atoll provides key income to the RMI economy and is estimated to deliver about one-third of RMI's economic activity.[539]

In search of economic opportunities, people have been steadily migrating from the outer atolls and islands to the two urban centres of Majuro and Kwajalein, where about seventy percent of RMI's population lives.[540] Migration is also suspected to be accelerating from Marshall Islands to the United States: under the Compact, Marshallese citizens may work and study in the United States without a visa. These forces of migration contribute to further decline of the outer islands' economies, increasing the income gap between the urban and outer atoll and island populations. In the urban areas of Majuro and Ebeye there is a concentration of highly paid public servants but the ADB estimates that two thirds of outer islanders live on less than USD1 per day. COFA and federal funding largely benefit urban areas, and nuclear compensation and lease payments benefit communities on a limited number of islands.[541] There is a continuing decline in the price of copra (the economic mainstay of the outer islands) and a lack of low-skilled jobs in both urban and rural areas.[542]

Current provision of climate services: strengths, priorities and barriers

The RMI Weather Service Office (WSO) experiences barriers to its effective delivery of essential services common to all five very small island countries. The vast ocean areas, the changing climatic conditions, the dispersion of its islands and capacity constraints make it difficult for WSO to put in place comprehensive and sustained climate information services. The economic value of climate information and its importance to human safety is often not reflected in national budgets and there is limited potential for cost recovery for agrarian advice, infrastructure planning advice, public health early warnings or even essential aviation and maritime services. Specialised services requiring highly trained staff are difficult to sustain in very small countries—qualified meteorologists are in demand in developed Pacific rim countries, which can offer higher pay, better professional development and other opportunities. Ageing and obsolete equipment and unreliable internet access add to the challenges faced by small NMHSs.

The RMI WSO is not governed by a Meteorology Act, but by the Compact of Free Association (COFA) with the US, which came into effect in 1983 and in 2003 was renewed for another 20 years. This treaty

[537] The World Bank, 2018, available at <https://data.worldbank.org/country/marshall-islands?view=chart> [August 2019].
[538] RMI will continue to receive annually declining grants averaging US$45 million (26 percent of GDP as of FY2012) until FY2023. A Compact Trust Fund (CTF) is being built up to provide funding from FY2024 onwards. (Government of RMI, 2013, IMF Country Report No. 14/26; RMI Staff Report for the 2013 Article IV Consultation.)
[539] Government of the Republic of the Marshall Islands, 2007, National Action Plan for Disaster Risk Management 2008–2018.
[540] SPC, 2011, Government of the Republic of the Marshall Islands 2011 Census.
[541] ADB, 2003, Priorities of the People, Hardship in the Marshall Islands.
[542] Government of the Republic of the Marshall Islands, 2007, National Action Plan for Disaster Risk Management 2008–2018.

arranged for the United States' National Weather Service (NOAA) to provide weather services and related programmes in the Republic in accordance with Article VII (Weather Services and Related Programmes) of COFA. According to Sections 5 to 13 of Article VII of COFA, US NOAA NWS provides weather services through the Weather Services Office (WSO) Majuro. The National Weather Service Pacific Region Headquarters based in Hawaii provides administration, financial, operational, management and oversight assistance to WSO Majuro. NOAA NWS Weather Forecast Offices in Guam and Honolulu prepare and provide weather forecasts, watches, warnings and advisories to the Republic.

The WSO Majuro consists of three main programs: Operation; Forecast and Warnings; and Electronic and Facility. The supervisory program comprises of US NWS Pacific Region Headquarters and the Office of the Meteorologist-In-Charge of WSO Majuro.

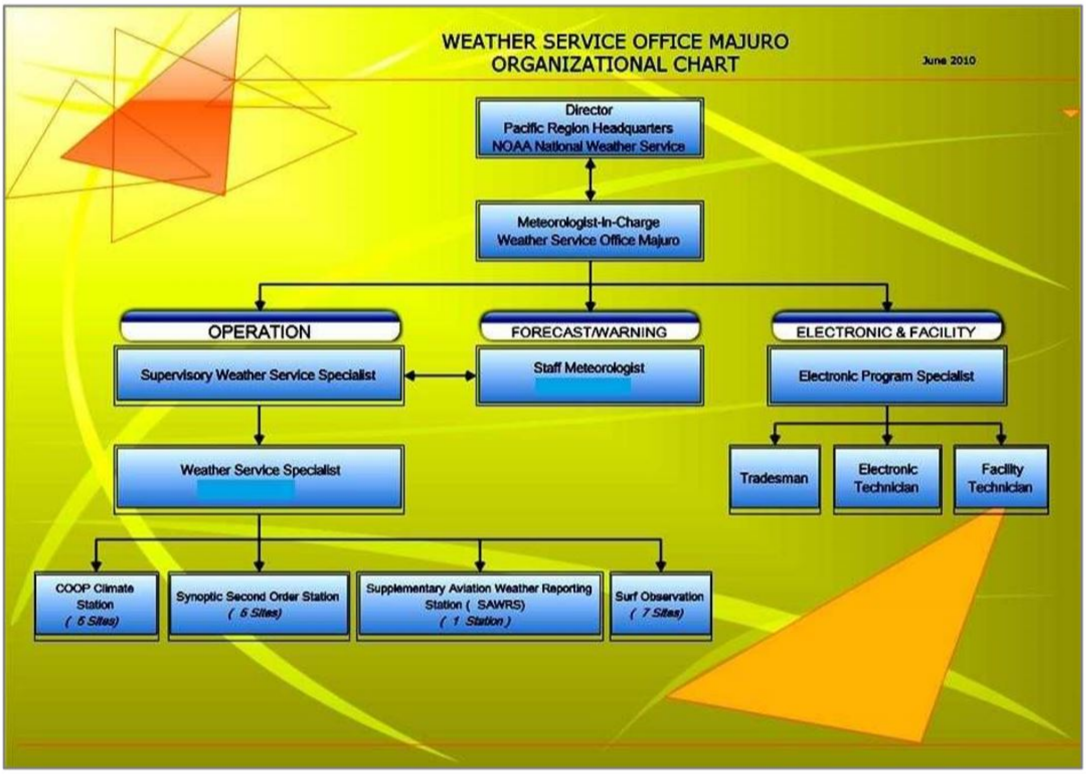

Figure 93. RMI Weather Service Office (WSO) organisational chart (Source: PMC 4 Working Paper for RMI)

Currently, WSO has:

- Director (Class 1 Forecaster) – Reggie White;
- Class 2 Forecasters – (Lee Jacklick and Nover);
- Class 3 Forecasters – (Samson, Simon, Ronald, Elai);
- Senior level Meteorological Technician – (Corrie).

The staff meteorologist and the Weather Service Specialists prepare and transmit adaptive or tailored weather forecast products and information to the communities in the Republic of Marshall Islands using weather forecasts, watches, warnings and advisories from the US NWS Weather Forecast Offices (WFO) in Guam and Honolulu and the US Joint Typhoon Warning Center (JTWC).

To support the preparation of weather forecasts, watches, warnings and advisories for Micronesia, WSO Majuro and other WSOs in Micronesia operate surface and upper air observation programs making available weather and climate observation data to WFOs Guam and Honolulu, and other countries. These observations provide important confirmation of remotely sensed data.

There are currently ten operational meteorological stations in the Marshall Islands. Multiple observations within a 24-hour period are taken at eight of these stations (Majuro, Utirik, Ailinglaplap, Jaluit, Wotje, Mili, Amata Kabua International Airport and Kwajalein) and a single daily observation is taken at Laura and Arno. The primary stations are located at Majuro on the southern end of the Ratak chain and at Kwajalein near the centre of the Ralik chain. Observations began at Majuro in 1951 and at Kwajalein in 1949. Rainfall and temperature records from 1960 onwards are homogeneous and more than 99% complete.[543]

There are a number of sea-level records available for the Marshall Islands, at Eniwetok (1951–1972), Kwajalein (1946–present), Majuro-B (1968–2001) and Majuro-C (1993–2009). The Australian Government continues to support the monitoring of sea level rise and other climate data at the Majuro wharf and deployed an earth monitoring system instrument to estimate vertical land motion in the Marshall Islands in 2007 which will provide valuable direct estimates of local vertical land motion in future years.

RMI has real-time access to data from two tidal gauges: NOAA gauge in Kwajalein in operation since 1946 (https://tidesandcurrents.noaa.gov/stationhome.html?id=1820000) and the BOM gauge in Majuro, in operation since 1993 (http://www.bom.gov.au/pacific/marshall_islands/index.shtml).

The University of Hawaii provides an outlook of monthly sea level anomalies for the next one to two seasons for RMI, through combining sea level forecasts with astronomical tide predictions to provide more accurate predictions of coastal water level compared to tide predictions alone.[544]

Surface aviation observations include hourly METAR/SPECI[545] (as required); SYNOPs every 6 hours (0000, 0600, 1200 and 1800 UTC); and additional SYNOPs are taken as required. Daily oversight of SAWRS observations are carried out by WSO Majuro's staff. WSO Majuro collects and transmits weather and climate data from observation stations around the country.[546]

The WSO Majuro also provides some marine weather products, warnings, and advisories:

- Near-real time wave heights, characteristics, velocities and current observation from an off-shore wave-rider buoy at Majuro Atoll only;
- Near-real time sea-level height and sea surface temperatures from the Seaframe tide gauge at Majuro Atoll lagoon;
- Tidal information / tide calendar for RMI with data derived from the Majuro tide gauge;
- Wave run-up forecasts for Majuro and Kwajalein Atolls;
- Coastal flooding watches, warnings and statements for RMI;
- High surf advisories, watches, warnings and statements for RMI.

WSO Majuro staff have advanced in their capacity to interpret and use meteorological data, largely through training provided by Australia's Climate and Ocean Support Program in the Pacific (COSPPac), in which they have participated since 2013. The project installed purpose-built software that enables meteorological service staff in all five countries (and nine others) to generate forecasts of the local climate 3 to 9 months ahead. The software—Seasonal Climate Outlook for Pacific Island Countries

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[543] PCCS, 2013, available at <https://www.pacificclimatechangescience.org/wp-content/uploads/2013/06/PCCSP_Vol2_Ch7_Marshallislands.pdf> [August 2019]
[544] University of Hawaii, Sea Level Forecasts, available at <https://uhslc.soest.hawaii.edu/sea-level-forecasts/> [August 2019]
[545] A Meteorological Terminal Aviation Routine (METAR) is a routine report of meteorological conditions at an aerodrome. A SPECI is a special report of meteorological conditions, issued when one or more elements meet specified criteria significant to aviation. SPECI is also used to identify reports of observations recorded ten minutes following (BOM, available at <http://www.bom.gov.au/aviation/data/education/metar-speci.pdf> [August 2019])
[546] Government of RMI, 2017, Meteorological Service Country Report.

(SCOPIC)—uses each country's local data to generate a forecast statistically, focussing on expected rainfall and scalable down to the level of the weather station recording the data, if necessary. The data used in SCOPIC is drawn from a climate data management system called CliDE (Climate Data for the Environment, used in all 14 Pacific island countries) which ingests and archives digitised climate data and makes it available for manipulation and use in information products. The collection of local data allows the WSO to monitor and report on Majuro's climate at local scale.

Since 2013, COSPPac has mentored RMI's climate officer in the use of SCOPIC to produce a monthly report on upcoming climate conditions and to evaluate the accuracy of the previous climate forecast. During this time, the officer's confidence and accuracy has improved markedly, and the value of the forecasts has been noted. This mentoring continues, now by the Pacific Regional Environment Programme (SPREP) climate officer, who manages a monthly conference call with up to 11 Pacific climate officers and the Australian Bureau of Meteorology (BOM). The RMI climate officer discusses the calculation of his or her current climate forecast with the SPREP climate officer one-to-one ahead of the roundtable phone call. The group discussion then considers the forecasts across the region for the next few months and compares each country's previous predictions with the recorded data for those months. Confidence and accuracy continue to improve, and Australia continues to provide support to SPREP for the maintenance and further development of the software. WSO Majuro also uses CLIKP[547] and the NOAA Marshall Islands Climate Outlook.[548]

SPC maintains and provides access to the Pacific Ocean Portal[549] originally developed by BOM through COSPPac: the Portal allows a user with limited internet access to select a location and a sector such as tourism, fisheries, and shipping, ask for ocean parameters such as sea temperature, wave heights, coral bleaching, currents, salinity and chlorophyll, and receive the information visualised as maps and diagrams. The Portal is one of the tools the WSO can use to demonstrate to stakeholders.

RMI can cope with climate threats only if adaptation decisions are based on scientifically rigorous, standardised weather and climate data and if systematic end-to-end early warning practices are institutionalised. For RMI to achieve this, it must be able to collect and manage climate data; use its data to provide tailored advice to government agencies, climate-sensitive sectors and vulnerable communities; and have sufficient capacity to apply the advice in its planning, policies and activities.

RMI WSO has identified the following priorities: [550]

- Staff capacity building;
- Better observational coverage (e.g. more rain gauges);
- Establishment of more additional observing sites in the cooperative climate network;
- Training of two climate officers to become climatologists;
- Training in climate science, forecasting, climate tools, products and services, and communication.

One of the challenges for improving the qualifications of RMI WSO staff may be their level of English because the most common language spoken in RMI is Marshallese. A 2018 UNDP study reported that staff would benefit from receiving BIP-M training focused on delivery of services for aviation and to support a population exposed to the tropical climate hazards. However, BIP-M training would likely

[547] CLIKP has been developed for the ROK-PI CLIPS project and it is based on the established CLIK (CLimate Information toolKit) at APCC (SPREP, available at <http://clikp.sprep.org/> [August 2019].)
[548] http://apdrc.soest.hawaii.edu/dashboard_RMI/
[549] SPC, Ocean Portal, available at <http://oceanportal.spc.int/portal/ocean.html> [August 2019].
[550] Government of RMI, 2017, Marshall Islands Country Report to PMC 4.

need to be preceded by a 12-18 month "foundation" course in English, maths and physics to prepare participants for the advanced concepts in a BIP-M course.[551]

Disaster Risk Management

The National Disaster Committee (NDC) is the principal body responsible for DRM policy, strategic action and monitoring in RMI. The Secretariat for the NDC is the National Disaster Management Office (NDMO), which is the coordination centre for day-to-day DRM activities and in times of disaster. At the outer island / atoll level, the implementation of national DRM arrangements are the responsibilities of the Outer Island / Atoll Disaster Risk Management Committees.[552]

Financing for climate services and disaster risk management

There is no national budget allocation for climate change programming in RMI, with funding provided by donors and therefore off-budget.[553] However, in May 2019, a climate finance management workshop for key ministries and development partners was held in collaboration with the NDC Partnership. The aim of the workshop was to explore the setup of a national climate finance mechanism to support the Government in managing and leveraging climate change-related funds, strategic projects for mitigation, adaptation and resilience, and strengthened internal systems for climate action. The meeting resulted in agreement on a "Climate Finance Action Plan"[554] for strengthening climate financing in RMI.[555] A Contingency Fund of USD 200,000 is resourced annually by the Government of RMI and can be accessed for any emergency, including natural disasters. The Disaster Assistance Emergency Fund (DAEF) is resourced annually by the Governments of RMI and the U.S. RMI must contribute a minimum of USD 200,000 to be matched by the U.S. Government. In 2016, a Disaster Response Fund was established to allocate USD 2 million from the general budget for emergencies.[556] The DAEF is reserved only for disaster response. Disaster risk reduction is funded through ad-hoc projects and initiatives.[557]

Previous national climate change adaptation and awareness activities

The **India-UN Development Partnership Fund (India-UNDPF)** is a South-South cooperation programme, funding demand-driven transformational sustainable development activities. It provided an AWS and hydrological and meteorological training at the Regional Training Centre in Pune for RMI WSO staff.[558]

The **Green Climate Fund** has donated 13 additional synoptic observing stations to RMI to strengthen its capture of weather and climate data.

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[551] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre
[552] Republic of the Marshall Islands, 2017. National Disaster Risk Management Arrangements
[553] Global Climate Change Alliance: Pacific Small Island States (GCCA: PSIS) Project, 2013. Review of mainstreaming of climate change into national plans and policies: Republic of the Marshall Islands
[554] RMI, 2019. Climate Finance Action Plan. Available at: https://www.dropbox.com/s/1e6ker0nnfe42cf/RMI%20Climate%20Finance%20Action%20Plan%20-%20Final%20Draft%20-%20May%202019.docx?dl=0
[555] NDC Partnership, 2019. Press Release: Marshall Islands Takes Next Steps on National Climate Finance Mechanism. Available at: https://ndcpartnership.org/news/marshall-islands-takes-next-steps-national-climate-finance-mechanism
[556] Government of RMI and Pacific Humanitarian Team, 2017. Republic of the Marshall Islands Country Preparedness Package
[557] Center for Excellence in Disaster Management & Humanitarian Assistance, 2019. Republic of the Marshall Islands Disaster Management Reference Handbook
[558] https://www.unsouthsouth.org/2018/06/28/india-hosts-meteorologists-for-tailor-made-courses-in-climate-early-warning-systems/

The **Climate and Oceans Support Program in the Pacific** (COSPPac) Phase 2[559] is being implemented in 14 Pacific countries, strengthening analysis and interpretation of climate, oceans and tidal data to generate critical services to inform adaptation to climate change. The aim of COSPPac 2 is “Pacific island national meteorological services understand and use climate, ocean and sea level information to develop and disseminate useful products and services to Pacific Island governments and communities building resilience to the impact of climate change, climate variability and disasters”. The program includes the Pacific Sea Level and Geodetic Monitoring Project (phase 5), the Climate Data for the Environment Project (CliDE), the Seasonal Climate Prediction Project and a program support unit.

The **Climate and Ocean Support Program in the Pacific Phase 1**[560] was supported by the Australian Government (2012–2018) and implemented with 14 Pacific countries including RMI by BOM with SPREP and SPC. It aimed to enhance the capacity of Pacific Islands to manage and mitigate the impacts of climate variability and change. COSPPac included a tailored training program for Pacific meteorological service staff, an Online Climate Outlook forum which mentored Pacific climate officers in developing their seasonal forecasting skills using SCOPIC, and the long-running sea level monitoring project. Meteorological services began work on the effective communication of climate information to their climate sensitive sectors and in several countries, on the collection and use of traditional climate knowledge. Participating meteorological services made significant advances in capacities and confidence with the support of this program and contributed to several innovative projects, most notably a Malaria Early Warning system in the Solomon Islands and the Ocean Portal.

The **Finland-Pacific (FINPAC) Project**: climate and disaster ready communities through improved national meteorological services[561] was a four-year project implemented by SPREP in 14 countries including RMI. It aimed “to improve livelihoods of Pacific island communities by delivering effective weather, climate and early warning services.” Its two key components were providing National Meteorological Services (NMHS) with the capacity and tools to deliver and communicate timely weather and climate services to support communities; and working with communities to strengthen their ability to use and apply meteorological data and information and to develop appropriate plans to address climate change and disasters.

Inform: Environmental Information for Decision Making 2017–2021[562] is being implemented by UNEP and executed by SPREP in 14 Pacific countries, including RMI. It is establishing a network of national and regional data repositories and reporting tools to support the monitoring, evaluation, and analysis of environmental information, to support environmental planning, forecasting, and reporting requirements. Inform addresses three problems and vulnerabilities common to Pacific SIDS:

- Need for historical and current evidence of the status and trends of various environmental resources and drivers of environmental change;
- Challenges with information management, including the need for standard procedures for collecting and aggregating relevant environmental data; and
- Lack of timely access to available information by those who need it, including technical staff, governments, or communities and citizens, for national and international reporting and planning, and most importantly, for sound and informed decision making.

[559] SPREP, Climate and Oceans Support Program in the Pacific: Phase 2.
[560] Government of Australia, Climate and Oceans Support Program: Phase 2, available at <https://www.pacificmet.net/project/climate-and-oceans-support-program-pacific-phase-2> [August 2019]
[561] Pacific Meteorological Desk & Partnership, available at <https://www.pacificmet.net/project/finland-pacific-finpac> [August 2019]
[562] SPREP, 2017, Inform Environmental Information for Decision Making.

SPREP hosts RMI's national environment portal, which has datasets for biodiversity, coastal and marine data, atmosphere and climate, land, built environment, culture and heritage, and the Marshall Islands' nuclear legacy. The Marshall Islands Government has endorsed its national portal and the regional environment portal as the formal repository for national datasets and knowledge products.

The **Pacific Adaptation to Climate Change** (PACC)[563] aimed to reduce vulnerability and increase adaptive capacity to the adverse effects of climate change in key development sectors: coastal zone management, food security and water resource management. In RMI, support focused on water resources management on the main atoll of Majuro and included a detailed assessment of the water sector and its vulnerabilities to current and projected climate change impacts, through a Vulnerability and Adaptation Assessment. The project made recommendations for investments in adaptative measures including for the airport water catchment and drainage system, the reservoirs and water treatment plant, distribution lines and household rainwater harvesting systems. All were all found to be "highly vulnerable to tropical cyclones, storm surges and extreme high tides." [564]

The **Pacific Climate Change Science Program** 2009–2011[565] conducted a comprehensive climate change science research program aimed at providing in-depth information about past, present and future climate in 15 partner countries including RMI.

The **Pacific-Australia Climate Change Science and Adaptation Planning Program** (PACCSAP) 2011–2015[566] helped 14 Pacific countries, including RMI, to build resilience to current and future climate risks through improved science and data, increased awareness of climate change and its impacts, and better adaptation planning. It produced very detailed reports on scientific modelling of climate change impacts on each country under three different emissions projections.

The **Program for implementing the Global Framework for Climate Services** (GFCS) at Regional and National Scales 2015[567] was funded by Environment and Climate Change Canada (ECCC) through WMO and implemented by SPREP and the Pacific Meteorological Council. The goal of the Program was to enhance the resilience of social, economic and environmental systems to climate variability and climate change through the development of effective and sustainable Regional and National Climate Services under the GFCS in selected regions and countries.

The **Republic of Korea-Pacific Islands Climate Prediction Services Project**[568] is implemented through the Pacific Island Forum Secretariat and implemented by the APEC Climate Centre and SPREP. It provides nationally tailored seasonal climate prediction information and builds the prediction capacity of Pacific meteorological services. Its objective is to strengthen the adaptive capacity of vulnerable communities to climate risks at seasonal timescales. The project has developed region-specific downscaling methodologies and established an online climate prediction system. Its on-line climate prediction system CLIKP, or Climate Information Toolkit for the Pacific, is available to Pacific Island National Meteorological Services at http://clikp.sprep.org/.

Alignment with national priorities

[563] PCCP, Pacific Adaption to Climate Change, 2009.
[564] SPREP, 2014, Vulnerability and adaption (V&A) assessment for the water sector in Majuro, Republic of the Marshall
[565] SPREP, 2009, Pacific Climate Change Science Program (PCCSP).
[566] PCCP, 2011, PACCSAP.
[567] Pacific Meteorological Desk & Partnership, 2015, Program for implementing the Global Framework for Climate Services (GFCS) at Regional and National Scales.
[568] https://www.pacificmet.net/project/republic-korea-pacific-islands-climate-prediction-services-project-rok-pi-clips SPREP, The Republic of Korea-Pacific Islands Climate Prediction

International

- Sustainable Development Goals (SDGs) of the UN Development Programme;
- Sendai Framework on Disaster Risk Reduction;
- Paris Agreement on Climate Change.

Regional

- Framework for Resilient Development in the Pacific (FRDP) 2017–2030;
- SAMOA Pathway;[569]
- Pacific Island Meteorological Strategy (PIMS) 2017–2026;[570]
- Pacific Roadmap for Strengthened Climate Services (PRSCS) 2017–2026;[571]
- 2017 Honiara Ministerial Statement on Sustainable Weather, Climate, Oceans and Water Services for a Resilient Pacific;
- 2015 Nuku'alofa Ministerial Declaration on Sustainable Weather and Climate Services for a Resilient Pacific.

National

- 2016 State of Environment Report;
- National Strategic Plan 2015–2017;
- 2015 Second National Communication Report to the UNFCCC;
- Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management 2014–2018 (JNAP);
- National Climate Change Policy Framework 2011 on Adaptation and Reducing Risks for a Climate Resilient Future;
- Climate Change Country Profile—GFDRR, 2011.

In its 2017 report to the Pacific Meteorological Council, RMI noted that, like all small island states, it faces serious challenges in dealing with climate variability and change. RMI's official communications to the United Nations Framework Convention on Climate Change points to significant research, data and information gaps in relation to its changing and projected climate. The following have been identified as research, data and information gaps that need to be addressed.

- Lack of coordination, capacity and effective institutional systems to collect and manage climate-related data and information. A lack of specific information and data on current and future vulnerability, impacts and risks across RMI hampers its ability to plan for and respond to these risks.
- Information generated through technical assistance programs and projects are not consolidated, in part because there is no designated coordination mechanism. This can be addressed through SPREP's Inform project.
- Lack of climate vulnerability and impacts data and of a centralised data system to access climate vulnerability and impacts data to be used for planning and decision making. Detailed assessments of climate change impacts and risks across a variety of sectors are required to inform sound response strategies.

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[569] UN, 2014, Small Island Developing States Accelerated Modalities of Action (Samoa Pathway).
[570] Pacific Roadmap for Strengthened Climate Services 2017–2026.
[571] SPREP, Pacific Roadmap for Strengthened Climate Services 2017–2026.

- RMI needs an operational portal on adaptation that allows for consolidation of all relevant information in one place, so that the user community can have easy access to climate information, services and knowledge. It is critical that such information and knowledge is packaged in a user-friendly format and is made available to all users from government to community level, in a language that can be understood. To be effective, training will be needed to enhance the capacities of Ministries and relevant line agencies. SPREP's Inform project will contribute to this priority.
- Analysis of the adaptive capacity of communities and institutions for each major vulnerability have not been done because technical capacity is limited, and a structured process and prioritisation of resources for undertaking longer term assessments is lacking. Most of the current information is for immediate and short-term adaptation planning. Longer term scenarios need to be analysed with respect to impacts on climate sensitive sectors.
- Little work has been done to downscale climate models to individual islands. Realistically, it may not be possible to derive more accurate climate change information due to the small size of these islands, but more work needs to be done to acquire local scale data sets. New information should be useful to island scale decision making.
- Applied research assistance is required to establish properly an island-specific and robust baseline from which to gauge projected changes and impacts.
- The use of existing meteorological information is limited to specific agencies, and this information needs to be tailored to decision makers across a wider series of sectors including water resources management.[572]

RESULT 1 – STRENGTHENED DELIVERY MODEL FOR CLIMATE INFORMATION SERVICES AND MHEWS COVERING OCEANS AND ISLANDS

Activity 1.1 Strengthen institutional and policy frameworks and delivery models for climate services

Under this Activity, the Programme will establish comprehensive institutional and policy frameworks and delivery models for strengthened climate services in RMI. This will include the development of a National Framework for Climate Services (NFCS), which will be supported by effective coordination mechanisms to mainstream climate risk knowledge into the decision making of climate-sensitive sectors. Moreover, RMI will conduct a climate services market assessment and develop a policy for sustainable financing and delivery of climate services. Amongst others, engagement with the development of national budgets will enable justification of the value of climate services, strengthen existing funding for disaster relief and contribute to the identification of long-term sources of funds.

R1.1.1 Develop the RMI Framework for Climate Services

National Framework for Climate Services

Throughout the implementation of this Programme, RMI WSO proposes to conduct a series of consultative workshops with stakeholders to develop and refine a National Framework for Climate Services (NFCS). In the first half of year one, RMI WSO will invite representatives of government agencies responsible for key sectors including the five Global Framework for Climate Services (GFCS) sectors—water, health, renewable energy, food security and agriculture, and disaster risk reduction—

[572] GCF, 2018, Concept Note, Enhancing climate resilient planning and decision making in the Republic of Marshall Islands.

to take part in a 3-day workshop facilitated by an international and a local consultant. The workshop will begin with a presentation of basic climate science, an explanation of the kinds of data the WSO collects, and a presentation of the products and services their data has been used to create. The WSO will explain the use of its data in planning climate-proof infrastructure, preparing for extremes of rainfall and drought, delivering timely disaster warnings and informing RMI's advocacy in international forums. Sectors will also be asked to present on how they use climate information and how they would best like to work with RMI WSO. The workshop would begin the process of agreeing with these stakeholders more specific functions, relationships and services.

The two consultants will use the outcomes of the first workshop to draft the NFCS, which will inform the future work of RMI WSO. Objectives will be to agree with key sectors a suite of directly applicable information products, with a process for checking their utility regularly and revising them when needed. In year five the NFCS will be re-evaluated using feedback and learnings from each sector over the previous four years.

Meteorology Act

RMI Weather Service Office (WSO) is not governed by a Meteorology Act, but by the Compact of Free Association (COFA) with the US, which came into effect in 1983 and in 2003 was renewed for another 20 years. This treaty arranged for the United States NOAA National Weather Service to provide weather services and related programmes in the Republic in accordance with Article VII (Weather Services and Related Programs) of COFA. According to Sections 5 to 13 of Article VII of COFA, US NOAA NWS provides weather services through the Weather Services Office (WSO) Majuro.

In the first year of the Programme, the RMI WSO proposes to engage a legislative drafting consultant, supported by a local consultant, to prepare a draft Meteorology Act for submission to Parliament. The Act should mandate the responsibilities of the WSO for provision of weather and climate services, clearly state its role in early warning and disaster management, formalise its relationship with allied agencies, and provide budget security.

The consultants will work with the Ministry of Justice, Immigration and Labor and with NOAA to ensure the draft is consistent with RMI's existing legislation, takes COFA into account and looks to the future. The National Disaster Management Office (NDMO), disaster relief agencies and media organisations will be consulted to ensure the draft legislation supports their collaboration with RMI WSO. The consultants may also consult with WMO, which has advised other Pacific island countries on developing a Meteorology Act, and with NOAA, BOM and NIWA on model legislation.

National Meteorological Strategy

RMI WSO will engage an international consultant, supported by a local consultant, to draft a National Meteorological Strategy, which will document the process by which RMI WSO will put the draft Meteorology Act, Pacific Islands Meteorological Strategy and the Pacific Roadmap for Strengthened Climate Services into operation. The consultants will undertake two principal tasks:

Review stage

- Review sectors' use of weather and climate information services, including use and demand within the public and private sectors, and by communities.
- Review Palau's existing sector policies and institutional and governance arrangements as they relate to climate variability and change and consider how the National Meteorological Strategy can promote better use of climate information.
- Review previous consultations, investigations and analyses of the mainstreaming of climate information into sectors' decision-making processes, focusing on the five GFCS primary

sectors— Agriculture, Tourism, Water, Fisheries and Infrastructure—and on the use of weather and climate information services in early warning systems.

Drafting stage

- Conduct preparatory work with each government agency to ensure their interests are taken into account in the Strategy.
- Conduct workshops with the private sector, NGOs and community representatives to ensure their input to the Strategy.
- Facilitate a public workshop to validate and finalise the draft.

RMI WSO will put the National Meteorological Strategy into effect through the Climate Information Services Sector Action Plans (R1.1.3).

R1.1.2 Conduct market assessment to explore viable opportunities for climate information services in sectors and business segments

This Sub-activity will support RMI to understand its existing market for climate services and potential sustainable climate services models; and utilise a value chain approach to mobilise private sector finance in climate services delivery. In the longer term, this will support establishment of a foundation for a cycle of investment, service enhancement, research and development, and re-investment, which has already created commercial markets for climate services in developed countries.[573]

The Programme will conduct a detailed market assessment, which will assess the following:

- **Involved actors in climate services** – This include providers, intermediaries and users: i) Government agency/s (including RMI WSO) responsible for the operation of the national meteorological infrastructure and provision of public weather and climate services; ii) Academic (university) research community; iii) Media entities; iv) Private sector and other providers; and v) Users, which consists of the general public, as the users of basic services, and the economic and social sectors and organisations as the users of specialised, tailored services.[574]

- **Regulatory environment** – Analysis of the current regulatory environment for climate information and early warning services in RMI and subsequent identification of policy incentives to unlock barriers to private sector investment;

- **Supply and demand analysis** – Identification of country-relevant sector and business needs for climate services (for example, level of information, scales and access required);

- **Private sector engagement** – Building on the analysis of supply and demand, the Programme will support RMI WSO to engage with the private sector – including through the National Climate Outlook Forums (Sub-activity 1.1.3) – to identify private sector sponsors' interest in the generation, translation and transfer function and in purchasing climate-related information.

- **Business models** – Analysis of business models for climate services that are successful in other countries, with a focus on Small Island Developing States (SIDS). This will include case studies on private sector company provision of climate services as well as government-led initiatives.

[573] SAID, 2018. Climate Information Services Market Assessment and Business Model Review
[574] WMO, 2015. WMO-No. 1153. Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services

Based on the above analysis, the Programme will support RMI to identify opportunities to develop value-added climate products and services; and potential for public-private partnerships and private sector investment in climate services. Private sector engagement will improve the cost-effectiveness of RMI WSO and increase potential for catalysing innovation in climate information technologies. This Activity will also inform development of the national policy for financing climate services in Sub-activity 1.1.4.

R1.1.3 Mainstream climate risk knowledge into sectors

National Climate Outlook Forum

In the second half of the year, RMI WSO will run a National Climate Outlook Forum (NCOF) before the onset of the cyclone season (April for RMI) and after the Pacific Islands Climate Outlook Forum (PICOF).

The participants in the earlier workshop (for government officials) will be better prepared to understand the Outlook and how it supports specific sectoral advice. The NCOF will be refined in response to the contributions of workshop participants, explaining how they use RMI WSO's advice.

In years two, three and four, RMI WSO will hold similar 2-day workshops successively with the private sector, NGOs and communities combining information about the climate, how it is changing and what the implications are for RMI, with a presentation on the products and analyses the WSO can generate. The workshops will be used also to help the private sector, NGOs and communities to articulate what information they want from RMI WSO and the formats in which it will be most useful to them.

In year five the NCOF will be presented to all stakeholders, as usual after the NFCS review workshop.

Climate Information Services Sector Action and Communication Plan

In the first half of the second year of the Programme, RMI WSO will engage an international and a national consultant to facilitate a workshop with stakeholders from government agencies and communities and from outer islands (community representatives) to identify sector specific priorities and actions for climate information services, targeting five sectors. The workshop will further develop the ideas about the information needs of specific sectors gained from the NFCS. It will also consider, with sector representatives, how climate information can be mainstreamed into their work and applied in their decision-making.

The consultants will use the outcomes of the workshop to draft a Climate Information Services Sector Action Plan and a Communication Plan for an agreed number of important sectors. The plans will address sector-specific needs for information services relating to both disaster risk reduction and management, and effective climate change adaptation.

The Plans will document an agreed process for testing the best ways of regularly communicating climate information to sectors. This will include both finding ways to make information easily accessible and exploring potential methods of improving the understanding of climate information by all workers in a sector, and by the users of that sector's own services.

This is likely to include a range of activities, such as improving RMI WSO's use of social media, but to begin with a programme of capacity building in understanding climate and weather information for government workers. The sector communication plans will be tailored to the specific interests and needs of each sector and will cover basic climate science, an explanation of the kinds of data the WSO collects, and a presentation of the products and services it provides. It should include support to the sector in communicating climate information within the sector, and to the sector's clients and end users.

Sector-Specific Climate Training Programme

The Climate Information Services (CIS) Sector Action Plans for RMI will guide sector-specific climate training for the five sectors identified in the action plans: these may include fisheries, tourism, water, health, renewable energy, food security and agriculture, and disaster risk reduction.

RMI WSO will engage an international and a national consultant in the second half of the second year to develop a training programme, with guidance materials and capacity building resources, to facilitate the uptake of climate information services by the targeted sectors and their stakeholders. The training will be non-technical and directly relevant to each sector and applicable to its activities. This intervention is replicating an activity implemented by a GCF funded Climate Information Services for Resilient Development Project in Vanuatu.[575]

The consultants will conduct a CIS training needs assessment with the WSO, and based on the assessment, will use existing and new CIS information to develop a tailored training programme. The Training Programme will be in line with the RMI Framework for Climate Services (NFCS), the National Meteorological Strategy (R1.1.1), the Pacific Island Meteorological Strategy (PIMS) 2017–2026 and the Pacific Roadmap for Strengthened Climate Services.

In year five the sector plans and the communication plans will be re-evaluated and updated using feedback and learnings from each sector.

Train the Trainer for Sectors

RMI WSO will engage an international consultant to demonstrate the use of the CIS training programme through facilitating Train the Trainer sessions for sector personnel, non-governmental organisations (NGOs) and the WSO. The training will use sector-specific case studies.

Five workshops will run in the third and fourth year, each targeting a different sector. There will be an opportunity to update the training programme after each workshop.

R1.1.4 Develop national policies for financing climate services

This Sub-activity will provide the foundation for the establishment of a financially sustainable business model for climate services in RMI. Based on the NFCS established under Sub-activity 1.1.1, the Programme will develop a national climate services financial policy to ensure that RMI WSO has the means to sustain and ensure the ongoing operation of its mandated services in order to mitigate weather-, climate-, and water-related risks.[576]

RMI does not have an established national climate finance policy or dedicated Fund. However, RMI organised a workshop in May 2019 to explore the setup of a national climate finance mechanism, in collaboration with the NDC Partnership.[577] The workshop resulted in agreement on a “Climate Finance Action Plan”[578] to strengthen climate financing in RMI. The Programme will coordinate with the Climate Finance subgroup in RMI to ensure that development of the national policy is aligned with, and facilitates, climate services-oriented actions outlined in the Plan.

[575] SPREP, 2018, Climate Information Services for Resilient Development in Vanuatu. The Project has a Bislama name, “Vanuatu Klaemet Infomesen blong Redy, Adapt mo Protekt (Van-KIRAP)”.
[576] World Bank, 2013. Weather and Climate Resilience. Effective Preparedness through National Meteorological and Hydrological Services
[577] NDC Partnership, 2019. Press Release: Marshall Islands Takes Next Steps on National Climate Finance Mechanism. Available at: https://ndcpartnership.org/news/marshall-islands-takes-next-steps-national-climate-finance-mechanism
[578] Republic of the Marshall Islands, 2019. RMI Climate Finance Action Plan. Available at: https://www.dropbox.com/s/1e6ker0nnfe42cf/RMI%20Climate%20Finance%20Action%20Plan%20-%20Final%20Draft%20-%20May%202019.docx?dl=0

The financial policy will be carefully developed with the support of the World Meteorological Organization (WMO) to ensure that it is tailored to the context of RMI. In line with World Bank guidance,[579] the financial policy will cover the following elements:

- Opportunities for greater cooperation between the public and private sectors and academia given that many economic sectors increasingly depend on meteorological information for safe and efficient operations.
- Opportunities for win-win situations that fulfil the public sector responsibility to help the economically disadvantaged while meeting the needs of enterprises for climate services. To this end, the Programme will ensure that the Government of RMI is made aware of the economic value of climate information in, for instance, reducing the need for dangerous marine rescues, reducing the need for transport of drinking water to outer islands in drought, and reducing the costs of recovery from cyclone damage.
- Opportunities to coordinate and/or integrate financing for climate services and disaster risk management to strengthen existing disaster relief funds and establish reliable funding for disaster preparedness activities, which are often limited to ad-hoc donor funding. This would facilitate a more efficient and streamlined approach to implementing often overlapping actions for climate change adaptation and disaster risk management.
- Identification of elements for a sustainable financial model for RMI WSO based on the climate services value chain, which highlights the different roles of NMHSs in providing basic forecasts and warnings to protect society from the adverse effects of severe weather (a public good typically supported by governments) but also in providing specialised value-added services to government agencies and individual businesses (which may offer opportunities for cost-recovery from governmental and non-governmental sources).
- Potential to establish a National Climate Fund (NCF) as a mechanism to support RMI's engagement with climate finance by facilitating the collection, blending, coordination of, and accounting for climate finance directed towards climate services.[580] According to UNDP guidance,[581] these funds could have the following goals:
    - Collect sources of funds and direct them toward climate change activities that promote national priorities;
    - Blend finance from public, private, multilateral and bilateral sources to maximise a country's ability to advance national climate priorities;
    - Coordinate country-wide climate change activities to ensure that climate change priorities are effectively implemented; and
    - Strengthen capacities for national ownership and management of climate finance, including for "direct access" to funds.

  Functions of NCFs could include:

    - Support goal setting and the development of programmatic strategies for climate resilience;
    - Fund capitalisation;

[579] Ibid.
[580] UNDP, 2015. Blending Climate Finance Through National Climate Funds.
[581] Ibid.

- Management of partnerships;
- Provide project approval and support implementation;
- Supply policy assurance;
- Provide financial control;
- Manage performance measurement, including monitoring and reporting on activities and resource disbursement; and
- Provide and support knowledge and information management.

- Potential for continued support from the Systematic Observations Financing Facility (SOFF) as part of the Alliance for Hydromet Development, which was launched in December 2019 by 12 international organizations including UNEP. The SOFF is envisaged to ensure provision of basic systematic observations as a global public good by providing equitable, predictable, sustainable, and performance-based finance as well as technical assistance to developing countries for the provision of foundational observational data as per the Global Basic Observing Network (GBON) standard adopted by the WMO Congress in 2019. GBON aims to improve the global availability of the most essential surface-based data by defining the obligation for countries to implement a minimal set of surface-based observations for which international exchange of observational data will be mandatory.

RESULT 2 – STRENGTHENED OBSERVATIONS, MONITORING, MODELLING AND PREDICTION OF CLIMATE AND ITS IMPACTS ON OCEAN AREAS AND ISLANDS

Activity 2.1 Infrastructure and technical support for observations and monitoring

R2.1.1 Enhance national observations and monitoring networks to GBON standards and establish QMSs

Strengthen the network of land-based observations and improve observation station density in compliance with GBON

The Programme will procure equipment to strengthen the network of land-based observation stations measuring atmospheric pressure, temperature, humidity, horizontal wind and precipitation and regular reporting of data in compliance with the provisions of the WMO Global Basic Observing Network (GBON). WMO have proposed a target number of 51 observation points across the EEZ of RMI.[582] The Programme will facilitate observations through a mix of surface-based, upper air and marine observations. Critically, funding will be supplied for communications to ensure that observations can be made available via GTS to WMO, in compliance with GBON.

Installation of 20 AWS and four AWOS stations

The Programme will install 20 new/upgraded Automatic Weather Stations (AWS) across RMI, with sensors for rainfall, air temperature, barometric pressure, wind speed and direction, soil temperature (10, 20, 30 cm) and soil moisture. The stations will contain all-parameter local Modbus Meteorological Display Consoles (MMDC) including METAR/SYNOP coded message display. In addition, four new/upgraded Automated Weather Observing Systems (AWOS) will be installed at Majuro, Kwajalein,

[582] SOFF, 2020. Systematic Observations Financing Facility. Collaborative thinking workshop. Workshop outcomes and the way ahead. February 25-26 2020, Offenbach, Germany

Jaluit and Wotje. The AWOS station will contain AWS sensors (as above) as well as a ceilometer and visibility meter.[583]

RMI will also procure eight sets of AWS spares and a bench-top instrument calibration kit.

