Vulnerability of Caribbean *Blue* and *Green* Ecosystems: Commonalities in Exposure to Climate-Related Risks

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Green Climate Fund

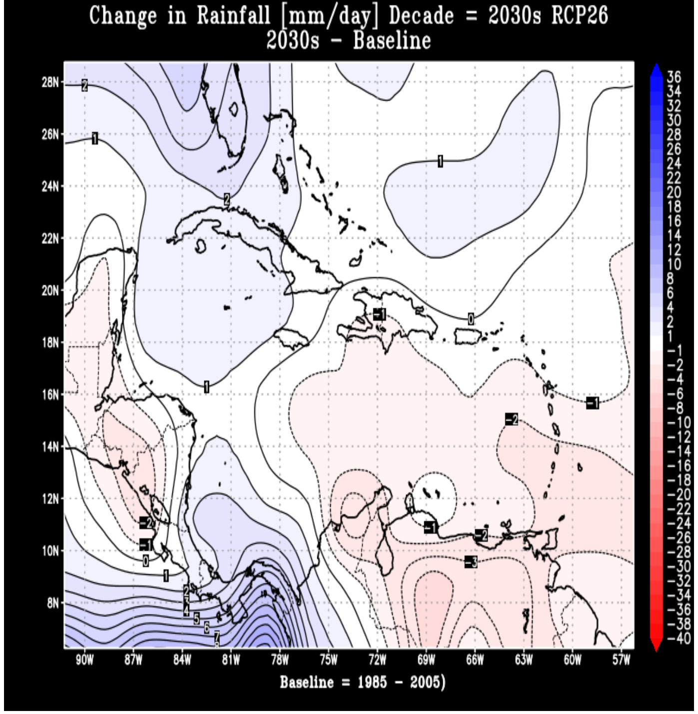
Structured Dialogue with the Caribbean

Belize, June 19-22, 2017

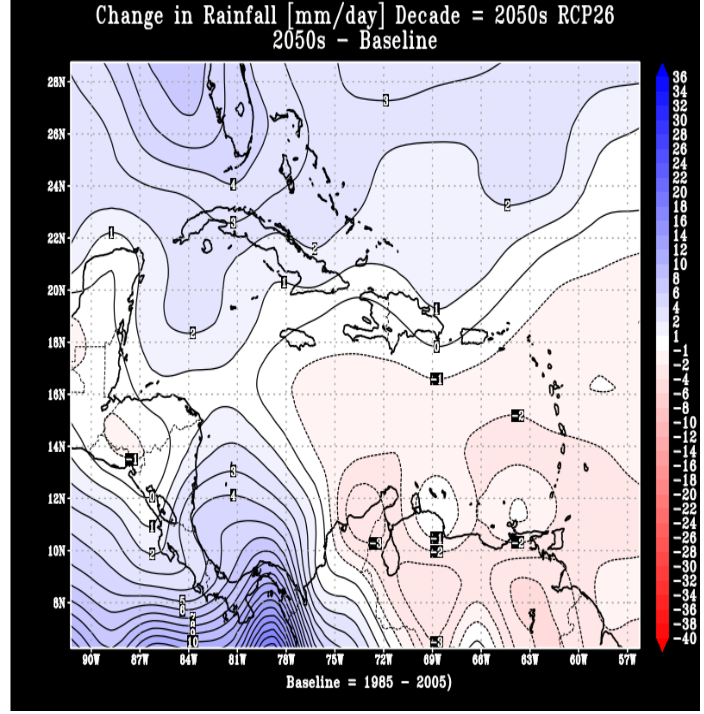
Observed Rainfall Changes in Caribbean Since 1900

- Mean annual rainfall over Caribbean, 1900-2000 → a consistent decline by around 0.18 mm yr^{-1}
- Southern Caribbean region → contraction in 'traditional' wet season (June-Oct), 1900-1980
- Longer dry spells and increasing drought incidence since 1900
- Increase in number of heavy rainfall events in last 75 years