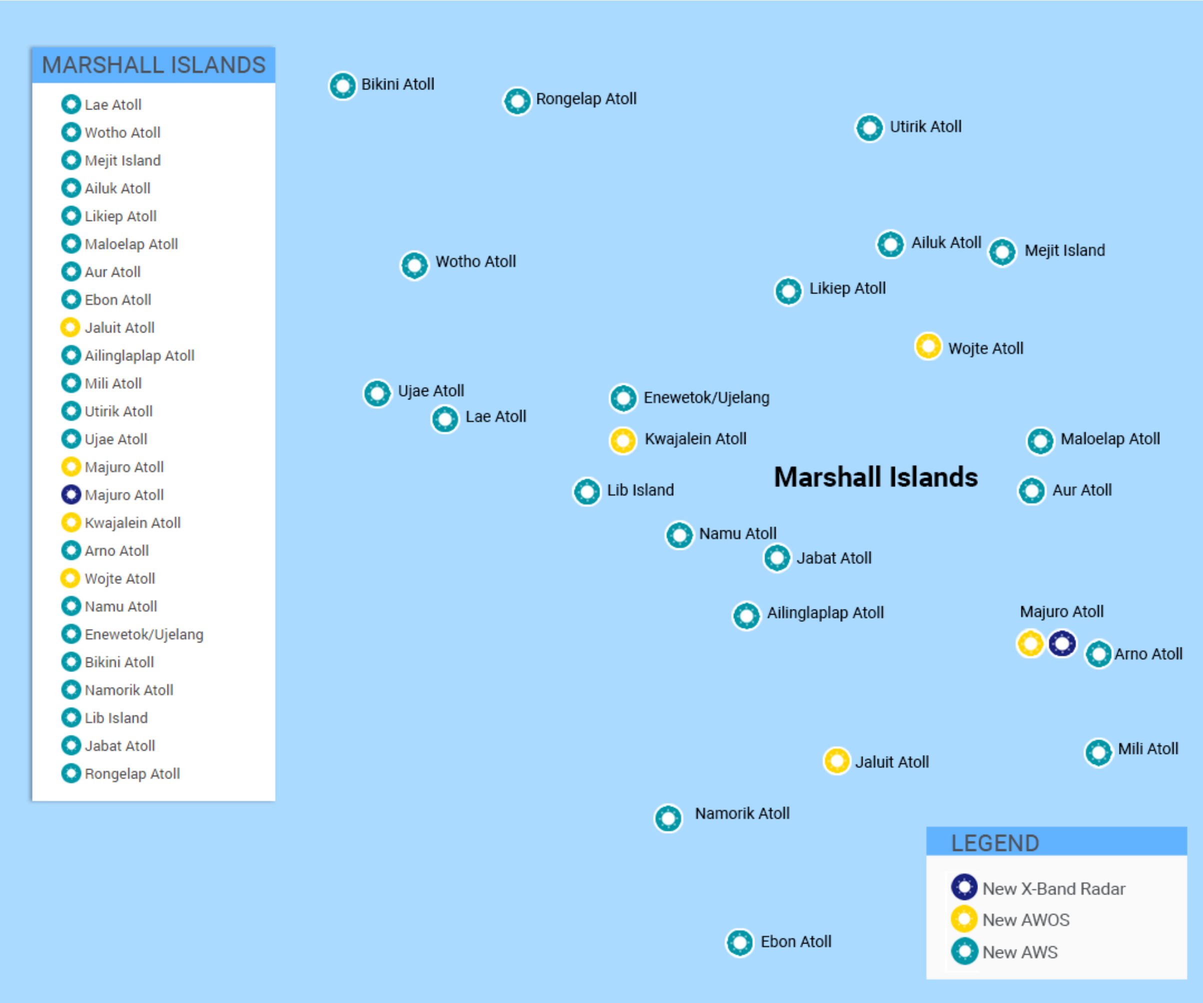

Figure 94. Proposed land-based observation network in RMI

Installation of a dual-polarization X-band Doppler radar

The Programme will install a dual-polarization X-band Doppler radar in Majuro. Dual-polarization radars obtain information on both the horizontal and vertical dimensions of precipitation particles, which gives meteorologists a better understanding of the size and shape of particles. The advantages of dual polarization include:

- Improved accuracy of precipitation estimates, leading to better flash flood determination;
- Ability to differentiate between differentiate between different types of precipitation;
- Improved detection of non-meteorological echoes (e.g. tornado debris, birds, etc.);

[583] These are the proposed sites under the current baseline and to support GBON. Given the dynamic nature of projects in the Pacific, these sites will be reconfirmed during each year of implementation and should site locations require changes, this will be done within the context of GBON and within the current budget.

- Detection of aircraft icing conditions.[584]

A Doppler radar is capable of measuring the velocity of precipitation particles (and thus, the wind). This enables Doppler radars to identify the detailed wind structure within severe thunderstorms.

The choice of an X-band system is on account of its low cost – in comparison to S or C band systems – and its small size, with potential for portable options. This is particularly important for the Pacific SIDS, which may have complex topography that limits accessibility for larger systems.

In addition to infrastructure, the Programme will provide technical training (Sub-activity 4.1.2) to build in-country capacity for radar operations, maintenance and data applications for weather and climate monitoring and analyses.

Quality Management System (QMS)

The RMI WSO will establish a QMS to help to enhance the quality of its activities, including streamlining and optimising the processes and procedures applied and the products and services provided. The WSO will aim to obtain certification of compliance with relevant ISO standards.[585] RMI WSO staff will engage with experts from the WMO network and participate in training and an annual QMS workshop. The objective is to become compliant with ISO9001:2015. RMI has a close relationship with NOAA, who will be fully engaged in the QMS process.

Activity 2.2. Ocean and climate modelling and impact-based forecasting

R2.2.1 Establish ocean information services

Marshall Islands Conservation Society (MICS) in-situ ocean data collection

This sub-activity will introduce and expand the use of indicators and methodologies that will support in-situ ocean data collection. It will enable RMI to establish baselines and to provide ground testing and verification data for strengthening coral bleaching prediction models.

A. Collection of in situ data on sea surface temperature at ten atolls

Based on an existing work programme, the Marshall Islands Conservation Society (MICS), Marshall Islands Marine Resource Authority (MIMRA), and members of the Coastal Management Advisory Council (CMAC) will expand the long-term deployment of seawater temperature sensors from Majuro Atoll to a total of ten atolls across the country.[586] The selected sites for ocean water temperature monitoring will add locally-derived sea surface temperature (SST) data to the set of indicators currently collected in coral reef fish and benthic surveys. Initial costs include planning, procurement, preparation, ship or air transportation and logistics, and field operations and supplies for deployment. Additional costs include transportation and supplies for device collection, data retrieval, storage and later analysis and reporting. Temperature data will be provided to the WSO and other scientific agencies attempting to better understand and document relationships between coral bleaching and SST, to improve predictive models for the Marshall Islands. This information and process will strengthen climate adaptation planning and decision-making for coastal fisheries. It is designed to enhance observations, monitoring, modelling to improve impact-based forecasting, and national multi-hazard early warning services that incorporate coral bleaching threats. Tentative deployment

[584] National Weather Service. Dual Polarization Radar. Available at: https://www.weather.gov/bmx/radar_dualpol
[585] https://library.wmo.int/doc_num.php?explnum_id=4141.
[586] Currently in-situ water temperatures near or within atolls are collected at Kwajalein by NOAA ocean buoys and at Majuro by NOAA and PacIOOS ocean buoys and a SEAFRAME measuring station.

sites are Mili, Arno, Majuro, Jaluit, Ailinglaplap, Namu, Kwajalein, Rongerik, Rongelap and Bikini. Lead Partners: MICS, MIMRA, and RMI WSO.

Multiparameter sensors or sondes will be deployed at a subset of index monitoring atolls to collect and transmit information on water biophysical parameters[587] to the WSO. This activity is designed to test the cost-effectiveness and reliability of available and emerging technology in making real-time data transmission more affordable. It will make ocean information from three atolls available to climate, coral reef and fisheries research partners interested in developing early warning predictive systems and science informed management alternatives. Costs include planning, procurement, preparation, data transmission services, deployment, device maintenance, data storage and later analysis and reporting. Deployment sites: three atolls, TBD. Lead Partners: MICS, MIMRA, and RMI NWS.

B. Acquisition of high-definition photogrammetry to document and assess the spatial structure, composition, diversity, and cover of coral and other benthic organisms

This activity will augment coral reef baseline surveys (conducted through the Reimaanlok[588] Process) of marketable fish, invertebrates, and basic benthic composition. The Scripps Institution of Oceanography of UC San Diego and its 100 Island Challenge (100IC)[589] will work with the Marshall Islands Conservation Society to survey and digitally archive coral reefs using innovative imaging and data technologies, and to track how these populations change through time. The 100IC project conducts large-area imaging of permanent coral reef plots and photogrammetry to document the spatial structure and dynamics of benthic taxa over time, including areas damaged and/or recovered from coral bleaching. Information on fish populations is also gathered using standard fish surveying methods to provide estimates of potential fisheries production.

The 100IC team and partners will document core descriptions of the oceanographic context of each island, using remotely-sensed products—satellite-derived data, wave models from buoy data. These data will be complemented with in situ temperature data and other data collected by local and regional partners. A key aspect of the 100IC project is building interested local resource managers' and practitioners' skills in how to carry out these surveys and interpret their outputs. Data storage, processing and analysis, visualization and summary reports and other outputs and information products will be supported by the 100IC project, due to the large storage and high processing power that is required for country data sets.

Importantly, the 100IC project is committed to making data products open and widely available to inform, resource, and educate managers, scientific colleagues, and other stakeholders about coral reefs, how to ensure their persistence, and the benefits they provide into the future. Outputs of these activities include digital archives of photo plots and 3D visual models of coral structure and composition, in-depth analysis of change over time in coral reef communities related to environmental (e.g. water temperature) and other factors, as well as documentation and recommendations on ways to continue the methodology into the future.

Documentation and outputs will be used to refine prediction models and improve the accuracy of coral reef bleaching warnings in the Marshall Islands and beyond. Ideally, 100IC project activities will coincide with the logistics and field activity schedule listed under the in-situ data collection activity to

587 Parameters to include temperature, salinity, pH, and chlorophyll levels among potential others.

588 RMI, 2018, Reimaanlok: Looking to the Future: National Conservation Area Plan for the Marshall Islands 2007-2021 was developed to fill the need for a conservation area planning framework, and "develop principles, process and guidelines for the design, establishment and management of conservation areas that are fully owned, led and endorsed by local communities based on their needs, values and cultural heritage."

589 Scripps Institution of Oceanography, 100 Island Challenge, available at <100islandchallenge.org/overview/> [August 2019]

share costs; otherwise, activities listed under 1b will be planned and occur independently through a separate budget managed by SIO/UCSD. Prioritised sites: Mili, Arno, Majuro, Jaluit, Ailinglaplap, Namu, Kwajalein, Rongerik, Rongelap, Bikini. Lead Partners: MICS and 100IC/SIO/UCSD.

C. Stakeholders' workshop to analyse and assess the correlation of coral bleaching data and predictions for model refinement and predicting skill development

Continuous satellite monitoring of sea surface temperature at large scales and modelled predictions of approaching bleaching-level heat stress provide resource managers, scientific researchers, and other stakeholders with information products to understand and manage the complex interactions that contribute to coral bleaching. When bleaching conditions occur, these tools can be used to initiate response plans and support appropriate management decisions and communication with the public. Because variances occur between projections and actual coral bleaching, much can be learned from comparing forecasts and warning with records and effects of bleaching events. This is especially true in sub-regional areas where limited data and analysis capacity historically exist, such as some of the more remote coral reef locations within the Marshall Islands and the wider Pacific.

A gathering of forecasting professionals, coral reef and fisheries scientists, natural resource managers and other stakeholders is proposed to improve coral bleaching model forecasting skill and warning efficacy. A national stakeholders' workshop will be planned with partners to discuss and consider ways in which models and impact-based forecasting of existing climate products related to coral bleaching outlooks and alert systems[590] can be improved, based on lessons learned, emerging technologies and methodologies, and newly available data and analysis from the Programme. Representatives from the other four countries will be invited to participate virtually for the purpose of knowledge transfer. The use of new country-wide (and potentially region-wide) in situ data and descriptions, advances in the science of seasonal prediction, improvements in observations of all types and how they feed into models, and increases in supercomputing power are some of the ways the accuracy of models can improve over time. Lead Partners: MICS and MIMRA, NOAA, BOM, SPREP, UoGuam, 100IC/SOI/UCSan Diego.

National Ocean Portal

RMI will work with NOAA and WSO Palau on the development of National Ocean Portals and a regional portal for the two north Pacific countries. The proposed work represents a collaboration between NOAA and the University of Hawaii (UH), but it will also involve the other lead agencies in WMO's Regional Area 5 (RA-V: Asia Pacific region) Pacific Islands Regional Climate Centre—SPC, SPREP, NIWA, BoM and Meteo-France.

Funds are requested to support the development of web-based national "dashboards" that provide location specific and relevant climate information, including (where available) real-time observations, climatologies, seasonal to interannual forecasts, and long-term trends. These "dashboards" will draw existing data and products from different data centres and national agencies, downscaling the information, tailoring it and combining it as users require. Site visits and face-to-face meetings will establish key climate indicators, stakeholders and management needs for a regional page focusing on

[590] Key examples include 1) the NOAA Coral Reef Watch programme which uses satellite data to provide current reef environmental conditions to quickly identify areas at risk for coral bleaching and a modelled outlook - based on CFSv2 a dynamical (physics-based), fully coupled ocean-land-atmosphere seasonal climate forecast model - that predicts the likelihood of coral bleaching heat stress on a week-by-week basis, up to four months in the future (NOAA, Four-Month Coral Bleaching Heat Stress Outlook, available at <https://coralreefwatch.noaa.gov/satellite/bleachingoutlook_cfs_v4/outlook_cfs_pacific.php> [August 2019]) , and 2) the Australia Bureau of Meteorology's seasonal forecasts from coupled dynamical models such as ACCESS-S that can be used to detect anomalous SSTs several months in advance (BOM, Analyses – Sea Surface Temperature (SST) Available at <http://www.bom.gov.au/oceanography/oceantemp/sst.shtml> [August 2019]), both allowing for proactive management responses.

a subset of variables. After the portals are developed, the developers will train key personnel from RMI on the use of the site, enabling the developers to get direct feedback on the site's utility, informing the development of a national dashboard into the portal for RMI.

The philosophy and technology behind the dashboard developed for the Marshall Islands could serve as a model for the wider Pacific region, and even expand to include other domain-specific indicators in support of sector-specific climate early warning systems (CLEWS). For example, in the same way a site was developed for agroforestry in the RMI, additional sites could be developed for health, shoreline development and fisheries, and for regions beyond the RMI.

At the core of these would be the build-out of an underlying national dashboard or site. Underlying these national sites would be the regional system that would form the backbone of the Pacific Islands Climate Monitoring Node. This backbone would be developed in the first year of the project. This activity will full under the WMO RA-V and will be done in close collaboration with partners and will complement existing assets—COSPPac's Ocean Portal, APDRC data services, PacIOOS coastal observations, etc.

National portals for RMI and Palau will focus on a subset of variables, starting by focusing on three key essential variables. For example, sea level, sea surface temperature and precipitation data are of high interest, regionally relevant, and have relatively wide coverage in terms of data availability (*in-situ*, satellite and model). Significant effort would go into the addition of the first variable, but subsequent variables would require less effort as the mechanism for adding content becomes better understood. The new site would bring in data from the global tide gauge network (sea level), drifting floats and observing system arrays, meteorological stations, and satellite measurements from AVISO (sea level), Pathfinder (SST) and PERSIANN (precipitation).

The new site would first be designed in terms of web-page layout, specifying what menu access (e.g. region, indicator, variable) will be provided and where. Next, the specific choices under each of these will be determined. Finally, the "results" region of the portal will need to be planned, for example, where the latitude/longitude map view will go, what and where time-series will be displayed, and where other ancillary data will go. After the regional portal is developed, key personnel from the region will work with the node developers to be trained on the use of the site and to give the developers direct feedback on the site's utility. This could be done at the annual PICOF meeting since most Pacific countries send representatives, and it will allow for a wider networking opportunity.

The proposed work will support the development of the WMO RA-V PI-RCC, established as a virtual Centre of Excellence that assists Pacific Islands' national meteorological services to deliver better climate services and products and to strengthen their capacity to meet national climate information and service delivery needs. The establishment of an ocean portal with a firm backbone based around data services and leading to region-specific sites will support many of the RA-V activities. It will also support, and leverage, many ongoing facilities and programmes such as the UH Asia-Pacific Data Research Center (APDRC; providing access to a wide array of observations and model output), the Pacific Regional Integrated Sciences and Assessments (providing sector-specific user requirements), the Climate and Ocean Support Program in the Pacific (specifically the ocean portal), the developing Climate Early Warning System (CLEWS) for the Pacific, the Pacific Islands Integrated Ocean Observing System (providing near-real-time observations and information in the coastal region), and more.

National Ocean Expert

One of RMI WSO's highest priorities—in response to user demand—is to acquire the capacity to generate ocean climate information. The Marshall Islands' landmass is very small, and its surrounding ocean is an integral part of its environment as well as the major influence on its climate. RMI WSO proposes to engage a Programme-hired National Ocean Expert to begin developing this new capacity, with support from the University of Hawaii, NOAA and BoM.

The National Ocean Expert will strengthen the Marshall Islands' local ocean monitoring programmes and oceanographic capability. Monitoring the local ocean climate directly helps people—seafarers, subsistence fishermen and tourists—to use their natural resources sustainably and avoid unnecessary risks. It will also contribute invaluable data to the scientific community. The National Ocean Expert will extend the WSO's capacity to give practical advice to subsistence fishers and tourists: for instance, the consultant will monitor threats to reefs—warming and bleaching—so that harm can be minimised. When coral is stressed by heat, if the reef is protected temporarily from human activity, it will recover more quickly; if people are warned of an elevated risk of ciguatera poisoning, they can avoid eating reef fish species during the warming episode.

R2.2.2 Enhance climate information and impact-based forecasting

Young Scientist Support Program

To support the enhancement of in-house forecasting capacity, the Programme will build a strong scientific and analytical foundation for NMHSs through training and mentoring attachments covering climatology and oceanography. Early-career scientists from NMHSs will be selected to undertake in-depth technical capacity building through a customised Young Scientist Support Program (supported by APCC), including highly in-depth training for 2-3 months exploring various climate prediction and analysis techniques such as downscaling predictions, generating sub-seasonal-to-seasonal forecasts, analysing large-scale patterns, and tropical cyclones, etc. This will equip participants, particularly those with less experience, with both the basic knowledge needed to perform their duties as climate officers, as well as more advanced knowledge that can help them develop downscaled or impact-based forecasts.

National Climate Expert

To support the provision of the much-expanded climate information services, the RMI WSO proposes to engage a Programme-hired National Climate Expert, at science graduate level, for the five year term of the Programme. Previous experience indicates that the position is likely to be made permanent thereafter, as the value of the extra services made possible is demonstrated. The National Climate Expert will focus on climate science and data analysis for new functions and will take day to day responsibility for sector coordination, working with the Ministries of Tourism, Transport, Infrastructure, Health, Agriculture, Environment Services and others. The consultant will develop new products in response to demand from the sectors.

BoM will arrange regular training and mentoring for the National Climate Expert through attachments and regional meetings and by supporting his or her attendance at key conferences throughout the term of the Programme. BoM will also provide training on ocean and tide information, and mentoring to the consultant using seasonal forecasting products from ACCESS-S.

Training attachments and mentoring

BoM is a long-term partner of Pacific island meteorological services, delivering the Pacific Sea Level Monitoring project since 1991 and supporting the development of seasonal climate forecasting capacity since 2003. Since 2012, BoM has collaborated with RMI WSO and other NMHSs in the Climate and Oceans Support Program in the Pacific (COSPPac), supporting the achievement of WSO's priorities for delivery of reliable and accessible climate information services.

BoM will provide attachments focusing on seasonal prediction (ACCESS-S) training and on the use of data and information in preparing for the tropical cyclone season, and for climate extremes such as drought or flood. It will deliver training on the use of seasonal forecasting products to generate information on the ocean and tides using ACCESS-S. Mentoring and professional development inputs will contribute to building regional knowledge, supporting the publishing of scientific materials and providing opportunities for WSO climate staff to attend conferences such as Advanced Maui Optical and Space Surveillance Technologies (AMOS) and to present academic papers and posters. Over the term of the Programme, BoM will provide 12 weeks training for the National Ocean Expert and 12 weeks for the National Climate Expert.

Health and drought early warning system

The US East-West Center is currently engaged in multiple projects to produce new climate-related products and services that stakeholders in the Marshall Islands have requested. In-country consultations have yielded information about the impacts of and risks associated with climate change in the Marshall Islands and have informed the Pacific Islands chapters of the 3rd and 4th US National Climate Assessments. The consultations have helped the East-West Center to set priorities for activities specific to each national context.

The NOAA Pacific Regional Integrated Sciences and Assessments (RISA) programme at the East-West Center has identified climate impacts on human health and the prevalence of drought as key priorities for the Marshall Islands. RISA is currently working with the Marshall Islands Ministry of Health and Human Services on a NOAA-funded 2-year project to define the Ministry's climate services needs and to improve climate information delivery to the health sector. Additional work to identify climate services needs related to drought is pending approval.

Representatives from the Health Ministries of the Marshall Islands, Palau, and Federated States of Micronesia attended a meeting on climate change and health at the East-West Center in 2018. They noted that human health in the region is particularly influenced by sub-seasonal and seasonal changes in temperature, rainfall, and extreme events, as well as the longer-term impacts of sea-level rise and ocean acidification. Storms and sea-level rise threaten the integrity of island infrastructure—homes, hospitals, roads, and essential health services. Drought and rising temperatures constrain freshwater supplies, while heavy rainfall events increase the risk of floods and vector-borne diseases. Food supplies are reduced by ocean acidification and impacts on reef fish populations, severe drought events resulting in crop failures, and increasing reliance on imported goods, which may exacerbate existing problems with diabetes and obesity.

Its lack of resources and funding means the Marshall Islands health sector is ill-equipped to prepare for the impacts of climate change, and better climate information is needed at timescales appropriate for planning and preparation. Over the last five years, between 25-45% of households surveyed from three locations experienced health-related impacts due to climate stress and many cited a lack of adequate healthcare and reduced fresh water supply as reasons for migrating away from the Marshall Islands. The Marshall Islands Ministry of Health and Human Services has asked for more useable climate information for focused and timely activities that maximise population health and well-being.

Working directly with the Marshall Islands Ministry of Health and Human Services, NOAA, and the University of Hawai'i Sea Level Center, the RISA project team is currently identifying the climate variables, timescales, and uncertainty associated with climate impacts that the Ministry needs for informed decision-making, and the current gaps in the provision and accessibility of climate information. For instance, if the Health Ministry could identify the areas and islands most vulnerable to extreme events and/or sea-level rise, those areas could be targeted for essential infrastructure upgrades; early warning of coming drought conditions would enable preparation for delivery of clean water. These findings will inform the development of sector-specific climate early warning systems and associated monitoring infrastructure in the Marshall Islands.

Another upcoming project led by the East-West Center will identify sector-specific requirements for drought and wildfire information systems in the US Associated Pacific Islands. In the Marshall Islands, the low-lying nature of these atolls and their dependence on rainwater catchment systems for drinking water make them highly vulnerable to drought. They are therefore reliant upon supplemental water from reverse osmosis units and wells, although wells can quickly become brackish from overuse. The severe 2015–2016 drought, for example, resulted in the Governments having to declare a state of disaster, and economic losses reached USD 4.9 million. RMI needs better early warning systems for drought, including improved accuracy of forecasts, better spatial distribution of automated weather stations, and improved capacity to target responses during drought.

This intervention to develop health and drought early warning systems for the Marshall Islands builds upon and leverages ongoing staff time and data products developed at the East-West Center and the University of Hawaii Sea Level Center.

Activity 2.3 Harmonised climate data and information management

R2.3.1 Establish and implement national climate data and information strategies

National Climate Data Consultant

The Programme will support the recruitment and training of a National Climate Data Consultant (NCDC) for climate data management, who will work within the Office of Environment Planning and Policy Coordination (OEPPC). The NCDC will build capacity among key government staff to collate and validate data from climate-sensitive sectors and to share and promote useful data with their primary audiences. The NCDC will serve as the national administrator for RMI's data portal (described in Programme Result 4), assigning access and ensuring users are making full use of the capacity of the system. The NCDC's role is to publicise the RMI Environmental Data Portal, to extend its user base and to help the users of its data to maximise their skills.

The NCDC will build capacity among key government staff working in climate-sensitive sectors to collate and validate their own sector data, and to share and promote it with their primary audiences. The NCDC will serve as national administrator for RMI's data portal, assigning access and ensuring users are making full use of the capacity of the system. To open lines of communication effectively between the various national providers, the NCDC will facilitate regular meetings with the national data community, communicate regularly with national and regional partners, and track the use and application of the national portal and its products. The NCDC will serve as the Programme focal point for the regional environment data manager at SPREP.

The NCDC will participate in training with the NCDCs of the other four countries in online cloud hosting skills and knowledge, and in sub-regional exchanges and South–South learning. With SPREP's support, the NCDC will be a member of the technical committee that drafts RMI's National Data and Information Strategic Action Plan and will lead the development and implementation of the Plan.

The NCDC's work on harmonising the way data is recorded and stored will make it possible to use UNEP's Country Level Impacts of Climate Change (CLICC) principles, using consistent formats for data records so that RMI's climate data can be presented with national data from other sources, coherently and transparently. This has potential to reduce significantly the burden of reporting the Marshall Islands' performance against Multilateral Environment Agreements (MEAs) and to improve the quality of its reports. This in turn has benefits for the Government's understanding of climate change impacts and its capacity to plan effective adaptation and to advocate in international forums.

National Climate Data Strategy and Action Plan

Climate data is usually collected and kept at a significantly higher standard than other national data: good quality data is collected systematically, recorded and stored digitally, backed-up reliably and readily retrieved for use in information products, and usually a country has reliable data dating back many decades. This is rarely the case for health data, environmental data or information on other sectors. In all five Programme countries there is currently a dearth of available impact data for most sectors. Most impact data and even most reports are held off-line by a small group of national officers, consultants and researchers. In this context, impact includes data and reports on trends in a variety of subjects such as forest cover, coral cover, agricultural productivity, impact of cyclones, water availability and seasonality, all highly relevant to climate change.

As a result, decisions are made based on sub-optimal evidence. The coordination of data related to climate science is very undeveloped and there is potential for much better information about terrestrial systems and the impacts of warming to be derived from bringing data sources together.

The Government of RMI plans to use climate data and information in concert with data from other sectors in order to mainstream climate considerations into the work of those sectors. This is particularly important for the very climate-sensitive sectors of agriculture, fisheries and health already being affected by atmospheric and ocean warming. The Government also wants to be able to use data from various sector sources with climate data when it reports to the international community on its implementation of multilateral environmental agreements. Much improved information about terrestrial systems and the impacts of warming can be derived from a database that can bring these sources together and harmonise them sufficiently for the data to be used in planning and reporting. The RMI State of Environment Report, 2015 highlights the need for a national information hub, so that all agencies know what data and information exists and know how to access and use it. The Data Strategy will use high-level quarterly meetings to monitor progress towards the robust management of climate data, the locating of related data sources and their harmonisation.

The National Climate Data Consultant will support a technical committee in drafting a Data Strategy for the Office of Environment Planning and Policy Coordination (OEPPC). The Data Strategy and its action plan will be developed through a national 3-day workshop with stakeholders—OEPPC and WSO staff, other agencies and individuals who hold or need to use climate and environment data.

The National Data Strategy activity is very much helped by an established UNEP project executed by SPREP—the Inform project (GEF-funded: USD4.3M: 2017–2021). Inform has already set up an Environmental Data Portal for each of the five Programme countries (and nine other SPREP member countries) and an over-arching regional portal. SPREP and SPC recently agreed to host all information in a shared data ecosystem. The data portals are hosted on-line by SPREP and networked together at the regional level in the Pacific Environment Portal (https://Pacific-data.sprep.org). All the portals are protected by having their data stored and retrieved from multiple machines on the cloud: if one of the servers crashes unexpectedly, the Data Portal won't go down. The Government of RMI has endorsed its national portal and the regional environment portal as the formal repository for national datasets and knowledge products and is already storing data and key documents in it.

This Programme will add a dataset focusing on Climate and Oceans knowledge, information and data to the Marshall Islands Environment Data Portal. The Portal "provides an easy way to find, access and reuse national data." [591] Its "main purpose is to provide easy access and safe storage for Environmental datasets to be used for monitoring, evaluating and analysing environmental conditions and trends to support environmental planning, forecasting and reporting requirements at all

[591] SPREP, NEDP Environmental Information for Decision Making, available at < https://rmi-data.sprep.org/> [August 2019]

levels."[592] The Portal allows data to have different access levels, so a country can ensure its formal permission is required for access to specific datasets or information.

The Data Portal already helps government agencies to prepare better reports against the Sustainable Development Goals and the Multilateral Environment Agreements (MEAs) to which the Marshall Islands is a party. It also allows the Government to archive reliably and relatively cheaply national environment-related reports and policy documents. The addition of a climate and oceans subset will extend this capacity to the WSO, holding its data securely but encouraging its much broader use in monitoring changes, planning national adaptation initiatives and reporting on MEAs.

Quarterly one-day meetings will monitor progress towards the robust management of climate data, the locating of related data sources and their harmonisation.

RESULT 3 – IMPROVED COMMUNITY PREPAREDNESS, RESPONSE CAPABILITIES AND RESILIENCE TO CLIMATE RISKS

Activity 3.1 Warning dissemination and communication

Under this Activity, the Programme will enhance the dissemination and communication of climate risk information and early warnings based on the enhanced data generated under Result 2. The Programme will particularly focus on strengthening last-mile communication systems to ensure that people and communities in remote locations receive warnings in advance of impending hazard events. RMI WSO will be supported to develop a range of communications products tailored to end-users at the community level.

R3.1.1 Strengthen EWS organisational and decision-making processes

This sub-activity will ensure the effective and coordinated delivery of early warning services through strengthened organisational and decision-making processes of RMI WSO, the National Disaster Management Office (NDMO), civil society organisations and other key actors.

An annual workshop will be conducted to define the functions, roles and responsibilities of key EWS actors; develop warning communication strategies; and develop, trial and refine Standard Operating Procedures (SOPs). The workshops will be attended by various EWS stakeholders, NDMO and RMI WSO representatives. The warning communication strategies to be developed will facilitate coordination between RMI WSO – as warning issuers – and with downstream dissemination channels, such as island community volunteer networks. The strategies will include the development of community feedback mechanisms to verify that warnings have been received and to alert RMI WSO to potential gaps in communication networks. At the start of Programme implementation, an in-country deep dive study on gender and community stakeholders will be conducted to facilitate that the design of EWS organisational and decision-making processes is gender-responsive and that such processes proactively consider and address the specific needs, concerns and capabilities of different gender groups. Knowledge gained and outputs from the workshops will be leveraged in development of the Forecast-based Financing mechanism (Activity 3.3).

R3.1.2 Strengthen communication systems to reach the last-mile

This sub-activity will enhance connectivity and communication systems to facilitate that climate information and early warnings reach communities at the last-mile, including on remote outer islands;

[592] Ibid

and that communication channels are resilient to the impacts of extreme climate events. This will be achieved through the following interventions:

Enhance communication channels and early warning systems

Web-based dashboard

MICS and the Coastal Management Advisory Council (CMAC) propose to develop a dashboard that gives access to a regional portal, making access to the Marshall Islands' ocean data easy and understandable (R2.3). Users / communities will be able to enter their location and check the health status of their reef and its corals, the currently likelihood of bleaching and whether the reef needs temporary protection. The dashboard will maintain similar information on fisheries and their health, drawn from many different data sources by the portal.

MICS will conduct a workshop to determine how best to tailor information and messages to Marshallese audiences, including warnings of extremes and advice on mitigating impacts on reefs and fisheries, and on terrestrial resources such as crops. The workshop outcomes will be used as the basis for a nation-wide social marketing campaign of information, messaging and alerts to urban and remote rural communities. Messages will relate to status, warnings, and actionable management steps that can be taken to improve preparation, reduce threats, mitigate impacts, and increase resilience related to these fragile natural resources.

Management advice may focus on the themes of "fish in the correct location with the correct gear" and "harvest less herbivores". The activity will recruit a staff position to manage the curation of an RMI-based Coral Reef Watch programme and/or campaign illustrating the connections among The staff member will work with partners in the coordination of activities, organising dedicated consultations with partners to develop key messages and management alternatives related to coral bleaching and coastal fisheries, getting information out to and interacting with practitioners, owners, and managers.

Community-based coral health chart kits

MICS proposes to purchase community-based coral health chart kits for distribution to rural communities and to train communities in their use. The kits will be used by early warning response teams at remote locations to easily identify signs of the early onset of coral reef bleaching. Response teams will be trained in how to observe, record and report bleaching incidents to central locations and receive advice and instructions on possible management actions. The "citizen science" data collected will be valuable in helping to establish links between climate processes and changes in coral health. Communities' increased understanding of coral health and how it is measured will reinforce warnings from the WSO and environmental NGOs about human pressures on reefs during times the corals are stressed by high temperatures or storms.

Localised mobile climate information communication system

The Programme will develop and implement localised mobile climate information communication systems with early warning to reach last-mile populations. Through mobile-cellular communication channels, this system will provide predicted risks and alerts utilising geostationary satellite nowcast and local/regional forecast information. The system will be designed to handle potential and existing risks on a 24/7 basis and will be customisable for any population group size – from small communities to larger central governments. For short-term disasters, the system will utilise satellite imagery analysis based on 2 km, 10-minute resolution (e.g. Chollian 2A) for nowcasting of wind, wave height and convective initiation of rapidly developing thunderstorms two hours in advance, which is not possible with Numerical Weather Prediction. Localised communication systems will support disaster risk management on various timescales from short-term disasters (e.g. torrential rainfall, coastal flooding, etc.) to long-term disasters (e.g. droughts). The possibility to integrate a two-way communication channel between end-users and information providers would allow for continued enhancements to the system based on user feedback.[593]

R3.1.3 Communicate early warnings to island communities

Co-design of early warnings

The Programme will conduct annual multi-stakeholder workshops focused on the co-design and co-production of early warning information products to improve early warning messaging to island communities and provide clear guidance for triggering response actions. Participants will include various EWS stakeholders, community representatives, the National Disaster Management Office (NDMO) and RMI WSO. A local consultant will support delivery of the workshops and will draw on the specialised knowledge of stakeholders and communities to create impact-based early warning messages that are actionable and effective. The workshops will provide an opportunity for engagement between warning issuers and warning 'users' to facilitate that the public and other stakeholders are aware of which authorities issue the warnings, and build trust and acceptance of information disseminated. Furthermore, the Programme will seek to engage a wide variety of community representatives to ensure that warnings are targeted to the different risks and needs of vulnerable subpopulations.

Develop climate change information and warning for persons with disabilities

This intervention will make the Republic of the Marshall Islands a barrier-free country for people with disabilities in relation to effective communication and information sharing on climate change and disaster preparedness. The Disability Coordination Office at the Ministry of Culture and Internal Affairs ensures that people with disabilities are consulted from the earliest planning stages about issues and activities that will affect them. The Marshall Islands Disabled Persons Organization, established as an advocacy group, will partner with the National Disaster Risk Reduction and Preparedness committee to ensure climate change and disaster risk information is accessible to everyone. Often, people with disabilities and their families are excluded from public services or cannot access information, and they can be effectively rendered invisible and neglected. RMI's 2011 census reported nearly 12% of the population reports some form of disability, most commonly visual, followed by hearing, mobility and memory.

The Disability Coordination Office in the Human Rights and Community Development Division at the Ministry of Culture and Internal Affairs will partner with the Disabled Persons Organization to ensure effective communication on disability-inclusive programming for climate change and disaster preparedness activities.

They propose to produce an educational video using a Sign Language Interpreter on climate change early warnings in Marshallese with English captions.

Activity 3.2 Preparedness and response capabilities

R3.2.1 Enhance disaster preparedness and response measures

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[593] This will be delivered by the APEC Climate Center in collaboration with the Ewha Womans University, utilising a proven method that is currently being implemented in Cambodia, with the endorsement of the Cambodia Ministry of Water Resources and Meteorology, Asian Disaster Preparedness Center (ADPC) and the Preah Vihear National Authority

This sub-activity will use community-based approaches to enhance risk ownership at the local level and help establish collaborative community networks for coordinated action for preparedness and response to climate-induced hazards. This will include the following interventions:

Capacity building for disaster response

Red Cross training in outer islands

The Marshall Islands Red Cross Society is active throughout the country and is a trusted partner with both urban and outer island communities in a wide range of activities. MIRCS proposes to establish 70 outer island Emergency Response Teams (ERTs) in RMI, with 25 participants in each team. In the first two years of the Programme, MIRCS will charter a boat for eight weeks and carry out refresher training and re-certification of previously trained teams, so they are ready to establish new outer island ERTs.

MIRCS will supply a resource kit for each of the new ERTs established in Years 1 and 2, essential for their immediate response needs. Kits include shovels, gloves, rakes, machetes, and a sturdy storage bag. Equipment needed by MIRCS for training purposes will include solar chargers, satellite phones, tablets, a drone for mapping, laptops, a printer and first aid mannequins for demonstration purposes.

Each year of the Programme, MIRCS will run a capacity building exercise (an ERT Forum) to ensure the new ERTs are sustained in their communities and to reinforce their initial training. The ERT Forum will be held on Majuro—outer island flight schedules vary from weekly to bi-weekly, and so outer island participants will receive per diems for one week's training.

First Aid training and certification is a key element of ERT capacity building, essential in community resilience and disaster risk reduction and response, as well as a very effective team-building exercise. MIRCS is limited by the number of its First Aid Instructors and will conduct a Training of Trainers programme during Year One to ensure it has enough qualified instructors for the establishment of the island ERTs. The existing ERT Training curriculum will be reviewed, in a workshop with WSO, and expanded to include information about the WSO's climate and weather services, traditional climate knowledge and effective ways to convey climate information. The expanded curriculum will include capacity building activities on the use and integration of WSO services, traditional knowledge and climate information to enable communities to adopt climate-resilient livelihoods.

For optimal efficacy and sustainability, materials will be translated into the Marshallese language and other languages commonly used in RMI—i-Kiribati, Chinese and Tagalog.

MIRCS proposes to engage a disability advocate to manage outreach activities, a disaster management assistant with some meteorological experience who can liaise with WSO, an accounts officer to manage the funds and a communications officer to ensure the best possible coverage of emergency response information. A fifth officer will manage the administration of the grant and ensure regular monitoring and reporting is conducted to a high standard.

R3.2.2 Conduct public awareness and education campaigns on climate hazards and risks

RMI WSO will conduct community-based workshops to enhance community knowledge and understanding of climate hazards and the potential impacts on the lives and livelihoods of local populations. The workshops will build capacity of participants to apply the knowledge to their individual circumstances and consider suitable options for livelihood diversification or alternative livelihoods. The workshops will be conducted annually in all 24 outer islands of RMI.

R3.2.3 Integrate traditional knowledge into early warning services

RMI has undertaken early work on a TK project, and will progress the work through this Programme, recognising the potential to engage communities in understanding climate science through discussion of traditional forecasting methods. SPREP will support RMI's traditional climate knowledge activities with communities, providing inputs from a TK expert at intervals during its progress. The work will include both contributions to the technical challenges of storing and using TK and input to discussions with elders about the application of their knowledge to seasonal forecasting. Over time, these discussions generate acceptance of the technically derived climate forecasts made by the WSO—one of the immediate benefits is that communities are more likely to take notice of extreme weather warnings. As the climate becomes more chaotic, scientifically derived climate forecasts are expected to have greater predictive power than traditional climate indicators. It will be beneficial if Marshallese communities learn to trust WSO's information and to act upon their advice on likely impacts and on effective preparation and response.

WSO will engage a local consultant as TK officer to oversee the collection and storage of TK and reporting on progress. Other WSO staff will assist with the project's development as determined by the Director of WSO and the Programme-hired National Climate Expert. SPREP will contribute professional development and other support.

The proposed intervention has following key components:

- Understand the current use of traditional climate and geo-hazard forecasts, warnings and responses (includes community visits and participation in the project)
- Incorporate traditional knowledge into WSO products and services (including forecasts, warnings and responses)
- Develop educational and communication products, incorporating traditional knowledge, such as climate glossaries, seasonal or crop calendars, ENSO impact and response booklets to improve communication of climate and ocean information.

The intervention will deliver:

- Training and resources for international best practice collection of traditional knowledge on weather, climate and geo-hazards (to both the WSO and key sector partners)
- State-of-the-art customised database to store traditional knowledge related to weather, climate and geo-hazard (forecasts and responses)
- In-country and regional capacity to collect, store and build products and services that incorporate traditional knowledge, including Early Warning Systems
- Educational and communication products on climate, hazards and responses (e.g. climate glossaries, seasonal or crop calendars, ENSO impact and response booklets)
- In-country workshops to build national capacity and to allow a participatory approach for sectors and community members.

The TK Officer will initially work on the data collection and monitoring phase, and then move on to verification/validation. S/he will work with relevant government stakeholders and communities to coordinate all Programme work relating to Traditional Climate Knowledge, and will also provide education and awareness for local communities, collect, record and archive relevant TK information, data and images, and set out the national workplan and programme for the TK Project. Beyond this stage, WSO plans to develop seasonal calendars and to collaborate with SPREP on publications and presentations on traditional knowledge.

Activity 3.3 Forecast-based Financing (FbF)

Under this Activity, the Programme will introduce Forecast-based Financing (FbF) in RMI, in partnership and coordination with the International Federation of Red Cross and Red Crescent Societies (IFRC), Marshall Islands Red Cross Society (MIRCS) and the National Disaster Management Office (NDMO).

R3.3.1 Develop FbF Roadmaps defining thresholds and triggers

This sub-activity will develop a Forecast-based Financing (FbF) Roadmap for RMI, which will identify forecasts (magnitude, probability and lead time) that can trigger humanitarian actions.[594]

The first phase of the Roadmap will begin with a scoping study that will cover feasible hazards to target with FbF, forecasting capability, and the institutional landscape in RMI. This will include consultations with national agencies such as NDMO, RMI WSO, the Division of Agriculture (under the Ministry of Natural Resources and Development) and the Ministry of Health; regional agencies such as SPREP, SPC, WFP, UNDP and others; and partnerships with the IFRC and the Red Cross Red Crescent Climate Centre. For FbF to be a sustainable and effective mechanism, Early Action Protocols (EAPs) need to be embedded in national institutions, who have roles and responsibilities for taking early action. The scoping phase will identify the national and/or sub-national actors (government and civil society) in RMI and enter into a dialogue with them about the potential for early action.

The second phase of FbF Roadmap development will consist of collaborative consultations with country institutions to delineate three key elements that would enable country-led design of an FbF mechanism:

1. Menu of Triggers – A 'trigger' is a forecast that is issued, which exceeds a pre-defined danger level and probability threshold, leading to the initiation of early actions.
2. Forecast-based Actions – Identification of possible early actions that can be triggered by existing forecasts, which aim to avoid losses and damages if an extreme event materialises.
3. Institutional Arrangements – A potential architecture of country-level technical working groups and institutional ownership for FbF, including funding mechanisms when necessary.

The FbF Roadmaps will provide a set of 10 recommendations for critical next steps to move forward with Forecast-based Financing. These next steps will be focused on filling capacity gaps that enable the design and activation of an FbF mechanism by the identified lead agency/s, and the design and testing process for EAPs. The Roadmaps will include the following components:[595]

- **Stakeholder Identification** – The Programme will identify the key stakeholders to be involved in the development and implementation of FbF, including international, national, regional and local actors and lead agency/s.
- **Risk Assessment** – The Assessment will include individual analysis of risk factors, key hazards, past impact, exposure and vulnerability. Based on the analysis, the priority hazards to be addressed by FbF early actions will be identified. The assessment will also provide an overview of the different types of early actions that could be taken to mitigate risk by the identified stakeholders, in different sectors (agriculture, health, etc).
- **Impact-based Forecasting (Triggers)** – The Trigger analysis will provide an overview of all available forecasts – including lead time, skill/confidence and extreme event probability.

[594] Lopez, Coughlan de Perez, Bazo, Suarez,Van den Hurk, Van Aalst, 2018: Bridging forecast verification and humanitarian decisions: A valuation approach for setting up action-oriented early warnings
[595] IFRC, 2018. Forecast-based Financing Early Action Protocol template

- **Resourcing Overview** – The Assessment will identify various options for accessing funding or necessary resources for potential early actions that are more costly or resource-intensive.

R3.3.2 Build capacity for FbF

In this sub-activity, up to five of the 10 "next steps" that were identified in the Roadmap will be developed and executed. Depending on the national context and the findings of the scoping study, these activities could include the following:

- Scientific collaboration with national or regional forecasters to carry out a forecast verification analysis or forecast calibration to support the development of triggers;
- Technical support to build enthusiasm for anticipatory actions and change mindsets;
- Specific links between the FbF and EWEA narrative with the principles and activities embedded in other outputs of the Programme;
- Technical support in finding ways to connect with existing regional systems, mechanisms and/or priorities to have a region-wide understanding or buy-in of FbF;
- Table-top exercise to discuss a historical extreme event and what could have been done by different actors to prevent impacts;
- Round-table discussion on financing mechanisms for critical early actions that could be part of an FbF mechanism.

R3.3.3 Support development of Early Action Protocols (EAPs)

Marshall Islands Red Cross Society (MIRCS) will support the development of Early Action Protocols (EAPs) through technical working groups for the priority impacts identified in Sub-activity 3.3.1. A series of conversations will be initiated to develop an EAP, which could range from focusing on a simple life-saving action by one actor to a more complex document with a greater variety of actions and forecast analysis.

To identify what should be in the EAP, the identified FbF lead agency/s will convene a technical working group, engaging stakeholders at all levels – including community representatives, disaster risk reduction committees, civil society organisations, local and national government departments, NGOs and private sector actors. MIRCS will provide technical guidance to the lead agency on the process and provide quality assurance, but delivery of the EAP will rest with the lead agency.

Following identification of the most suitable forecast-based actions, the EAPs will be developed by the lead national agency/s. The EAPs will describe which forecast will trigger which action; where to act – based on the forecast and trigger information; and assign responsibilities to specific stakeholders for implementation of each action. In the case of more complex EAPs, they can also include a proposal for a Financial Mechanism, which will outline what funds need to be made available (including readiness costs, stock pre-positioning and activation cost for trigger-based early actions) and how they will be accessed by specific stakeholders. This sub-activity will collaborate with national climate finance policies (Sub-activity 1.1.4) to explore situations when funding for early action can be linked to government budgets.[596] Depending on local capacity, simulations can be held to carry out a "test" of the actions of the EAP.

[596] IFRC, 2018. Monitoring and Evaluation (M&E) of Forecast-based Financing (FbF). A practical reference for country-level implementation

RESULT 4 – ENHANCED REGIONAL KNOWLEDGE MANAGEMENT AND COOPERATION FOR CLIMATE SERVICES AND MHEWS

Activity 4.1 Enhance regional data, knowledge management and cooperation

Under this Activity, the Programme will enhance coordination and knowledge sharing among the five countries to improve data and knowledge management, including establishment of an interactive ICT platform and regional data centre. The organisation of joint learning, mentoring and training events through existing WMO, USP and other centres to facilitate sharing of successes and lessons learned will further strengthen climate and ocean information services across the region.

R4.1.1 Establish interactive ICT platform

This sub-activity will establish an interactive ICT platform, which will serve as a data analytic centre for the management and organisation of climate data, information, experiences, case studies and other forms of knowledge from the five Programme countries in standardised, comparable formats most useful for end-users. The platform will include the establishment of a regional data centre fed by national data centres in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu. The countries will make as much as possible of their climate-related data publicly available through their national data portals and the regional Pacific Environmental Portal.

This Activity takes advantage of the already established GEF-funded "Inform" project, which is being implemented by UNEP and executed by SPREP. Inform is already working with staff in Pacific environment ministries to find and harvest useful datasets and information on their countries' environment and to publicise the existence of the information. The five Programme countries now have national data portals, which can be used to develop workflows to share data seamlessly between sectors.

RMI has endorsed the national data portal that SPREP hosts for it as the principal home for its environmental impact data and contextual information. RMI has also endorsed the regional Pacific Environment Portal hosted by SPREP as the repository and access point for regional data and information. SPC and SPREP have agreed to host all the information they hold in a shared ecosystem and the five countries are encouraged to make as much as possible of their data publicly available.

The Programme will add a new category for climate data and information in RMI's national portal – existing categories include health, fisheries, tourism and disaster management as they relate to the environment – and bring the bring data management and coordination into its schedule of capacity building activities. The National Climate Data Consultant (Sub-activity 2.3.1) will take part in technical workshops and training at SPREP and implement a comprehensive data strategy in-country with SPREP's support. Improved data sharing and discoverability will provide a conduit for RMI WSO to assess partners' sector data or knowledge products, while hosting and sharing its own on a common platform. Enhancement in data management capacity will be achieved through the following steps:

- Addition of a new category for climate data and information to each national portal;
- Training and engagement of national climate data consultants (see Sub-activity 2.3.1);
- Support for countries to prepare their national reporting for climate-related agreements (e.g. NDCs, VNRs, National Communications to UNFCCC). This is currently a major administrative burden for very small countries, but with access to good quality data, it provides an opportunity to evaluate policy and assess progress on adaptation. A two-way flow of information from NMHSs to and from relevant sectors for national and global reporting will

ensure coordination in the use of climate data and information and raise the profile of NMHSs in other sectors thereby supporting demand and fostering sustainability.

- Participation of data consultants in regional forums to enhance the use of data in national planning;
- Establishment of electronic links with existing data sources and back-up in the regional portal; and
- Management of the ICT platform for the five Programme countries through support for ICT interventions across the five countries, including application of ICT in NMHSs operations and upgrading or introducing new methods and systems, such as wireless communications and Internet of Things (IoT) infrastructure for climate services.

SPREP usually provides significant support to countries preparing their reporting against the many MEAs and climate-related agreements to which they are party. This regular process includes updating each country's State of the Environment report, clearly documenting and illustrating climate impacts. This process will give SPREP an entry point for discussing the data strategy with RMI's senior officials. Better access to more data will make it easier to identify meaningful indicators for indicator based reporting, and the project will help non-specialists understand the analysis and interpretation of data.

Improved data is only useful to decision makers, development partners and other user groups if there is wide knowledge of its existence, location, purpose and openness. As this Programme progresses, reporting for international climate agreements will be much improved by the countries' ability to draw upon a longer and more extensive body of high quality data—officers will know what data exists, how it can be sourced and how to use it well. The participation of data consultants in regional forums will build capacity to advocate for effective use in national planning and development of useful data products.

The Inform team estimates there is valuable climate change material held in more than 24 active and legacy systems among the five countries; and in many cases the obsolete hardware needed to read it is still functioning. SPREP will establish electronic links with existing data sources so they can be translated and will back them up on the regional portal. There are multiple datasets held by researchers or by individual departmental officers in danger of being lost, and SPREP will help RMI to locate and salvage them.

R4.1.2 Organise learning, mentoring and training

This sub-activity will comprise training, mentoring and advisory services for local consultants and staff in NMHSs in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu on strengthening climate information services; strengthening observations, monitoring, modelling and prediction; strengthening of marine weather and ocean services; establishing MHEWSs at national and community levels; and building community resilience against climate risks. This will be facilitated through partnerships with existing WMO regional training centres (e.g. China Meteorological Administration (CMA) Training Centre [597] through coordination by the Chinese Academy of Meteorological Sciences), USP and others in the organisation of:

- Joint learning events for exchanging knowledge and sharing experiences and lessons learned in strengthening climate information services and MHEWs in the five countries. This will have

[597] CMA propose to provide free in-person and remote training courses covering the top seven training priorities of Pacific NMHSs

a major focus on the development and implementation of National Frameworks for Climate Services (NFCSs) through all components and related activities of this Programme.

- Targeted training of NMHS staff (e.g. meteorologists, ICT administrators, forecasters) in key areas that are essential for the Programme's impact and long-term sustainability. This will be undertaken through existing training centres in the WMO network, the University of the South Pacific (USP), the International Centre for Theoretical Physics (ICTP) and others. Training will be delivered through a combination of on-site workshops and remote learning courses. Topics of training could include:

    - Forecasting and Numerical Weather Prediction (NWP) by suitably qualified providers such as WMO regional training centres and other WMO-approved meteorological organisations. This could include nowcasting techniques for severe weather, and short-term climate monitoring and prediction in disaster prevention and mitigation.
    - Observation and Instrumentation, including Operation and Maintenance (O&M) of equipment for long-term sustainability.
    - Innovative and cost-saving technologies for observation, modelling and prediction with special focus on the application of ICT. Hence, these events will also be critical for regularly reviewing options for upgrading or introducing new methods and systems in NMHSs in the five countries, such as wireless communications and Internet of Things (IoT) infrastructure for climate services and disaster management.
    - Principles of satellite remote sensing and use of meteorological satellite images in weather analysis and forecasting.
    - Demonstration and training on the operation and maintenance of weather radar systems – installed under Sub-activity 2.1.1 by regional partners from the WMO network (possibly the Fiji Met Service in cooperation with USP under the new WMO Regional Training Center). The demonstrations and training will build capacity of the NMHSs for the provision of improved and more accurate weather monitoring and forecasts; tracking of local extreme events; better determination of rainfall rate/intensity, which is important for determining the potential for extreme rainfall and flash flooding enabling hazard warnings to be issued more accurately and in more timely fashion; and validating Numerical Weather Prediction (NWP) forecasts.
    - Enhancing institutional effectiveness of NMHSs through Quality Management Systems (QMS), Weather Forecast Service Standard and related certification.
    - Enhancing NMHS services through Impact-based forecasting and Forecast-based Financing.
    - Enhancing Climate services in NMHSs, including options for ensuring long-term financing and cost-recovery such as private sector investment, public-private partnerships and the application of National Climate Funds.
    - Use of alerts, information exchange and coordination in the first phase after major sudden-onset disasters, including through the Global Disaster Alert and Coordination System (GDACS).

Furthermore, the Programme will provide mentoring and technical advisory services to NMHSs in the five countries through capacity building, training and awareness raising initiatives and materials for a range of stakeholders; provide technical backstopping and capacity support to the national delivery of Programme activities; and provide expert advice to the Programme team on key climate information services and best practices, including gender-responsive implementation. In order to enhance synergies and avoid creating parallel structures, the Programme will work closely with the WMO-SPREP Pacific Meteorological Desk Partnership (PMDP), a regional coordination mechanism that supports and coordinates meteorological activities in the Pacific, and the Pacific Meteorological Council (PMC) at large.

TUVALU

BACKGROUND

Tuvalu is a parliamentary democracy, independent since 1976 and a member of the Commonwealth of Nations. Its 15 Members of Parliament are elected every four years and there are eight Government ministries. Each inhabited island has a high chief, several sub-chiefs and elders who together form an island council or falekaupule. The falekaupule cooperates with the national government on matters relating to the island and on matters of custom, acting as a local government system based on traditional ways of decision making in Tuvaluan society. Parliament and official functions are conducted in the Tuvaluan language. English is an official language but is little spoken.

Tuvalu consists of nine small islands (Niulakita, Nukulaelae, Funafuti, Nukufetau, Vaitupu, Nui, Niutao, Nanumaga and Nanumea) with a total land area of about 26 km^2 scattered over 500,000 km^2 of the western Pacific, about half way between Australia and Hawaii and very close to the equator. "Six of the islands are low lying atolls made up of motus (islets) fringing the edges of lagoons. These are made up of young, poorly developed, infertile, sandy or gravel coralline soils. Nanumaga, Niutao and Niulakita are raised limestone reef islands. Similarly, soils are generally of poor quality, supporting a limited variety of flora."[598]

At its highest point, the country is just 4.5 meters (15 ft) above sea level, making it the second lowest-lying nation in the world (after the Maldives), and thus highly vulnerable to sea level rise. Few of its atolls have land areas more than 800 m wide. The country has already begun to experience extreme high "king tides" that raise the normal sea level and cause flooding in low-lying areas. It is estimated that a rise in sea level of between 20 to 40 cm over the next century could submerge the nation entirely.[599]

The Tuvalu Government's revenues come mainly from the sale of fishing licenses, income from the Tuvalu Trust Fund, the lease of its .tv internet domain name, remittances and foreign aid. The ADB estimates that at any time about 15% of the adult men of Tuvalu are employed as seafarers or as inspectors on distant fishing nations' vessels in Tuvalu's exclusive economic zone. Remittances from relatives working overseas or for the government in Funafuti are important income sources for the residents of outer islands.

Established in 1987, the Tuvalu Trust Fund was set up by the Government to contribute to Tuvalu's financial stability by providing an additional source of revenue for recurrent expenditures and to set the country on a path towards greater financial autonomy. The fund's capital initially came from donors (Australia, New Zealand, Japan, the Republic of Korea and the United Kingdom), and the Government. It is regarded as a well-run trust fund.[600]

Tuvalu has a limited natural resource base; a widely scattered and sparsely populated island geography; a small domestic market with little potential for economies of scale; expensive and limited access to international markets; a social and cultural system with limited experience of business concepts and practices; and low absorptive capacity for major investment.[601] These factors severely limit its capacity to adapt to the effects of global warming on its surrounding ocean.

[598] Government of Tuvalu, 2011, National Strategic Action Plan for Climate Change and Disaster Risk Management 2012–2016.
[599] Current and Future Climate of Tuvalu, 2015, PACCSAP.
[600] IMF, available at <https://www.imf.org/en/News/Articles/2017/08/01/pr17312-imf-staff-concludes-2017-staff-visit-to-tuvalu> [August 2019]
[601] Government of Tuvalu, 2016, Te Kakeega III.

Funafuti is the biggest of the nine islands. It hosts the capital, most Government offices, Tuvalu's only radio station and newspaper, its only international airport and the only sealed roads in the country. About half the population of about 11,508 [602] lives on the main atoll, now one of the most densely populated places on earth—in 2002, more people lived in the outer islands than in Funafuti.[603] Inter-island migration to the capital continues and has created significant water-related challenges.[604]

One of the key development challenges for Tuvalu is providing residents of the outer islands with access to services and opportunities for paid employment. The lack of transport infrastructure severely constrains service delivery to the small populations dispersed across Tuvalu's remote atolls—two inter-island ships make a round trip of the nine islands every three or four weeks.

Tuvalu is located in relatively calm latitudes and losses generated by tropical cyclones are rare, although wind, flood and inundation losses from weaker tropical storms and depressions are not uncommon. Losses due to tsunami are also infrequent. Nevertheless, Tuvalu has a high vulnerability ranking internationally. This is because the exposure of people and physical assets is very high, relative to gross domestic product, while adaptive and response capacities are very low.[605]

Tuvalu has a hot, humid, tropical maritime climate, between the inter-tropical and South Pacific convergence zones. In the capital, Funafuti, there is little variation in temperature throughout the year. The maximum temperature is between 31–32°C and the minimum temperature between 25–26°C all year round. The country has two distinct seasons—a wet season from November to April and a dry season from May to October—but rainfall averages more than 200 mm each month of the year in Funafuti and more than 160 mm in Nanumea. This is due to Tuvalu's location near the West Pacific Warm Pool, where thunderstorm activity occurs all year round.

[602] The World Bank, 2018, available at <https://data.worldbank.org/country/tuvalu?view=chart> [August 2018]
[603] Government of Tuvalu, 2015, Te Kakeega III: National Strategy for Sustainable Development 2016 to 2020
[604] Roy EA, Tuvalu's sinking islands, available at <https://www.theguardian.com/global-development/2019/may/16/one-day-disappear-tuvalu-sinking-islands-rising-seas-climate-change?>, [August 2019]
[605] Australian DFAT, 2018, Australia's Commitment to Climate Change Action in Tuvalu.

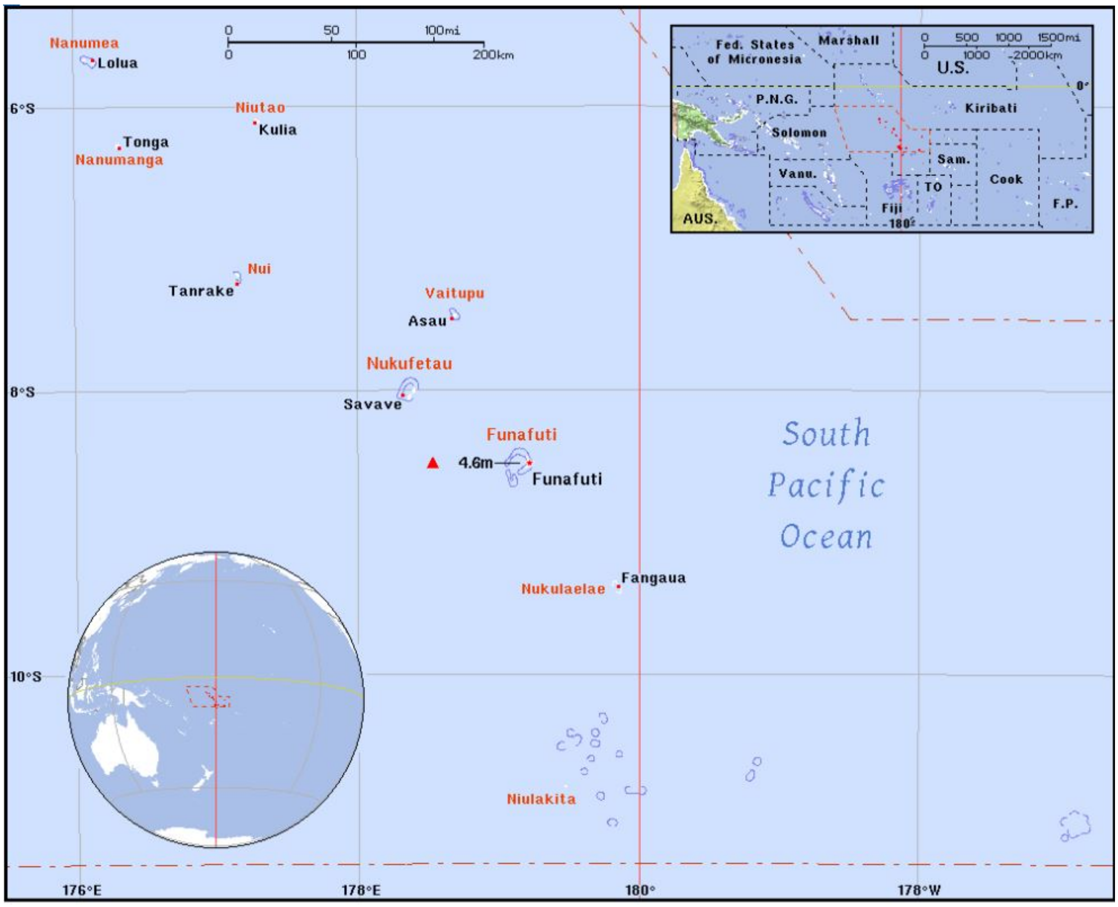

Figure 95. Map of Tuvalu (Source: https://ian.macky.net/pat/map/tv/tv_blu.gif), Copyright 2013 by Ian Mackay)

Tuvalu's wet season is affected by the movement and strength of the South Pacific Convergence Zone. The West Pacific Monsoon can also bring heavy rainfall to Tuvalu during the wet season. In Funafuti, El Niño events tend to bring wetter, warmer conditions than normal, while La Niña events usually bring drier, cooler than normal conditions. Tropical cyclones tend to affect Tuvalu between November and April.[606]

[606] Government of Tuvalu, 2015, Current and Future Climate of Tuvalu, PACCSAP

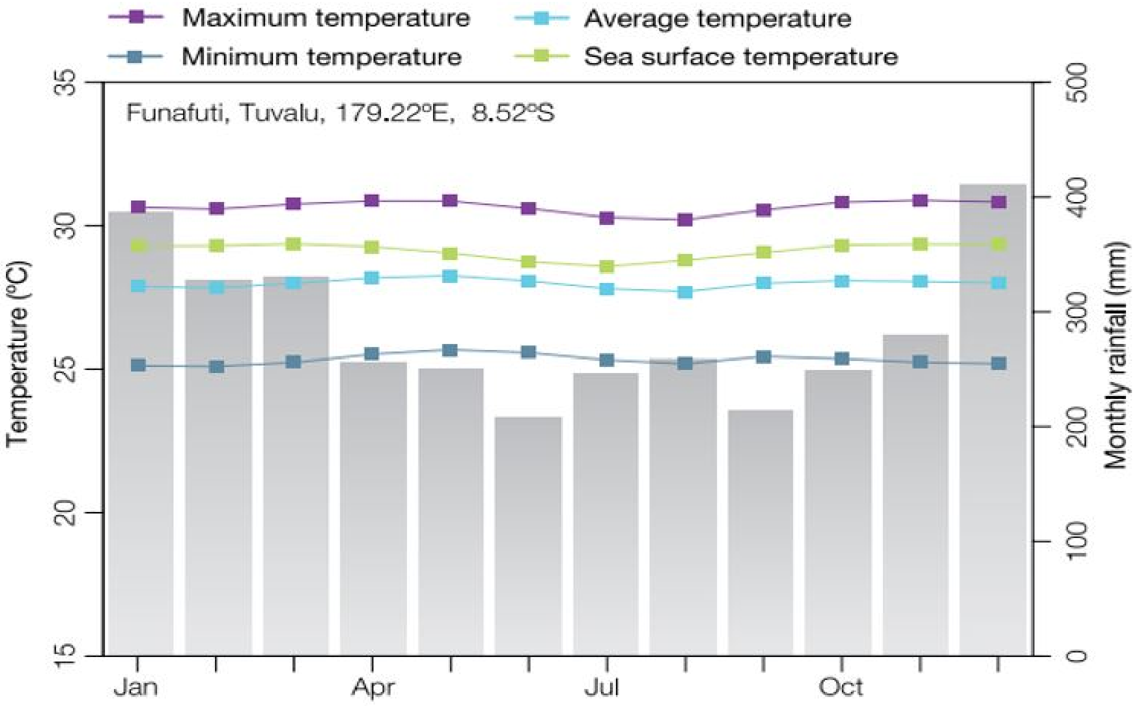

Figure 96. Seasonal rainfall and temperature at Funafuti

Environmental issues add to Tuvalu's challenges. Until this century, Tuvalu's islands, like other inhabited atolls, had a usable lens of fresh water replenished by rainfall and accessible from wells, floating on the layer of saltwater that permeates its porous, sandy soils. People are now dependent on rainwater captured from small areas of corrugated iron roofing and stored in tanks as their main source of drinking water, because the groundwater has been polluted by saltwater intrusion and human activity and is no longer fit for human consumption or agriculture. Crops are grown in raised beds to reduce root contact with salt, or even in wicking beds or concrete-lined pits, which prevent any contact with the salinated soil. Coastal erosion and saltwater intrusion are killing coconut trees and increasing temperatures and more frequent droughts reduce the productivity of other fruit trees.

Pacific Community's (SPC) Centre for Pacific Crops and Trees and its Land Resources Division are researching and developing "climate-ready" and salt-tolerant crops: climate data from Pacific countries is vital both to inform research about projected growing conditions and for determining where and when to trial new crops and new varieties.

Te Kakeega III, the National Strategy for Sustainable Development (2016–2020) states unequivocally that Tuvalu's national budget is unable to fund effective adaptation to rising sea levels, increasing ocean acidification, higher average temperatures and extremes, and more extreme climate-related events, without the help of external donors.[607] Tuvalu is an active participant in international climate change forums and advocates that the cost of limiting and addressing the impacts of climate change must be primarily borne by major greenhouse gas producing countries.

The Government of Tuvalu's Budget 2019 estimates the following income:

Tuvaluan / Australian Dollars	$million
Distribution from the Tuvalu Trust Fund	3.8

[607] Government of Tuvalu, 2016, Te Kakeega III.

Taxation	8.6
Fishing licenses	30.7
DotTV licenses	7.1
Investment revenue	5.5
Other charges	1.5
Budget support from development partners	28.5
Total	84.3

Total expenditure of $85.6 million is projected for 2019.[608]

Current provision of climate services: strengths, priorities and barriers

The Tuvalu Meteorological Service (TMS) is a division of the Ministry of Transport. Climate data has been recorded at Funafuti since 1951, when Tuvalu was administered as part of the Gilbert and Ellice Islands. TMS's Vision is: "Achieving services on meteorological and climatological products on [a] timely basis in order to enhance the safety, security and general-wellbeing of the community, and to support the national development in all sectors through skilled and trained professional and technical staff by means of adequate operating facilities."[609] The main observational office of TMS is located at Funafuti, with outstations on Nanumea, Nui and Niulakita.

Types of climate products and services by national climate service provider:	List in detail the activities being undertaken to fulfil	Requirements to improve your services
Number of Staff involved in climate Services	TMS manned by 19 staffs - Director (1), Scientific Officer (2), Data & Communication Officer (1), Senior Climate Officer (1), Technical Officer (2), Senior Observer (1), Assistant Forecasters (10), Carpenter (1)	Established new post within the division: Data Officer; Communication Officer; and Data Entry Officers (x2)
Climate Observations	4 manned synoptic stations 5 rainfall stations – non-operational except Vaitupu 1 upper air programme 1 tide gauge with tsunami warning system	Upgrading observing equipment on out-stations, e.g. barometers & manual rain gauges; Install AWS on outer islands and inhabitant islets; Establishment of an ongoing annual inspection & report; and Installation of automatic rain gauges (Data-logger) on the 5 existing rainfall stations.
Climate Data Management	CliDE Database	
Interaction with Users	Has climate awareness materials in Tuvaluan	Conduct awareness programme especially on

[608] Government of Tuvalu, 2018,National Budget 22 November 2018

[609] Katea, T. 2007, Strategic Planning of Tuvalu Meteorological Service 2007-2011, WMO Regional Seminar on Enhancing Service Delivery by National Meteorological & Hydrological Services (NMHSs) in RA V Kuala Lumpur, Malaysia, 2—6 April 2007

		outer islands – schools, community etc.; Develop Climate/Weather glossary in local context; Tailored products to meet user needs; Review Climate Communication Strategy; and Establish a higher frequency on HF radio with Telecom for better transmission & reception of data delivery with our out-station.
Seasonal Climate Outlooks	Climate Outlook using SCOPIC Island Climate Update EAR Watch National Statements – Tropical Cyclone Outlook	
Climate Monitoring		
Specialised climate products (Sector	Funafuti Drought Monitoring Plan Drought thresholds – EAR Watch	MoU between key stakeholders and TMS on data sharing
Decadal Climate Prediction		
Long-term Climate Predictions		
Customized climate products		
Climate Application Tools		

Table 33. Current capabilities and climate services provided by TMS and requirements to improve climate services in Tuvalu (Source: PSS In-country consultations)

TMS has noted the need for the following infrastructure enhancements:

- Installation of Himawari Cast (satellite-based distribution system) equipment by JICA;
- Completed installation of HF radio for early warning communications;
- Transmission of daily weather observations every six hours;
- Installation of a new tide gauge for monitoring sea level rise;
- Container storage for hard copies of Met data.

TMS publishes weather forecasts, tropical cyclone warnings, weather charts and weather satellite images on its website, with weather forecasts and storm warnings also broadcast by the Tuvalu Media Corporation, which operates Radio Tuvalu. It provides 3-month climate outlooks and advises on the progression of droughts.

TMS staff have advanced in their capacity to interpret and use meteorological data, largely through training provided by Australia's Pacific Islands Climate Prediction Project (PICPP) and Climate and Oceans Support Program in the Pacific (COSPPac). These two projects installed purpose-built software that enables meteorological service staff in all five Programme countries (and nine others) to generate forecasts of the local climate 3 to 9 months ahead. The software—Seasonal Climate Outlook for Pacific Island Countries (SCOPIC)—uses each country's locally observed and recorded data to generate a forecast statistically, focussing on expected rainfall. The forecast is scalable down to the level of the weather station recording the data, if necessary and if there is at least 30 years' data from that site. The data used in SCOPIC is drawn from a climate data management system called CliDE (Climate Data for the Environment) which ingests and archives digitised climate data and makes it available for manipulation and use in information products. The collection of local data allows the TMS to monitor and report on Funafuti's climate at local scale.

Over the ten years from 2009, PICPP and then COSPPac have mentored climate officers in Pacific NMHSs to use SCOPIC to produce a monthly report on upcoming climate conditions and to evaluate the accuracy of their previous climate forecasts. During this time, the officers' confidence and accuracy has improved markedly, and the group supports new entrants to achieve the same competence. This mentoring continues, now by SPREP's climate officer, who manages a monthly conference call with up to 11 Pacific climate officers and the Australian Bureau of Meteorology (BoM). Each Pacific climate officer discusses the calculation of his or her current climate forecast with the SPREP climate officer one to one, ahead of the roundtable phone call. The group discussion then considers the forecasts across the region for the next few months and compares each country's previous predictions with the observed data for those months. Confidence and accuracy continue to improve, and Australia continues to provide support to SPREP for the maintenance and further development of the software.

The Australian Government continues to support the monitoring of sea level rise and other climate data at the Fongafale wharf. Geoscience Australia supports an earth monitoring station nearby measuring geodetic movements, so these can be excluded from the sea level changes, allowing calculation of absolute sea level rise.

SPC maintains and provides access to the Pacific Ocean Portal originally developed by BoM through COSPPac: the Portal allows a user with limited internet access to select a location and a sector such as tourism, fisheries, and shipping, ask for ocean parameters such as sea temperature, wave heights, coral bleaching, currents, salinity and chlorophyll, and receive the information visualised as maps and diagrams. The Portal is one of the tools TMS demonstrates to stakeholders.

TMS experiences barriers to its effective delivery of essential services common to all five very small island countries, some of which this Programme will address collectively, adding to existing networking among the countries and achieving economies of scale.

TMS has an innovative and very practical Drought Monitoring Plan for Funafuti[610] (FDMP) which sets guidelines for monitoring water stress and responsibilities for acting to prevent hardship. Developed through a 2-day workshop, it recognises the real difficulties of collecting data, the challenges of storing drinkable water and the particular vulnerabilities of productive gardens on tropical atolls. It uses an interesting proxy measure for water stress, in combination with analysis of high quality meteorological and hydrological data.

Tuvalu experienced very severe droughts in 1999 and 2011 and was obliged to declare states of emergency. Drinking water ran dangerously low and even ran out in some communities. Large-scale emergency assistance was required from international donor.[611] The level of hardship was exacerbated by delays in response—the inter-island ships did not begin taking water to the outer islands until the drought was formally declared, and it can take two weeks to reach some islands by sea. The National Disaster Management Office, provincial committees, sectors and non-governmental organisations had no clear guidelines for who was responsible for what tasks during a drought. Sector agencies were unable to link drought information to the potential impacts on their sector. They needed more specific advice, but it was not clear from whom they should get it. All participants noted

[610] Government of Tuvalu, 2018, Funafuti Drought Monitoring Plan.
[611] Government of Tuvalu, 2016 to 2020, 2015, Te Kakeega III: National Strategy for Sustainable Development.

that Funafuti residents are highly dependent on rainwater—conflicts arise over the ownership of water tanks and water sources during droughts.

The workshop participants—TMS, Public Works Department (PWD), National Disaster Management Office and community organisations—agreed that drought thresholds for Funafuti and triggers for drought declaration would be determined by measuring both current water availability and assessing the rainfall forecast, rather than using meteorological measures alone. They agreed:

- TMS will issue an advisory warning after two weeks without rain—the advisory is the first step towards drought declaration.
- The Public Works Department will determine the current demand for water by assessing the number of receipts collected by the Water Division for supplying desalinated water (New Zealand sent two desalination plants to Funafuti after the 2011 drought). Householders seek supplementary water when their tank levels fall to 50% full.

The two measures combine to give enough warning to the agencies (now) responsible for responding so that, for instance, PWD has enough fuel for the desalination plants and people know they need to monitor water use.

TMS would like to extend the Functional Decision Making Procedures (FDMP) to the outer islands, where drought needs to be managed even more carefully. They would take the same approach to developing an agreed set of measures for what could be termed sociological drought. The warning would be triggered not only on the basis of how much rain has fallen in the last few months—it would draw on a community's understanding of all the underlying factors of soil condition, weather, the time of year, population numbers and health, and crop growth stages. Each island may have its own proxy measure for rising risk—their awareness of how much water they need to use might mean a warning is issued when water tanks are 60% full rather than 50%. The outer island's meteorological officer should then warn TMS, PWD and NDMO that their responses may soon be needed. A set of scientific (meteorological and hydrological) and social measures that combines to trigger an early drought warning will be more reliable for preventing hardship than rainfall statistics alone.

The vast ocean areas, the changing climatic conditions, the great dispersion of its islands—the distance between the most northerly and most southerly of Tuvalu's islands is about 900km—and capacity constraints make it difficult for TMS to put in place comprehensive and sustained climate information services. The economic value of climate information and its importance to human safety and wellbeing is often not reflected in national budgets and there is limited potential for cost recovery for agrarian advice, infrastructure planning advice, public health early warnings or even essential aviation and maritime services.

Specialised services requiring highly trained staff are difficult to sustain in very small countries—qualified meteorologists are in demand in developed Pacific rim countries, which can offer higher pay, better professional development and other opportunities. Ageing and obsolete equipment and unreliable internet access add to the challenges faced by small NMHSs.

TMS identified the following priority education and training needs:

- "Competent staff to gather, process, archive and facilitate the rapid exchange of data and products;
- Capability to prepare and deliver high quality early warnings and forecasts of weather, climate and water-related hazards to respond effectively to stakeholder needs;
- More in-country scientific research to support climate change adaptation and mitigation projects and decision making;

- Capacity to maintain high standards of observation instruments, equipment and data backup systems, calibration of instruments;
- Effective approaches in management and administration;
- Certifying of eight technical staff as Aeronautical Meteorological Observer (AMO) under ICAO/WMO requirements – to achieve this, BIP-MT training is needed;
- Water resources management, hydrological and hydrological technician training."[612]

TMS also notes its need for information on its surrounding ocean. "As a natural regulator of the Earth's climate and cornerstone of the global climate system, the importance of the ocean can no longer be underestimated. From greater risk to coastal areas due to rising sea levels, strong winds, storms and cyclones, to food insecurity among island populations linked to declining marine resources, an unhealthy ocean in a changing climate can yield great environmental, economic and social imbalances."[613]

Tuvalu's climate change policy emphasises the need to understand and communicate climate change and its impacts. To enable the Tuvalu Meteorological Service to carry out its role in this work, the policy identifies priority areas including:

- Enabling legislation and policy within the Tuvalu Meteorological Service;
- Capacity building for climate services;
- Replacement and maintenance of old equipment;
- Translating weather and climate information for end users;
- Enhancing public and school awareness of weather and climate information;
- Improving inter-island communication.[614]

Disaster Risk Management

The National Disaster Committee (NDC) is coordinated by the National Disaster Management Office (NDMO), which is house in the Office of the Prime Minister. The NDC is responsible for coordinating all activities related to disaster management programming, policy development and implementation. The Island Disaster Committees (IDCs) act as a bridge between the NDC and outer island communities during disasters and are responsible for the coordination of disaster management and public education programmes in their respective islands.[615]

The National Strategic Action Plan (NSAP) for Climate Change and Disaster Risk Management 2012-2016 recommends that the National Climate Change Advisory Committee and NDC should merge for the purpose of coordinating and driving implementation of the NSAP.[616]

Financing for climate services and disaster risk management

The Tuvalu Climate Change and Disaster Survival Fund – the "Tuvalu Survival Fund" (TSF) – was established in 2016 to support adaptation and mitigation actions to respond to climate change impacts

[612] UNDP, 2018. Feasibility Study for a Pacific based WMO Regional Training Centre
[613] United States of America, U.S. Climate Resilience Toolkit Storm Surge, available at <https://toolkit.climate.gov/topics/coastal/storm-surge> [August 2019].
[614] Government of Tuvalu, 2012, Te Kaniva: Tuvalu's climate change policy.
[615] Tuvalu, 1997. National Disaster Risk Management Plan
[616] Tuvalu, 2012. Tuvalu National Strategic Action Plan for Climate Change and Disaster Risk Management 2012-2016

and disaster risks.[617] Contributions to the TSF are made from the national budget, with 10% of GDP allocated in 2016 (although no contribution was made in 2017 due to a fiscal deficit).[618] A transfer of USD 2,166,667 to the TSF was forecast for 2018.[619] The financial cost of implementing the NSAP over the period 2012 – 2016 was estimated to be AUD 6,338,004 (approximately USD 4 million), to be sourced entirely from development partners.[620]

Previous national climate change adaptation and awareness activities

Tuvalu has implemented several completed, current and long term climate change related projects.

The **Tuvalu Climate Change and Disaster Survival Fund** – the **Tuvalu Survival Fund (TSF)** – established in 2016 provides a mechanism for the Government of Tuvalu to manage development partner contributions and ensure that they support national priorities and objectives. The TSF has two main objectives: i) "Provide immediate vital services to the people of Tuvalu in combating the devastating impact of climate change and natural disasters"; and ii) "Allow the Government and the people of Tuvalu to respond to future climate change impacts and natural disasters in a coordinated, effective and timely manner."[621]

The **Tuvalu Coastal Adaptation Project (TCAP)** launched in 2017 is a 7-year project implemented by UNDP, with financing from the Green Climate Fund and the Government of Tuvalu. TCAP is focused on improving coastal protection in Tuvalu through implementing measures that reduce exposure to coastal hazards in three target islands (Funafuti, Nanumea and Nanumaga); developing a long-term coastal adaptation strategy; building capacity of national and local authorities to better implement adaptation actions; and investing in young people as "future stewards of a resilient Tuvalu".[622]

The **Pacific Sea Level Monitoring Project (1991 – present)** operates under the Australian Bureau of Meteorology (BoM) Climate and Oceans Support Program in the Pacific (COSPPac). Its primary goal is to generate a high-quality record of long-term sea level data for the Pacific region. The tide gauge at Fongafale was installed in 1993 and data has been recorded continuously since then. The data and other information are available at http://www.bom.gov.au/pacific/tuvalu/index.shtml.

The **Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Program (2011 – 2015)** supported the Government of Tuvalu to develop improved climate change projections and adaptation planning activities. The outputs are detailed in the Pacific Climate Change Portal – Tuvalu profile: https://www.pacificclimatechange.net/node/62.

The **Climate and Oceans Support Program in the Pacific Phase II (COSPPac2)**, with the support of the **Red Cross Red Crescent Climate Centre**, worked with TMS to develop and implement a National Early Action Rainfall (EAR) Watch bulletin for use in disaster preparedness activities. An EAR Watch workshop was held in Tuvalu in 2018 in which TMS staff received training on drought monitoring and seasonal prediction. This was followed by a National Climate Outlook Forum and Stakeholder Consultation Workshop.[623]

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617 Tuvalu, 2015. Climate Change and Disaster Survival Fund Act 2015

618 IMF, 2018. Tuvalu: 2018 Article IV Consultation – Press Release; Staff Report; and Statement by the Executive Director for Tuvalu

619 Tuvalu, 2019. National Budget 2019

620 Tuvalu, 2012. Tuvalu National Strategic Action Plan for Climate Change and Disaster Risk Management 2012-2016

621 Government of Tuvalu, 2015. Climate Change and Disaster Survival Fund Act 2015. Available at: https://www.tuvalu-legislation.tv/cms/images/LEGISLATION/PRINCIPAL/2015/2015-0011/ClimateChangeandDisasterSurvivalFundAct2015_1.pdf

622 Tuvalu Coastal Adaptation Project, 2018. About TCAP. Available at: https://tcap.tv/about-tcap

623 SPC, 2018. Updates from SPC. Climate Information for Early Action in Tuvalu. Available at: https://www.spc.int/updates/blog/2018/11/climate-information-for-early-action-in-tuvalu

Tuvalu Red Cross Society (TRCS) convened a workshop on early warning early action in March 2019, which brought together national climate and disaster management stakeholders – including TMS – with representatives from community disaster committees from Tuvalu's outer islands. The workshop dialogue focused on the challenges of reaching the 'last mile' and the partnerships required to address these. TMS also shared details of recent initiatives to improve communication of information on drought through the public ENSO signboard on Funafuti and the EAR Watch bulletin.[624]

The **Second National Communication of Tuvalu to the UNFCCC** was developed from 2009 – 2012, with the support of UNDP. The preparatory activities were a continuation and update of the work done by Tuvalu to prepare its Initial National Communication, which were undertaken through the regional Pacific Islands Climate Change Assistance Project (PICCAP). Through enhanced knowledge and awareness of climate impacts and improved identification of national circumstances, the project strengthened and built national capacities to facilitate adequate adaptation and mitigation of climate change.[625]

The **Pacific Adaptation to Climate Change (PACC) Programme** (2009 – 2013) was the first major climate change adaptation initiative in the Pacific region. PACC was implemented by UNDP and executed by SPREP. The multi-country regional programme – covering all 14 Pacific island countries – aimed to demonstrate best-practice adaptation in key climate-sensitive areas, with each country hosting a pilot project in one of the key areas. In Tuvalu, the programme focused on water resources management through improved water infrastructure and a village water management plan.[626]

The JNAP Process (2012 – 2016) supported Tuvalu to develop both a **National Strategic Action Plan (NSAP)** for Climate Change and Disaster Risk Management and a **National Climate Change Policy**, with technical assistance from SPREP, SPC and GIZ. The establishment of a 'formal' JNAP development governance arrangement – with an identified lead agency supported by a committed inter-agency task force contributing scientific and experiential data – was identified as a key success factor for joint ownership, efficient development and government endorsement in Tuvalu. The inclusive stakeholder-based process also facilitated that key development issues and the needs of the most vulnerable groups, including women and children, were considered.[627]

The **Global Climate Change Alliance: Pacific Small Island States (GCCA: PSIS) Project** (2011 – 2015) supported the Government of Tuvalu to mainstream climate change in national and sector strategies – including sector budget support – and to implement specific adaptation actions into the nationally selected sector of Agriculture, focusing on root crops including cassava, sweet potato and yams that are not traditionally grown in Tuvalu.[628]

The GCCA: PSIS Project complemented the outcomes of the AusAID-funded **"Establishing nurseries in Tuvalu to support conservation and distribution of staple food crops and climate ready diversity"** project (2011 – 2014). The project was implemented in two outer islands (Vaitupu and Nukulaelae) to establish nurseries to grow pulaka and other "climate ready" plant varieties.

[624] Red Cross Red Crescent Climate Centre, 2019. Forging partnerships for early warning early action in Tuvalu. Available at: https://www.climatecentre.org/news/1128/forging-partnerships-for-early-warning-early-action-in-tuvalu
[625] Pacific Climate Change Portal, 2015. Enabling Activity for the Preparation of Tuvalu's Second National Communication to the UNFCCC. Available at: https://www.pacificclimatechange.net/project/enabling-activity-preparation-tuvalu%E2%80%99s-second-national-communication-unfccc
[626] SPREP, 2009. Adapting to Climate Change in the Pacific: The PACC Programme
[627] SPREP, 2013. JNAP Development and Implementation in the Pacific: Experiences, Lessons and Way Forward
[628] SPC, 2016. Global Climate Change Alliance: Pacific Small Island States. Volume 1: Final Report

The **GEF Pacific Integrated Water Resources Management (IWRM) Project** (2009 – 2013) supported development of a National Water and Sanitation Policy; introduced dry sanitation as the preferred option through the "Eco-Sanitation Demonstration IWRM Project"; strengthened arrangements for improved wastewater management; and mainstreamed IWRM into national policy.[629]

The **Increasing Resilience of Coastal Areas and Community Settlements to Climate Change in Tuvalu** project (2009 – 2013), executed by UNDP and Tuvalu Ministry of Natural Resources and Environment, aimed to strengthen institutional capacities to identify and address climate change-related threats – particularly to its highly vulnerable, low-lying atoll island communities – based on Tuvalu's NAPA priorities.[630]

The **Coping with Climate Change in the Pacific Island Region** project (2009 – 2020), executed by SPC – is supporting Tuvalu to strengthen the competence and capabilities of its local population and government authorities to cope with the adverse impacts of climate change.[631]

Alignment with national priorities

Te Kakeega III—National Strategy for Sustainable Development 2016–2020 has thirteen strategic areas: climate change; good governance; the economy, growth and stability; health and social development; falekaupule[632] and island development; private sector development, employment and trade; education and human resources; natural resources: fisheries, agriculture, land and sea; infrastructure and support services; environment; migration and urbanisation; ocean and seas; and implementation, monitoring and evaluation. It is noteworthy that the previous strategy document, Te Kakeega II (2005–2015), did not list climate change as one of its eight areas of focus, but in this eighth national plan, climate change is the first priority.

Te Kaniva—the Tuvalu National Climate Change Policy 2012–2021—is a ten year policy document prescribing responses to climate and hydrological hazards and prioritizing the implementation of activities to mitigate impacts. The National Strategic Action Plan for Climate Change and Disaster Risk Management 2012–2016 (NSAP) addresses geological and anthropogenic hazards. The NSAP is also the five year action plan for Te Kaniva: the NSAP and Te Kaniva should be read and considered together. The NSAP details goals, strategies, key actions and responsible agencies.

Te Kaniva identifies seven thematic goals:

- Strengthening adaptation actions to address current and future vulnerabilities;
- Improving understanding and application of climate change data, information and site specific impacts assessment to inform adaptation and disaster risk reduction programmes;
- Enhancing Tuvalu's governance arrangements and capacity to access and manage climate change and disaster risk management finances;
- Developing and maintaining Tuvalu's infrastructure to withstand climate change impacts, climate variability, disaster risks and climate change projection;
- Ensuring energy security and a low carbon future for Tuvalu;
- Planning for effective disaster preparedness, response and recovery; and

629 Tuvalu Public Works Department, 2013. GEF Pacific IWRM Project Results Note
630 UNDP, 2013. Increasing Resilience of Coastal Areas and Community Settlements to Climate Change in Tuvalu. Available at: https://www.adaptation-undp.org/projects/ldcf-tuvalu
631 GIZ, 2020. Coping with climate change in the Pacific island region. Available at: https://www.giz.de/en/worldwide/14200.html
632 The Falekaupule of each of Tuvalu's islands is its elected assembly of elders.

- Guaranteeing the security of the people of Tuvalu from the impacts of climate change and the maintenance of national sovereignty.

Tuvalu's **National Adaptation Programme of Action (NAPA)** identifies its main objectives: [12]

- To develop a country-wide programme that [encompasses] the urgent and immediate needs of communities;
- To implement immediate and urgent adaptation activities to climate change and variability;
- To enhance communities' awareness and livelihood;
- To mainstream adaptation measures into national and sectoral planning.

A **NAPA 2** project is being developed and will focus on implementing three priorities:

- Strengthening community based conservation programmes on highly vulnerable near-shore marine ecosystems;
- Adaptation to near-shore coastal shellfish fisheries resources and coral reef ecosystem productivity; and
- Strengthening community disaster preparedness and response potential.

Tuvalu's Water Policy 2013 outlines the following goals:

- Goal 1: To provide a safe, reliable, affordable and sustainable water supply;
- Goal 2: To manage and conserve scarce water supplies;
- Goal 3: To establish and maintain effective early warning and response systems;
- Goal 4: To enable effective, equitable and integrated governance of water and sanitation;
- Goal 5: To increase community awareness and participation in the management of water and sanitation;
- Goal 6: To improve access to reliable, affordable and environmentally sustainable technologies ;
- Goal 7: To improve the affordability of water and sanitation services and increase access to sustainable sources of finance.[15]

The **Tuvalu-WHO Country Cooperation Strategy 2018-2022** [633] outlines the World Health Organization (WHO)'s vision for technical cooperation to support the Government of Tuvalu in pursuing its national strategic priorities for health and development. Priority 1 of the Strategy is "To build resilient health systems to bolster health security and climate change preparedness". In particular, the Programme will contribute to Strategic Activity 1.1 under Priority 1: "Build capacities to respond to environmental hazards, the effects of climate change, and the health consequences of disasters."