2030s



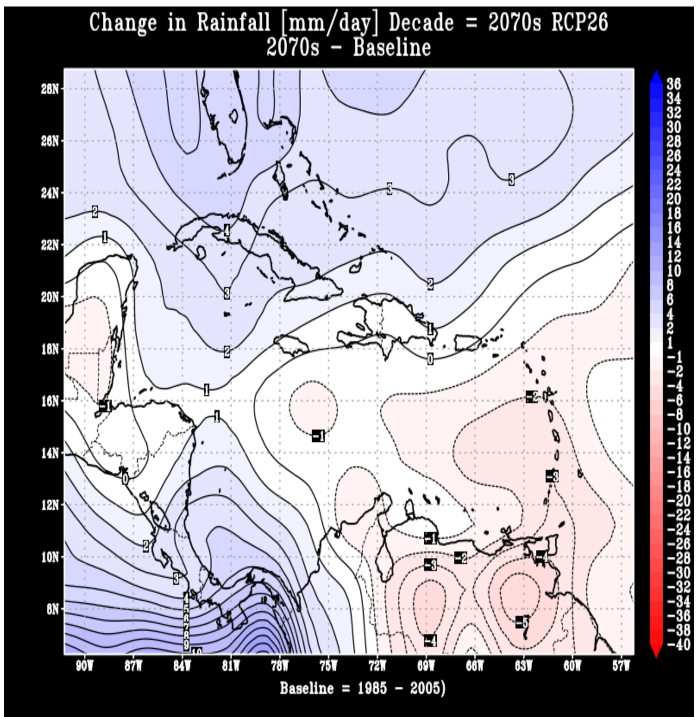
Mean Rainfall



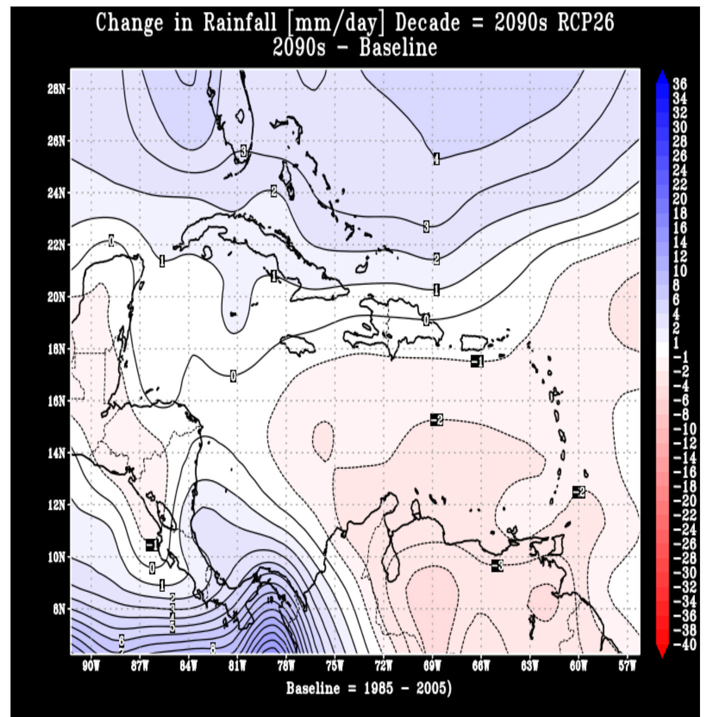
2050s

RCP 2.6

2070s



CMIP5 Multi-Models



2090s

Mean Rainfall

RCP 4.5

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