[12] Government of Tuvalu, 2007, Tuvalu's National Adaptation Programme of Action, Ministry of Natural Resources, Environment, Agriculture and Lands – Department of Environment.
[15] Government of Tuvalu, 2013, Fakanofonofoga Mo Vai Mote Tumaa: Sustainable and Integrated Water and Sanitation Policy 2012—2021.
[633] WHO, 2018. Tuvalu-WHO Country Cooperation Strategy 2018-2022. Available at: https://iris.wpro.who.int/bitstream/handle/10665.1/13958/WPRO-2017-DPM-024-tuv-eng.pdf

The Government of Tuvalu's National Budget for 2019 records among Tuvalu's key achievements in 2018 the following:

- Passage of the Climate Change Bill 2018;
- Review of the Disaster Management Act 2018;
- Review of the National Climate Change Policy and Action Plan (2016-2017) and Disaster Risk Management Arrangements (2018);
- New Climate Change Policy (Te Vaka Fenua o Tuvalu);
- National Adaptation Plan and Mitigation Action Plan (2018).
- Operationalising the Tuvalu Climate Change & Disaster Survival Fund (2018);
- Property Registration System (2016-18);
- Securing Green Climate Fund (2016);
- Progress in National Implementing Entity accreditation to the Adaptation Fund (2015-2018).
- Adaptation plans: Vulnerability Assessment and National Adaptation Plan (~2018).
- Mitigation Action Plan (~2018)
- Information, Knowledge & Capacity Building - Capacity Building and Community Awareness on climate change and disaster risk reduction (2016-18).
- Loss & Damage specific focus on the Pacific Island Climate Change Insurance Facility (2016-18);
- Draft UN Resolution on Persons Displaced by Climate Change (2016-18).
- Disaster Risk Reduction: TC Pam Recovery and Vulnerability Reduction Plan (2015);
- Post-TC Pam recovery and reconstruction (2015-18);
- TC Pam and Ula updates, food relief and financial analysis reports; and
- Early warning systems for all islands (2016-18).[634]

Legislative and regulatory framework

Tuvalu would benefit from support to finalise its Meteorology Act, currently being drafted. The Act should mandate the responsibilities of the Tuvalu Meteorological Service for provision of weather and climate services, clearly state its role in early warning and disaster management and formalise its relationship with allied agencies, and provide budget security.

Existing legislation and regulations relevant to the management of climate and disaster related risks include: the Constitution of Tuvalu of 1986; the National Disaster Management Act of 2007; the Tuvalu Emergencies and Threatened Emergencies (Special Powers) Act of 1987; the Falekaupule Act of 1997; the Food Safety Act of 2006; the Public Health Act of 1926; the Public Health Ordinance of 1978; the Environment Protection Act of 2008; the Marine Pollution Act of 1991; the Foreshore and Land Reclamation Act of 2008; the Foreshore License Regulations of 1979; the Marine Resources Act of 2006; the Community Rehabilitation Funds (Special Funds) Regulations of 1995; the Water Supply Act of 1967; the Water Supply Delivery of Bulk Supplies Regulations of 1976; the Quarantine Act of 1929; and the National Bank (Insurance Fund) Act of 1981.

[634] Government of Tuvalu, 2019, National Budget.

Much of this legislation pre-dates concern about climate change and may even conflict with current requirements for clear statements of responsibility for the generation and dissemination of information. The climate change portfolio falls within the Department of Environment as provided by the 2008 Environment Act, whereas TMS is in the Ministry of Transport, reflecting its role in aviation and maritime safety—this can make harmonising the work of the two agencies difficult.

RESULT 1 – STRENGTHENED DELIVERY MODEL FOR CLIMATE INFORMATION SERVICES AND MHEWS COVERING OCEANS AND ISLANDS

Activity 1.1 Strengthen institutional and policy frameworks and delivery models for climate services

Under this Activity, the Programme will establish comprehensive institutional and policy frameworks and delivery models for strengthened climate services in Tuvalu. This will include the development of a National Framework for Climate Services (NFCS), which will be supported by effective coordination mechanisms to mainstream climate risk knowledge into the decision making of climate-sensitive sectors. Moreover, Tuvalu will conduct a climate services market assessment and develop a policy for sustainable financing and delivery of climate services. Amongst others, engagement with the development of national budgets will enable justification of the value of climate services, strengthen existing funding for disaster relief and contribute to the identification of long-term sources of funds.

T1.1.1 Develop the Tuvalu Framework for Climate Services

The Government of Tuvalu is currently drafting a Meteorology Act with support from World Meteorological Organisation (WMO). The Act will cover climate monitoring, climate variability forecasting and climate change responsibilities as well as setting out the Tuvalu Meteorology Service's role in disaster management. The Tuvalu Disaster Management Act (2007) does not refer to TMS and TMS is not represented on the Disaster Management Committee or the National Disaster Preparedness Group. The Meteorology Act will ensure all agencies with roles in multi-hazard early warning systems coordinate to provide effective services. In the interim, TMS continues to collect both weather and climate data and makes information available for use in developing well-informed adaptation to climate variability and change. TMS is keen to develop its capacity to communicate climate information more effectively and to tailor its information to the needs of its end-users.

Throughout the implementation of this Programme, TMS proposes to conduct a series of consultative workshops with stakeholders to develop and refine a National Framework for Climate Services (NFCS). In the first half of year one, TMS will invite representatives of government agencies responsible for key sectors including the five Global Framework for Climate Services (GFCS) sectors—water, health, renewable energy, food security and agriculture, and disaster risk reduction—to take part in a 3-day workshop facilitated by an international consultant and a local consultant. The workshop will begin with a presentation of basic climate science, an explanation of the kinds of data TMS collects, and a presentation of the products and services their data has been used to create. Sectors will also be asked to present on how they use climate information and how they would best like to work with TMS. The workshop will begin the process of agreeing with these stakeholders more specific functions, relationships and services.

The two consultants will use the outcomes of the first workshop to draft the NFCS, which will inform the future work of TMS. Objectives will be to agree with key sectors a suite of directly applicable information products, with a process for checking their utility regularly and revising them when needed. In year five the NFCS will be re-evaluated using feedback and learnings from each sector over the previous four years.

T1.1.2 Conduct market assessment to explore viable opportunities for climate information services in sectors and business segments

This Sub-activity will support Tuvalu to understand its existing market for climate services and potential sustainable climate services models; and utilise a value chain approach to mobilise private sector finance in climate services delivery. In the longer term, this will support establishment of a foundation for a cycle of investment, service enhancement, research and development, and re-investment, which has already created commercial markets for climate services in developed countries.[635]

The Programme will conduct a detailed market assessment, which will assess the following:

- **Involved actors in climate services** – This include providers, intermediaries and users: i) Government agency/s (including TMS) responsible for the operation of the national meteorological infrastructure and provision of public weather and climate services; ii) Academic (university) research community; iii) Media entities; iv) Private sector and other providers; and v) Users, which consists of the general public, as the users of basic services, and the economic and social sectors and organisations as the users of specialised, tailored services.[636]
- **Regulatory environment** – Analysis of the current regulatory environment for climate information and early warning services in Tuvalu and subsequent identification of policy incentives to unlock barriers to private sector investment;
- **Supply and demand analysis** – Identification of country-relevant sector and business needs for climate services (for example, level of information, scales and access required);
- **Private sector engagement** – Building on the analysis of supply and demand, the Programme will support TMS to engage with the private sector – including through the National Climate Outlook Forums (Sub-activity 1.1.3) – to identify private sector sponsors' interest in the generation, translation and transfer function and in purchasing climate-related information.
- **Business models** – Analysis of business models for climate services that are successful in other countries, with a focus on Small Island Developing States (SIDS). This will include case studies on private sector company provision of climate services as well as government-led initiatives.

Based on the above analysis, the Programme will support Tuvalu to identify opportunities to develop value-added climate products and services; and potential for public-private partnerships and private sector investment in climate services. Private sector engagement will improve the cost-effectiveness of TMS and increase potential for catalysing innovation in climate information technologies. This Activity will also inform development of the national policy for financing climate services in Sub-activity 1.1.4.

T1.1.3 Mainstream climate risk knowledge into sectors

National Climate Outlook Forum

In the second half of the year – likely during the Climate Resilience Week in November – TMS will present the National Climate Outlook Forum (NCOF), as they already do every year, before the onset

[635] SAID, 2018. Climate Information Services Market Assessment and Business Model Review
[636] WMO, 2015. WMO-No. 1153. Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services

of the cyclone season (November for Tuvalu) and after the Pacific Islands Climate Outlook Forum (PICOF).

The participants in the earlier workshop (for government officials) will be better prepared to understand the Outlook and how it supports specific sectoral advice. The NCOF presentation will be given to 35 participants, including representatives of all the outer islands. The inter-islands ships' schedule means that everyone from the outer islands needs two weeks' accommodation, but it is important to disseminate the NCOF information widely and effectively.

In years two, three and four, TMS will hold similar 2-day workshops successively with the private sector, NGOs and communities to articulate what information they want from their meteorological service and the formats in which it will be most useful to them.

On the second day of their national workshops, TMS will present that year's NCOF for all stakeholders. This will encourage wide communication of the outlook for the upcoming cyclone season and for growing conditions to all Tuvaluan communities—the outlook will also be discussed by TMS staff travelling twice annually to all Tuvalu's islands for equipment calibration and maintenance. The NCOF presentation will provide an annual opportunity for sectors to articulate their priorities and preferences for delivery throughout the year of climate information.

Climate Information Services Sector Action and Communication Plan

In the first half of the second year of the Programme, TMS will engage an international and a national consultant to facilitate a workshop with stakeholders from government agencies and communities to identify sector specific priorities and actions for climate information services, targeting five sectors. The workshop will further develop the ideas about the information needs of specific sectors gained from the NFCS. It will also consider, with sector representatives, how climate information can be mainstreamed into their work and applied in their decision-making.

The consultants will use the outcomes of the workshop to draft a Climate Information Services Sector Action Plan and a Communication Plan for an agreed number of important sectors. The plans will address sector-specific needs for information services relating to both disaster risk reduction and management, and effective climate change adaptation.

The Plans will document an agreed process for testing the best ways of regularly communicating climate information to sectors. This will include both finding ways to make information easily accessible and exploring potential methods of improving the understanding of climate information by all workers in a sector, and by the users of that sector's own services.

This is likely to include a range of activities, such as improving the TMS's use of social media, but to begin with a programme of capacity building in understanding climate and weather information for government workers. The sector communication plans will be tailored to the specific interests and needs of each sector and will cover basic climate science, an explanation of the kinds of data the NMS collects, and a presentation of the products and services it provides. It should include support to the sector in communicating climate information within the sector, and to the sector's clients and end users.

Sector-Specific Climate Training Programme

The Climate Information Services (CIS) Sector Action Plans for Tuvalu will guide sector-specific climate training for the five sectors identified in the action plans: these may include fisheries, tourism, water, health, renewable energy, food security and agriculture, and disaster risk reduction.

TMS will engage an international and a national consultant in the second half of the second year to develop a training programme, with guidance materials and capacity building resources, to facilitate the uptake of climate information services by the targeted sectors and their stakeholders. The training will be non-technical and directly relevant to each sector and applicable to its activities. This intervention is replicating an activity implemented by a GCF funded Climate Information Services for Resilient Development Project in Vanuatu.[637]

The consultants will conduct a CIS training needs assessment with TMS, and based on the assessment, will use existing and new CIS information to develop a tailored training programme. The Training Programme will be in line with the Tuvalu Framework for Climate Services (NFCS), the Pacific Island Meteorological Strategy (PIMS) 2017–2026 and the Pacific Roadmap for Strengthened Climate Services.

In year five the sector plans and the communication plans will be re-evaluated and updated using feedback and learnings from each sector.

Train the Trainer for Sectors

TMS will engage an international consultant to demonstrate the use of the CIS training programme through facilitating Train the Trainer sessions for sector personnel, non-governmental organisations (NGOs) and TMS. The training will use sector-specific case studies.

Five workshops will run in the third and fourth year, each targeting a different sector. There will be an opportunity to update the training programme after each workshop.

Climate change risk assessment for staple crops

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Pacific Regional Programme (SPREP) have prepared a guideline[638] to assist NMHSs and their sectoral stakeholders to jointly undertake national and sub-national climate change risk assessments. This includes ancillary communication products to support sectoral stakeholder engagement. It provides step by step guidance to identify, develop and apply climate change information. In Tuvalu, the Department of Climate Change and Disaster, and the Department of Agriculture will conduct climate change risk assessments for key staple crops, which will inform agricultural crop planning. Key staple crops in Tuvalu are breadfruit, coconut, bananas, small taro and *pulaka* (giant taro), which can take seven years to grow.

In this intervention, CSIRO scientists will work with the local sectoral agencies to run a workshop with the key sectoral stakeholders in Funafuti, conduct field studies, collect and evaluate climate model data, construct climate change projections, assess climate change risk and communicate results to decision makers.

T1.1.4 Develop national policies for financing climate services

This Sub-activity will provide the foundation for the establishment of a financially sustainable business model for climate services in Tuvalu. Based on the NFCS established under Sub-activity 1.1.1, the Programme will develop a national climate services financial policy to ensure that TMS has the means to sustain and ensure the ongoing operation of its mandated services in order to mitigate weather-, climate-, and water-related risks.[639]

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[637] SPREP, 2018, Climate Information Services for Resilient Development in Vanuatu. The Project has a Bislama name, “Vanuatu Klaemet Infomesen blong Redy, Adapt mo Protekt (Van-KIRAP)”.
[638] Government of Australia, Developing Climate Change Information, Available at <https://www.pacificclimatechangescience.org/publications/developing-climate-change-information/> [August 2019] . These are designed to facilitate application of the science to inform sectoral risk and impact assessments in the Pacific.
[639] World Bank, 2013. Weather and Climate Resilience. Effective Preparedness through National Meteorological and Hydrological Services

Tuvalu established a Climate Change and Disaster Survival Fund – the "Tuvalu Survival Fund" (TSF) –in 2015. The TSF is intended to support both immediate disaster response efforts and longer-term responses to future climate change impacts and natural disasters.[640] The Programme will work with the TSF Board and Committee to enhance the functions of the existing Fund to ensure that Tuvalu's national climate services are adequately and sustainably financed.

The financial policy will be carefully developed with the support of the World Meteorological Organization (WMO) to ensure that it is tailored to the context of Tuvalu. In line with World Bank guidance,[641] the financial policy will cover the following elements:

- Opportunities for greater cooperation between the public and private sectors and academia given that many economic sectors increasingly depend on meteorological information for safe and efficient operations.
- Opportunities for win-win situations that fulfil the public sector responsibility to help the economically disadvantaged while meeting the needs of enterprises for climate services. To this end, the Programme will ensure that the Government of Tuvalu is made aware of the economic value of climate information in, for instance, reducing the need for dangerous marine rescues, reducing the need for transport of drinking water to outer islands in drought, and reducing the costs of recovery from cyclone damage.
- Opportunities to coordinate and/or integrate financing for climate services and disaster risk management to strengthen existing disaster relief funds and establish reliable funding for disaster preparedness activities, which are often limited to ad-hoc donor funding. This would facilitate a more efficient and streamlined approach to implementing often overlapping actions for climate change adaptation and disaster risk management.
- Identification of elements for a sustainable financial model for TMS based on the climate services value chain, which highlights the different roles of NMHSs in providing basic forecasts and warnings to protect society from the adverse effects of severe weather (a public good typically supported by governments) but also in providing specialised value-added services to government agencies and individual businesses (which may offer opportunities for cost-recovery from governmental and non-governmental sources).
- Potential to establish a National Climate Fund (NCF) as a mechanism to support Tuvalu's engagement with climate finance by facilitating the collection, blending, coordination of, and accounting for climate finance directed towards climate services.[642] According to UNDP guidance,[643] these funds could have the following goals:
    - Collect sources of funds and direct them toward climate change activities that promote national priorities;
    - Blend finance from public, private, multilateral and bilateral sources to maximise a country's ability to advance national climate priorities;
    - Coordinate country-wide climate change activities to ensure that climate change priorities are effectively implemented; and

[640] Tuvalu, 2015. Climate Change and Disaster Survival Fund Act 2015
[641] Ibid.
[642] UNDP, 2015. Blending Climate Finance Through National Climate Funds.
[643] Ibid.

- Strengthen capacities for national ownership and management of climate finance, including for "direct access" to funds.

Functions of NCFs could include:

- Support goal setting and the development of programmatic strategies for climate resilience;
- Fund capitalisation;
- Management of partnerships;
- Provide project approval and support implementation;
- Supply policy assurance;
- Provide financial control;
- Manage performance measurement, including monitoring and reporting on activities and resource disbursement; and
- Provide and support knowledge and information management.

- Potential for continued support from the Systematic Observations Financing Facility (SOFF) as part of the Alliance for Hydromet Development, which was launched in December 2019 by 12 international organizations including UNEP. The SOFF is envisaged to ensure provision of basic systematic observations as a global public good by providing equitable, predictable, sustainable, and performance-based finance as well as technical assistance to developing countries for the provision of foundational observational data as per the Global Basic Observing Network (GBON) standard adopted by the WMO Congress in 2019. GBON aims to improve the global availability of the most essential surface-based data by defining the obligation for countries to implement a minimal set of surface-based observations for which international exchange of observational data will be mandatory.

RESULT 2 – STRENGTHENED OBSERVATIONS, MONITORING, MODELLING AND PREDICTION OF CLIMATE AND ITS IMPACTS ON OCEAN AREAS AND ISLANDS

Activity 2.1 Infrastructure and technical support for observations and monitoring

T2.1.1 Enhance national observations and monitoring networks to GBON standards and establish QMSs

Strengthen the network of land-based observations and improve observation station density in compliance with GBON

The Programme will procure equipment to strengthen the network of land-based observation stations measuring atmospheric pressure, temperature, humidity, horizontal wind and precipitation and regular reporting of data in compliance with the provisions of the WMO Global Basic Observing Network (GBON). WMO have proposed a target number of 19 observation points across the EEZ of Tuvalu.[644] The Programme will facilitate observations through a mix of surface-based, upper air and

[644] SOFF, 2020. Systematic Observations Financing Facility. Collaborative thinking workshop. Workshop outcomes and the way ahead. February 25-26 2020, Offenbach, Germany

marine observations. Critically, funding will be supplied for communications to ensure that observations can be made available via GTS to WMO, in compliance with GBON.

Installation of eight AWS and one AWOS station

The Programme will install eight new/upgraded Automatic Weather Stations (AWS), located at Nanumea, Nui, Nukufetau, Nukulaelae, Vaitupu, Nanumanga, Niulakita and Niutao, with sensors for rainfall, air temperature, barometric pressure, wind speed and direction, soil temperature (10, 20, 30 cm) and soil moisture. The stations will contain all-parameter local Modbus Meteorological Display Consoles (MMDC) including METAR/SYNOP coded message display. In addition, one new/upgraded Automated Weather Observing System (AWOS) will be installed at Funafuti. The AWOS station will contain AWS sensors (as above) as well as a ceilometer and visibility meter.[645]

Tuvalu will also procure three sets of AWS spares and a bench-top instrument calibration kit.

The AWOS installation in Funafuti (and the AWS' in the outer islands) will improve TMS's ability to monitor and report the current weather in real time, including providing timely METAR and SYNOP messages to the WMO Global Telecommunication System GTS to help improve global weather forecasting services over Tuvalu. The near real time data transmissions will help the regional forecast centre (Regional Specialised Meteorological Centre, Nadi) to provide improved TAFs (Terminal Aerodrome Forecasts) for Funafuti International Airport. The AWOS will improve Tuvalu's capability to monitor potential changes in the frequency and severity of climate and weather extremes, such as extreme wind speeds and periods of dry weather and drought.

Improved monitoring of climate on remote islands and provide timely advice to local inhabitants during periods of extreme weather such as during drought. Rainfall is typically the only source of water on some islands and monitoring of changes in rainfall patterns due to seasonal and long term climate changes is crucial to ensuring islands do not run out of essential supplies of water such as for drinking, crop irrigation, and sanitation. The equipment will enable TMS to provide the Tuvalu Government with early detection of low rainfall and water storage levels, so that early remedial action can be planned and implemented before critical water shortages occur.

The new AWS' will provide for the five new proposed outer island stations and other islands as well and will enable TMS to detect the beginning of slow onset extreme events such as drought. That means TMS can warn the Government that they should plan for a shortage in the next weeks or months and pre-order shipments of drinking water—in the past, by the time a drought is declared and transport arranged, the situation on outer islands has been desperate.

[645] These are the proposed sites under the current baseline and to support GBON. Given the dynamic nature of projects in the Pacific, these sites will be reconfirmed during each year of implementation and should site locations require changes, this will be done within the context of GBON and within the current budget.

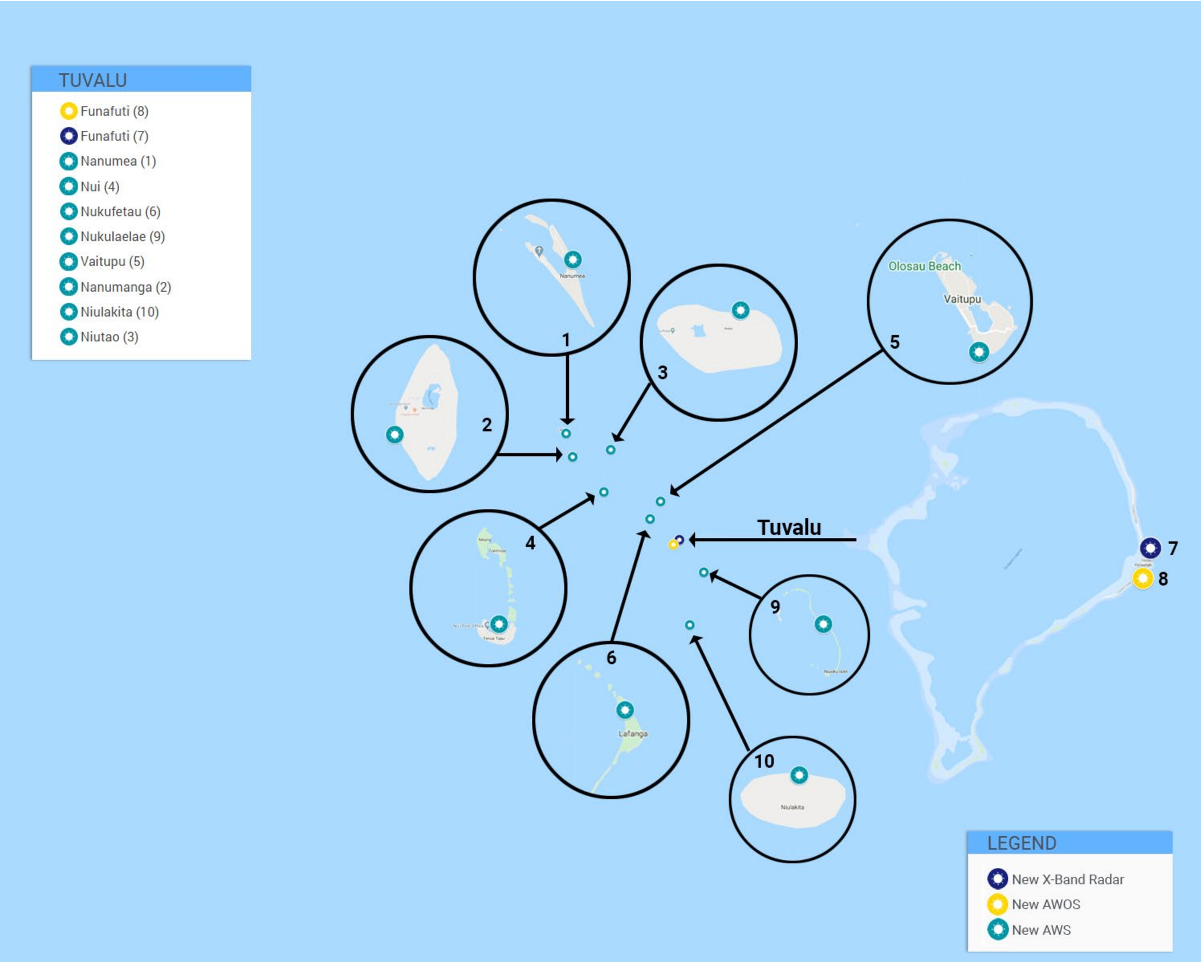

Figure 97. Proposed land-based observation network in Tuvalu

VSAT for Funafuti

TMS proposes to purchase a Very Small Aperture Terminal (VSAT) which will enable it to maintain communications during severe weather. A VSAT can transmit and store data from the Funafuti automated weather station, and transmit information to Tuvalu's outer islands, using the very narrow band width available. Observation data during severe weather is absolutely vital for forecasters and TMS's current communication equipment is not reliable. Often important data is not received when it is most needed and the data essential to long term climate records may even be lost, and must be estimated. The VSAT is robust and will ensure the accurate collection of a very valuable dataset for the analysis of climate change. NIWA has developed the Modbus Meteorological Display Console (MMDC), which will be made available to both outer island weather stations and the Funafuti AWS at a marginal cost per unit.

VSAT is generally used as a last option where no other terrestrial communications infrastructure is economically possible. VSAT is also used as a bandwidth delivery solution for WiMax and cellular "last mile" distribution systems, for example, to island resorts. A VSAT network is completely independent from any terrestrial infrastructure, each remote site is autonomous and can be powered from a solar power system, thus even the most remote location can have a VSAT service. A VSAT remote site can be deployed in any location, as long as there is visibility towards a satellite—some villages in the bottom of the valleys may not be able to get a clear line of sight to a satellite. Almost all VSAT system have performance and throughput capabilities exceeding most real customer requirements. Practically, the system throughput is not determined by the technology, it is determined by the customer's available budget to pay for satellite bandwidth. Using appropriate design, a VSAT system can be tailored to support almost any application or service. The key factor is versatility, adaptability and choosing appropriate technology for the job at hand.

Construction of meteorological offices on five outer islands

The Tuvalu Meteorological Service proposes to construct small stations on each of five outer islands, Nanumaga, Niutao, Vaitupu, Nukufetau and Nukulaelae to improve its service to island communities, expand the range of its data collection and contribute to understanding the impacts of climate change. Each island has an Island Strategic Plan, and typically these propose the establishment of a meteorological presence on the island—a trained observer and basic observation equipment such as rain gauges, thermometers and anemometers.

Island communities understand that the collection of their local data provides the basis for downscaled climate services. Their strategic plans prioritise practical advice on adaptation and resilience to climate change, restoration and sustainable use of ecosystems, reversing land degradation and preventing the loss of their biodiversity. Automated Weather Stations need frequent expert maintenance and are difficult to keep operational in tropical environments: the equipment will be manual or semi-automated and data will be ingested to a data logger.

Communication with outer islands is also expensive and unreliable, and Tuvalu Meteorological Service (TMS) will try several approaches to retrieving the data and ingesting it to Climate Data for the Environment[646] (CliDE), starting with emailed observations or using a system in which the inter-island ships' captains pick up a data storage device on their regular trips and leave an empty one for the meteorological officer. Climate data does not need to be collected in real time, as it is a record of monthly, seasonal or long-term trends.

[646] CliDE is a purpose-built climate data management system used in all 14 Pacific island countries.

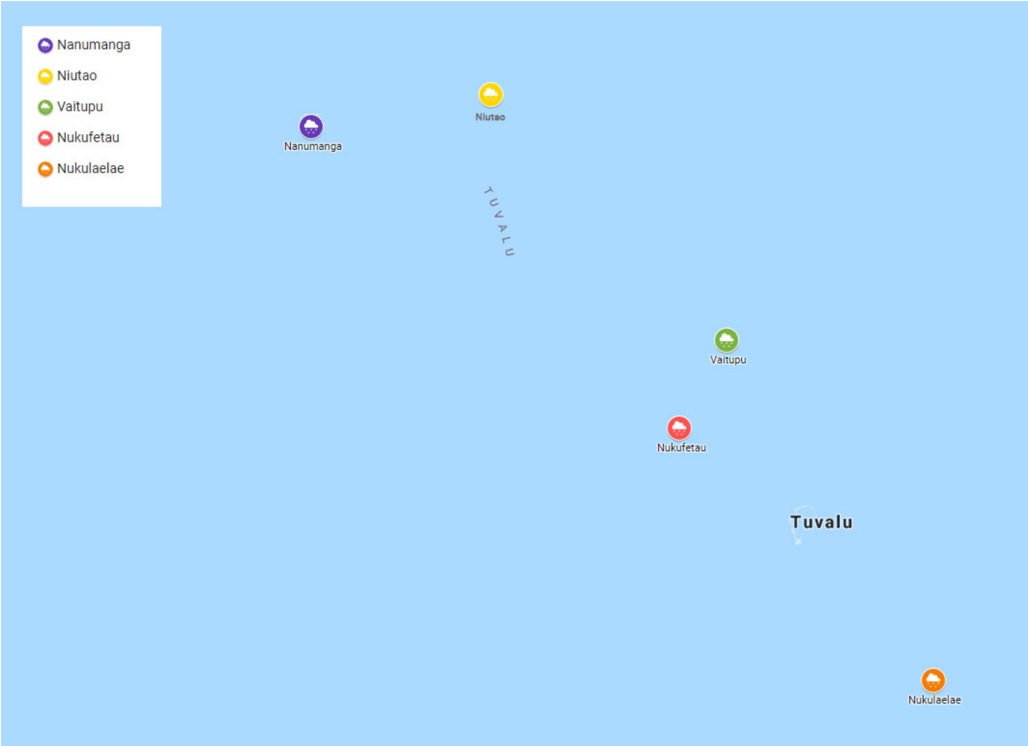

Figure 98. Map of Tuvalu Met offices and equipment locations

TMS has formal permission in writing from the five islands' Falekaupules to use an area of land for the construction of a small building to house and power the meteorological equipment. Detailed construction plans have been provided by TMS. The equipment itself will be maintained and calibrated by TMS officers making the twice annual trip around all the islands, during one of which the officers will present the National Climate Outlook. This presentation will be given before the start of the cyclone season each year and will include practical advice on preparation. During the other maintenance visit, the TMS will deliver climate awareness information and advice on applying the current long range forecast.

Improved monitoring of the climate on remote islands will enable TMS to advise communities during periods of extreme weather, particularly cyclones, high seas and drought. Rainfall, either replenishing the freshwater lens or captured in rainwater tanks, is the only source of water on most islands.

TMS is already able to predict seasonal rainfall trends using SCOPIC. When climate conditions indicate the next few months are likely to be dry, they can advise communities to check their rooves are sound, gutters are clean, and tanks are in good repair so that what rain does fall is collected and stored. When TMS can monitor rainfall accurately on outer islands, they will be able to detect an approaching hydrological drought and to advise communities, before their supplies run low, that they will need to manage consumption carefully for months to avoid critical water shortages.

Installation of a dual-polarization X-band Doppler radar

The Programme will install a dual-polarization X-band Doppler radar. Dual-polarization radars obtain information on both the horizontal and vertical dimensions of precipitation particles, which gives meteorologists a better understanding of the size and shape of particles. The advantages of dual polarization include:

- Improved accuracy of precipitation estimates, leading to better flash flood determination;

- Ability to differentiate between differentiate between different types of precipitation;
- Improved detection of non-meteorological echoes (e.g. tornado debris, birds, etc.);
- Detection of aircraft icing conditions.[647]

A Doppler radar is capable of measuring the velocity of precipitation particles (and thus, the wind). This enables Doppler radars to identify the detailed wind structure within severe thunderstorms.

The choice of an X-band system is on account of its low cost – in comparison to S or C band systems – and its small size, with potential for portable options. This is particularly important for the Pacific SIDS, which may have complex topography that limits accessibility for larger systems.

In addition to infrastructure, the Programme will provide technical training (Sub-activity 4.1.2) to build in-country capacity for radar operations, maintenance and data applications for weather and climate monitoring and analyses.

Basic Information Package Meteorological Training (BIP-MT)

Providers such as the Fiji Meteorological Service will deliver Basic Information Package Meteorological Training (BIP-MT) to new TMS technicians to enable them to take observations correctly, record them correctly and save the data securely. New observers will also be trained to calibrate and maintain the TMS's in situ observational equipment. This is fundamental to cost effective and consistent data collection and is a WMO requirement. Existing staff will be able to take the course as a refresher in maintenance and calibration. The course consists of foundation topics in maths and physics, physical and dynamical meteorology, basic synoptic and mesoscale meteorology, basic climatology, meteorological instruments and methods of observation.

Quality Management System (QMS)

The Programme will establish a Quality Management System (QMS) to help to enhance the quality of TMS activities, including streamlining and optimising the processes and procedures applied and the products and services provided. TMS staff will engage with experts from the WMO network and participate in training and an annual QMS workshop. The objective is to become compliant with ISO9001:2015.

Activity 2.2. Ocean and climate modelling and impact-based forecasting

T2.2.1 Establish ocean information services

The Pacific Community (SPC) is the principal scientific and technical organisation in the Pacific region, supporting development since 1947. One of the key objectives of the Geoscience, Energy and Maritime (GEM) Division of SPC is to strengthen ocean and coastal monitoring and prediction services in Pacific island countries.

SPC is currently implementing several projects and methodologies relevant to this proposal. It is a key implementing partner in the Australian-funded Climate and Oceans Support Program in the Pacific (COSPPac) managed by BoM and hosts the region's oceanographic capacity building and technical training hub, home to the Pacific Ocean Portal and several other marine meteorology training tools. Since 2016, SPC staff have conducted training in Tuvalu on introductory ocean science, ocean monitoring, and the application of ocean data and forecasts for improved decision-making. SPC has supported stakeholder engagement workshops to facilitate feedback to TMS from potential users in

[647] National Weather Service. Dual Polarization Radar. Available at: https://www.weather.gov/bmx/radar_dualpol

fisheries, tourism, environment, national disaster management, maritime police, shipping companies and others. The lessons learned from these workshops inform future engagement with key ocean stakeholders and communities.

Ocean observations and monitoring

Environmental and wave buoys

SPC will support the establishment of medium to long term in-situ ocean observation environmental buoys and wave buoys providing data on currents, waves and water quality directly to the TMS.

These will make possible routine ocean monitoring efforts using medium to long-term water quality sensors, and in-situ coral mapping. Baseline monitoring via regular (and post disaster) drone survey will allow shoreline changes and erosion to be recorded and analysed.

Once monitoring sites are established, SPC will link this data to calibrate satellite derived ocean observations, improving understanding of local impacts and establishing proxy relationships between ocean drivers and coastal impacts for algal blooms and other monitoring priorities. This monitoring equipment will improve downscaled ocean forecast models for Tuvalu.

Ocean information services

Development of an ocean modelling framework to inform risk-based planning and early warning

Coastal ocean processes are driven by large-scale oceanic and atmospheric conditions, such as atmospheric pressure and sea surface temperature. With support from SPC, the Programme will develop an ocean modelling framework, which will link these large-scale regional drivers to local (island to lagoon scale) impacts. The framework will provide Tuvalu with state-of-the-art coastal oceanography and hazard data. This will inform improved local risk-knowledge and impact-based early warning (e.g. annual, monthly, and intra-daily).

The development of this framework requires a three-step methodology:

1. Analysis of long-term large-scale ocean and atmospheric data to map their spatial and temporal variabilities and identify annual, monthly and daily predictors that drive localised ocean conditions and their impacts.
2. Statistical and dynamic downscaling of localised ocean information based on individual country needs and priorities. For example, the Programme will develop downscaled wave, circulation and inundation models at country, island and lagoon scales.
3. Establishment of a long term integrated ocean and coastal impact monitoring program combining remote sensing and in-situ ocean and coastal impact data collection and analysis. The monitoring program will be tailored around the local impacts either directly or via a proxy indicator (for example, turbidity, chlorophyll, inundation, erosion information). The monitoring information will be used to refine downscaled solutions.

The following table provides further details on proposed downscaled ocean products, their various coverage and resolutions as well as proposed monitoring sites, equipment and techniques.

Downscaled Models (resolution)	Observation / Monitoring	Proposed Target Sites
Country scale (kilometres) • Wave • Circulation ***Island scale (100s metres)***	***In-situ observation*** • Surface wave and environmental buoy (modular system that can measure a wide range of physical and environmental oceanic	***Tuvalu lagoon downscaling and monitoring sites:*** • Funafuti

• Wave • Circulation ***Lagoon / coastal scale (metres)*** • Wave • Circulation • Inundation (country-scale coverage)	variables – e.g. real-time temperature, salinity, dissolved oxygen, waves, pH, etc.) • Various temporary physical and environmental oceanography loggers • Drone survey for shoreline change and post-disaster impact survey ***Remote sensing derived coastal observation*** • Water quality mapping (e.g. turbidity, chlorophyll, coloured dissolved oxygen matter) • Marine habitat mapping – including in-situ sample data collection • Shoreline change analysis • Post-disaster impact mapping	• Additional atoll to be determined in the inception phase

Table 34. Proposed downscaled products, monitoring sites, equipment and techniques (Source: SPC)

Provision of ocean services, data management systems and visualisation via the Pacific Ocean Portal

The data collected and produced through the ocean modelling framework will be integrated into a data management system and converted into actionable information through decision making tools tailored to fulfil ocean stakeholder needs. Due to the limited internet bandwidth in the region, all downscaled ocean products and monitoring information will be easily accessible via local servers to ensure optimised use of the information. Furthermore, the data will be integrated into the Pacific Ocean Portal – the region's centralised platform for ocean data visualisation.

Capacity building to strengthen local ocean monitoring programs and oceanographic capability

To facilitate a sustainable local monitoring program, SPC will provide training and capacity building for technical, ocean monitoring focal points at TMS, such as the Programme-hired National Ocean Expert (see intervention below). Focal points will be trained at SPC and in-country on maintenance of monitoring equipment and undertaking of coastal impact surveys. Over the five years of the Programme, focal points will receive on-going oceanographic capacity building through various regional and international trainings including certified trainings those offered through the International Oceanographic Data and Information Exchange (IODE). In addition, 2 – 3 key climate and forecasting staff identified at TMS will undertake attachment training at SPC on applications of the ocean data and forecasts made available through the Programme.

SPC will work with TMS to develop information products and ocean services and carry out at least one in-country stakeholder engagement workshop in each country to socialise users to these new services and incorporate feedback to enhance their usability (see intervention below).

In addition, through this Programme and in coordination with complementary disaster management initiatives, SPC will work closely with the National Disaster Management Office (NDMO) to capitalise on the improved hazard and risk information to inform planning and investment. Through this proposal SPC will work closely with WMO to support Tuvalu to fulfil its requirements under the WMO Marine Meteorology competency framework.

National Ocean Expert

One of TMS's highest priorities—in response to user demand—is to acquire the capacity to generate ocean climate information. Tuvalu's landmass is very small and the vast surrounding ocean is an integral part of its environment as well as the major influence on its climate. TMS proposes to engage a Programme-hired National Ocean Expert to begin developing this new capacity, with support from oceanographers in SPC.

A new ocean modelling framework will be developed with the support of SPC and working with the National Ocean Experts recruited by the other Programme countries. SPC will support the development of ocean data management systems, and the provision of new ocean services will inform Tuvalu's risk-based planning and early warning systems. New data will feed into the Pacific Ocean Portal (managed by SPC), which visualises data on request, converting it to easily understood, tailored maps and diagrams.

The National Ocean Expert will strengthen Tuvalu's local ocean monitoring programmes and oceanographic capability. The benefits of monitoring the local ocean climate directly help people—subsistence fishermen and tourists—to avoid unnecessary risks and will contribute invaluable data to the scientific community. The National Ocean Expert will extend TMS's capacity to give practical advice to subsistence fishers and tourists. The consultant will monitor threats to reefs—warming and bleaching—so that harm can be minimised. When coral is stressed by atypical heat, if the reef is protected temporarily from human activity, it will recover more quickly; if people are warned of an elevated risk of ciguatera poisoning, they can avoid eating reef fish species during the warming episode.

SPC will support the National Ocean Expert and TMS to conduct ocean data stakeholder engagement workshops, including outer islands, twice yearly in Years 2 – 5 of the Programme. The emphasis will be on communicating the impact of hazards, rather than simply conveying technical information from the forecasting system.

The capacity of TMS to communicate impact-based forecasting and warnings, and the ability of other agencies and communities to understand the warnings and take effective action, will be improved through this more frequent interaction. The National Ocean Expert will establish feedback mechanisms to make sure his/her delivery of information is effective and is modified if needed. TMS will use existing in-country early warning systems and compatible software to deliver ocean information to ensure its accessibility to all users. An ocean outlook, presented as a bulletin or via other media, can be made very useful to users in sectors affected by ocean conditions.

Expected results

The expected results and key deliverables of the Ocean Information Services intervention in Tuvalu are outlined below:

1. **Improved hazard risk knowledge**
    a. Analysis of inundation hazard and risk for all islands;
    b. Localised impacts to coral reefs and vulnerable bleaching areas;
    c. Water quality and lagoon residence time in Funafuti Lagoon.

    Through the development of an ocean modelling framework, this component will assess and quantify the multiple marine hazards and physical vulnerabilities that contribute to coastal inundation, decreased lagoon health and marine life (coral and fish) in coastal waters. Via the development of decision-making tools (e.g. graphical user interface with capacity to generate automated reports tailored to stakeholder needs), the risk knowledge generated will inform response planning, coastal adaptation solutions and investment. This component will also commence a comprehensive approach for capacity building to meet the WMO competency framework requirements for marine meteorology and oceanographic services.

2. **Detection and monitoring procedures established**

   a. Establishment of quasi-permanent in-situ data collection using HF Radar and wave buoys providing near real-time data on currents and waves directly to TMS;

   b. Strengthening routine ocean monitoring efforts using medium to long-term water quality sensors, and in-situ coral mapping;

   c. Baseline monitoring via regular (and post disaster) drone survey quantifying 3D shoreline change and erosion;

   d. Once monitoring sites are established, SPC will link this data to calibrate satellite derived ocean observations, improving understanding of local impacts and establishing proxy relationships between ocean drivers and coastal impacts for algal blooms and other monitoring priorities.

   This component will improve downscaled ocean forecast models for all islands in Tuvalu. This includes installing observation systems and procedures such as real-time ocean data from surface buoys and radar systems, developing tailored remote sensing solution for lagoon water quality monitoring and conducting post-event assessments to collect sound impact data. An emphasis will be placed on training on the use and maintenance of in-situ and remote sensing observation data and equipment as well as conducting tailored impact surveys. Throughout the Programme lifetime, SPC in partnership with Tuvalu will develop the foundation of an ocean-driven impact-based forecasts based on an open source and affordable monitoring solution. The success of this ambitious system relies on a long-term impact monitoring effort; as the monitoring data will inform the continuous improvement of the impact-based forecast.

3. **Enhanced ocean services, impact forecasting, and data accessibility**

   a. Inundation early warning system for all islands;

   b. High-resolution circulation model and particle tracking forecast and hindcast models;

   c. Accessibility of near real-time ocean data for decision making via local and regional portals.

   The ocean framework developed will provide annual, and monthly impact-based ocean outlook as well as impact-based forecasts. The warning system will be tailored to local conditions and circumstances, including capacity in its use and maintenance. The system will comprise a multivariate forecasting tool to obtain fast and accurate estimates of potential site-specific impact. Meanwhile, the high-resolution circulation model and particle tracking forecasts will support decision making on search and rescue, pollution management control, navigational safety, and establishment of temporary MPAs to protect turtle hatchlings, coral and fish larvae. This quality controlled data will be directly available to TMS via local servers in near real-time, but will also be integrated into existing local databases and regional interfaces including the Pacific Ocean Portal, thus facilitating public access, understanding and application.

4. **Strengthened local oceanographic capacity, communications and ocean data stakeholder engagement**

   a. National Ocean Expert position established;

   b. Twice annual ocean data stakeholder engagement workshops, including outer islands.

This component places an emphasis on communicating the impact of the hazard, rather than simply conveying technical information from the forecasting system. The capacity of TMS to communicate impact-based forecasting and warnings, as well as the improved ability of other agencies and communities to understand the warnings and take effective action, will be improved via more frequent interaction and collaborative establishment of feedback mechanisms. The products will be disseminated within standards and institutional mechanisms that are compatible with existing in-country EWS communication platform.

T2.2.2 Enhance climate information and impact-based forecasting

Young Scientist Support Program

To support the enhancement of in-house forecasting capacity, the Programme will build a strong scientific and analytical foundation for NMHSs through training and mentoring attachments covering climatology and oceanography. Early-career scientists from NMHSs will be selected to undertake in-depth technical capacity building through a customised Young Scientist Support Program (supported by APCC), including highly in-depth training for 2-3 months exploring various climate prediction and analysis techniques such as downscaling predictions, generating sub-seasonal-to-seasonal forecasts, analysing large-scale patterns, and tropical cyclones, etc. This will equip participants, particularly those with less experience, with both the basic knowledge needed to perform their duties as climate officers, as well as more advanced knowledge that can help them develop downscaled or impact-based forecasts.