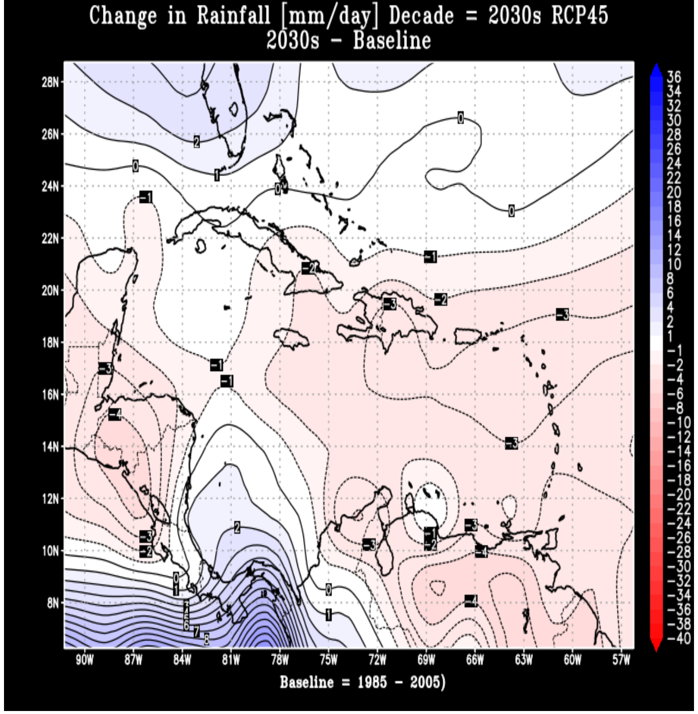

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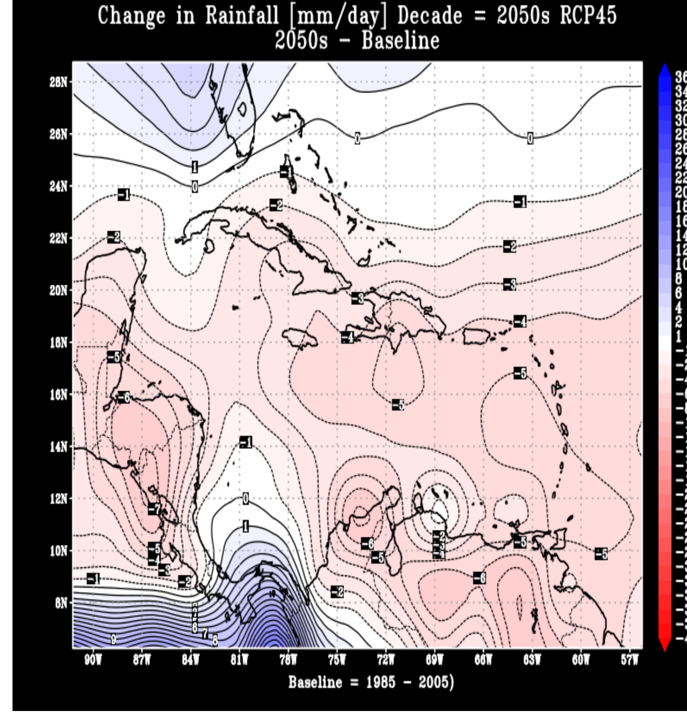

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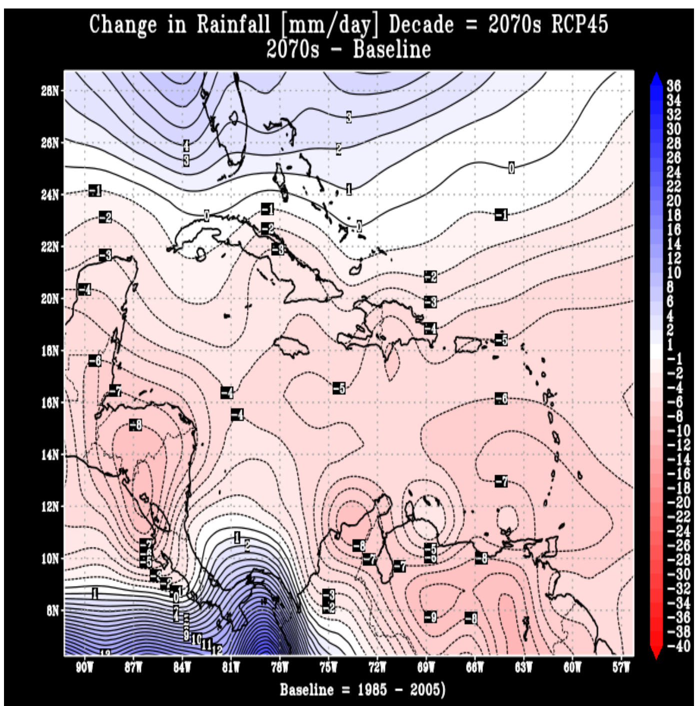