National Climate Expert

To support the provision of the much-expanded climate information services, TMS proposes to engage a Programme-hired National Climate Expert, at science graduate level, for the five-year term of the Programme. Previous experience indicates the positions are likely to be made permanent thereafter, as the value of the extra services made possible is demonstrated. The National Climate Expert will focus on climate science and data analysis for new functions and will take day to day responsibility for sector coordination, working with the sectoral ministries including National Disaster Committee, Health, Environment, Agriculture, Water and Fisheries. The consultant will develop new products in response to demand from the sectors.

Training attachments and mentoring

The Australian Bureau of Meteorology (BoM) is a long-term partner of Pacific island meteorological services, delivering the Pacific Sea Level Monitoring project since 1991 and supporting the development of seasonal climate forecasting capacity since 2003. Since 2012, BoM has collaborated with TMS and other NMHSs in the Climate and Oceans Support Program in the Pacific (COSPPac), supporting the achievement of NMHS's priorities for delivery of reliable and accessible climate information services. TMS proposes staff attachments for training and mentoring with BoM, specifically to improve climate and ocean monitoring and prediction skills. Familiarity with the range of different climate models used in large meteorological services will give TMS climate officers a stronger understanding of climate and ocean processes.

BoM will provide training attachments focusing on seasonal prediction using ACCESS-S software and on the use of information in preparing for the tropical cyclone season and for climate extremes such as droughts and floods. TMS staff will learn the use of ACCESS-S for seasonal forecasting for ocean conditions.

BoM will help TMS staff on attachment to prepare scientific material for publication and provide opportunities for them to present papers and posters at climate conferences. TMS's budget allows for a total of 12 weeks' attachments for the National Climate Expert over the term of the Programme and 12 weeks for the National Ocean Expert.

Early Warning Systems (CREWS, EAR Watch and Impact Forecasts)

The larger Pacific meteorological services are generating products and developing services in response to demand from climate-sensitive sectors in their countries, and BoM's training inputs will benefit from their experience in facilitating this work over the last ten years. NMHS staff are ready to use the seasonal forecasts they now generate every month into tailored products for specific sectors with support from BoM in establishing the format of products and the technical process of generating the information. This sub-activity will build on early work undertaken through COSPPac and COSPPac 2.

BoM will conduct workshops in partnership with TMS to build the scientific understanding of staff and their capacity to explain to their clients the application of climate monitoring and prediction products to their sectors. It will conduct three Climate Risk Early Warning System (CREWS) and Early Action Rainfall Watch (EAR Watch) workshops over the term of the Programme. It will provide seasonal prediction training and training in the use of information for preparing impact-based forecasts, which give specific advice to government and communities on preparation for extreme events.

Through this sub-activity BoM will contribute to TMS's knowledge sharing by supporting an officer to publish scientific material and to attend a relevant conference.

Climate data digitisation

Meteorological data on climate trends and risk information can help identify existing vulnerable areas and communities located in or adjacent to these areas. It also can assist in supporting more targeted activity in community-based disaster risk management and climate change adaptation actions. In the occurrence of a natural disaster the database also provides extremely useful baseline data and information for conducting timely and effective post-disaster damage assessments.

The Australian Bureau of Meteorology (BoM) has worked with TMS since 2013 on a robust open source climate data management system (CDMS) for all 14 Pacific NMHSs, the Climate Data for the Environment (CliDE) software package. CliDE has replaced the multitude of CDMSs used in the past in Pacific countries, now mostly obsolete and unsupported. The software has gone through a continuous process of improvement and is now used in all the partner countries to ingest data, store it securely with backup, and make it available for manipulation for information products. CliDE is used as the basis for donor-provided add-on software such as NIWA's CliDEsc and for tools developed by BoM such as a drought monitoring tool.

The Tuvalu Meteorological Data Digitisation Project proposes to convert a large volume of historical observation records on paper into digital form and to ingest them into CliDE. Records held in NIWA's database also be converted to a form compatible with CliDE so they too can be used in analyses. CliDE will improve the availability of data for National Meteorological Services, other government agencies and researchers. The Tuvalu Data Digitisation project aligns with the Pacific Islands Meteorological Strategy (PIMS) 2012–2021 under Pacific Key Outcome 8: Pacific island countries and territories' historical climatological data are preserved.

A long time series, in Tuvalu's case potentially from 1951 for Funafuti, has great value for a meteorological service. A decades-long reliable dataset from a specific location makes it possible to discover long term trends, and to make projections of future changes.

The benefits of this sub-activity will be:

- TMS will have extended time series, valuable for developing accurate long-term climate trends;

- A true representation of how the climate has evolved in Tuvalu will be reported on, as part of Annual Climate Summary Report, Monthly Seasonal Climate Outlooks, etc.;
- It will make possible climate services and products tailored to meet societal demands, through the availability of good quality datasets to support modelling and prediction system developments, in accordance with the WMO Global Framework for Climate Services;
- It will enable Tuvalu to develop a fully-fledged Climate Early Warning System (CLEWS) to improve people's resilience—a solid data foundation is an important element.

Risk assessments in communities and climate sensitive sectors will benefit from the availability of meteorological data, available in different digestible formats including GIS, raw statistics and processed reports.

National Climate Data Consultant

The Programme will support the recruitment and training of a National Climate Data Consultant (NCDC) who will work within the Department of Environment, with support from the manager of SPREP's Inform data management project. The NCDC's role is to publicise the Tuvalu Environment Data Portal, to extend its user base and to help the users of its data to maximise their skills.

The NCDC will build capacity among key government staff to validate data as well as to share and promote their data with their primary audiences. The NCDC will serve as national administrator for the data portal, assigning access and ensuring users are making full use of the capacity of the system. To open lines of communication among the various national owners of data, the NCDC will host regular meetings with the national data community, communicate regularly with national and regional partners, and track the use and application of the national portal and its products. The NCDC will serve as the project focal point for the regional environment Data Manager at SPREP.

The NCDC will participate in training with the NCDCs of the other four countries in online cloud hosting skills and knowledge, and in sub-regional exchanges and South–South learning. The Inform project manager in SPREP will focus on helping the NCDC to locate data and to develop workflows enabling the Department of Environment to access and use climate impact data.

The NCDC's work will contribute to achievement of Goal 2 of the National Climate Change Policy[648] and its National Strategic Action Plan (NSAP): *Improving understanding and application of climate change data, information and assessment to inform adaptation and disaster risk reduction programmes.* Harmonisation of the way in which data is recorded will make it possible to use UNEP's Country Level Impacts of Climate Change (CLICC) principles, using consistent formats for data records so that the TMS's climate data can be presented with national data from other sources, coherently and transparently. This has potential to reduce significantly the burden of reporting Tuvalu's performance against multilateral environmental agreements and to improve the quality of its reports. This in turn has benefits for the Government of Tuvalu's understanding of climate change impacts and its capacity to plan effective adaptation.

CliDE sector data management

Better monitoring of monthly sector data will provide climate information that TMS can use to provide data analysis back to their client sectors including health, fisheries and agriculture. Risk assessments in communities and climate sensitive sectors will benefit from the availability of meteorological data, available in different digestible formats including GIS, raw statistics and processed reports. BoM will conduct two training attachments for TMS staff (and Niue NMHS staff) and during the term of the

[648] Government of Tuvalu, 2011. National Climate Change Policy 2012 – 2021

Programme will make four trips by BoM staff to Funafuti for installation of CliDE and to deliver in-country training in the use of the software. In addition, BoM will replace the ageing CliDE server in TMS, update user and administrator manuals and provide refresher user and administrator training on CliDE and its new products.

TMS has already discussed data availability and harmonisation with the Ministry of Health and the Fisheries Department, in the context of developing data and information products that will be useful to those sectors. Tuvalu's climate data is collected and kept at a significantly higher standard than other national data: good quality data is collected systematically, recorded and stored digitally, backed-up reliably and readily retrieved for use in information products.

This is not the case for health data or information, and probably for other sectors, although the fisheries sector has a database that allowed them to undertake work with SPREP on ciguatera incidence. These two agencies are interested in developing data entry forms that would enable Health to use CliDE for data storage and allow both agencies potentially to create information products that use both climate and sector data.

This intervention will enhance TMS's ability to use CliDE to monitor Tuvalu's sectoral data in several steps:

- Develop a key entry form for monthly sector data (health, fisheries and agriculture);
- Build and upgrade the analysis of sector data in CliDE;
- Develop training modules – this could potentially be delivered as an accredited tertiary course through the Pacific Climate Change Centre at the SPREP campus in Apia.

Customised climate information and early warnings

NIWA will support the design, customisation and production of CliDEsc (CliDE Client Services) early warning products. CliDEsc is a product generator platform managed by NIWA that enables real time analysis of climate and other environmental data from the CliDE database and other sources of data.

CliDEsc products, reports and advisories can be customised for early warning reporting. TMS climate officers can use CliDEsc products to get up-to-date information to key risk managers, helping to inform their decisions and so make early action and responses possible. CliDEsc is currently used in eight Pacific countries, but has yet to be installed in Tuvalu and Niue. The basic software platform is soon to be installed in Tuvalu and Niue under Australia's COSPPac program. This Programme will enable NIWA to discuss with TMS (and with climate and environmental risk managers) its information needs, and to customise information derived from climate observations that can be routinely generated and delivered.

This work builds on earlier climate early warning system (CLEWS) projects that NIWA has implemented in the Pacific region, funded by the GEF, World Bank, and through NIWA's capital development program. Examples under the GEF include the "*Solomon Islands Water Sector Adaptation Project* (SIWSAP)", the *Integration of Climate Change Risk and Resilience into Forestry Management in Samoa* (ICCRIFS), and the Cook Islands project "*Strengthening the resilience of our islands and our communities to climate change (SRIC-CC)*". These were implemented in collaboration with UNDP and the partner countries' ministries. The World Bank project "*A Drought Risk Visualisation Tool Kit for Pacific Island Countries"* was funded under the GFDRR Challenge Fund. The combined value of these example projects exceeds US$1.5M. The products developed using the combined CliDE/CliDEsc data management and product generator platform are transferrable between Pacific countries where CliDEsc is installed, currently numbering eight countries in all. Installation of the basic CliDEsc package in a further six countries, including Tuvalu, will be funded under COSPPac.

RESULT 3 – IMPROVED COMMUNITY PREPAREDNESS, RESPONSE CAPABILITIES AND RESILIENCE TO CLIMATE RISKS

Activity 3.1 Warning dissemination and communication

Under this Activity, the Programme will enhance the dissemination and communication of climate risk information and early warnings based on the enhanced data generated under Result 2. The Programme will particularly focus on strengthening last-mile communication systems to ensure that people and communities in remote locations receive warnings in advance of impending hazard events. TMS will be supported to develop a range of communications products tailored to end-users at the community level.

T3.1.1 Strengthen EWS organisational and decision-making processes

This sub-activity will ensure the effective and coordinated delivery of early warning services through strengthened organisational and decision-making processes of TMS, the National Disaster Management Office (NDMO), civil society organisations and other key actors.

An annual workshop will be conducted to define the functions, roles and responsibilities of key EWS actors; develop warning communication strategies; and develop, trial and refine Standard Operating Procedures (SOPs). The workshops will be attended by various EWS stakeholders, NDMO and TMS representatives. The warning communication strategies to be developed will facilitate coordination between TMS – as warning issuers – and with downstream dissemination channels, such as island community volunteer networks. The strategies will include the development of community feedback mechanisms to verify that warnings have been received and to alert TMS to potential gaps in communication networks. At the start of Programme implementation, an in-country deep dive study on gender and community stakeholders will be conducted to facilitate that the design of EWS organisational and decision-making processes is gender-responsive and that such processes proactively consider and address the specific needs, concerns and capabilities of different gender groups. Knowledge gained and outputs from the workshops will be leveraged in development of the Forecast-based Financing mechanism (Activity 3.3).

T3.1.2 Strengthen communication systems to reach the last-mile

This sub-activity will enhance connectivity and communication systems to facilitate that climate information and early warnings reach communities at the last-mile, including on remote outer islands; and that communication channels are resilient to the impacts of extreme climate events. This will be achieved through the following interventions:

Last-mile communication strategies

Weather and climate glossary

"Last mile" communication of climate information and extreme weather warnings is a perennial issue for most Pacific countries. Information is generated by climatologists and meteorologists who have studied physics in English, but many people in their audiences have high school level education at most, in their national language. Scientists prefer to make statements they know to be correct, such as that a low pressure system is approaching their country, and to avoid making statements they regard as speculative, such as that the system will bring storms of specific severity in a specific time period: this, however, is what their listeners need to know. There is always a level of uncertainty in a forecast, and it is difficult to explain degrees of confidence. This uncertainty adds to the reluctance of staff to make definitive statements predicting rainfall or wind speeds and their likely impacts.

Everyone agrees[649] that communities need to get timely reliable forecasts, particularly for extreme events, that include clear statements on the probable impacts and specific advice on how to prepare, in their own language. This Programme's contribution to the generation of timely and reliable local forecasts is addressed in Result 2. The development of a coherent process for sharing information with the National Disaster Management Office, the Tuvalu Media Department, Red Cross and island disaster committees is addressed in Result 1.

Tuvalu's Te Kaniva Tuvalu Climate Change Policy 2012 identified a "lack of capacity and resources to translate weather and climate information to end users" as a serious issue that required immediate address. The Tuvalu Media Department has expressed concern at the complexity and technical terminology of the climate information it receives. Surveys indicate people in communities outside the capital, particularly women, who need climate information for fishing and gardening as well as warnings, do not use the scientific forecasts available to them, although they listen to the radio. They rely on traditional family-held climate knowledge, which is already becoming unreliable for forecasting, as warming disrupts familiar weather patterns.[650]

The Finnish-Pacific (FINPAC) project, implemented by SPREP, conducted a workshop in Tuvalu in 2015, bringing together TMS officers, sector agencies, women's organisations, the Media Department and NGOs to begin the development of a glossary of climate and weather terms. The workshop was productive, and a basic glossary was begun. Participants noted the challenges—the term "swell", straightforward to meteorologists, takes a paragraph to explain in Tuvaluan, for instance and may need a new Tuvaluan word to be created for it. Where an equivalent word does exist, the change can be made easily if all parties agree that TMS should always use the Tuvaluan term.

TMS would like to promulgate the glossary through its work with the Media Department, NGOs and community organisations, in order to get the terms into common usage until they are widely understood. This will be a long-term project—more words can be added as the glossary's terms become accepted and commonly used. The new outer island observers will contribute to the adoption of terms, as can schoolteachers, with support from TMS.

This intervention has great potential to overcome one of the more intractable barriers to effective communication on climate and climate change.

Community-based Early Warning System and DRR (CB-EWS/DRR)

TMS will work with SPREP and with communities to develop a community-based early warning system (CB-EWS) and a disaster risk reduction (DRR) plan. They will establish a National Coordination Team (NCT) to coordinate community consultation meetings and the implementation of the CB-EWS and DRR plans. The NCT will be made up of TMS, the NDMO, NGOs, the Public Works Department, the Ministry of Health and other relevant government and private institutions. SPREP will help TMS agree terms of reference for its engagement with support partners such as IFRC and WMO.

The NCT will convene an initial meeting to discuss the project. A community engagement specialist will deliver a 2 – 3 day training exercise on how to carry out a community consultation so that it enables the community to articulate its priorities. The NCT will ensure that the discussions and activities implemented complement existing activities and are aligned with national policies.

SPREP, IFRC and WMO will support the NCT in conducting a 2 – 3 day consultation with each island community, collecting disaggregated information on different vulnerable groups to identify risks and capture the different priorities. TMS will give a presentation on its work and demonstrate its

[649] UNEP/GCF Stakeholder engagement, PSS, March 2019: Tuvalu consultation minutes: Red Cross, Gender Unit, NDMO, TMD, TMS.
[650] UNEP/GCF Stakeholder engagement, PSS, March 2019: Tuvalu consultation minutes: Red Cross, Gender Unit, NDMO, TMD, TMS.

information services. The NCT will gather feedback and hold separate discussions with men, women and vulnerable groups to identify hazards, vulnerabilities and priority activities for a potential CB-EWS.

The NCT will develop a community action/response plan addressing the priorities of all the sub-groups and design a draft EWS with each island community. When the EWS is finalised the NCT will document it and will help the community to organise drills and exercises to test it.

Previous project funding (FINPAC) enabled the development of protocols for responding to disaster warnings in Tuvalu's outer islands, but the drills have not yet been put into practice. TMS proposes to use the protocols, developed by each island's community, to run drills during one of their twice yearly maintenance visits.

Upgrade last-mile communications infrastructure

Install signboards and compass points for eight islands

Emergency Sign Boards (ESBs) have been installed on each island to show people of the islands which way to go during different extreme events. TMS will use billboards to extend the reach of climate forecasts for slow onset events such as droughts or anticipated heavy rainfall, drawing on the monthly on-line climate forecast (OCOF) reports the TMS staff develop with support from SPREP. The billboards will give information relevant for maritime safety and food gardening, in the Tuvaluan language. This information will also benefit from work on the translation of climate terms and the ongoing collection of traditional climate knowledge, to make it both more readily understood and more acceptable as an authoritative source. Experience from previous activities collecting traditional knowledge has enabled TMS to refine its approaches to community elders, farmers—which means most women living in villages—and artisanal fishers, focusing on activities that attract the most interest and participation.

TMS has invented a novel way of indicating wind direction for island communities who are unfamiliar with the compass points: so close to the equator they are less relevant than at higher latitudes. TMS will replicate its Funafuti "compass" post, installing one near the meteorological station on each island: these use the fact that people name wind directions by naming an island, village or country in that direction rather than naming compass points. The compass post has pointers to known places. Climate information can be delivered in a format such as "a severe cyclone is approaching from the direction of Nanumea", with confidence that the warning will be understood.

This (hypothetical) warning will be further improved by being given in Tuvaluan and with impact information, such as “prepare for very strong winds before this afternoon, by bringing loose items indoors and covering windows securely, and don’t let children play outdoors”.

Figure 99. Funafuti compass post (Source: PSS in-country consultations)

PACTOR modems and FM radio on outer islands

Tuvalu struggles with communicating climate related information effectively and punctually throughout the islands, particularly during extreme weather events. TMS’s report to the 2015 PMC highlights the current lack of “capability to prepare and deliver high quality early warnings and forecasts of weather, climate and water related hazards”: this is exacerbated by telecommunications problems. The Tuvalu Country Preparedness Package (a joint initiative by Pacific Governments and UNOCHA’s Pacific Humanitarian Team intended to strengthen preparedness and collaboration between national and international actors in a disaster response) also determined in 2018 that Tuvalu’s “communication channel for public information is too slow”.[651]

Telephone lines are not connected to the meteorological stations on the outer islands. During disasters or for daily data transmission duties, on the islands with a station, the observers use the phone line at the Telecom Office, but this is often unreliable and does not allow for real time reporting.

In response, the establishment of FM radio on all eight outer islands in Tuvalu has been suggested as a viable activity. Melali Taape, the General Manager of the Tuvalu Media Department (TMD), has advocated for the benefits of implementing FM radio. Firstly, Mr. Taape points outs the weather resilience of FM radio and its ability to continue to relay or broadcast information during unfavourable conditions. Also, radio is easily accessible to members of the community and will not impose upon them any additional burdens, financial or otherwise.

TMS proposes to use PACTOR modems in conjunction with HF radio sets to support communications with outer islands during a disaster. PACTOR is a radio modulation mode used by amateur radio operators, marine radio stations, military or government users, and radio stations in isolated areas to send and receive digital information via radio. A robust network of PACTOR stations can be

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[651] Relief Web, Tuvalu, Available at <https://reliefweb.int/country/tuv> [August 2018]

established to relay data between radio stations and the Internet, extending Internet access to sea based and other isolated users.

Localised mobile climate information communication system

The Programme will develop and implement localised mobile climate information communication systems with early warning to reach last-mile populations. Through mobile-cellular communication channels, this system will provide predicted risks and alerts utilising geostationary satellite nowcast and local/regional forecast information. The system will be designed to handle potential and existing risks on a 24/7 basis and will be customisable for any population group size – from small communities to larger central governments. For short-term disasters, the system will utilise satellite imagery analysis based on 2 km, 10-minute resolution (e.g. Chollian 2A) for nowcasting of wind, wave height and convective initiation of rapidly developing thunderstorms two hours in advance, which is not possible with Numerical Weather Prediction. Localised communication systems will support disaster risk management on various timescales from short-term disasters (e.g. torrential rainfall, coastal flooding, etc.) to long-term disasters (e.g. droughts). The possibility to integrate a two-way communication channel between end-users and information providers would allow for continued enhancements to the system based on user feedback.[652]

T3.1.3 Communicate early warnings to island communities

The Programme will conduct annual multi-stakeholder workshops focused on the co-design and co-production of early warning information products to improve early warning messaging to island communities and provide clear guidance for triggering response actions. Participants will include various EWS stakeholders, community representatives, the National Disaster Management Office (NDMO) and TMS. A local consultant will support delivery of the workshops and will draw on the specialised knowledge of stakeholders and communities to create impact-based early warning messages that are actionable and effective. The workshops will provide an opportunity for engagement between warning issuers and warning 'users' to facilitate that the public and other stakeholders are aware of which authorities issue the warnings, and build trust and acceptance of information disseminated. Furthermore, the Programme will seek to engage a wide variety of community representatives to ensure that warnings are targeted to the different risks and needs of vulnerable subpopulations.

Activity 3.2 Preparedness and response capabilities

T3.2.1 Enhance disaster preparedness and response measures

This sub-activity will use community-based approaches to enhance risk ownership at the local level and help establish collaborative community networks for coordinated action for preparedness and response to climate-induced hazards. This will include the following interventions:

Disaster drills and drought management plan review

TMS has been planning to extend the Funafuti Drought Monitoring Plan to Tuvalu's outer islands, developing a plan with each island community. TMS makes a regular round trip of all of Tuvalu's islands twice each year. They propose to spend two weeks on seven outer islands in year one to review the

[652] This will be delivered by the APEC Climate Center in collaboration with the Ewha Womans University, utilising a proven method that is currently being implemented in Cambodia, with the endorsement of the Cambodia Ministry of Water Resources and Meteorology, Asian Disaster Preparedness Center (ADPC) and the Preah Vihear National Authority

island's drought management plan and to practise the disaster drills. They will repeat this in Year 5. The Drought Management Plans will outline locally relevant adaptation strategies, including options for livelihood diversification.

The following 14-day schedule has been proposed:
1st week – Disaster Drills

Monday – Meet with Island Kaupule Council;
Tuesday – Consult with key stakeholders;
Wednesday – Meet with island community;
Thursday – Climate variability and change awareness;
Friday – Disaster drills.

2nd week – Island Drought Monitoring Plan

Monday – Workshop with key stakeholders;
Tuesday – Workshop with key stakeholders;
Wednesday – Get data from each household;
Thursday – Team compiles the Island Drought Plan / presents the Island Drought Plan draft to key stakeholders;
Friday – Present the Island Drought Plan to the community.

T3.2.2 Conduct public awareness and education campaigns on climate hazards and risks

TMS will conduct community-based workshops to enhance community knowledge and understanding of climate hazards and the potential impacts on the lives and livelihoods of local populations. The workshops will build capacity of participants to apply the knowledge to their individual circumstances and consider suitable options for livelihood diversification or alternative livelihoods. The workshops will be conducted annually in seven outer islands of Tuvalu.

T3.2.3 Integrate traditional knowledge into early warning services

Building on the Community-based Early Warning System and DRR (CB-EWS/DRR) intervention implemented by SPREP (Sub-activity 3.1.2), this sub-activity will undertake consultations with communities and traditional knowledge (TK) holders to develop a training program on the collection and documentation of TK. Training will be delivered to TK stakeholders and a list of TK indicators will be developed. The Programme will conduct surveys to collect and document TK utilising the indicators developed. The results of the survey will be inputted into a TK database.

RESULT 4 – ENHANCED REGIONAL KNOWLEDGE MANAGEMENT AND COOPERATION FOR CLIMATE SERVICES AND MHEWS

Activity 4.1 Enhance regional data, knowledge management and cooperation

Under this Activity, the Programme will enhance coordination and knowledge sharing among the five countries to improve data and knowledge management, including establishment of an interactive ICT platform and regional data centre. The organisation of joint learning, mentoring and training events through existing WMO, USP and other centres to facilitate sharing of successes and lessons learned will further strengthen climate and ocean information services across the region.

T4.1.1 Establish interactive ICT platform

This sub-activity will establish an interactive ICT platform, which will serve as a data analytic centre for the management and organisation of climate data, information, experiences, case studies and other forms of knowledge from the five Programme countries in standardised, comparable formats most useful for end-users. The platform will include the establishment of a regional data centre fed by national data centres in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu. The countries will make as much as possible of their climate-related data publicly available through their national data portals and the regional Pacific Environmental Portal.

This Activity takes advantage of the already established GEF-funded "Inform" project, which is being implemented by UNEP and executed by SPREP. Inform is already working with staff in Pacific environment ministries to find and harvest useful datasets and information on their countries' environment and to publicise the existence of the information. The five Programme countries now have national data portals, which can be used to develop workflows to share data seamlessly between sectors.

The Programme will add a new category for climate data and information in Tuvalu's national portal – existing categories include health, fisheries, tourism and disaster management as they relate to the environment – and bring the bring data management and coordination into its schedule of capacity building activities. The National Climate Data Consultant (Sub-activity 2.3.1) will take part in technical workshops and training at SPREP and implement a comprehensive data strategy in-country with SPREP's support. Improved data sharing and discoverability will provide a conduit for TMS to assess partners' sector data or knowledge products, while hosting and sharing its own on a common platform. Enhancement in data management capacity will be achieved through the following steps:

- Addition of a new category for climate data and information to each national portal;
- Training and engagement of national climate data consultants (see Sub-activity 2.3.1);
- Support for countries to prepare their national reporting for climate-related agreements (e.g. NDCs, VNRs, National Communications to UNFCCC). This is currently a major administrative burden for very small countries, but with access to good quality data, it provides an opportunity to evaluate policy and assess progress on adaptation. A two-way flow of information from NMHSs to and from relevant sectors for national and global reporting will ensure coordination in the use of climate data and information and raise the profile of NMHSs in other sectors thereby supporting demand and fostering sustainability.
- Participation of data consultants in regional forums to enhance the use of data in national planning;
- Establishment of electronic links with existing data sources and back-up in the regional portal; and
- Management of the ICT platform for the five Programme countries through support for ICT interventions across the five countries, including application of ICT in NMHSs operations and upgrading or introducing new methods and systems, such as wireless communications and Internet of Things (IoT) infrastructure for climate services.

SPREP usually provides significant support to countries preparing their reporting against the many MEAs and climate-related agreements to which they are party. This regular process includes updating each country's State of the Environment report, clearly documenting and illustrating climate impacts. This process will give SPREP an entry point for discussing the data strategy with TMS's senior officials. Better access to more data will make it easier to identify meaningful indicators for indicator based reporting, and the project will help non-specialists understand the analysis and interpretation of data.

Improved data is only useful to decision makers, development partners and other user groups if there is wide knowledge of its existence, location, purpose and openness. As this Programme progresses, reporting for international climate agreements will be much improved by the countries' ability to draw upon a longer and more extensive body of high quality data—officers will know what data exists, how it can be sourced and how to use it well. The participation of data consultants in regional forums will build capacity to advocate for effective use in national planning and development of useful data products.

The Inform team estimates there is valuable climate change material held in more than 24 active and legacy systems among the five countries; and in many cases the obsolete hardware needed to read it is still functioning. SPREP will establish electronic links with existing data sources so they can be translated and will back them up on the regional portal. There are multiple datasets held by researchers or by individual departmental officers in danger of being lost, and SPREP will help Tuvalu to locate and salvage them.

T4.1.2 Organise learning, mentoring and training

This sub-activity will comprise training, mentoring and advisory services for local consultants and staff in NMHSs in Cook Islands, Niue, Palau, the Republic of the Marshall Islands and Tuvalu on strengthening climate information services; strengthening observations, monitoring, modelling and prediction; strengthening of marine weather and ocean services; establishing MHEWSs at national and community levels; and building community resilience against climate risks. This will be facilitated through partnerships with existing WMO regional training centres (e.g. China Meteorological Administration (CMA) Training Centre [653] through coordination by the Chinese Academy of Meteorological Sciences), USP and others in the organisation of:

- Joint learning events for exchanging knowledge and sharing experiences and lessons learned in strengthening climate information services and MHEWs in the five countries. This will have a major focus on the development and implementation of National Frameworks for Climate Services (NFCSs) through all components and related activities of this Programme.
- Targeted training of NMHS staff (e.g. meteorologists, ICT administrators, forecasters) in key areas that are essential for the Programme's impact and long-term sustainability. This will be undertaken through existing training centres in the WMO network, the University of the South Pacific (USP), the International Centre for Theoretical Physics (ICTP) and others. Training will be delivered through a combination of on-site workshops and remote learning courses. Topics of training could include:
    - Forecasting and Numerical Weather Prediction (NWP) by suitably qualified providers such as WMO regional training centres and other WMO-approved meteorological organisations. This could include nowcasting techniques for severe weather, and short-term climate monitoring and prediction in disaster prevention and mitigation.
    - Observation and Instrumentation, including Operation and Maintenance (O&M) of equipment for long-term sustainability.
    - Innovative and cost-saving technologies for observation, modelling and prediction with special focus on the application of ICT. Hence, these events will also be critical for regularly reviewing options for upgrading or introducing new methods and

[653] CMA propose to provide free in-person and remote training courses covering the top seven training priorities of Pacific NMHSs

systems in NMHSs in the five countries, such as wireless communications and Internet of Things (IoT) infrastructure for climate services and disaster management.

- Principles of satellite remote sensing and use of meteorological satellite images in weather analysis and forecasting.
- Demonstration and training on the operation and maintenance of weather radar systems – installed under Sub-activity 2.1.1 by regional partners from the WMO network (possibly the Fiji Met Service in cooperation with USP under the new WMO Regional Training Center). The demonstrations and training will build capacity of the NMHSs for the provision of improved and more accurate weather monitoring and forecasts; tracking of local extreme events; better determination of rainfall rate/intensity, which is important for determining the potential for extreme rainfall and flash flooding enabling hazard warnings to be issued more accurately and in more timely fashion; and validating Numerical Weather Prediction (NWP) forecasts.
- Enhancing institutional effectiveness of NMHSs through Quality Management Systems (QMS), Weather Forecast Service Standard and related certification.
- Enhancing NMHS services through Impact-based forecasting and Forecast-based Financing.
- Enhancing Climate services in NMHSs, including options for ensuring long-term financing and cost-recovery such as private sector investment, public-private partnerships and the application of National Climate Funds.
- Use of alerts, information exchange and coordination in the first phase after major sudden-onset disasters, including through the Global Disaster Alert and Coordination System (GDACS).

Furthermore, the Programme will provide mentoring and technical advisory services to NMHSs in the five countries through capacity building, training and awareness raising initiatives and materials for a range of stakeholders; provide technical backstopping and capacity support to the national delivery of Programme activities; and provide expert advice to the Programme team on key climate information services and best practices, including gender-responsive implementation. In order to enhance synergies and avoid creating parallel structures, the Programme will work closely with the WMO-SPREP Pacific Meteorological Desk Partnership (PMDP), a regional coordination mechanism that supports and coordinates meteorological activities in the Pacific, and the Pacific Meteorological Council (PMC) at large.

9 – GOVERNANCE AND IMPLEMENTATION ARRANGEMENTS

9.1 ACCREDITED ENTITY (AE)

UNEP will be the Accredited Entity for the Programme and will be responsible for overseeing the implementation, financial management, evaluation, reporting and closure of the activities under the Programme. UNEP will monitor and supervise the execution of the Programme and ensure the proper management and application of GCF Grant Proceeds by the Executing Entities. UNEP will ensure that the Grant Proceeds are utilised in accordance with the terms of the Funded Activity Agreement and the Accreditation Master Agreement. UNEP will also assume a limited role as Executing Entity, as described in the relevant section below.

UNEP brings more than 20 years' experience working on climate change and is an established GCF Accredited Entity. It brings a comprehensive approach to climate change mitigation and adaptation that is grounded in both natural science and economics and is tied to the environmental and development concerns of countries. Based on its core science-based mandate, one of UNEP's seven sub-programs is entirely dedicated to keeping the world environment under review.

Through its Science Division, UNEP has longstanding expertise in environmental and climate change information management and early warning systems. For example, with GEF and EC funding it is currently supporting over 50 countries in establishing or strengthening their environmental information management systems and using them for reporting progress on SDGs and MEAs. Its Science Division manages the CLIMWARN and Country Level Impacts of Climate Change (CLICC) projects, and UNEP also convenes and facilitates regional environmental information networks and the world adaptation science program (formerly PROVIA). Through its work on early warning and foresight, UNEP enables stakeholders to respond to the latest emerging issues related to environment and climate change. UNEP has a strong convening power at regional and sub-regional level including a Sub-regional Office for the Pacific co-located with the Secretariat of the Pacific Regional Environment Programme (SPREP) in Apia, Samoa.

Under its 7th sub-programme, 'Keeping the Global Environment under Review', UNEP also produces a major Global Environmental Outlook (GEO) report every four years, assessing the states, trends and outlooks of the environment. Five Regional GEO assessment reports are produced between each global GEO report—their contents are later used to inform the latter. The Regional and Global reports would greatly benefit from climatic data, information, models, projections, lessons and experiences, capacity assessment reports and other products from the proposed GCF Programme. UNEP and SPREP are respectively implementing and executing a GEF-funded cross-cutting capacity development project—the "Inform" project—which is putting in place national and regional repositories of existing environmental data and reporting tools in Pacific Island States. This Programme will partner with Inform and, more generally, build on existing climate information inputs to policymaking in the region.

The Pacific Meteorological Council (PMC) has defined issues and priorities for the region in the *Pacific Islands Meteorology Strategy 2017–2026*, endorsed by the Council members and Pacific government ministers responsible for meteorology. The PMC fulfills a crucial convening and coordination role in the region that will be leveraged for this Programme. It is an influential body and may advise the PMU and the Programme partners on coordination, technological and political issues if required. Programme annual reports will be provided as meeting papers to PMC members before their biennial meetings. Members of the PMC endorsed the Programme at their 5th biennial meeting in July 2019.

9.2 PROGRAMME MANAGEMENT UNIT (PMU)

The proposed Programme will set up a central Programme Management Unit (PMU) hosted by UNEP's Sub-regional Office for the Pacific, which is co-located with SPREP and the new Pacific Climate Change Center (PCCC) in Apia, Samoa. The PMU will provide management and support to the national implementation of the Programme through coordination by the five national Executing Entities (EEs) and the Regional Technical Partners involved in Programme execution, in line with their obligations under the respective legal instruments and will coordinate to ensure that reports are received. The PMU will consolidate all half yearly progress reports and quarterly financial reports, including co-financing reports and annual audit reports, from EEs and Regional Technical Partners and submit these to the AE. The PMU will provide guidance and source expertise as needed on project management, financial management, procurement and technical issues. It will establish contact with other development partners working with the Programme countries to ensure that activities in related fields are complementary, and to seek opportunities for collaboration. The PMU will also provide secretariat services to the Programme Steering Committee.

The PMU will be staffed by three full-time staff administered by UNEP: a Programme Coordinator (PC), a Fund Management, Monitoring and Procurement Officer (FMMPO) and a National Finance and Administrative Assistant (NFAA). Both the FMMPO and NFAA will report directly to the PC. All staff will be recruited in line with UN regulations, rules and policies. The PC will be overall responsible for the day-to-day management of the Programme. This role will include an overall responsibility for:

i. Coordinating the Programme Steering Committee (PSC);
ii. Managing the Programme in line with the budget and workplans, and in accordance with GCF and UNEP guidelines;
iii. Being responsible for financial management and disbursements;
iv. Coordinating national EEs and Regional Technical Partners to manage the Programme effectively;
v. Consolidating national EE and Regional Technical Partner reports and report to the AE; and
vi. Ensuring exchange of information and knowledge across the five countries.

To achieve the targets of the proposed Programme the PM will, inter alia:

i. Acquire on-the-ground information to inform UNEP progress reports;
ii. Engage with Programme stakeholders;
iii. Arrange PSC, PMU and other meetings;
iv. Provide technical support, including measures to address challenges to Programme implementation;
v. Participate in training activities;
vi. Write technical reports; and
vii. Facilitate relevant expert activities.

Additionally, the PC will liaise with members of the PSC and PMU, technical experts, government staff, civil society and stakeholders involved to coordinate the implementation of the proposed Programme's activities. For technical aspects of the Programme, the PC will work closely with the SPREP-WMO Pacific Meteorological Desk Partnership (PMDP), with which the PMU will be co-located in Apia, Samoa. In cooperation with the PMDP, the PC will coordinate expert advice to the Programme on key climate information services and best practices and support the development of technical terms of reference for the engagement of services and procurement of meteorological and other project-related equipment.

A range of equipment (i.e. AWS, AWOS, weather radars etc.) and communication infrastructure upgrades will be procured to strengthen observations in the five countries, based on identified national priorities. In addition to undertaking direct procurement as part of UNEP's EE function, the PMU will provide guidance and support to national EEs and technical partners on procurement in line with the provisions of the respective Project Cooperation Agreements (PCAs). The PMU will ensure compliance with the UN rules and regulations related to procurement.

9.3 EXECUTING ENTITIES (EES)

The national Executing Entity designated by the Government in each country will be respectively accountable to UNEP for Programme execution at a national level, and for the effective and efficient use of resources. Each EE is an existing established national agency with financial management responsibilities and expertise. Each is an experienced manager of externally funded development activities, and routinely partners with multiple regional and international donors, contributing to the effective coordination of nationally and internationally funded projects and programs. All are adequately resourced and meet the stringent reporting and fiduciary standards of multilateral funding agencies, developed country partners and their own governments.

UNEP will also undertake Executing Entity functions through its Sub-regional Office for the Pacific. UNEP will execute the Programme in line with its programme manual and standard business procedures and will contract international consultants and Technical Partners to support technical activities as appropriate.

Country	Executing Entity	Details of EE and track record
Cook Islands	The Cook Islands, acting through the Ministry of Finance and Economic Management (MFEM).	The Development Coordination Division of MFEM is responsible for all external funding programmes/projects and activities in Cook Islands and working closing with the NDA in Climate Change Cook Islands (CCCI). MFEM was accredited by GCF as a Direct Access Entity for Cook Islands in October 2018. MFEM has a significant track record in managing projects, with recent examples including: • Performance Based Budget Support by New Zealand ($5.6 million); • Sanitation Upgrade Programme ($11 million); • Te Mato Vai - Water Programme ($39 million); • Tereora College Rebuild ($7.6) million); • Renewable Energy programme ($40 million); • Apii Nikao Rebuild ($10 million); • SRIC Adaptation Fund ($5.6 million); • GEF-funded Ridge to Reef programme (UNDP) ($4.5 million); • PEARL (Pa Enua Action for Resilient Livelihoods project ($3 million).
Niue	Niue, acting through the Project	The Central Agency for Finance and Planning (equivalent to a Ministry of Finance) is part of the Premier's Office of Niue. In turn, the Central Agency comprises the PMCU. The PMCU provides a centralised project management

	Management Coordinating Unit (PMCU) in the Central Agency for Finance and Planning within the Premier's Office.	service dedicated to coordinating project management activities for all donor funded projects in Niue through effective stakeholder relationships (including for this Programme). PMCU has a track record in managing projects, with recent examples including: • Niue Waste Management ($2,827,052); • Alofi Waste Septic Tanks ($249,421); • Asbestos replacement (GEF) ($200,000); • GCF Readiness Programme 1 ($132,000); • Fale Fono (New Zealand AID) ($3,283,500); • Tuapa Learning Centre ($98,505); • Airport Tower ($249,546); • GEF Small Grants • programme ($124,773); • Community Projects ($65,670); • Wharf Upgrades ($656,700).
Palau	Palau, acting through the Ministry of Finance.	The Bureau of Budget and Planning in the Ministry of Finance houses the Office of Climate Change and is working closely with the NDA in the Office of the President. The Ministry has a track record in managing similar projects, with recent examples including: • GEF-funded Sustainable Resource Management to Improve Livelihoods and Protect Biodiversity ($3,747,706); • GEF-funded Integrating Biodiversity Safeguard and Conservation into Development in Palau ($150,000); • UNDP-funded Enhancing Disaster & Climate Resilience in Palau through Improved Disaster Preparedness and Infrastructure ($7.5 million).
Marshall Islands	Republic of the Marshall Islands, acting through the Ministry of Finance	The Ministry of Finance has a Division of International Development Assistance (DIDA) and is working closely with the NDAs located in the Climate Change Directorate, Ministry of Environment. The Ministry has a track record in managing similar projects funded by ADB, the World Bank, the IUS Government and others, with recent examples including: • Public Financial Management Project ($2 million); • Technical Cooperation Facility (TCF) No. 2 Program Estimate 2 (PE2) ($243,000); • Kwajalein Landowners programme funded by the US Government ($21 million); • Compact Trust Fund funded by the US Government ($17 million); • Capacity Building for Resilient Agriculture in the Pacific ($140,525); • Building Capacity for resilient Agriculture in the Pacific ($500,000); • Telecommunications and ICT -Technical Assistance Project ($950,000); • RMI Pacific Resilience Program Phase 1 ($1.5 million); • Strengthening Budget Execution and Financial Reporting ($9.5 million).
Tuvalu	Tuvalu, acting through the	The Climate Change Department (CCD) sits under the Ministry of Finance and is established under Tuvalu laws, in particular the Climate Change Resilience Act. The Ministry has a track record in:

	Climate Change Department (CCD).	• Overall co-ordination and oversight of all ODA in Tuvalu; • Managing similar projects, such as the GCF Readiness project for which it is the Delivery Partner and Adaptation Fund projects (for which the Ministry is accredited as National Implementing Entity); Examples of other recent projects managed by the Ministry include: Strengthened Fiscal Sustainability Program (ADB, $2 million); and six active World Bank projects in Tuvalu totalling US$106 million in commitments across sectors including aviation and transport, climate resilience, energy and electricity, fisheries and telecommunications.[654]
All countries	UN Environment Programme (UNEP)	UNEP has significant experience in working on climate change and is an established GCF Accredited Entity. Through its Science Division, UNEP has longstanding experience in environmental and climate change information management and early warning systems, with recent examples including: • GEF-funded "Inform" project ($4.3 million); • Climate Change Early Warning (CLIM-WARN) project in Kenya, Ghana and Burkina Faso; • Country-Level Impacts of Climate Change (CLICC) project. UNEP also convenes and facilitates regional environmental information networks and the World Adaptation Science Programme (formerly PROVIA).

Table 36. Details and track record of Executing Entities (EEs)

The responsibilities of the national EEs are to coordinate the execution of the Programme at a national level. They are accountable to the AE for Programme execution and the effective and efficient use of resources. Therefore, UNEP shall enter into an appropriate agreement (Project Cooperation Agreement) with national EEs for the execution of the Programme. The Project Cooperation Agreements (PCAs) will establish clear roles and responsibilities of the respective parties for the delivery of the proposed activities, and the schedule and conditions for instalments, the determination of the prevailing fiduciary standards and the terms and conditions for arbitrations and termination of contract. The PCAs will include specific obligations for the national EEs on Programme execution, financial management, personnel administration and reporting, as well as on arbitration and liability terms. The EEs will be required to comply with UNEP rules, policies and procedures on procurement.

Each Executing Entity will be responsible for establishing national programme implementation in a relevant part of the government administration to provide implementation guidance and support to the national service providers and Regional Technical Partners (see below section) in each country. Thus, the EE will provide technical and implementation guidance and will facilitate cooperation among the implementing organisations. It will also convene the National Coordination Committee that will be established in each country, including quarterly reports on progress and expenditure. It will be accountable to the central PMU and the National Coordination Committee on Programme progress and will submit regular progress reports to the PMU.

The implementation arrangements for all EEs are outlined in the table below.

[654] World Bank. 2019. Press Release: Tuvalu Gets Big Boost for Fiscal, Infrastructure and Social Resilience. Available at: https://www.worldbank.org/en/news/press-release/2019/12/13/tuvalu-gets-big-boost-for-fiscal-infrastructure-and-social-resilience

Activity	Sub-Activity	Role of Executing Entity(ies) (EEs)
1.1 Strengthen institutional and policy frameworks and delivery models for climate services	1.1.1. Develop National Frameworks for Climate Services	National EEs will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant. Upon requests from countries, UNEP will contract international consultancy services to develop the National Frameworks for Climate Services.
	1.1.2. Conduct market assessments to explore viable opportunities for climate information services in sectors and business segments	UNEP will contract the international consultant(s) to conduct a climate services market assessment for all five countries.
	1.1.3. Mainstream climate risk knowledge into sectors	National EEs will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant. Upon requests from countries, UNEP will contract the international consultancy services to develop i) Climate Sector Action and Communication Plans for Disaster Management and other relevant sectors; and ii) Sector Specific Climate Training Programmes.
	1.1.4. Develop national policies for financing climate services	National EEs will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant. Upon requests from countries, UNEP will contract the international consultant(s) to develop comprehensive policies for financing climate services for each country.
2.1 Enhance infrastructure and technical support for observations and monitoring	2.1.1 Enhance national observations and monitoring networks to GBON standards and establish QMSs	National EEs will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant. UNEP will conclude Project Cooperation Agreements with NIWA, BoM and SPREP to provide technical support for the assembly, calibration, installation, operation and/or maintenance of observations equipment in compliance with the Global Basic Observing Network (GBON) requirements in each country – upon country

		request. UNEP will also undertake procurement directly upon request from countries.
2.2 Strengthen ocean and climate modelling and impact-based forecasting	2.2.1 Establish ocean information services	National EEs will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant. UNEP will conclude Project Cooperation Agreements with SPC and the University of Hawai'i, PACIOOS to deliver parts of this sub-activity.
	2.2.2 Enhance climate information and impact-based forecasting	National EEs will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant. UNEP will conclude Project Cooperation Agreements with APCC, BoM, NIWA and SPC to deliver parts of this sub-activity.
2.3 Harmonise climate data and information management	2.3.1 Establish and implement national climate data and information strategies	National EEs (excluding Tuvalu) will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant. UNEP will conclude a Project Cooperation Agreement with SPREP to provide technical support for climate data and information management; and develop and implement national climate data and information strategies.
3.1 Improve warning dissemination and communication	3.1.1 Strengthen EWS organisational and decision-making processes	National EEs will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant. UNEP will conclude a Project Cooperation Agreement with SPC to conduct an in-country deep dive study on gender and community stakeholders for all five countries.
	3.1.2 Strengthen communication systems to reach the last-mile	National EEs will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant. UNEP will conclude a Project Cooperation Agreement with APCC for the development of a localised mobile climate information communication system to support disaster risk management in all five countries; and with SPREP to support community-based disaster preparedness and response mechanisms and plans in Tuvalu.

	3.1.3 Communicate early warnings to island communities	National EEs will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant.
3.2 Enhance preparedness and response capabilities	3.2.1 Enhance disaster preparedness and response measures	National EEs will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant.
	3.2.2 Conduct public awareness and education campaigns on climate hazards and risks	National EEs will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant.
	3.2.3 Integrate traditional knowledge into early warning services	National EEs (excluding Cook Islands and Tuvalu) will deliver parts of this sub-activity in their countries and engage relevant national service providers and experts through procurement and sub-contracting as relevant. UNEP will conclude a Project Cooperation Agreement with SPREP to conduct training on traditional knowledge (TK) collection and documentation; and development of TK indicators in Tuvalu.
3.3 Establish Forecast-based Financing (FbF)	3.3.1 Develop FbF Roadmaps defining thresholds and triggers	UNEP will conclude a Project Cooperation Agreement with IFRC to deliver this sub-activity.
	3.3.2 Build capacity for FbF	UNEP will conclude a Project Cooperation Agreement with IFRC to deliver this sub-activity.
	3.3.3 Support development of Early Action Protocols (EAPs)	UNEP will conclude a Project Cooperation Agreement with IFRC to deliver this sub-activity.
4.1 Enhance regional data, knowledge management and cooperation	4.1.1 Establish interactive ICT platform	UNEP will conclude a Project Cooperation Agreement with SPREP to deliver this sub-activity.
	4.1.2 Organise learning, mentoring and training	UNEP will execute this sub-activity and contract international consultants, technical partners and training centres in the WMO network as relevant.

Table 37. Role of Executing Entities (EEs) in programme sub-activities

The EEs will convene regular Technical Meetings with national service providers to monitor the progress, facilitate cooperation among the implementing organisations and seek collaborative solutions to any issues that arise. As part of Programme management, the EEs will undertake regular monitoring exercises. The EEs will contribute to a formative Mid-Term Evaluation and a summative Terminal Evaluation of the whole Programme.

9.4 REGIONAL TECHNICAL PARTNERS

The Programme will benefit from the expertise of a broad coalition of Technical Partners, thereby ensuring coherence and complementarity. Technical Partners will include SPC, SPREP, NOAA, UH, (including PacIOOS and associated EWC), BoM, NIWA, IFRC, APCC and WMO and its network. These are highly qualified, internationally recognised professional agencies with many years' experience of partnership with Pacific countries. Based on the priorities of countries, some of the partners will lead or provide support for the implementation of specific interventions that require highly technical or scientific expertise and are in line with their mandates and comparative advantages. Although Technical Partners will work at national level, the agencies will be sub-contracted directly by UNEP in its capacity as Executing Entity, in line with UNEP procedures and policies – i.e. to deliver their agreed body of work in each country through consultation and coordination with the national EEs. Regional Technical Partners will report to the PMU and Programme Steering Committee (PSC).

In order to ensure the collaboration is documented between parties, UNEP will sign a Memorandum of Understanding (MoU) between all EEs, Regional Technical Partners supporting national execution, and UNEP to affirm the parties' commitment to meeting the objectives of the Programme.

An overview of the Technical Partner agencies is provided below:

The Pacific Community (SPC)[655]

SPC is the main technical and scientific organisation in the Pacific region, with 26 country and territory members. Its mandate is "*to contribute to sustainable development, reduce poverty and enhance resilience for the peoples of the Pacific by supporting the development of natural resources in particular non-living resources, investing in natural systems and management of vulnerability through applied environmental geosciences, appropriate technologies, knowledge management, technical and policy advice, human resource development and advocacy of Pacific issues.*"

SPC has the mandate to undertake research and technical work related to disaster risk reduction and to hold geospatial data including bathymetry, tidal, climate and oceans data for the Pacific region. SPC is renowned for knowledge and innovation in areas such as fisheries science, public health surveillance, geoscience and conservation of plant genetic resources for food security. It uses a multi-sector approach to respond to members' development priorities, focusing on major cross-cutting issues such as climate change, disaster risk management, food security, gender equality, human rights, non-communicable diseases and youth employment. To support its highly technical mandate, SPC has extensive and specific expertise in IT systems; and assists countries in this area as well as using IT systems for regional research and programs.[656]

SPC is a long-term partner in the Pacific Sea Level Monitoring Project (1991-) with 12 Pacific countries, the Australian Bureau of Meteorology (BoM) and Geoscience Australia.

SPC will support delivery of **sub-activity 2.2.1:** Technical support to establish ocean information services – including support for observations and monitoring; development of an ocean modelling framework; and decision-making tools in Cook Islands, Niue and Tuvalu; and **sub-activity 2.2.2:** Technical support and capacity building for high-resolution ocean forecasting and impact-based forecasting; and attachments to increase knowledge on oceanography, ocean-related impact based forecasting and coastal monitoring in Cook Islands, Niue and Tuvalu. SPC will also support delivery of

[655] SPC, 2020. Available at: https://www.spc.int/about-us
[656] COSPPac, 2015. Independent Progress Review Climate and Oceans Support Program in the Pacific (COSPPac)

sub-activity 3.1.1: Conduct an in-country deep dive study on gender and community stakeholders in all five countries.

Pacific Regional Environment Programme (SPREP)[657]

SPREP is the regional organisation established by the Governments and Administrations of the Pacific responsible for protecting and management the environment and natural resources of the Pacific. Its mandate is "*to promote cooperation in the South Pacific region and to provide assistance in order to protect and improve its environment and to ensure sustainable development for present and future generations.*"

SPREP is based in Samoa and has 21 Pacific island member countries and territories; and five developed country members. SPREP aims to achieve resilience and sustainable Pacific communities through its focus on i) climate change resilient; ii) island and ocean ecosystems; iii) effective waste management and pollution control; and iv) environmental governance. It has the primary coordination mandate related to climate policies and services in the Pacific. The Pacific Meteorological Council (PMC) is considered a specialised subsidiary body of the SPREP Meeting, which is the decision-making body of member countries. The Pacific Meteorological Desk Partnership (PMDP) assists the PMC and NMHSs to secure resources and implement the Pacific Islands Meteorological Strategy (PIMS) 2012-2021. SPREP has expressed interest in expanding the functions of the PMDP.[658]

In addition, SPREP hosts the virtual Pacific Regional Climate Centre; delivers the annual Regional Climate Outlook Forum with 12 NMHSs; maintains national Traditional Knowledge databases for Pacific NMHSs; and manages the Inform project.

SPREP will support delivery of **sub-activity 2.3.1:** Technical support for climate data and information management; and development and implementation of national climate data and information strategies in Cook Islands, Niue, Palau and RMI. SPREP will also support delivery of Result 3 through **sub-activity 3.1.2:** Technical support for community-based disaster preparedness and response mechanisms and plans in Tuvalu; and **sub-activity 3.2.3:** Training on traditional knowledge (TK) collection and documentation; and development of TK indicators in Tuvalu. Furthermore, SPREP will provide ICT technical expertise to support **sub-activity 4.1.1:** ICT training on standardised climate data, information and knowledge management; and **sub-activity 4.1.2:** ICT officer to manage the ICT platform; and technical support for applications of ICT in climate services in all five countries. SPREP (including through the PMDP) will also support the delivery of Result Area 2 related to the strengthening of observation networks under **sub-activity 2.1.1** – upon country request.

National Oceanographic and Atmospheric Administration (NOAA)[659]

NOAA is the United States scientific agency responsible for studying the climate, weather, oceans and coasts; sharing this knowledge and information with others; and conserving and managing coastal and marine ecosystems and resources. NOAA supports the NMHSs of US territories and associated states including Palau and RMI, and shares outputs with other Pacific countries. NOAA is a member of SPC and SPREP. NOAA has over 30 offices in the region and over 600 employees, with the majority located in Oahu (Hawaii). NOAA has several unique assets in the Pacific islands, including:

- Two (of five) baseline atmospheric observatories – Mauna Loa Observatory and American Samoa Observatory;

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[657] SPREP, 2020. Available at: https://www.sprep.org/about-us
[658] COSPPac, 2015. Independent Progress Review Climate and Oceans Support Program in the Pacific (COSPPac)
[659] NOAA, 2020. Available at: https://www.noaa.gov/about-our-agency

- The Pacific Tsunami Warning Center;
- International Tsunami Information Center (ITIC);
- Central Pacific Hurricane Center;
- Two permanent research vessels and two temporary vessels; and
- TAO/TRITON array – approximately 70 deep ocean moorings that measure surface meteorological and subsurface oceanic parameters.[660]

As administrator of the NMHSs in RMI and Palau, NOAA will support delivery of Result Area 2 related to the strengthening of the observation networks in the two countries. This will be done as in-kind support based on NOAA's existing mandate and without GCF funds flowing to NOAA.

University of Hawaii (UH)

The University of Hawaii is a public, co-educational college and university system that confers associate, bachelor's, master's, and doctoral degrees through three university campuses, seven community college campuses, an employment training centre, three university centres, four education centres and various other research facilities throughout Hawaii.

The International Pacific Research Center (IPRC)[661] is located within the UH Manoa School of Earth Science and Technology (SOEST) and operates under a cooperative agreement between the UH and Japan Agency for Marine-Earth Science and Technology (JAMSTEC). IPRC aims to improve "*understanding of the nature and predictability of climate variability and change in the Asia-Pacific sector, and to [develop] innovative ways to utilize knowledge gained for the benefit of society."* IPRC maintains a data centre for atmospheric and oceanic information of relevance to the Asia-Pacific region, including in-situ and remote (satellite) observations as well as outputs from operational forecasts and climate models. The data centre is accessible by researchers, policy makers and the general public.

IPRC is part of the Pacific Islands Regional Climate Centre, which is a virtual centre of excellence for the WMO RA-V RCC network. UH is the co-lead for the Climate Monitoring node of the WMO RA-V RCC network (alongside NOAA) and hosts the Pacific Islands Ocean Observing System (PacIOOS). The related East-West Center (EWC) serves as a resource for information and analysis on critical issues of common concern, bringing people together to exchange views, build expertise, and develop policy options.

UH will support delivery of **sub-activity 2.2.1:** Technical support for ocean observations and monitoring; training and technical support to establish ocean information services in Palau through the Pacific Islands Ocean Observing System (PacIOOS); and technical support to develop national ocean portals and web-based "dashboards" integrating climate and ocean data, information and products for Palau and RMI through the East-West Center and (in collaboration with NOAA).

Australian Bureau of Meteorological (BoM)[662]

BoM is Australia's national weather, climate and water agency. It provides observational, meteorological, hydrological and oceanographic services, and undertakes research in science and

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[660] NOAA, 2020. NOAA in the Pacific Islands Region. Available at: https://www.regions.noaa.gov/pacific-islands/index.php/noaa-resources-in-the-region/
[661] IPRC, 2019. About the IPRC. Available at: http://iprc.soest.hawaii.edu/about/about.php
[662] BoM, 2020. Available at: http://www.bom.gov.au/inside/index.shtml?ref=hdr

environment related issues in support of its operations and services. BoM is an Executive Agency that reports to the Minister of Environment on all general matters, and to the Minister for Agriculture and Water Resources on water-related matters. It fulfils Australia's international obligations under the Convention of the World Meteorological Organization (WMO) and related international meteorological treaties and agreements.

BoM supports and mentors Pacific NMHSs and is a member of SPC and SPREP. A major part of Australia's assistance to the Pacific region is through the Climate and Oceans Support Program in the Pacific (COSPPac). COSPPac provides a number of products and services, including the Ocean Portal, Seasonal Climate Outlook for Pacific Island Countries (SCOPIC), Online Climate Outlook Forum (OCOF), Water Storage Outlook Model, tidal information, sea level data, Malaria Early Warning System, Drought Monitoring and Response System, and the Climate Bulletin.[663]

BoM will support delivery of **sub-activity 2.1.1:** Technical support for the assembly, calibration, installation, operation and maintenance of observations equipment in compliance with the Global Basic Observing Network (GBON) requirements in all five countries – upon country request. BoM will also support delivery of **sub-activity 2.2.2:** Technical training, attachments and workshops on oceanography, climatology and climate forecasting – including dynamical prediction for multiple timescale climate outlooks and extreme event forecasting in all five countries; technical advisory and capacity building for ocean and climate modelling and impact-based forecasting in Cook Islands and Niue; NMHS and sector workshops on early warning services in Niue, Palau and Tuvalu; and technical support for climate data digitisation for Tuvalu.

New Zealand National Institute of Water and Atmospheric Research (NIWA)[664]

NIWA is a New Zealand government-owned Crown Research Institute. Its core purpose is "*to enhance the economic value and sustainable management of New Zealand's aquatic resources and environments, to provide understanding of climate and the atmosphere and increase resilience to weather and climate hazards to improve safety and wellbeing of New Zealanders."* NIWA hosts the secretariat of the New Zealand Climate Change Centre, which is a joint initiative between all New Zealand's Crown Research Institutes and two universities.

NIWA supports and mentors Pacific NMHSs; and is a member of SPC and SPREP. Through its Pacific Rim services, NIWA applies environmental science to contribute to sustainable development in the Asia-Pacific region. This includes coordination of the Island Climate Update – a regional climate bulletin that provides climate outlooks and projections, in association with SPC and SPREP; equipment supply and hydrological training support to the Pacific Hydrological Cycle Observing System (HYCOS) project; and support for the Cook Islands Ministry of Marine Resources to develop an integrated marine water quality monitoring network.

N.B. MetService[665] is the national weather authority for New Zealand. MetService is a state-owned enterprise and operates separately to NIWA.

NIWA will support delivery of **sub-activity 2.1.1:** Technical support for the assembly, calibration, installation, operation and maintenance of observations equipment in compliance with the Global Basic Observing Network (GBON) requirements in all five countries – upon country request. NIWA will also support delivery of **sub-activity 2.2.2:** Technical support to harmonise climate records; and generate customised early warning information and products in Niue and Tuvalu.

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663 COSPPac, 2020. Available at: http://cosppac.bom.gov.au/
664 NIWA, 2020. Available at: https://niwa.co.nz/
665 Meteorological Service of New Zealand, 2020. Available at: https://www.metservice.com/

International Federation of Red Cross and Red Crescent Societies (IFRC)[666]

IFRC is "a global humanitarian organisation that coordinates and directs international assistance following natural and man-made disasters in non-conflict situations." IFRC works with Red Cross and Red Crescent National Societies in relief operations combined with development work, which includes disaster risk reduction and preparedness programs. IFRC is a member of the Pacific Resilience Partnership Taskforce, which oversees the implementation of the Pacific Framework for Resilient Development (PFRD). The Red Cross Red Crescent Climate Centre – a specialist reference centre of the IFRC – is a member of the Pacific Islands Climate Services Panel, which advises the Pacific Meteorological Council (PMC).[667]

The Disaster Relief Emergency Fund (DREF) was established by IFRC in 1985 to provide immediate financial support to Red Cross and Red Crescent National Societies to act as first responders in disasters and health emergencies. In 2018, Forecast-based Action (FbA) by the DREF was launched as a mechanism specifically designed to fund Forecast-based Early Action Protocols (EAPs) developed by National Societies. The funding is pre-agreed in advance for the implementation of the EAP, which is a key element of Forecast-based Financing (FbF). Currently, eight EAPs have been approved (including for Bangladesh, Mongolia and Philippines in the Asia Pacific); three are under review; and 25 are under development (including for Indonesia, Myanmar, Nepal and Vietnam in the Asia Pacific).[668] Together with individual Red Cross Red Crescent National Societies where present in the five Pacific island countries and National Disaster Management Authorities, IFRC will support the Programme with expertise on last-mile delivery and FbF.

IFRC will support delivery of Activity 3.3 through **sub-activity 3.3.1:** Technical support to develop Forecast-based Financing (FbF) Roadmaps; **sub-activity 3.3.2:** Technical support and capacity building to operationalise FbF mechanisms; and **sub-activity 3.3.3:** Technical support to develop Early Action Protocols (EAPs) for FbF in all five countries.

APEC Climate Center (APCC)[669]

APCC is a non-profit public organisation located in the Republic of Korea that aims to enhance the socio-economic well-being of the Asia Pacific region by utilising up-to-date scientific knowledge, applying innovative climate prediction techniques, and promoting the application of climate information through various programs for capacity building and reducing climate risks in the region.

APCC has an Outreach Program for developing countries, which aims to contribute to the development of APEC member countries' climate change response and adaptation ability, and to sustainable development. This includes the Young Scientist Support Project (YSSP) – a capacity building program designed to strengthen the climate science abilities of early-career scientists in developing country NMHSs and national climate-related research centres; and to set up a cooperation network for future joint research. In 2017, YSSP focused on "Capacity Building and Enhancing Seasonal Prediction Services in the Pacific Island Countries", which included participants from Cook Islands, Niue, Palau and Tuvalu.

APCC previously implemented the Republic of Korea-Pacific Islands Climate Prediction Services (ROK-PI CliPS) project together with SPREP; and agriculture and water management projects with the Government of Tonga. APCC is also a delivery partner of the FP035 "Climate Information Services for Resilient Development in Vanuatu".

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[666] IFRC, 2020. Available at: https://www.ifrc.org/
[667] IFRC, 2018. Case Studies: Red Cross Red Crescent Disaster Risk Reduction in Action – What Works at Local Level
[668] IFRC, 2020. Forecast-based Action by the DREF. Available at: https://media.ifrc.org/ifrc/fba/
[669] APCC, 2020. Available at: https://www.apcc21.org/

APCC will support delivery of **sub-activity 2.2.2:** Technical training to enhance in-house forecasting and multi-model ensemble prediction capacity; training for early-career scientists through its Young Scientist Support Program; and technical support for the generation of sector-tailored climate information in all five countries. APCC will also support delivery of **sub-activity 3.1.2:** Development and implementation of localised mobile climate information communication systems in all five countries.

9.5 PROGRAMME STEERING COMMITTEE (PSC)

The Programme Steering Committee (PSC) will be established comprising the five NDAs and a UNEP representative. It will meet at least once per year and will be co-chaired by the NDAs (in rotation) and UNEP. The PSC will provide high-level oversight and guidance towards achieving Programme objectives. The PSC is a consensus-based decision-making body within the Programme governance structure and will provide, review and monitor strategic direction and policy guidance to the Programme team and other stakeholders. Among other functions, the PSC will review and approve the annual workplan and budget and approve the Programme's annual report as prepared by the PMU and national EEs. The committee also provides recommendations on Programme approaches and participates in discussing general strategies and opportunities for Programme planning and implementation.

The functions of the Steering Committee are:

i. Providing overall guidance for Programme execution to the PMU, especially on cross-cutting issues which require consensus from the various stakeholders involved in the Programme;

ii. Ensuring that recommended policy and institutional strengthening undertaken under the Programme is consistent with the Programme's overall agenda;

iii. Ensuring full cooperation of various regional and national stakeholders under their jurisdictions to provide access and support to the Programme team in carrying out their tasks;

iv. Representing the interests of civil society and communities in their countries derived from a regular formal dialogue between NDAs and national peak bodies; and

v. Reviewing and monitoring progress in Programme execution.

The members of the Steering Committee will be the five NDAs and the UNEP Representative. Observers will include:

i. the Programme Coordinator;

ii. the five National EEs;

iii. Representatives from the Regional Technical Partner agencies involved in Programme implementation—SPREP, SPC, NIWA, BoM, UH, NOAA, IFRC, APCC and others as appropriate;

iv. additional entities involved in Programme implementation, in particular the NMHSs, National Disaster Management Authorities and community-based organisations with experience in disaster risk management;

v. Representatives of civil society;

vi. Representatives of women's organisations; and

vii. Representatives of the private sector.

Secretariat services will be provided by the Programme Management Unit (PMU). The minutes of the Annual Meeting will be provided to the AE by the Programme Coordinator.

The Programme Steering Committee will also be used as a vehicle for enhancing South–South cooperation among the five participating countries.

9.6 NATIONAL COORDINATION COMMITTEES (NCCS)

A National Coordination Committee (NCC) will be established in each of the five countries. The NCCs will include key stakeholders from the national government (in particular, the NMHS and National Disaster Management Authority), national campuses of the University of the South Pacific (USP) (present in Cook Islands, Niue and Tuvalu), community representatives, private sector representatives, civil society and NGOs involved in early warning and disaster risk reduction, as well as the NDA (who represents the country in the PSC). The NCC is a decision-making body within the national-level programme governance structure and will also play a key role in the Grievance Redress Mechanism. It consists of agency or divisional managers and decision-makers who provide, review and monitor strategic direction and policy guidance to the national Programme team and other stakeholders including community-based organisations with experience in disaster risk management. Among other functions, the NCC will review and approve the national annual workplan and budget and approve the Programme's annual report for submission to the PMU and PSC. The Committee also provides recommendations on Programme approaches and participates in discussing general strategies and opportunities for Programme planning and implementation.

The functions of the Committee will include:

i. Providing overall guidance for Programme execution to the EEs, especially on cross-cutting issues that require consensus from the various stakeholders involved in the Programme;

ii. Ensuring that recommended policy and institutional strengthening undertaken under the Programme is consistent with the country's overall development priorities;

iii. Ensuring full cooperation of various stakeholders to provide access and support to the EEs in carrying out their tasks; and

iv. Reviewing and monitoring progress in national Programme execution.

Countries may use an existing national Project / Programme Steering Committee that is managing related activities with the same members—the NMHS, the climate change agency, the national broadcaster, disaster management and emergency services, etc. If such a standing Steering Committee does not exist, the National Coordination Committee for the Programme will be established as above.

The National Coordination Committee will meet quarterly. Minutes of the quarterly meeting will be provided to the central Programme Steering Committee through the PMU.

9.7 NATIONAL SERVICE PROVIDERS

National service providers will be subcontracted by the national EEs. These include the National Meteorological and Hydrological Services (NMHSs), National Disaster Management Authorities, the government climate change agencies and environment ministries, sectoral agencies such as health, agriculture and fisheries, civil society organisations, national campuses of the University of the South Pacific (USP) (present in Cook Islands, Niue and Tuvalu), Red Cross Red Crescent National Societies, other NGOs involved in early warning, and communities. These organisations will implement activities as described in the country profiles in the Feasibility Study.

For example:

- Emergency Management Cook Islands (the national disaster management authority) will use GIS mobile apps technology to undertake household disaster risk surveys in the outer islands, storing the data in a portal to be used to improve response times and effectiveness in disasters.
- The Girls' and Boys' Brigades in Niue will conduct disaster preparation training and collect traditional climate knowledge from elders; the Broadcasting Corporation of Niue will acquire graphical software to use in weather and climate forecasts and will develop and use climate terminology in Vagahau Niue.
- The Palau Red Cross Society and the Center for Women's Empowerment Belau, in cooperation with seven government and non-government agencies, will conduct training for women's organisations on community and individual needs and responses before, during, and after a disaster or single incident emergency.
- The Marshall Islands Red Cross (MIRCFbF) will enhance disaster preparedness and response measures through supporting Early Response Teams in outer-islands; the Marshall Islands Conservation Society will purchase community-based coral health chart kits for distribution to rural communities and will train communities in their use - the kits will be used by early warning response teams at remote locations to easily identify signs of the early onset of coral reef bleaching.
- The Red Cross Society in Tuvalu and WMO staff will conduct consultations with each island community, collecting disaggregated information on different vulnerable groups to identify risks and priorities for climate early warning systems; BoM will provide robust and user-friendly iPhone and iPad apps, to enable Tuvalu's NMHS to produce social media and video communication products for stakeholders and communities.

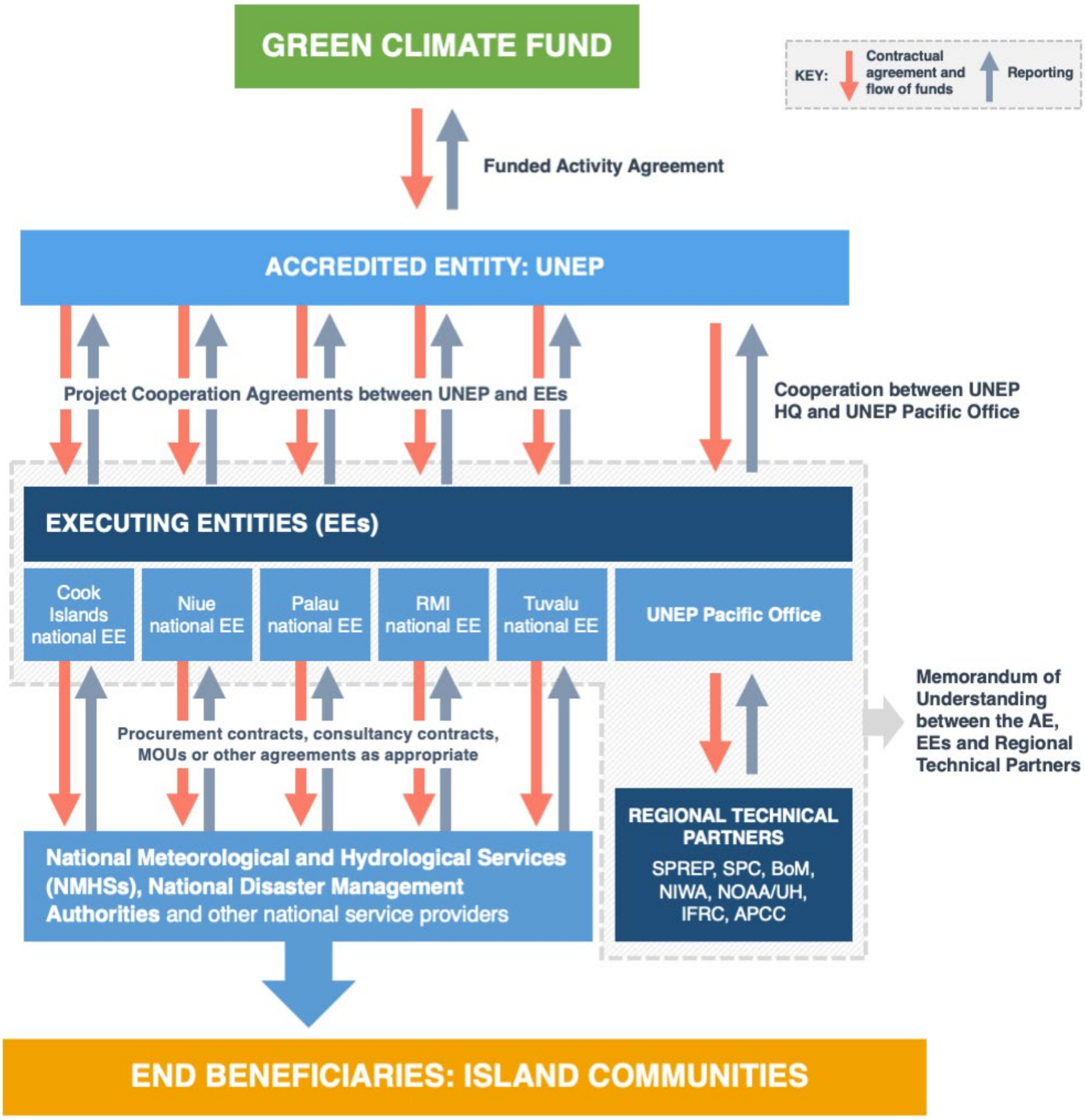


Figure 100. Flow of funds and contractual arrangements for Programme implementation. Red arrows indicate the contractual agreements, including the types of contracts between relevant parties, and flow of funds. Blue arrows indicate the reporting arrangements.

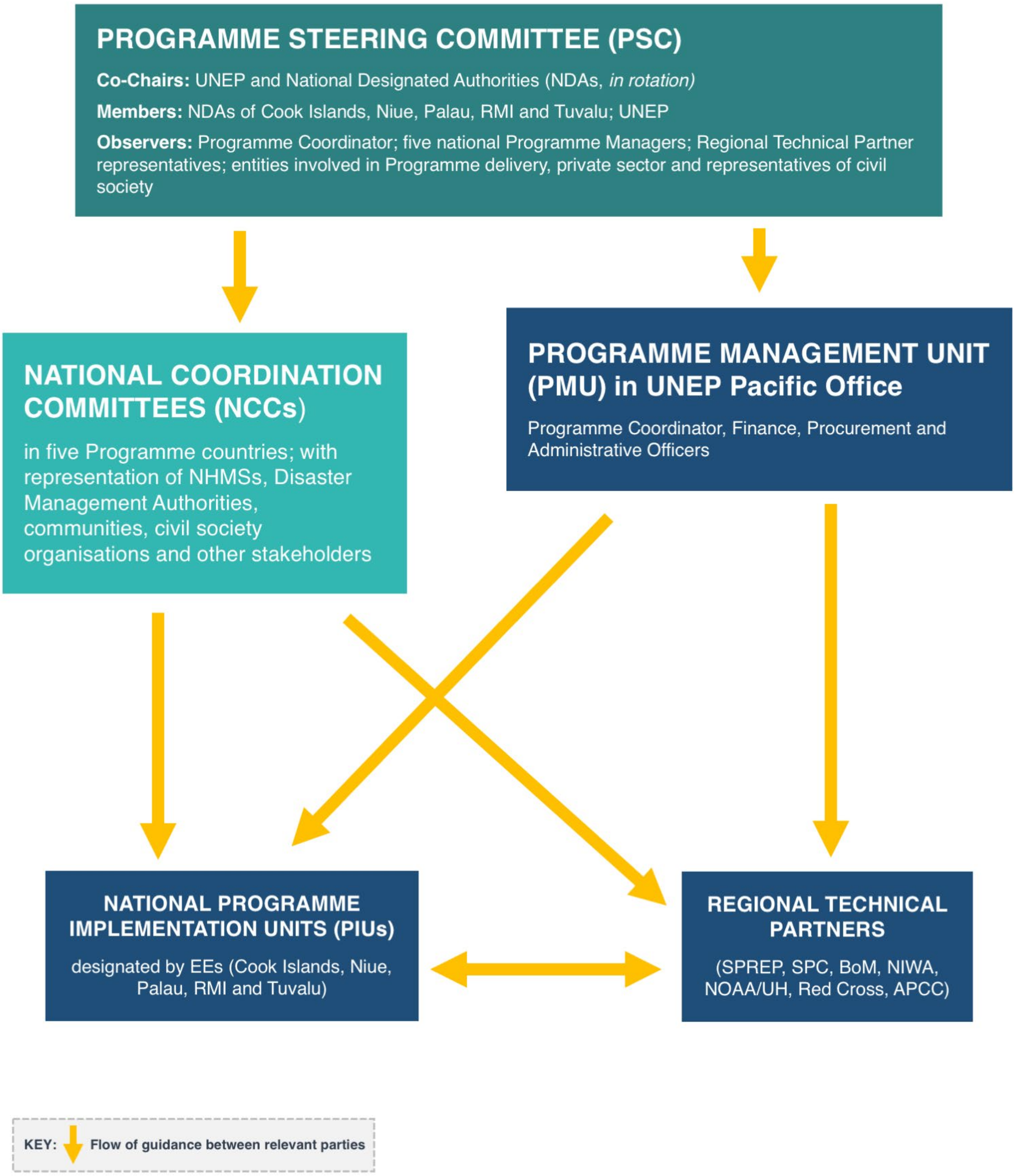


Figure 101. Programme governance arrangements. Yellow arrows indicate the flow of guidance between relevant parties.

APPENDIX 1 – LIST OF ACRONYMS

AE	Accredited Entity
APDRC	Asia Pacific Disaster Resilience Center
AR5	Fifth Assessment Report
AWS	Automatic Weather Station
BIP-MT	Basic Information Package Meteorological Training
BMT	Bureau of Marine Transportation
BOM	Australian Bureau of Meteorology
CCAM	Conformal Cubic Atmospheric Model
CCCI	Climate Change Cook Islands
CCP	Climate Change Policy
CDMS	Climate Data Management System
CIMS	The Cook Islands Meteorological Service
CLEWS	Climate Early Warning Systems
CLICC	Country Level Impacts of Climate Change
CliDE	Climate Data for the Environment
CMAC	Coastal Management Advisory Council
CMIP3	Coupled Model Intercomparison Project 3
CMIP5	Coupled Model Intercomparison Project 5
COFA	The Compacts of Free Association
COSPPac	Climate and Ocean Support Program in the Pacific
COSPPac 2	Climate and Oceans Support Program in the Pacific 2
CREWS	Climate Risk Early Warning System
CSIRO	Commonwealth Scientific and Industrial Research Organization
CTI	Climate Index for Tourism
DCCD	Department of Climate Change and Disaster
DRM	Disaster Risk Management
DRM NAP	Disaster Risk Management National Action Plan
EAR Watch	Early Action Rainfall Watch

EBSs	Emergency Sign Boards
EDA	Enhanced Direct Access
EE	Executing Entity
EEZ	Exclusive Economic Zone
EMCI	Emergency Management Cook Islands
ENSO	El Niño – Southern Oscillation
ERTs	Emergency Response Teams
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EWS	Early Warning Systems
FAO	Food and Agriculture Organization
FbF	Forecast-Based Financing
FDMP	Functional Decision-Making Procedures
FMS	Fiji Meteorological Service
FRDP	Framework for Resilient Development in the Pacific
GCCA	Global Climate Change Alliance
GCF	Green Climate Fund
GCM	General Circulation Model
GCOS	Global Climate Observing System
GDP	Gross Domestic Product
GEM	Geoscience, Energy and Maritime
GFCS	Global Framework for Climate Services
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Global Greenhouse Gas
GIS	Geographic Information System
GPS	Global Positioning System
GTS	Global Telecommunication System
ICAO	Convention and International Civil Aviation Organization
ICCRIFS	Integration of Climate Change Risk and Resilience into Forestry Management in Samoa
ICT	Information Communication Technology

IDL	International Date Line
IE	Implementing Entity
IFRC	International Federation of Red Cross
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPO	Inter-decadal Pacific Oscillation
ITCZ	Inter Tropical Convergence Zone
JNAP	Joint National Action Plan
JNAP II	The Second Joint National Action Plan for Climate Change and Disaster Risk Management
JTWC	US Joint Typhoon Warning Center
LDCs	Least Developed Countries
MEAs	Multilateral Environmental Agreements
METAR	METeorological Aviation Report
MIRCS	Marshall Islands Red Cross Society
MMDC	Modbus Meteorological Display Consoles
MNR	Ministry of Natural Resources
MRO	Mass Rescue Operations
NAPA	National Adaption Programme of Action
NC	National Coordinator
NCOF	National Climate Outlook Forum
NCT	National Coordination team
NDA	National Designated Authority
NDC	Nationally Determined Contribution
NDISAP	National Data and Information Strategic Action Plan
NDMO	National Disaster Management Office
NEMO	National Emergency Management Organization
NEOC	National Emergency Operation Centre
NES	National Environmental Service
NFCS	National Framework for Climate Services

NGO	Non-Government Organization
NIIP	National Infrastructure Investment Plan
NIWA	National Institute of Water and Atmospheric Research
NMHS	National Meteorological and Hydrological Services
NMS	Niue Meteorological Service
NNSP	Niue National Strategic Plan
NOAA	National Ocean and Atmospheric Administration
NSDP	National Sustainable Development Plan
NWP	Numerical Weather Prediction
NWS	National Weather Service
OCC	Office of Climate Change
OCOF	Online Climate Forecast
OEPPC	Office of Environment Planning and Policy Coordination
OOP	Office of the President
OSO	Ocean Science Officer
PACC	Pacific Adaptation to Climate Change
PACCSAP	Pacific Australia Climate Change Science and Adaption Planning program
PacIOOS	Pacific Islands Ocean Observing System
PAN	Protected Areas Network
PCC-CRE	Palau Community College-Cooperative Research and Extension
PCCSP	Pacific Climate Change Science Program
PDO	Pacific Decadal Oscillation
PEARL	Pa Enua Action for Resilient Livelihoods
PICOF	Pacific Islands Climate Outlook Forum
PICTs	Pacific Island Countries and Territories
PIMS	Pacific Island Meteorological Strategy
PI-RCC	Pacific Islands Regional Climate Centre
PIU	Programme Implementation Unit
PMC	Pacific Meteorological Council
PMCU	Project Management Coordination Unit

PMU	Programme Management Unit
PRCS	Palau Red Cross Society
PRSCS	Pacific Roadmap for Strengthened Climate Services
PWD	Public Works Department
PWSO	Palau Weather Services Office
R2R	Ridge to Reef
RESPAC	Disaster Resilience for Pacific SIDS
RISA	Pacific Regional Integrated Sciences and Assessments
RMI	Republic of Marshall Islands
RMI WSO	RMI Weather Services Office
SAP	Simplified Approval Process
SCOPIC	Seasonal Climate Outlook for Pacific Island Countries
SDGs	Sustainable Development Goals
SIDS	Small Island Developing States
SIWSAP	Solomon Islands Water Sector Adaptation Project
SLM	Sustainable Land Management
SOLAS	Safety of Life at Sea
SPC	Secretariat of the Pacific Community
SPCZ	South Pacific Convergence Zone
SPREP	Secretariat of the Pacific Regional Environment Programme
SREX	Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
SRIC	Strengthening the Resilience of our Island and our Communities to climate change
SRIC-CC	Strengthening the resilience of our islands and our communities to climate change
SST	Sea surface temperature
TAO	Tropical Atmosphere Ocean
the Programme	Enhanced Climate Information and Knowledge Services Programme
TK	Traditional Knowledge
TMS	Tuvalu Meteorological Service

UAS	Unmanned Aircraft System
UH	University of Hawaii
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations Office for Disaster Risk Reduction
UoGuam	University of Guam
USAPI	U.S.-Affiliated Pacific Islands
USP-EU	University of South Pacific – European Union
VN	Vagahau Niue
VOS	Voluntary Observing Ship Scheme
VSAT	Very Small Aperture Terminal
WFO	Weather Forecast Offices
WIS	Weather Information System
WMO	World Meteorological Organization
WPM	Western Pacific Monsoon
WPWP	West Pacific Warm Pool
WSO	Weather Services Office

APPENDIX 2 – SUPPLEMENTARY CLIMATE INDICES AND COUNTRY-SPECIFIC ANALYSES

EXTREME CLIMATE INDICES

The **Pacific Climate Change Data Portal** was developed through the Pacific Climate Change Science Program (2009 – 2011) to provide access to historical climate trends and basic climate information from observation sites across the Pacific islands and Timor-Leste. The Portal is the main means of sharing information for the Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Program.[670]

The Portal contains extreme temperature and rainfall indices based on those defined by the WMO Expert Team on Climate Change Detection Monitoring and Indices (ETCCDMI). The extreme climate analyses are calculated using high-quality daily temperature and rainfall datasets developed specifically for monitoring long-term trends and variability in the Pacific. The datasets are available at http://www.bom.gov.au/climate/pccsp/.

The extreme climate indices calculated for Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (Marshall Islands) and Funafuti (Tuvalu) additional to those provided in Section 3 are obtained from the Pacific Climate Change Data Portal and are provided on the following pages.