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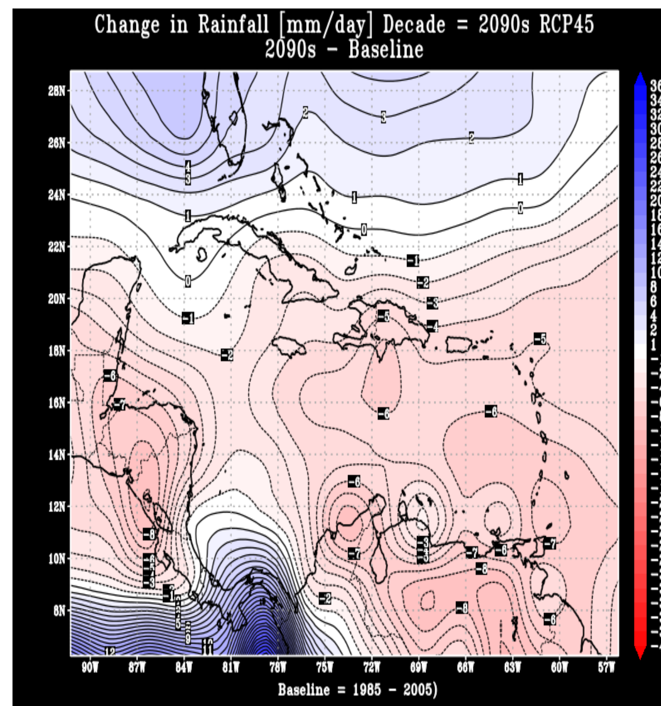

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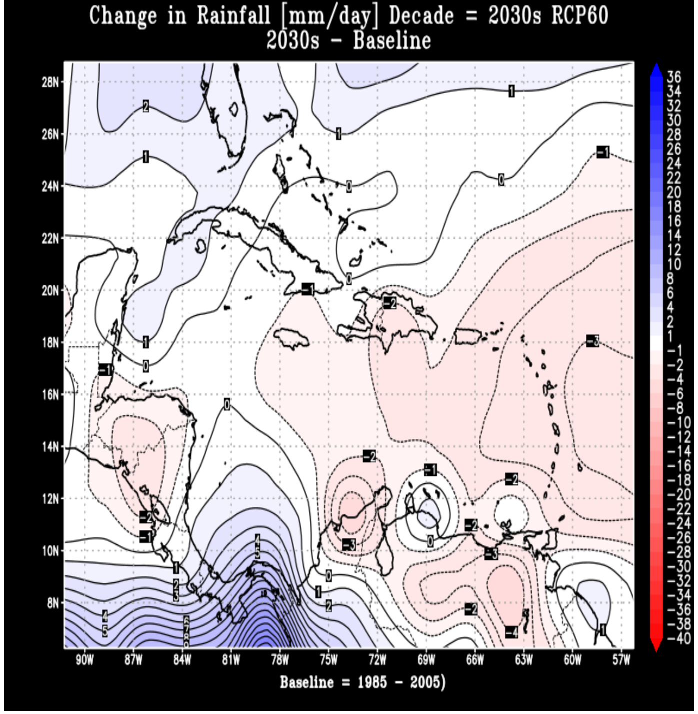