[670] Australian Bureau of Meteorology, 2020. Pacific Climate Change Data Portal. Available at: http://www.bom.gov.au/climate/pccsp/

Cool days

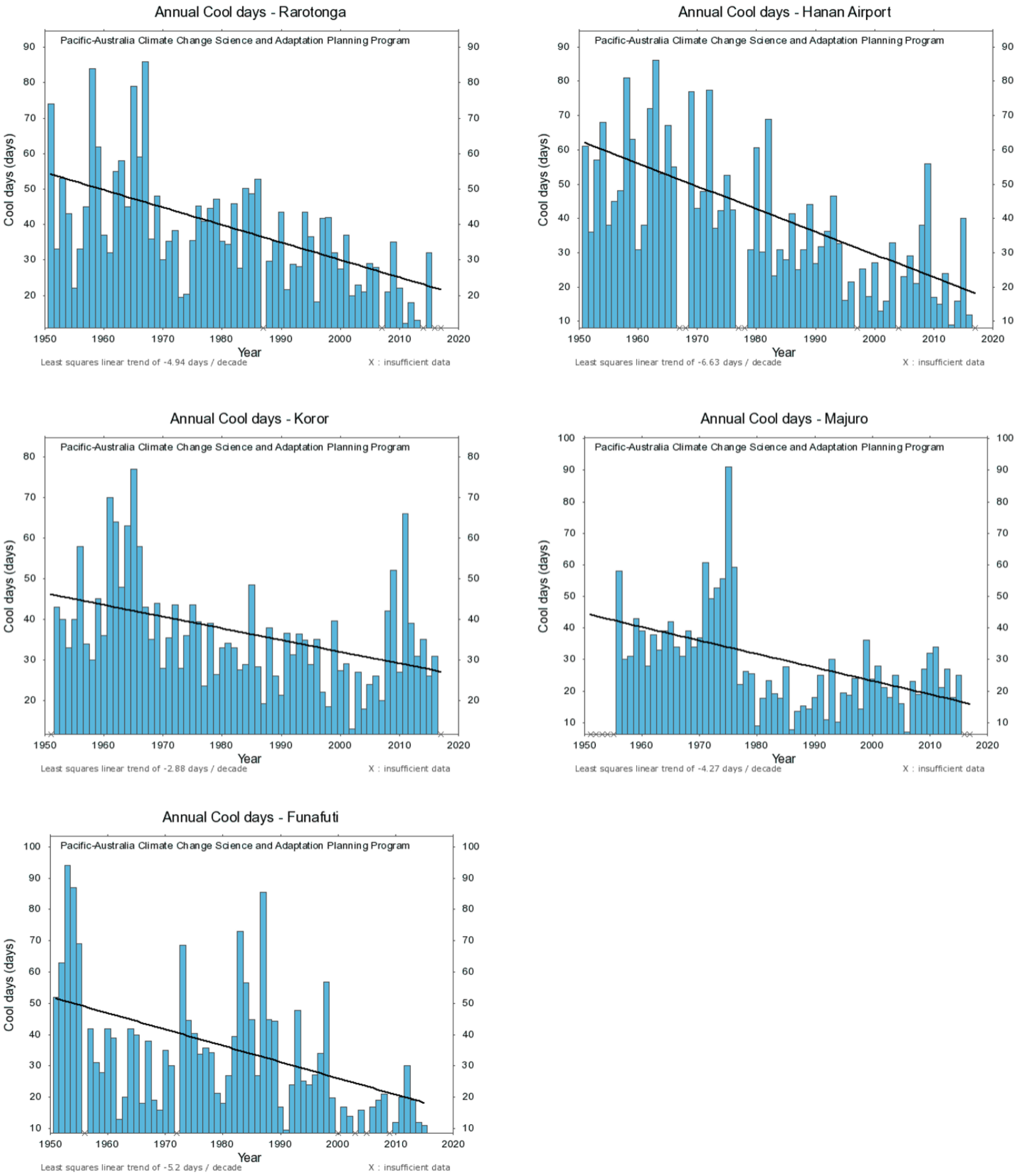


Figure 102. Time series of annual cool days (TX10p) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Cool nights

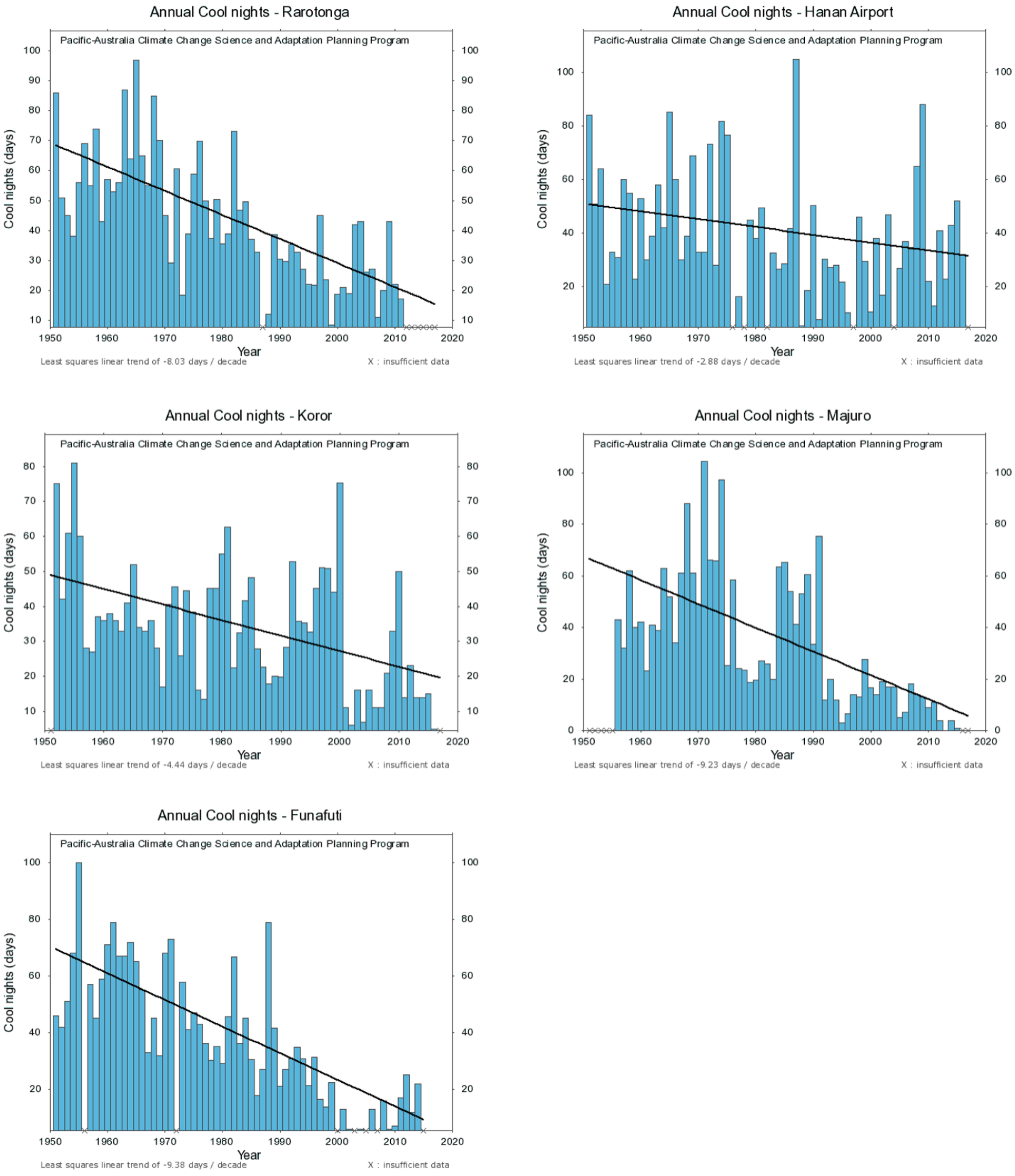


Figure 103. Time series of annual cool nights (TN10p) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Warm days

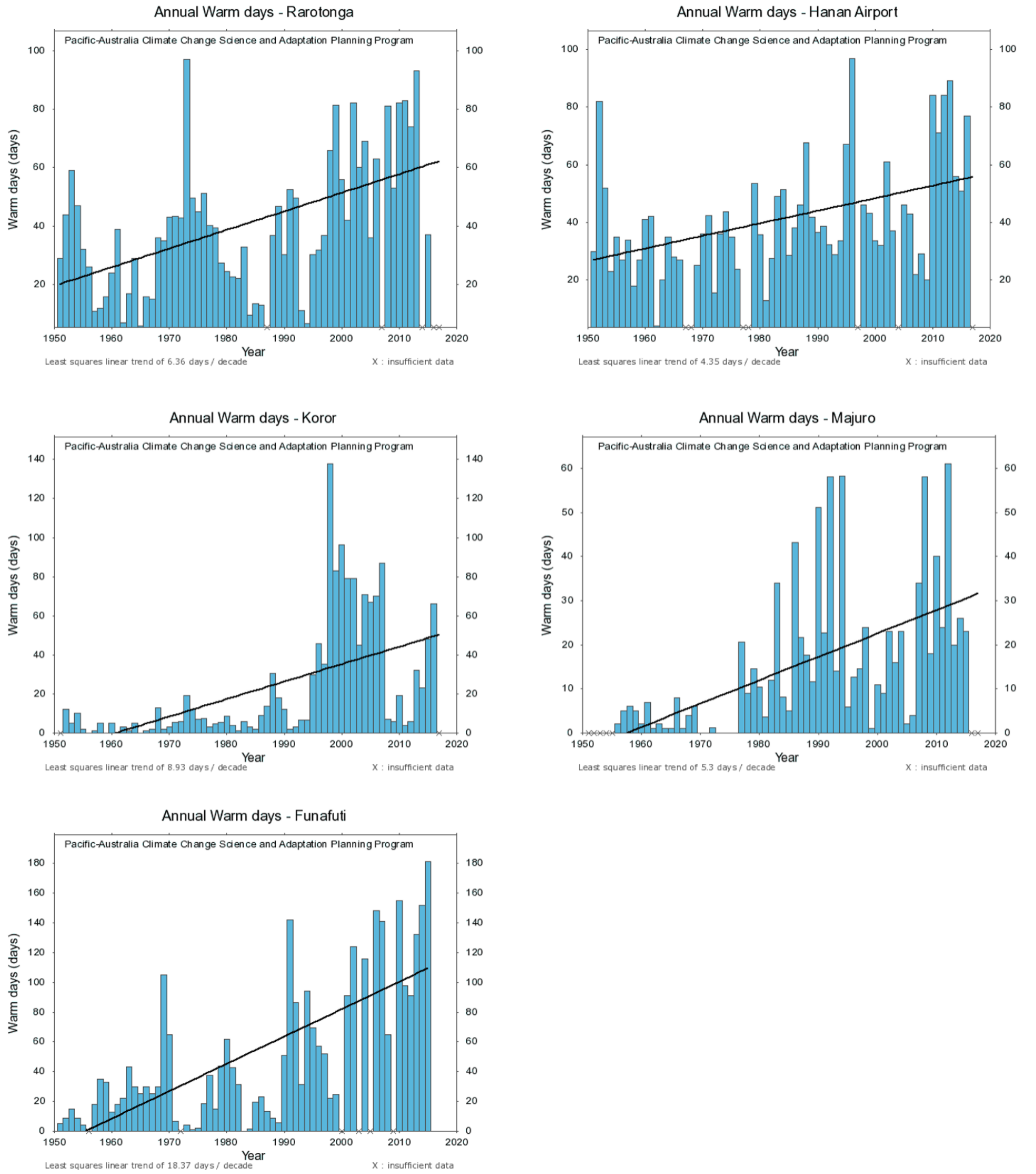


Figure 104. Time series of annual warm days (TX90p) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Warm nights

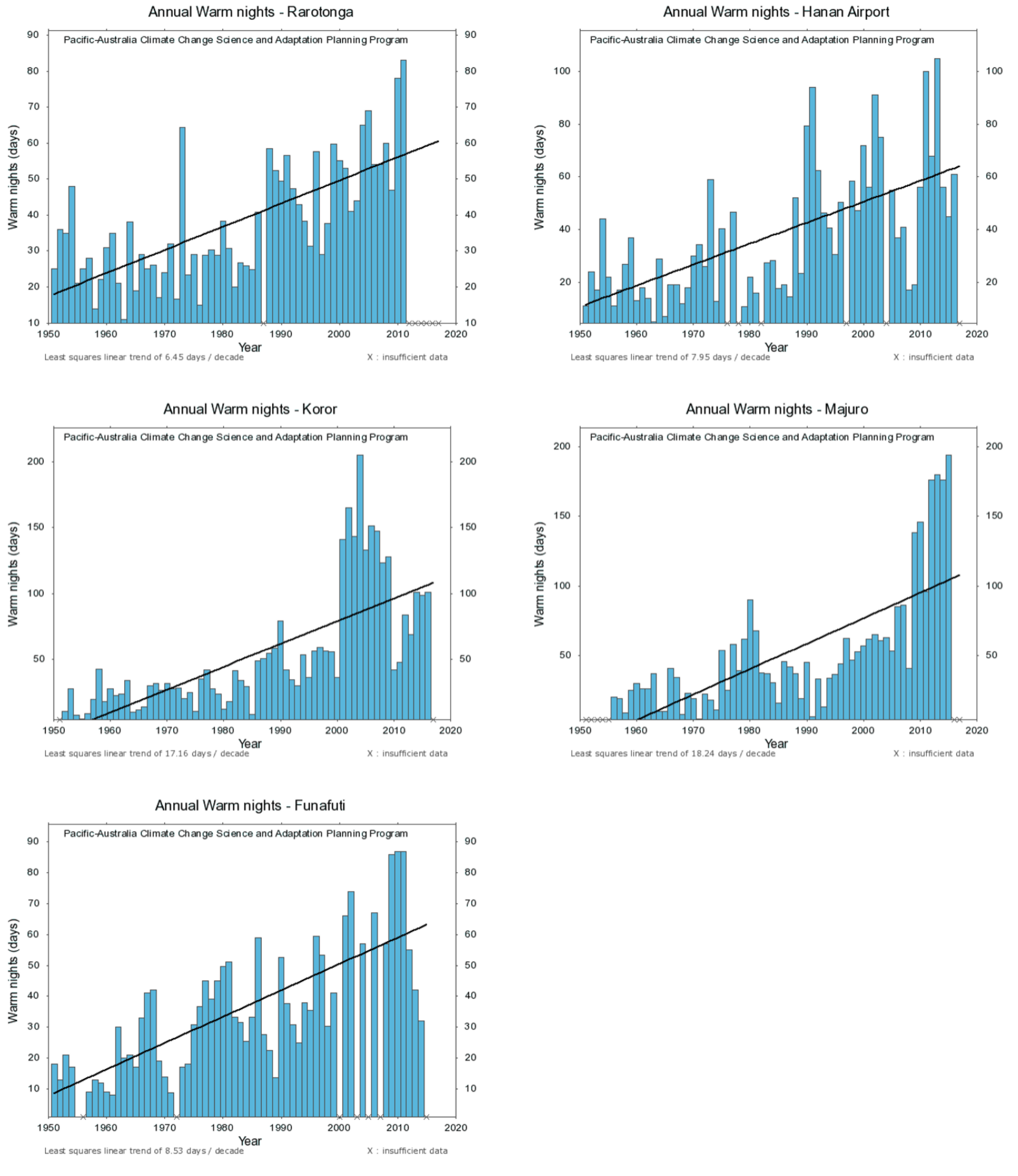


Figure 105. Time series of annual warm nights (TN90p) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Warm spell duration

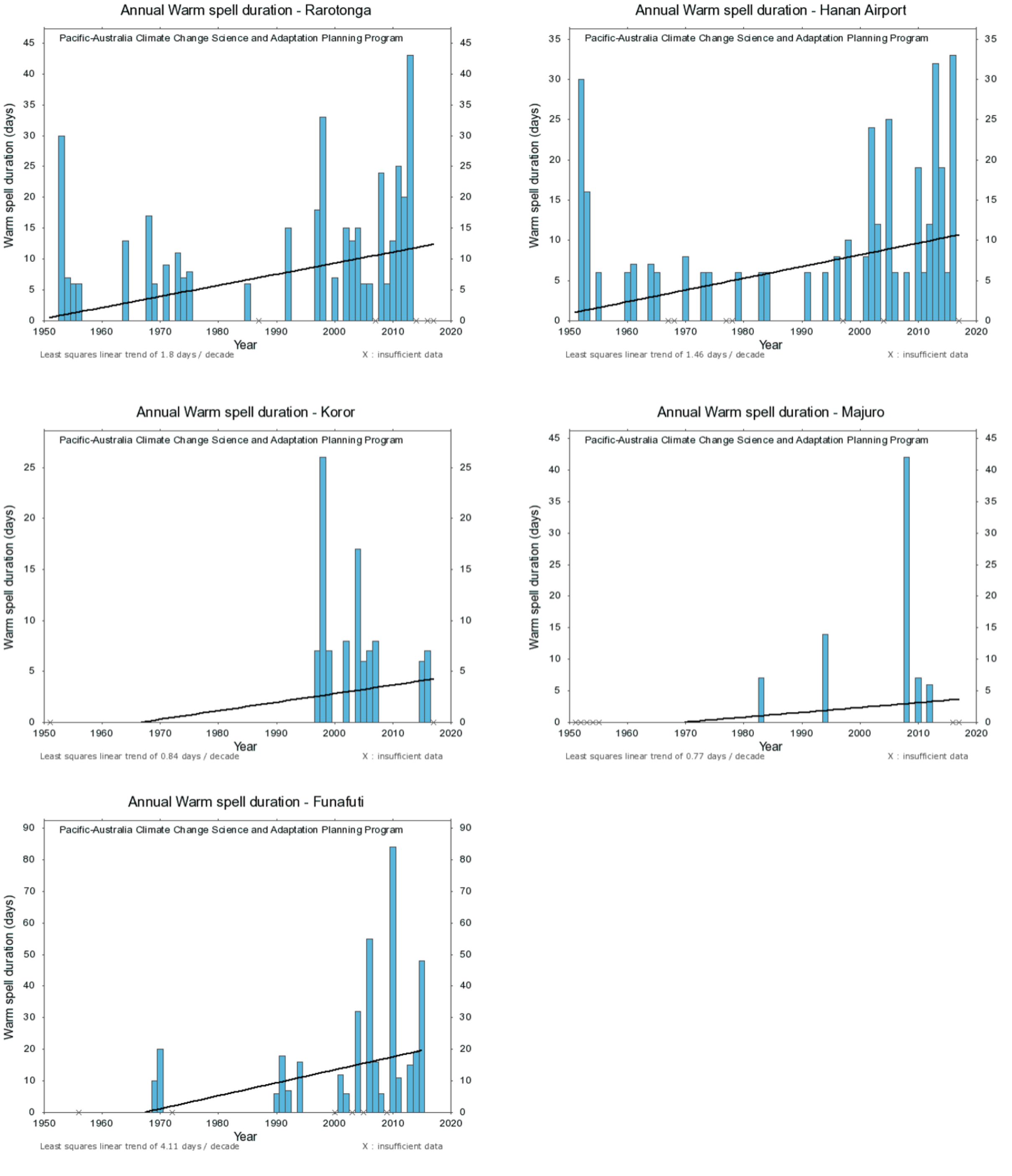


Figure 106. Time series of annual warm spell duration (WSDI) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Cold spell duration

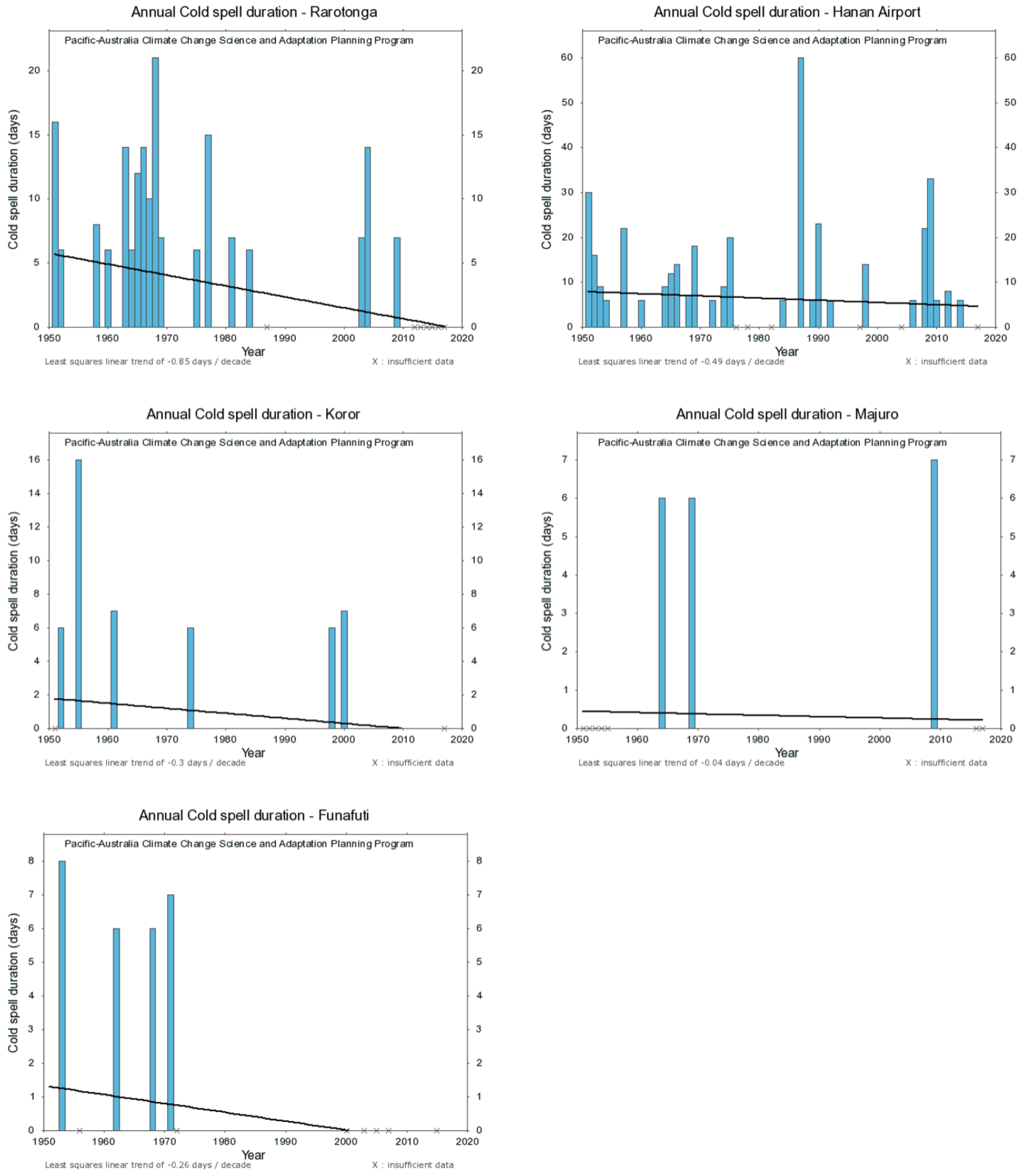


Figure 107. Time series of annual cold spell duration (CSDI) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Diurnal temperature range

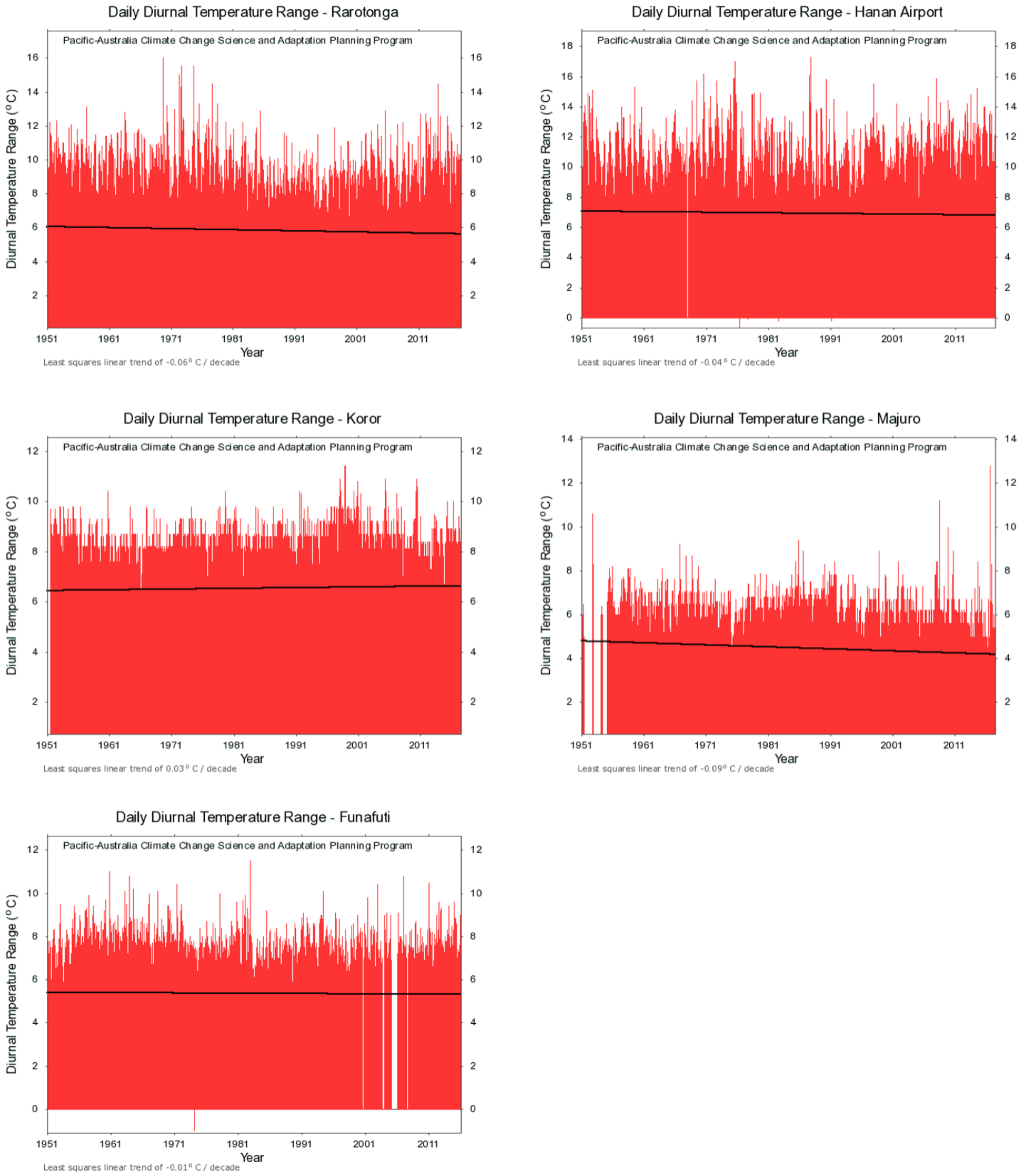
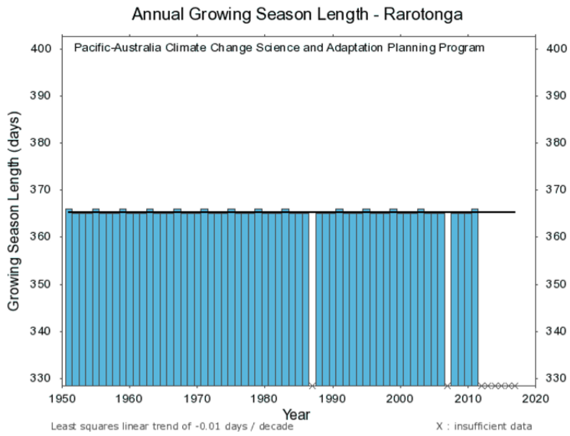
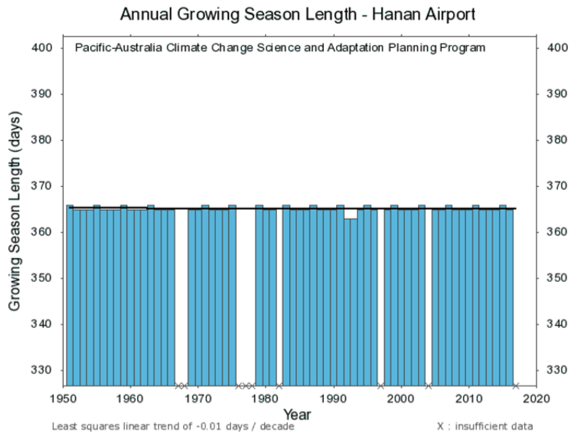
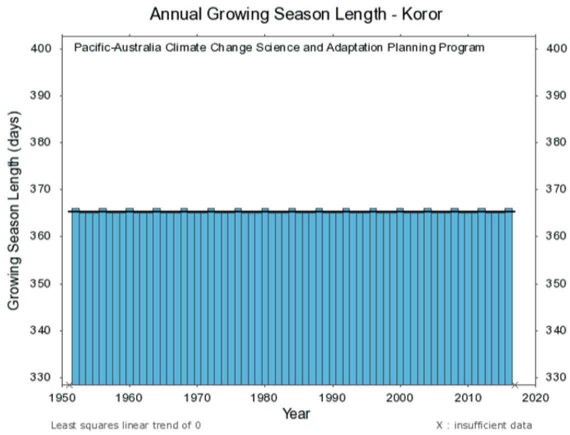


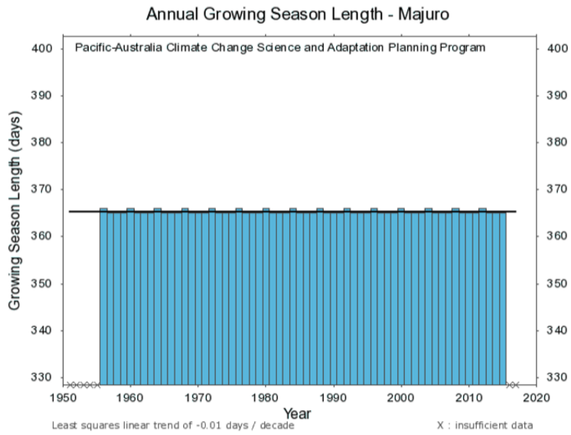
Figure 108. Time series of daily diurnal temperature range (DTR) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Growing Season Length









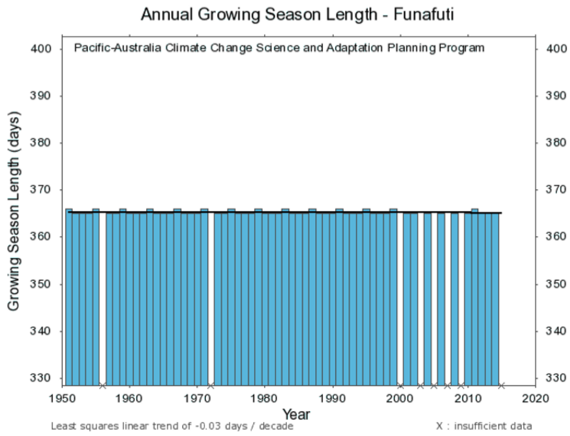


Figure 109. Time series of annual growing season length (GSL) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Max 1-day rainfall

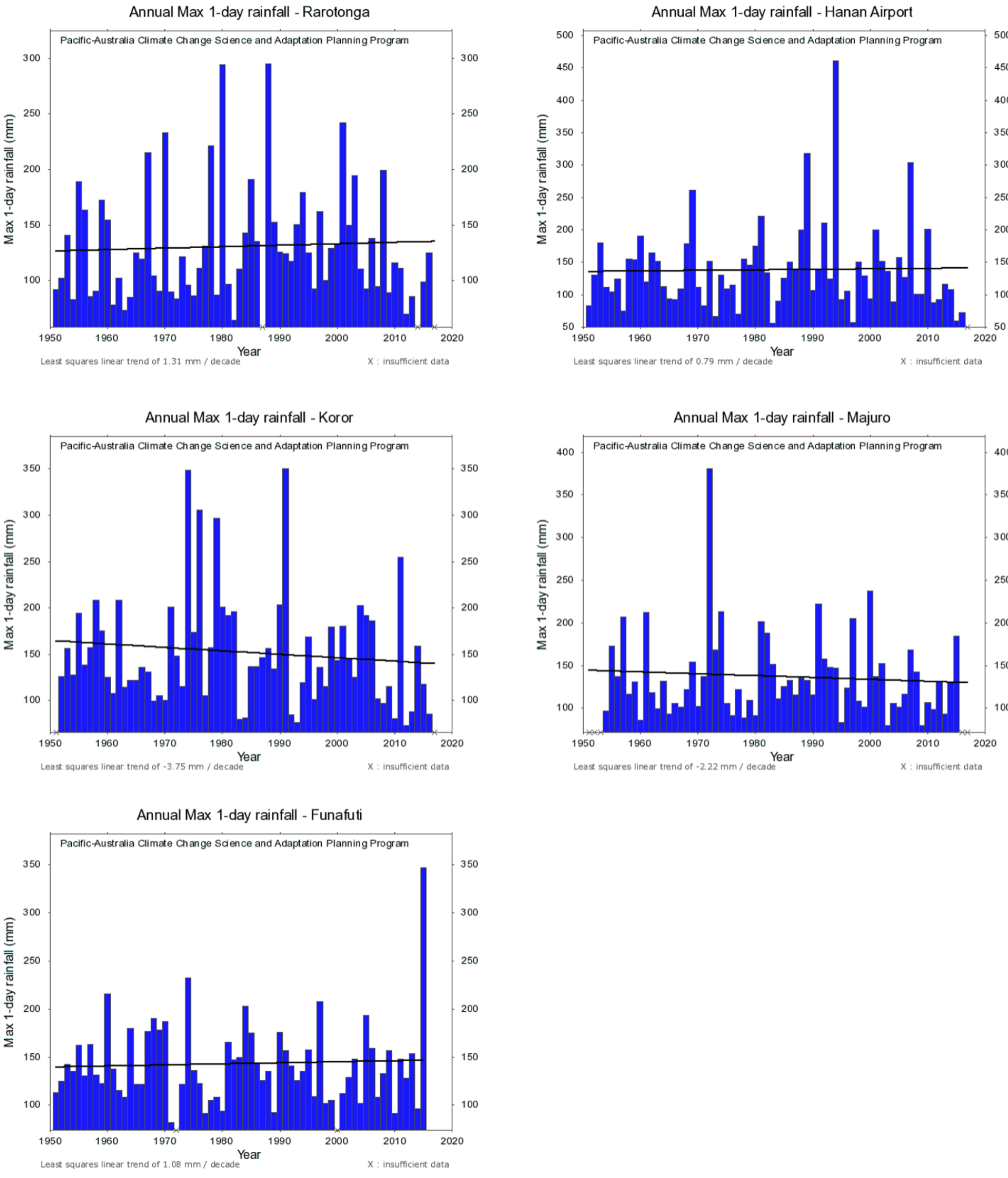


Figure 110. Time series of annual max 1-day rainfall (Rx1day) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Max 5-day rainfall

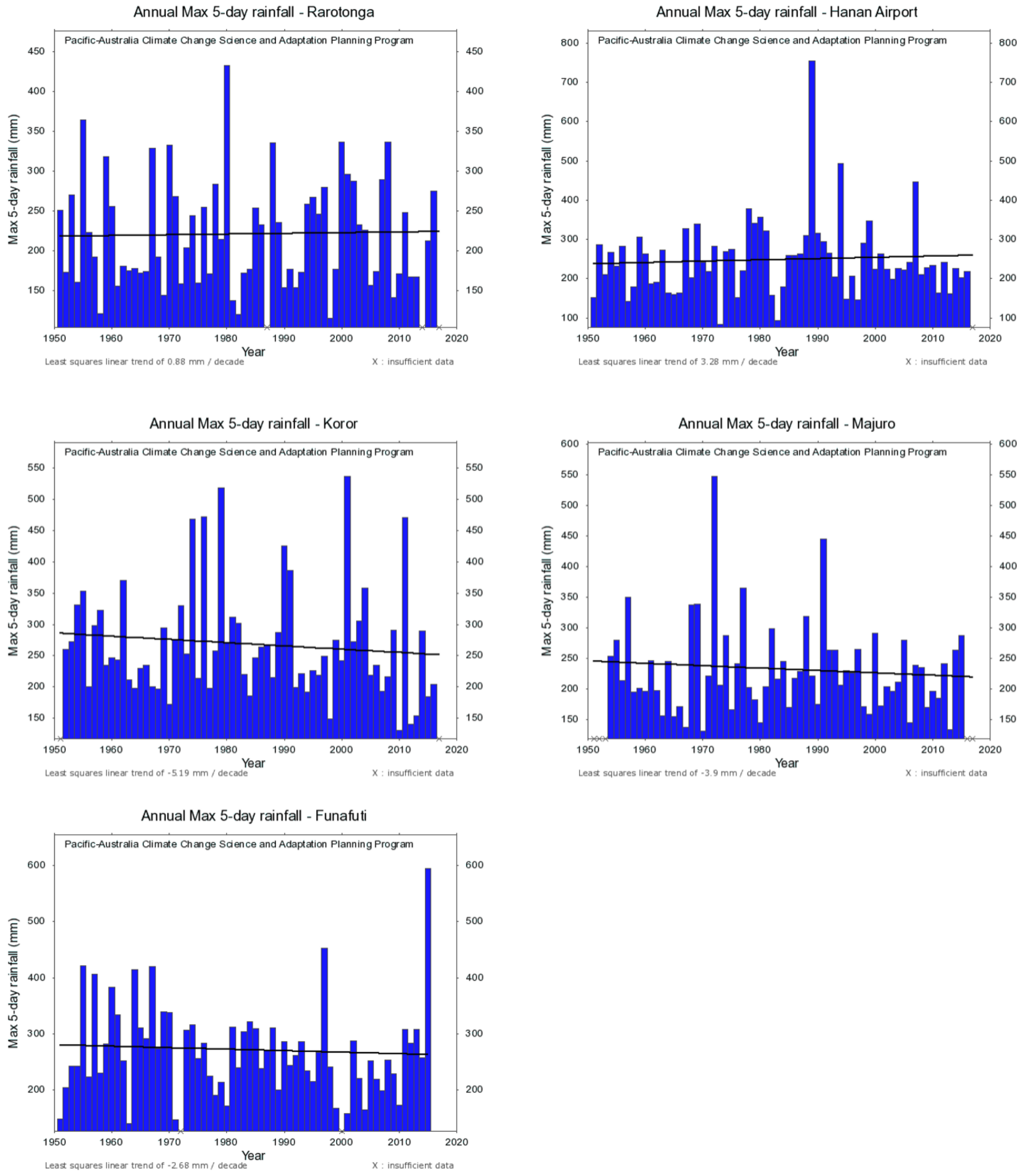


Figure 111. Time series of annual max 5-day rainfall (Rx5day) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Simple daily intensity

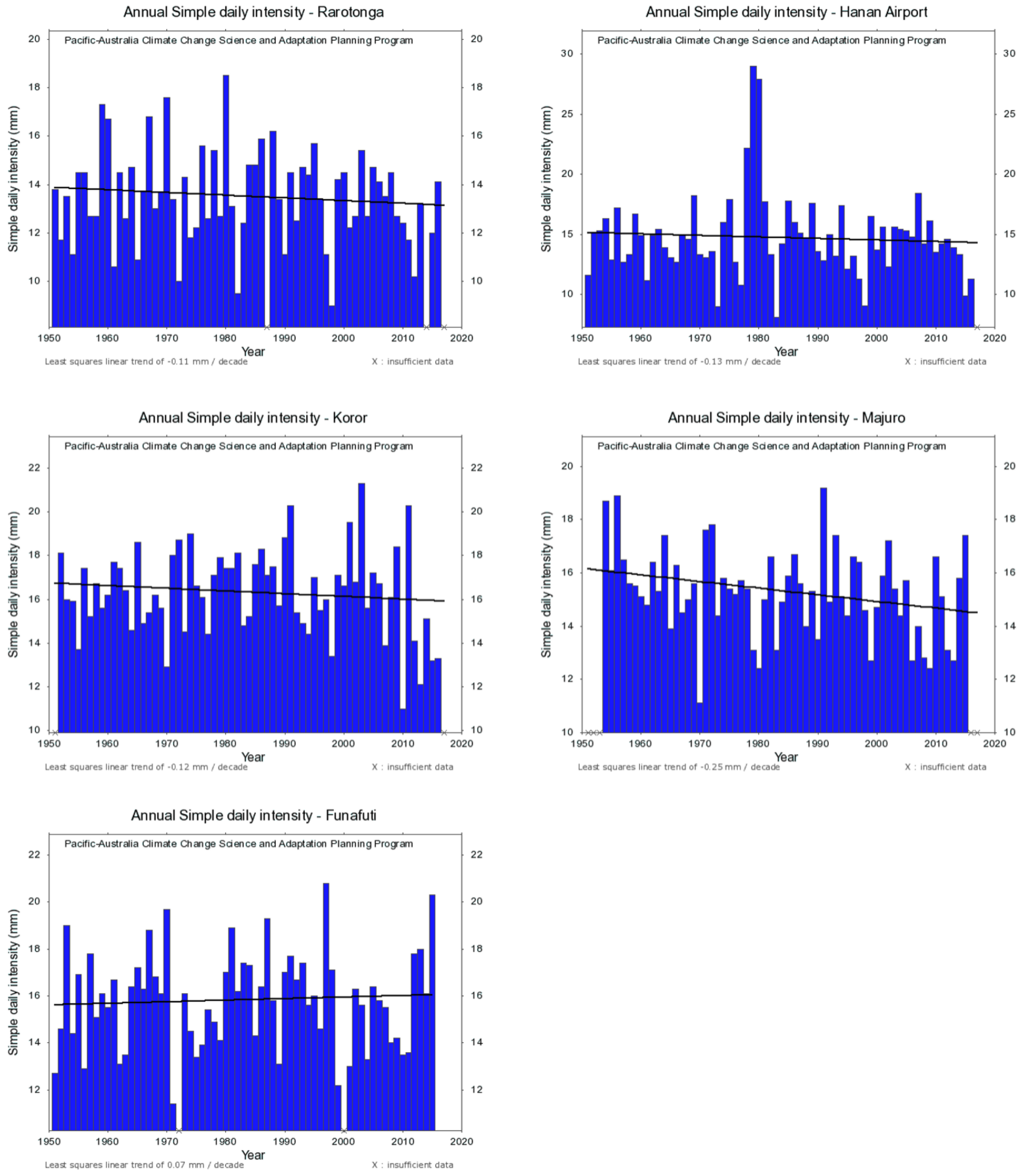


Figure 112. Time series of annual simple daily intensity (SDII) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Rain days ≥ 10 mm

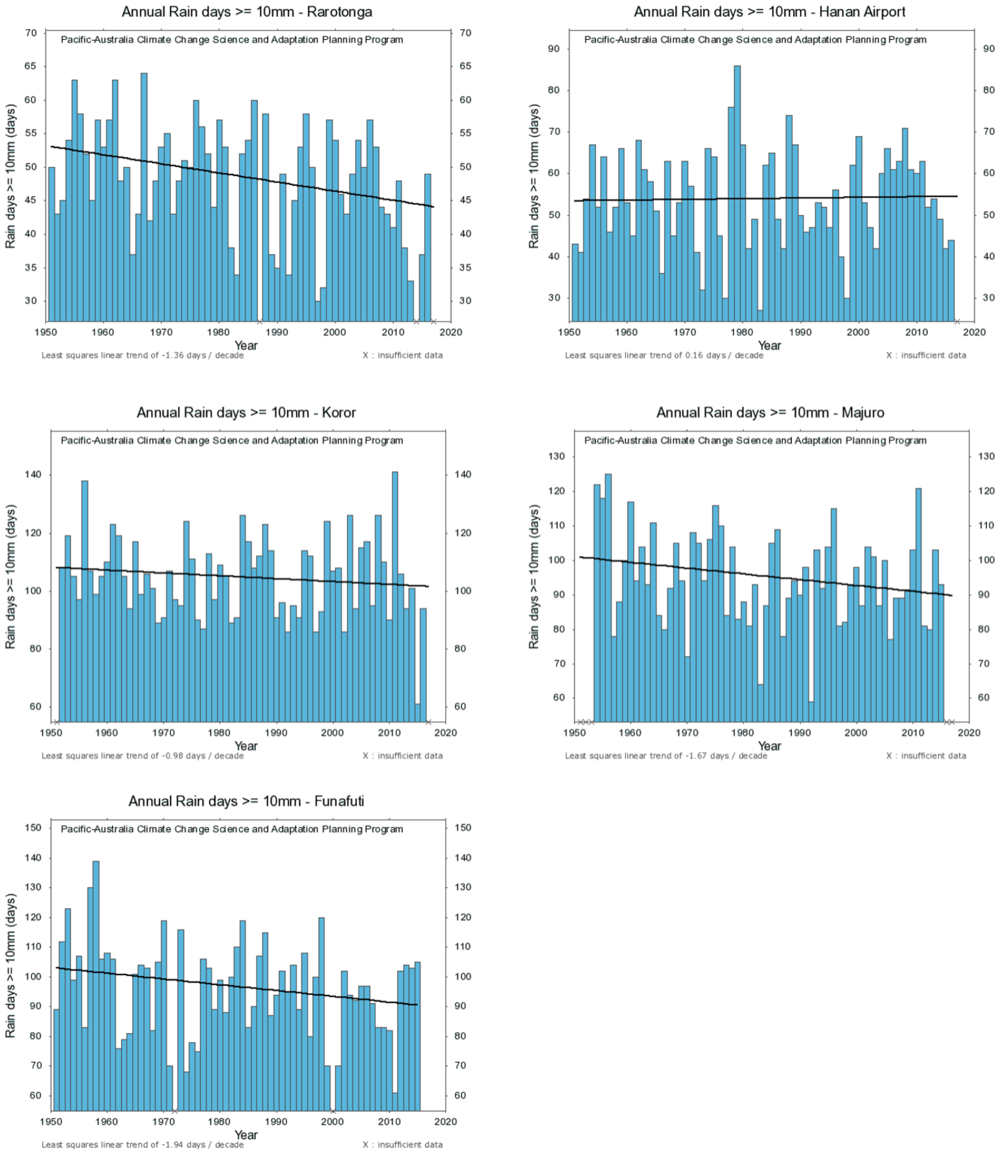


Figure 113. Time series of annual rain days ≥ 10 mm (R10) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

GREEN CLIMATE FUND

UN environment programme

Rain days ≥ 20 mm

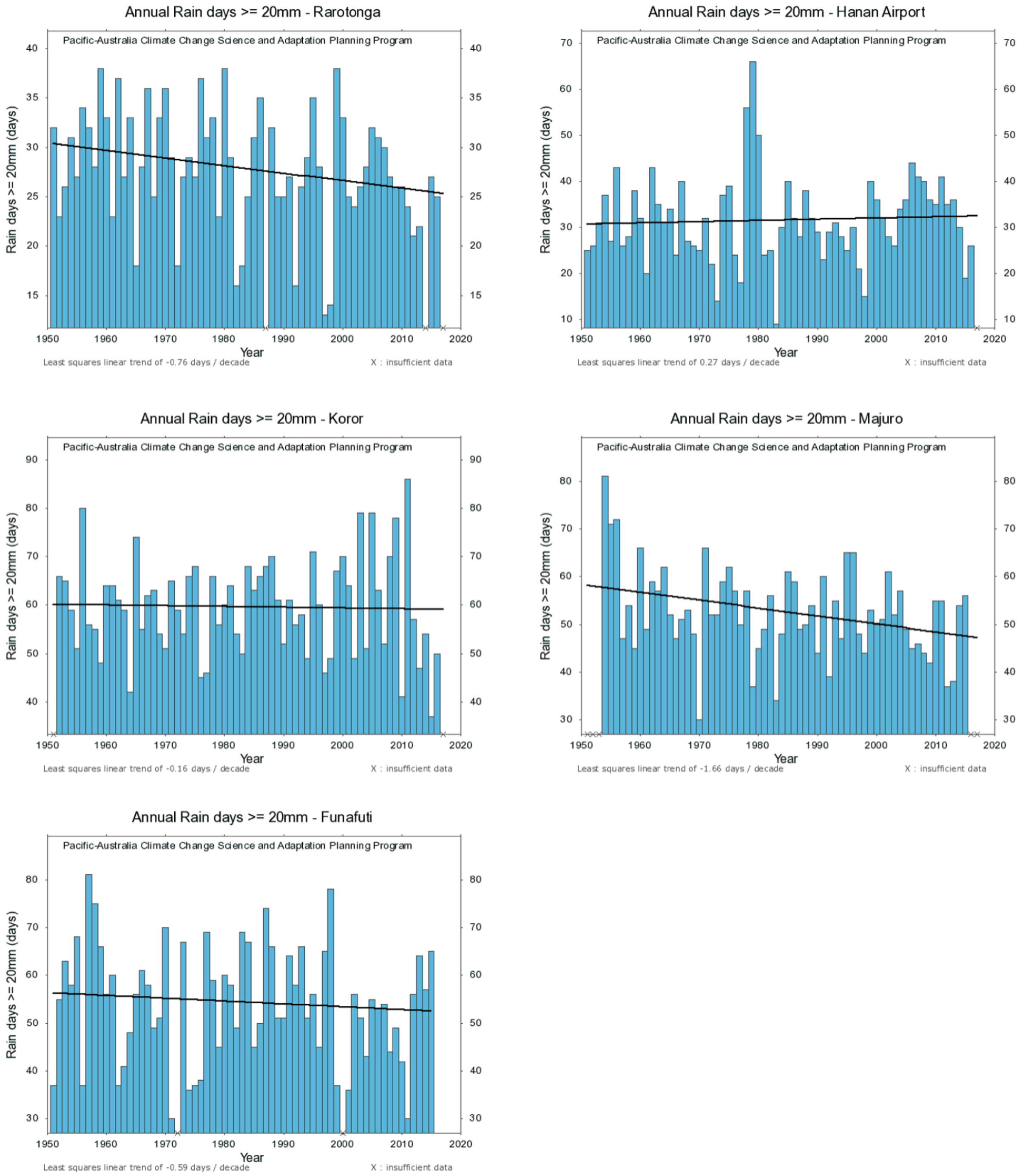


Figure 114. Time series of annual rain days ≥ 20 mm (R20) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Consecutive dry days