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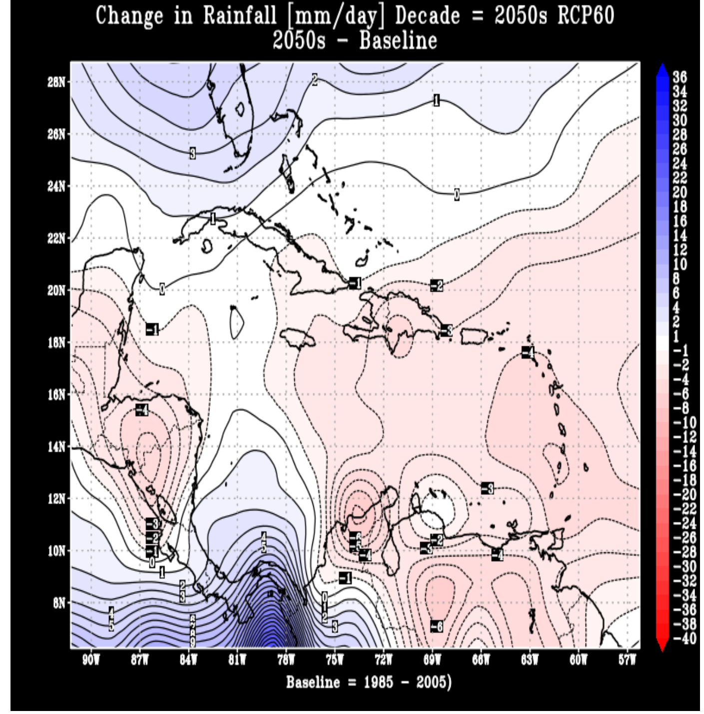
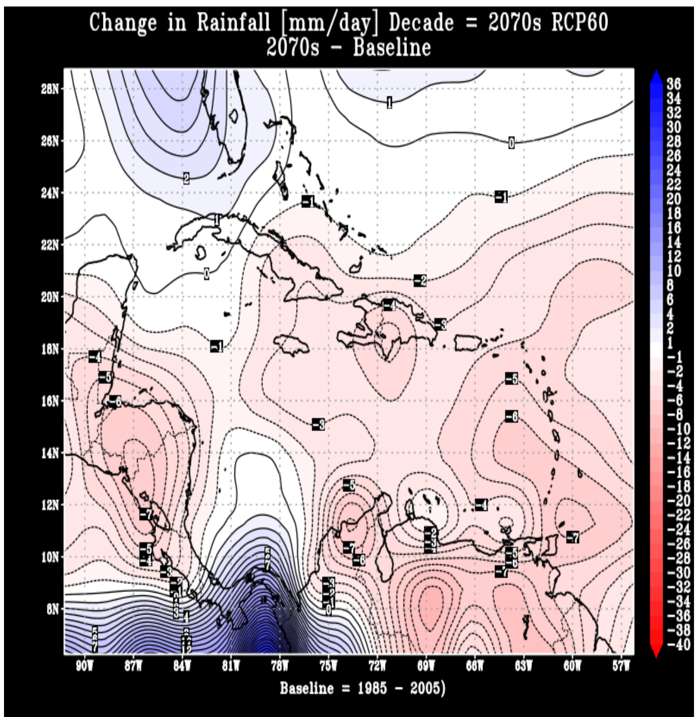


2050s

RCP 6.0

2070s



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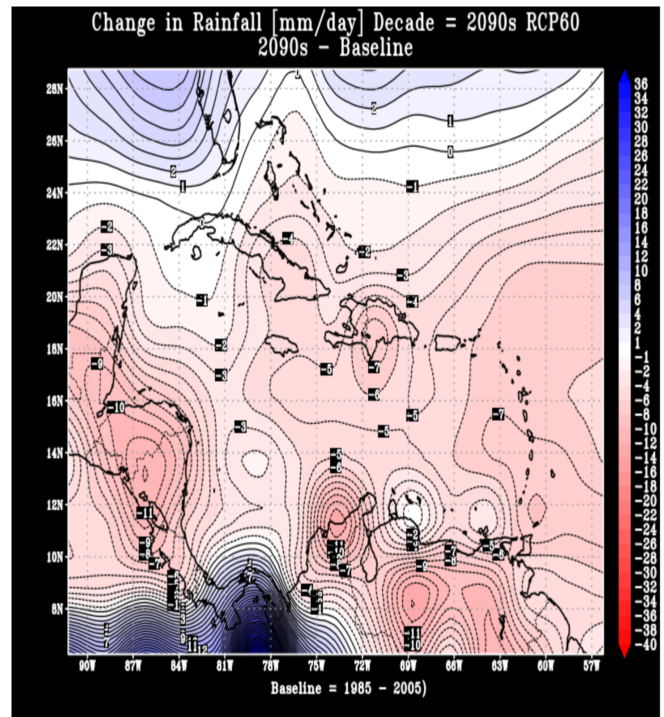