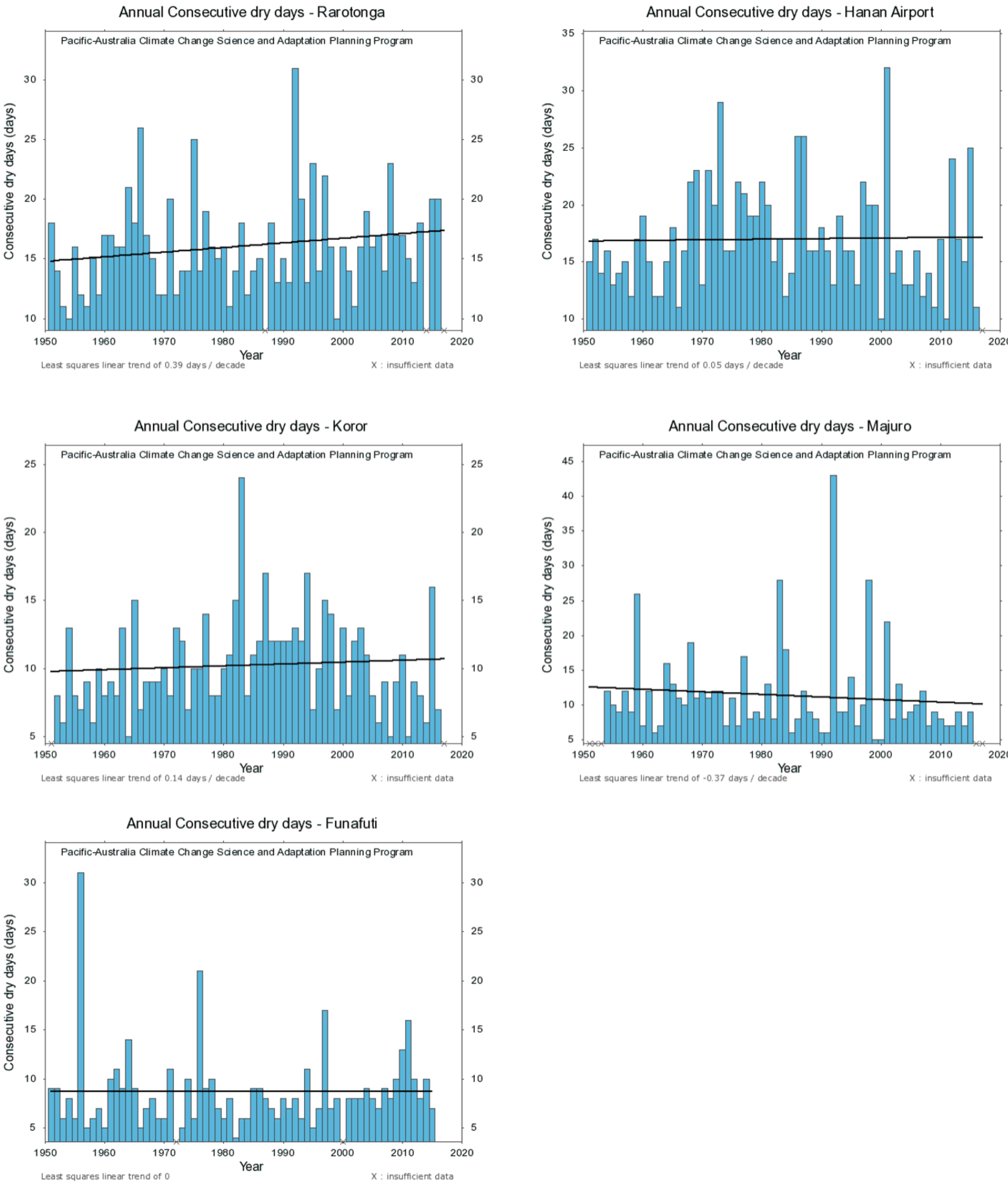


Figure 115. Time series of annual consecutive dry days (CDD) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Consecutive wet days

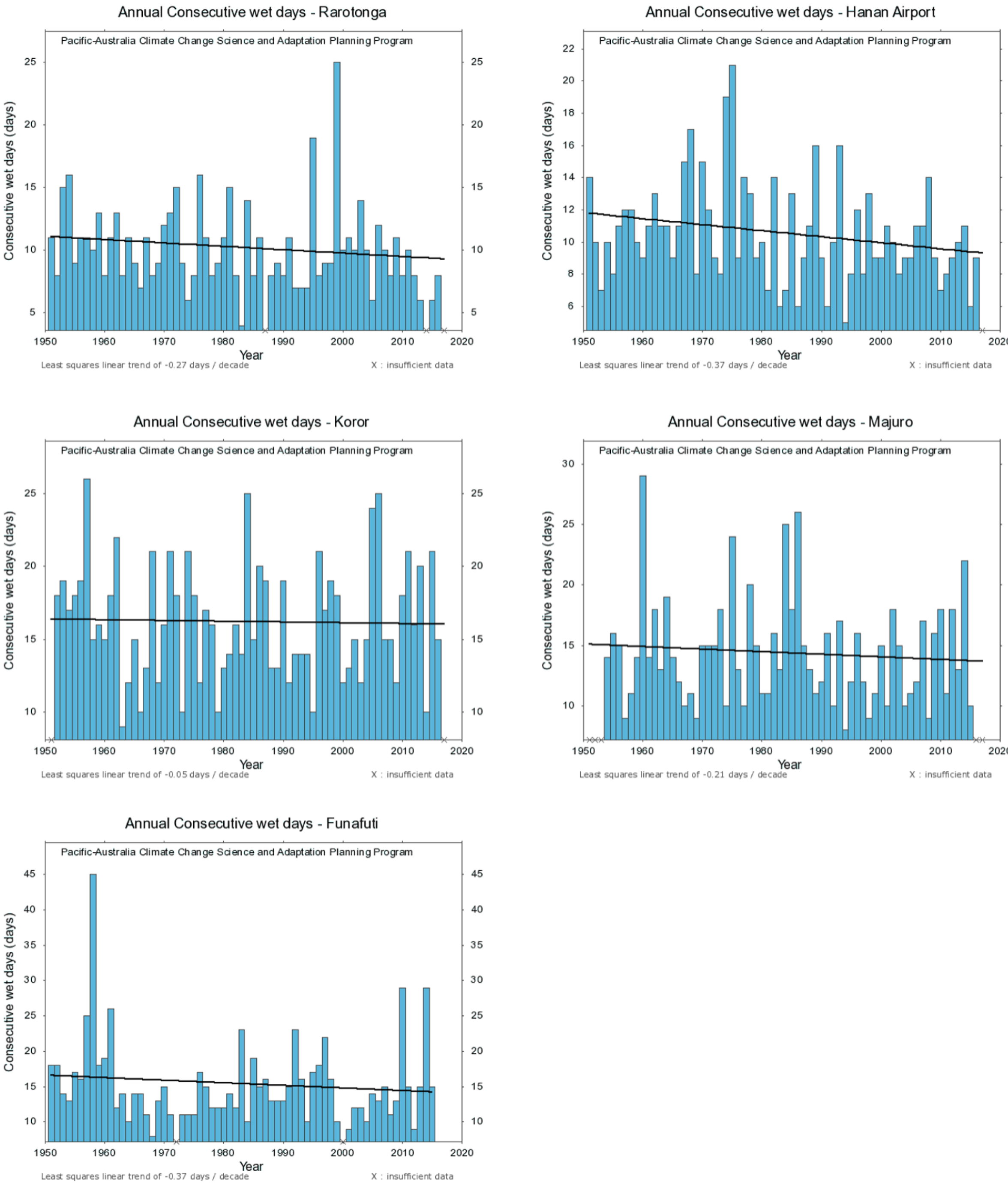


Figure 116. Time series of annual consecutive wet days (CWD) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

Very wet day rainfall

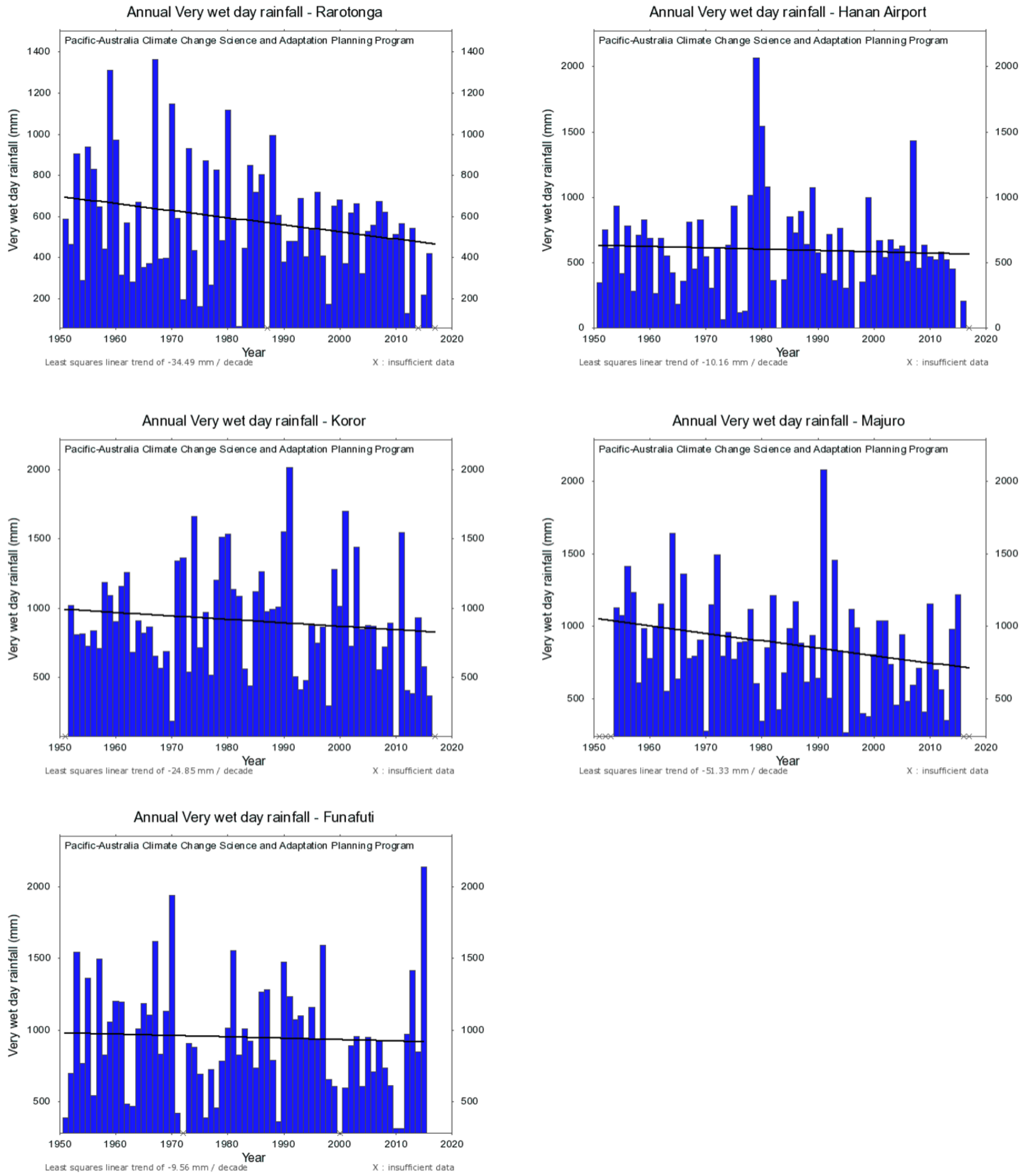


Figure 117. Time series of annual very wet day rainfall (R95p) in Rarotonga (Cook Islands), Hanan Airport (Niue), Koror (Palau), Majuro (RMI) and Funafuti (Tuvalu). The least squares linear trend line is shown in black. (Source: Pacific Climate Change Data Portal)

PROJECTIONS

The Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Program Report: *Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports 2014* documents the key scientific findings of PACCSAP (2011 – 2014). It describes large-scale climate processes, variability and extremes in the western tropical Pacific, together with projections for the 21st century based on Coupled Model Intercomparison Project (Phase 5) (CMIP5)-based global climate model (GCM) projections for individual countries.[671]

The projected changes in the annual and seasonal mean climate for the five Programme countries are shown below. The projections are for the four emissions scenarios: RCP2.6 (very low emissions, in dark blue), RCP4.5 (low emissions, in light blue), RCP6 (medium emissions, in orange) and RCP8.5 (very high emissions, in red). Projected changes are given for four 20-year periods centred on 2030, 2050, 2070 and 2090, relative to a 20-year period centred on 1995. Values represent the multi-model mean change, with the 5 – 95 % range of uncertainty in brackets.

Cook Islands

Extreme Temperature

For the Northern Cook Islands, the temperature of the 1-in-20-year hot day is projected to increase by approximately 0.6°C by 2030 under the RCP2.6 (very low emissions) scenario and by 0.8°C under the RCP8.5 (very high emissions) scenario. By 2090 the projected increase is 0.8°C for RCP2.6 and 2.8°C for RCP8.5.

For the Southern Cook Islands, the temperature of the 1-in-20-year hot day is projected to increase by approximately 0.5°C by 2030 under RCP2.6 scenario and by 0.7°C under RCP8.5 scenario. By 2090 the projected increase is 0.6°C for RCP2.6 and 2.7°C for RCP8.5.

There is *medium confidence* in the magnitude of projected change in extreme temperature because models generally underestimate the current intensity and frequency of extreme events. Changes to the particular driver of extreme temperatures affect whether the change to extremes is more or less than the change in the average temperature, and the changes to the drivers of extreme temperatures in the Cook Islands are currently unclear.

Extreme Rainfall

For the Northern Cook Islands, the current 1-in-20-year daily rainfall amount is projected to increase by approximately 3 mm by 2030 for RCP2.6 (very low emissions) and by 7 mm by 2030 for RCP8.5 (very high emissions). By 2090, it is projected to increase by approximately 6 mm for RCP2.6 and by 32 mm for RCP8.5. The majority of models project the current 1-in-20-year daily rainfall event will become, on average, a 1-in-9-year event for RCP2.6 and a 1-in-5-year event for RCP8.5 by 2090.

For the Southern Cook Islands, the current 1-in-20-year daily rainfall amount is projected to increase by approximately 7 mm by 2030 for RCP2.6 and by 9 mm by 2030 for RCP8.5. By 2090, it is projected to increase by approximately 5 mm for RCP2.6 and by 36 mm for RCP8.5. The majority of models project the current 1-in-20-year daily rainfall event will become, on average, a 1-in-9-year event for RCP2.6 and a 1-in-5-year event for RCP8.5 by 2090.

[671] Australian Bureau of Meteorology and CSIRO, 2014. Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports

Variable	Season	2030	2050	2070	2090	Confidence (magnitude of change)
Surface air temperature (°C)	Annual	0.5 (0.3–0.9)	0.6 (0.3–1)	0.6 (0.3–1.1)	0.6 (0.2–1.1)	*High*
		0.6 (0.3–0.9)	0.9 (0.6–1.5)	1.1 (0.7–1.8)	1.2 (0.7–2.1)	
		0.5 (0.3–0.9)	0.8 (0.5–1.4)	1.1 (0.8–1.9)	1.5 (1.1–2.4)	
		0.6 (0.4–1)	1.2 (0.8–2)	1.8 (1.3–3)	2.5 (1.7–4.2)	
Maximum temperature (°C)	1-in-20 year event	0.5 (0.2–0.8)	0.5 (0–0.9)	0.6 (0.1–1.1)	0.6 (0.1–1.1)	*Medium*
		0.5 (0.2–0.8)	0.8 (0.3–1.2)	1.1 (0.5–1.6)	1.2 (0.7–1.8)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.7 (0.2–1.1)	1.3 (0.9–1.8)	2 (1.1–2.8)	2.7 (1.6–3.9)	
Minimum temperature (°C)	1-in-20 year event	0.5 (0.1–0.7)	0.6 (-0.1–1)	0.6 (-0.1–0.9)	0.6 (-0.1–1)	*Medium*
		0.4 (0–0.8)	0.8 (0.4–1.4)	1.1 (0.5–1.9)	1.1 (0.6–1.8)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.7 (0.3–1)	1.3 (0.6–1.9)	2 (1.6–3)	2.8 (2–4.5)	
Total rainfall (%)	Annual	1 (-6–6)	0 (-6–5)	1 (-3–6)	0 (-8–5)	*Low*
		1 (-10–9)	2 (-8–11)	4 (-7–15)	0 (-12–10)	
		1 (-5–8)	1 (-8–10)	3 (-9–17)	1 (-12–16)	
		0 (-10–10)	1 (-10–9)	2 (-11–20)	3 (-14–24)	
Total rainfall (%)	Nov-Apr	0 (-9–7)	0 (-9–10)	1 (-7–9)	-1 (-9–7)	*Low*
		1 (-8–8)	2 (-10–17)	3 (-7–17)	1 (-15–18)	
		1 (-7–10)	-1 (-13–11)	1 (-13–19)	0 (-16–20)	
		1 (-10–14)	1 (-9–13)	2 (-13–26)	3 (-18–26)	
Total rainfall (%)	May-Oct	3 (-4–9)	1 (-8–12)	1 (-7–7)	4 (-4–10)	*Low*
		1 (-8–9)	1 (-8–10)	4 (-8–17)	0 (-8–12)	
		1 (-7–8)	5 (-3–12)	7 (-6–21)	3 (-12–19)	
		1 (-4–8)	2 (-12–15)	3 (-7–11)	3 (-15–26)	
Aragonite saturation state (Ωar)	Annual	-0.3 (-0.6–-0.1)	-0.4 (-0.7–-0.1)	-0.4 (-0.7–-0.1)	-0.3 (-0.6–0.0)	*Medium*
		-0.4 (-0.6–-0.1)	-0.6 (-0.8–-0.3)	-0.7 (-1.0–-0.4)	-0.8 (-1.0–-0.5)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		-0.4 (-0.7–-0.1)	-0.8 (-1.0–-0.5)	-1.1 (-1.4–-0.9)	-1.5 (-1.8–-1.3)	
Mean sea level (cm)	Annual	12 (7–17)	21 (13–29)	30 (18–43)	39 (22–57)	*Medium*
		12 (7–17)	22 (14–30)	33 (21–47)	46 (28–65)	
		11 (7–16)	21 (13–29)	33 (20–46)	46 (28–66)	
		12 (8–17)	24 (16–33)	40 (26–56)	61 (39–86)	

Table 38. Projected changes in the annual and seasonal mean climate for the Southern Cook Islands. (Source: PACCSAP)

Variable	Season	2030	2050	2070	2090	Confidence (magnitude of change)
Surface air temperature (°C)	Annual	0.6 (0.4–0.9)	0.7 (0.5–1.2)	0.8 (0.4–1.2)	0.8 (0.5–1.2)	*High*
		0.7 (0.4–1)	1 (0.6–1.3)	1.2 (0.8–1.8)	1.3 (0.9–2.1)	
		0.6 (0.4–0.9)	0.9 (0.6–1.4)	1.2 (0.8–1.8)	1.6 (1–2.4)	
		0.8 (0.5–1)	1.3 (0.9–1.8)	2 (1.5–2.9)	2.7 (2–3.8)	
Maximum temperature (°C)	1-in-20 year event	0.6 (0.1–0.8)	0.8 (0.1–1.2)	0.8 (0–1.4)	0.8 (0.2–1.1)	*Medium*
		0.6 (0.2–0.8)	0.9 (0.4–1.2)	1.1 (0.1–1.7)	1.3 (0.6–1.9)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.7 (0.2–1.1)	1.4 (0.5–2.1)	2.2 (0.8–3.1)	2.8 (1.3–4.2)	
Minimum temperature (°C)	1-in-20 year event	0.6 (0.3–1)	0.7 (0–1.1)	0.8 (0.2–1.2)	0.8 (0.2–1.1)	*Medium*
		0.6 (0.2–0.9)	0.9 (0.5–1.3)	1.1 (0.7–1.7)	1.3 (0.6–2)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.8 (0.4–1.1)	1.4 (0.9–2)	2.1 (1.5–2.9)	2.8 (1.9–4)	
Total rainfall (%)	Annual	-1 (-7–5)	0 (-7–7)	-1 (-10–7)	1 (-5–9)	*Low*
		1 (-6–9)	1 (-7–9)	0 (-8–9)	-1 (-10–7)	
		-1 (-8–6)	-3 (-7–1)	-5 (-15–4)	-8 (-22–6)	
		1 (-4–6)	-1 (-14–14)	-2 (-13–13)	-3 (-21–16)	
Total rainfall (%)	Nov-Apr	1 (-4–8)	2 (-5–10)	2 (-7–9)	3 (-3–16)	*Low*
		3 (-5–9)	2 (-7–13)	3 (-8–10)	2 (-5–9)	
		0 (-7–10)	-2 (-7–3)	-3 (-15–7)	-3 (-21–9)	
		3 (-5–7)	2 (-11–12)	3 (-10–14)	3 (-20–22)	
Total rainfall (%)	May-Oct	-4 (-12–4)	-3 (-16–5)	-5 (-16–6)	-3 (-10–6)	*Low*
		-1 (-9–9)	-2 (-14–12)	-4 (-16–9)	-5 (-20–4)	
		-3 (-12–5)	-6 (-13–0)	-9 (-22–4)	-15 (-30–0)	
		-2 (-11–7)	-5 (-21–16)	-9 (-27–12)	-11 (-35–13)	
Aragonite saturation state (Ωar)	Annual	-0.3 (-0.6–0.0)	-0.4 (-0.7–-0.1)	-0.4 (-0.6–-0.1)	-0.3 (-0.6–0.0)	*Medium*
		-0.3 (-0.6–0.0)	-0.5 (-0.8–-0.2)	-0.7 (-0.9–-0.4)	-0.7 (-1.0–-0.4)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		-0.4 (-0.7–-0.1)	-0.7 (-1.0–-0.4)	-1.1 (-1.4–-0.8)	-1.5 (-1.7–-1.2)	
Mean sea level (cm)	Annual	12 (7–17)	21 (13–29)	30 (18–43)	39 (22–57)	*Medium*
		12 (7–17)	22 (14–30)	33 (21–47)	46 (28–65)	
		11 (7–16)	21 (13–29)	33 (20–46)	46 (28–66)	
		12 (8–17)	24 (16–33)	40 (26–56)	61 (39–86)	

Table 39. Projected changes in the annual and seasonal mean climate for the Northern Cook Islands. (Source: PACCSAP)

Niue

Extreme Temperature

The temperature of the 1-in-20-year hot day is projected to increase by approximately 0.5°C by 2030 under the RCP2.6 (very low) scenario and by 0.7°C under the RCP8.5 (very high) scenario. By 2090 the projected increase is 0.7°C for RCP2.6 (very low) and 2.8°C for RCP8.5 (very high).

There is *low confidence* in the magnitude of projected change in extreme temperature because models generally underestimate the current intensity and frequency of extreme events. Changes to the particular driver of extreme temperatures affect whether the change to extremes is more or less than the change in the average temperature, and the changes to the drivers of extreme temperatures in Niue are currently unclear. Also, while all models project the same direction of change there is a wide range in the projected magnitude of change among the models.

Extreme Rainfall

The current 1-in-20-year daily rainfall amount is projected to increase by approximately 12 mm by 2030 for RCP2.6 and by 13 mm by 2030 for RCP8.5 (very high emissions). By 2090, it is projected to increase by approximately 7 mm for RCP2.6 and by 39 mm for RCP8.5 (very high emissions).The majority of models project the current 1-in-20-year daily rainfall event will become, on average, a 1-in-9-year event for RCP2.6 and a 1-in-4-year event for RCP8.5 (very high emissions) by 2090. These results are different to those found in Australian Bureau of Meteorology and CSIRO (2011) because of different methods used.

Variable	Season	2030	2050	2070	2090	Confidence (magnitude of change)
Surface air temperature (°C)	Annual	0.5 (0.3 to 0.9)	0.6 (0.3 to 1)	0.6 (0.3 to 1)	0.6 (0.2 to 1.1)	*Medium*
		0.5 (0.3 to 0.9)	0.8 (0.6 to 1.5)	1.1 (0.7 to 1.8)	1.2 (0.7 to 2.1)	
		0.5 (0.3 to 0.9)	0.8 (0.5 to 1.4)	1.2 (0.8 to 1.9)	1.6 (1.1 to 2.5)	
		0.6 (0.4 to 1.1)	1.2 (0.8 to 2)	1.9 (1.3 to 3)	2.6 (1.7 to 4.2)	
Maximum temperature (°C)	1-in-20 year event	0.5 (0.2 to 0.8)	0.6 (0.2 to 0.9)	0.7 (0.1 to 1.1)	0.7 (0.1 to 1.2)	*Medium*
		0.5 (0.2 to 1)	0.9 (0.5 to 1.3)	1.1 (0.6 to 1.5)	1.2 (0.6 to 1.8)	
		NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	
		0.7 (0.2 to 1.3)	1.4 (0.7 to 1.9)	2.1 (1.3 to 2.9)	2.8 (1.9 to 3.9)	
Minimum temperature (°C)	1-in-20 year event	0.5 (-0.1 to 0.9)	0.6 (0.1 to 1)	0.7 (0.4 to 1)	0.7 (-0.1 to 1.1)	*Medium*
		0.5 (-0.2 to 0.9)	0.9 (0.3 to 1.4)	1.2 (0.6 to 1.8)	1.2 (0.6 to 1.9)	
		NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	
		0.8 (0.3 to 1.2)	1.4 (0.7 to 2.2)	2.1 (1.4 to 3)	2.9 (2.1 to 4.6)	
Total rainfall (%)	Annual	2 (-9 to 11)	1 (-13 to 12)	1 (-8 to 12)	1 (-12 to 11)	*Low*
		0 (-11 to 12)	0 (-17 to 16)	3 (-18 to 16)	2 (-12 to 22)	
		1 (-10 to 12)	3 (-6 to 15)	6 (-9 to 27)	6 (-12 to 27)	
		1 (-12 to 18)	1 (-14 to 13)	4 (-16 to 32)	7 (-12 to 46)	
Total rainfall (%)	Nov-Apr	3 (-13 to 15)	2 (-13 to 18)	1 (-10 to 11)	0 (-17 to 12)	*Low*
		1 (-13 to 16)	1 (-18 to 21)	4 (-16 to 24)	3 (-14 to 31)	
		3 (-10 to 19)	3 (-10 to 16)	6 (-11 to 33)	7 (-14 to 33)	
		1 (-18 to 21)	2 (-16 to 17)	6 (-19 to 45)	10 (-14 to 67)	
Total rainfall (%)	May-Oct	1 (-8 to 9)	1 (-11 to 13)	1 (-9 to 11)	2 (-5 to 11)	*Low*
		0 (-9 to 12)	0 (-15 to 12)	3 (-16 to 19)	2 (-13 to 14)	
		-2 (-13 to 7)	4 (-5 to 14)	5 (-6 to 16)	5 (-6 to 25)	
		1 (-11 to 13)	1 (-11 to 13)	1 (-15 to 16)	4 (-15 to 31)	
Aragonite saturation state (Ωar)	Annual	-0.3 (-0.6 to 0.0)	-0.4 (-0.7 to -0.1)	-0.4 (-0.7 to -0.1)	-0.3 (-0.7 to 0.0)	*Medium*
		-0.4 (-0.6 to -0.1)	-0.6 (-0.8 to -0.3)	-0.7 (-1.0 to -0.4)	-0.8 (-1.0 to -0.5)	
		NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	
		-0.4 (-0.7 to -0.1)	-0.7 (-1.0 to -0.5)	-1.1 (-1.4 to -0.9)	-1.5 (-1.8 to -1.3)	
Mean sea level (cm)	Annual	12 (7 to 17)	21 (13 to 30)	30 (18 to 43)	40 (23 to 57)	*Medium*
		12 (8 to 17)	22 (14 to 31)	34 (22 to 47)	47 (29 to 66)	
		12 (7 to 17)	22 (13 to 30)	34 (21 to 47)	47 (29 to 67)	
		13 (8 to 18)	25 (16 to 34)	42 (27 to 57)	62 (41 to 87)	

Table 40. Projected changes in the annual and seasonal mean climate for Niue. (Source: PACCSAP)

Palau

Extreme Temperature

The temperature of the 1-in-20-year hot day is projected to increase by approximately 0.7°C by 2030 under the RCP2.6 scenario and by 0.8°C under the RCP8.5 scenario. By 2090 the projected increase is 0.8°C for RCP2.6 and 3.2°C for RCP8.5.

There is *low confidence* in the magnitude of projected change in extreme temperature because models generally underestimate the current intensity and frequency of extreme events. Changes to the particular driver of extreme temperatures affect whether the change to extremes is more or less than the change in the average temperature, and the changes to the drivers of extreme temperatures in Palau are currently unclear. Also, while all models project the same direction of change there is a wide range in the projected magnitude of change among the models.

Extreme Rainfall

The current 1-in-20-year daily rainfall amount is projected to increase by approximately 18 mm by 2030 for RCP2.6 and by 13 mm by 2030 for RCP8.5. By 2090, it is projected to increase by approximately 19 mm for RCP2.6 and by 50 mm for RCP8.5.The majority of models project the current 1-in-20-year daily rainfall event will become, on average, a 1-in- 8-year event for RCP2.6 and a 1-in-4-year event for RCP8.5 by 2090. These results are different to those found in Australian Bureau of Meteorology and CSIRO (2011) because of different methods used.

Variable	Season	2030	2050	2070	2090	Confidence (magnitude of change)
Surface air temperature (°C)	Annual	0.6 (0.5–0.9)	0.8 (0.6–1.1)	0.8 (0.5–1.2)	0.8 (0.4–1.2)	*Medium*
		0.7 (0.5–1)	1 (0.7–1.4)	1.3 (0.9–1.8)	1.4 (1–2.1)	
		0.6 (0.4–0.9)	0.9 (0.7–1.4)	1.4 (1.1–1.9)	1.8 (1.4–2.5)	
		0.8 (0.6–1)	1.4 (1–1.9)	2.2 (1.6–3.1)	3 (2.1–4)	
Maximum temperature (°C)	1-in-20 year event	0.7 (0.2–1)	0.8 (0.3–1.1)	0.8 (0.2–1.1)	0.8 (0.1–1.1)	*Medium*
		0.7 (0.4–1.1)	1 (0.5–1.4)	1.3 (0.7–1.6)	1.4 (0.9–2)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.8 (0.4–1.2)	1.5 (0.9–2.2)	2.3 (1.6–3.3)	3.2 (2–4.4)	
Minimum temperature (°C)	1-in-20 year event	0.7 (0.4–1.1)	0.7 (0.3–1)	0.7 (0.2–0.9)	0.7 (0.3–1)	*Medium*
		0.6 (0.4–0.8)	0.9 (0.6–1.2)	1.2 (0.6–1.6)	1.3 (0.9–1.7)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.8 (0.4–1)	1.5 (1.1–2)	2.3 (1.5–3.2)	3.2 (2.3–4.1)	
Total rainfall (%)	Annual	2 (.-4–10)	3 (-4–10)	2 (-5–9)	3 (-3–14)	*Medium*
		3 (-8–9)	3 (-5–11)	5 (-6–14)	5 (-2–15)	
		1 (-7–8)	3 (-4–11)	3 (-6–14)	5 (-5–19)	
		2 (-5–8)	4 (-7–13)	6 (-2–16)	8 (-4–25)	
Total rainfall (%)	Nov-Apr	1 (-7–12)	1 (-8–11)	0 (-10–8)	3 (-7–13)	*Low*
		2 (-6–10)	1 (-13–12)	4 (-12–16)	3 (-10–10)	
		1 (-7–11)	2 (-7–10)	2 (-10–17)	3 (-10–20)	
		1 (-5–10)	3 (-11–14)	2 (-12–14)	3 (-15–19)	
Total rainfall (%)	May-Oct	3 (-2–9)	6 (-1–13)	5 (-1–12)	5 (-1–14)	*Medium*
		4 (-5–15)	5 (-2–11)	8 (-2–19)	8 (-1–17)	
		1 (-6–6)	4 (-2–18)	5 (-2–13)	8 (0–20)	
		3 (-3–9)	7 (-1–15)	10 (3–20)	14 (1–38)	
Aragonite saturation state (Ωar)	Annual	-0.3 (-0.6–-0.1)	-0.4 (-0.7–-0.1)	-0.4 (-0.6–-0.2)	-0.3 (-0.6–-0.1)	*Medium*
		-0.3 (-0.6–-0.1)	-0.6 (-0.8–-0.3)	-0.7 (-0.9–-0.5)	-0.8 (-1.0–-0.5)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		-0.4 (-0.6–-0.2)	-0.7 (-1.0–-0.5)	-1.1 (-1.4–-0.9)	-1.5 (-1.7–-1.2)	
Mean sea level (cm)	Annual	13 (8–17)	22 (14–30)	32 (20–44)	42 (25–59)	*Medium*
		12 (8–17)	23 (15–31)	35 (23–48)	48 (30–67)	
		12 (8–17)	22 (14–30)	34 (22–47)	49 (31–68)	
		13 (8–18)	26 (17–35)	43 (28–58)	64 (41–88)	

Table 41. Projected changes in the annual and seasonal mean climate for Palau. (Source: PACCSAP)

Republic of the Marshall Islands

Extreme Temperature

For the northern Marshall Islands the temperature of the 1-in-20-year hot day is projected to increase by approximately 0.7°C by 2030 under the RCP2.6 (very low) scenario and by 0.8°C under the RCP8.5 (very high) scenario. By 2090 the projected increase is 0.8°C for RCP2.6 (very low) and 3.3°C for RCP8.5 (very high).

For the southern Marshall Islands the temperature of the 1-in-20-year hot day is projected to increase by approximately 0.7°C by 2030 under the RCP2.6 (very low) scenario and by 0.8°C under the RCP8.5

(very high) scenario. By 2090 the projected increase is 0.8°C for RCP2.6 (very low) and 3.1°C for RCP8.5 (very high).

There is *low confidence* in the magnitude of projected change in extreme temperature because models generally underestimate the current intensity and frequency of extreme events, especially in this area, due to the 'cold-tongue bias' (Chapter 1). Changes to the particular driver of extreme temperatures affect whether the change to extremes is more or less than the change in the average temperature, and the changes to the drivers of extreme temperatures in Marshall Islands are currently unclear. Also, while all models project the same direction of change there is a wide range in the projected magnitude of change among the models.

Extreme Rainfall

For the northern Marshall Islands current 1-in-20-year daily rainfall amount is projected to increase by approximately 1 mm by 2030 for RCP2.6 and by 7 mm by 2030 for RCP8.5 (very high emissions). By 2090, it is projected to increase by approximately 6 mm for RCP2.6 and by 32 mm for RCP8.5 (very high emissions).The majority of models project the current 1-in-20-year daily rainfall event will become, on average, a 1-in-8-year event for RCP2.6 and a 1-in-5-year event for RCP8.5 (very high emissions) by 2090.

For the southern Marshall Islands, the current 1-in-20-year daily rainfall amount is projected to increase by approximately 4 mm by 2030 for RCP2.6 and by 11 mm by 2030 for RCP8.5 (very high emissions). By 2090, it is projected to increase by approximately 9 mm for RCP2.6 and by 30 mm for RCP8.5 (very high emissions).The majority of models project the current 1-in-20- year daily rainfall event will become, on average, a 1-in-9-year event for RCP2.6 and a 1-in-6-year event for RCP8.5 (very high emissions) by 2090.

Variable	Season	2030	2050	2070	2090	Confidence (magnitude of change)
Surface air temperature (°C)	Annual	0.7 (0.4 to 0.9)	0.8 (0.6 to 1.2)	0.8 (0.5 to 1.2)	0.8 (0.5 to 1.2)	*Medium*
		0.7 (0.5 to 1)	1.1 (0.7 to 1.4)	1.4 (1 to 1.8)	1.5 (1 to 2.1)	
		0.6 (0.4 to 0.9)	1 (0.7 to 1.4)	1.4 (1 to 2)	1.8 (1.3 to 2.6)	
		0.8 (0.6 to 1.1)	1.4 (1 to 1.9)	2.2 (1.7 to 3.1)	3 (2.1 to 4)	
Maximum temperature (°C)	1-in-20 year event	0.7 (0.3 to 1.2)	0.8 (0.3 to 1.4)	0.8 (0.2 to 1.1)	0.8 (0.5 to 1.1)	*Medium*
		0.6 (0.3 to 1)	0.9 (0.5 to 1.4)	1.2 (0.7 to 1.7)	1.4 (0.9 to 2)	
		NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	
		0.8 (0.4 to 1.1)	1.5 (0.9 to 2.1)	2.3 (1.3 to 3.4)	3.1 (2 to 4.3)	
Minimum temperature (°C)	1-in-20 year event	0.6 (0.4 to 1)	0.8 (0.3 to 1.2)	0.8 (0.2 to 1.1)	0.8 (0.3 to 1.1)	*Medium*
		0.7 (0.4 to 1)	1 (0.6 to 1.4)	1.3 (0.8 to 1.8)	1.4 (1 to 1.8)	
		NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	
		0.8 (0.5 to 1.1)	1.5 (0.8 to 2.1)	2.4 (1.6 to 3.2)	3.2 (2.3 to 4.2)	
Total rainfall (%)	Annual	2 (-3 to 8)	3 (-4 to 8)	4 (-1 to 12)	3 (-4 to 10)	*Medium*
		1 (-4 to 5)	3 (-3 to 8)	4 (-2 to 10)	3 (-5 to 11)	
		1 (-2 to 5)	2 (-2 to 11)	4 (-5 to 13)	5 (-7 to 16)	
		2 (-3 to 11)	4 (-6 to 12)	5 (-3 to 20)	8 (0 to 25)	
Total rainfall (%)	Nov-Apr	2 (-4 to 9)	3 (-7 to 13)	4 (-5 to 15)	3 (-10 to 12)	*Medium*
		1 (-7 to 11)	2 (-9 to 14)	4 (-9 to 17)	2 (-11 to 14)	
		0 (-5 to 5)	2 (-7 to 12)	3 (-9 to 14)	3 (-10 to 15)	
		2 (-6 to 9)	4 (-7 to 14)	2 (-13 to 16)	5 (-11 to 31)	
Total rainfall (%)	May-Oct	3 (-2 to 11)	3 (-5 to 9)	3 (0 to 8)	4 (-1 to 12)	*Medium*
		2 (-4 to 6)	4 (-3 to 9)	5 (-5 to 13)	5 (-5 to 16)	
		2 (-1 to 6)	3 (-5 to 12)	5 (-6 to 16)	6 (-7 to 19)	
		3 (-1 to 8)	5 (-5 to 13)	8 (-6 to 17)	11 (-6 to 26)	
Aragonite saturation state (Ωar)	Annual	-0.3 (-0.6 to 0.0)	-0.4 (-0.7 to -0.1)	-0.4 (-0.7 to -0.1)	-0.3 (-0.6 to -0.0)	*Medium*
		-0.3 (-0.6 to 0.0)	-0.5 (-0.8 to -0.2)	-0.6 (-0.9 to -0.4)	-0.7 (-1.0 to -0.4)	
		NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	NA (NA to NA)	
		-0.4 (-0.7 to -0.1)	-0.7 (-1.0 to -0.4)	-1.1 (-1.3 to -0.8)	-1.4 (-1.7 to -1.1)	
Mean sea level (cm)	Annual	13 (7 to 18)	22 (13 to 30)	31 (19 to 45)	41 (23 to 60)	*Medium*
		12 (7 to 18)	23 (14 to 32)	35 (21 to 49)	48 (28 to 69)	
		12 (7 to 17)	22 (14 to 31)	35 (21 to 49)	49 (30 to 70)	
		13 (8 to 19)	26 (16 to 35)	43 (27 to 60)	65 (41 to 92)	

Table 42. Projected changes in the annual and seasonal mean climate for the southern Marshall Islands. (Source: PACCSAP)

Tuvalu

Extreme Temperature

The temperature of the 1-in-20-year hot day is projected to increase by approximately 0.5°C by 2030 under the RCP2.6 scenario and by 0.7°C under the RCP8.5 scenario. By 2090 the projected increase is 0.7°C for RCP2.6 and 3°C for RCP8.5.

There is *low confidence* in the magnitude of projected change in extreme temperature because models generally underestimate the current intensity and frequency of extreme events, especially in this area, due to the ‘cold-tongue bias’. Changes to the particular driver of extreme temperatures affect whether the change to extremes is more or less than the change in the average temperature, and the changes to the drivers of extreme temperatures in Tuvalu are currently unclear. Also, while all models project the same direction of change there is a wide range in the projected magnitude of change among the models.

Extreme Rainfall

The current 1-in-20-year daily rainfall amount is projected to increase by approximately 0 mm by 2030 for RCP2.6 and by 5 mm by 2030 for RCP8.5. By 2090, it is projected to increase by approximately 7 mm for RCP2.6 and by 28 mm for RCP8.5.The majority of models project the current 1-in-20-year daily rainfall event will become, on average, a 1-in-10-year event for RCP2.6 and a 1-in-6-year event for RCP8.5 by 2090.

Variable	Season	2030	2050	2070	2090	Confidence (magnitude of change)
Surface air temperature (°C)	Annual	0.6 (0.5–0.9)	0.8 (0.5–1.2)	0.8 (0.5–1.2)	0.8 (0.4–1.3)	*Medium*
		0.7 (0.5–1)	1 (0.7–1.4)	1.3 (0.9–1.8)	1.4 (1–2.1)	
		0.6 (0.4–0.9)	0.9 (0.6–1.4)	1.3 (0.9–2)	1.7 (1.1–2.6)	
		0.8 (0.5–1)	1.4 (1–1.9)	2.1 (1.5–3.1)	2.8 (2–4)	
Maximum temperature (°C)	1-in-20 year event	0.5 (-0.1–0.8)	0.7 (0.1–1.1)	0.7 (-0.1–1.1)	0.7 (-0.1–1.1)	*Medium*
		0.6 (-0.1–0.9)	0.9 (0.1–1.3)	1.2 (0.4–1.8)	1.3 (0.6–2)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.7 (0.1–1.1)	1.4 (0.5–2)	2.2 (0.7–3.1)	2.9 (1.4–4.2)	
Minimum temperature (°C)	1-in-20 year event	0.6 (0.3–0.8)	0.7 (0.2–1)	0.8 (0.4–1)	0.8 (0.4–0.9)	*Medium*
		0.6 (0.4–0.8)	0.9 (0.5–1.3)	1.1 (0.8–1.5)	1.3 (1–1.9)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.8 (0.4–1)	1.5 (1–2.1)	2.2 (1.6–3.3)	3 (2.2–4)	
Total rainfall (%)	Annual	2 (-2–5)	3 (-6–11)	3 (-10–12)	5 (-4–12)	*Low*
		4 (-2–12)	3 (-3–10)	6 (-5–15)	4 (-8–18)	
		4 (-4–10)	3 (-6–8)	1 (-10–8)	-1 (-20–13)	
		4 (-1–9)	3 (-11–17)	6 (-15–28)	6 (-26–31)	
Total rainfall (%)	Nov-Apr	2 (-5–7)	3 (-6–10)	4 (-10–13)	6 (-6–15)	*Low*
		4 (-3–11)	3 (-7–11)	6 (-4–14)	4 (-10–15)	
		4 (-4–10)	4 (-8–11)	1 (-13–11)	2 (-21–15)	
		4 (-4–10)	4 (-16–16)	7 (-18–24)	8 (-25–36)	
Total rainfall (%)	May-Oct	3 (-2–8)	2 (-5–14)	2 (-8–14)	4 (-2–17)	*Low*
		3 (-1–13)	4 (-3–15)	5 (-3–21)	4 (-7–19)	
		5 (-3–16)	3 (-4–15)	0 (-9–10)	-3 (-18–8)	
		3 (-1–11)	3 (-9–17)	4 (-15–30)	3 (-26–24)	
Aragonite saturation state (Ωar)	Annual	-0.3 (-0.6–0.0)	-0.4 (-0.7–0.0)	-0.4 (-0.7–0.0)	-0.3 (-0.7–0.0)	*Medium*
		-0.3 (-0.7–0.0)	-0.5 (-0.9–-0.2)	-0.7 (-1.0–-0.4)	-0.7 (-1.1–-0.4)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		-0.4 (-0.7–-0.1)	-0.7 (-1.0–-0.4)	-1.1 (-1.4–-0.8)	-1.5 (-1.8–-1.1)	
Mean sea level (cm)	Annual	12 (7–17)	21 (13–30)	31 (19–44)	41 (23–59)	*Medium*
		12 (7–17)	22 (13–31)	34 (20–48)	47 (28–67)	
		12 (7–16)	21 (13–29)	33 (20–47)	48 (28–67)	
		12 (7–18)	24 (16–34)	41 (26–57)	62 (39–87)	

Table 43. Projected changes in the annual and seasonal mean climate for Tuvalu. (Source: PACCSAP)