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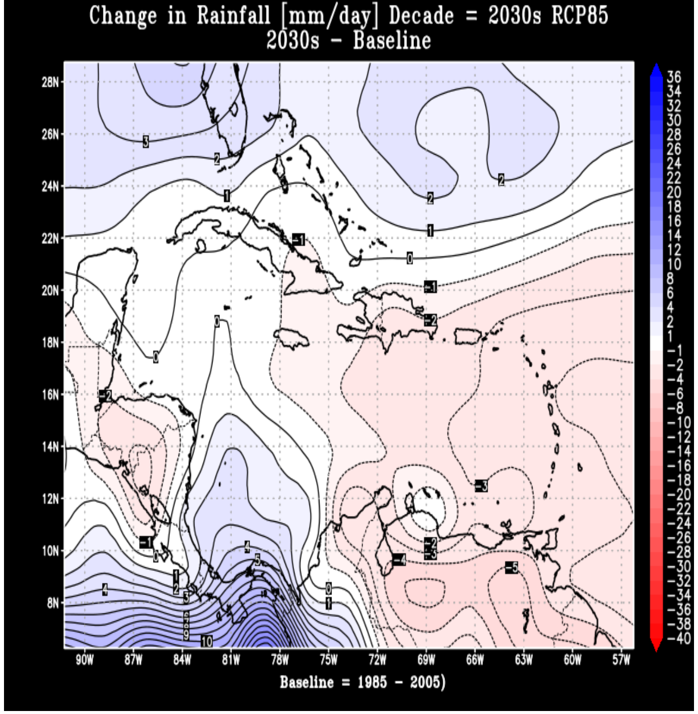

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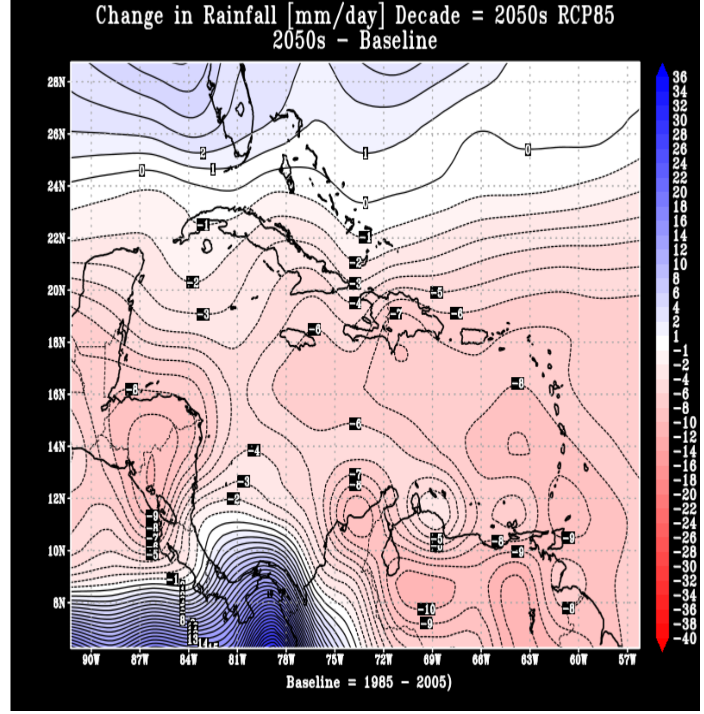
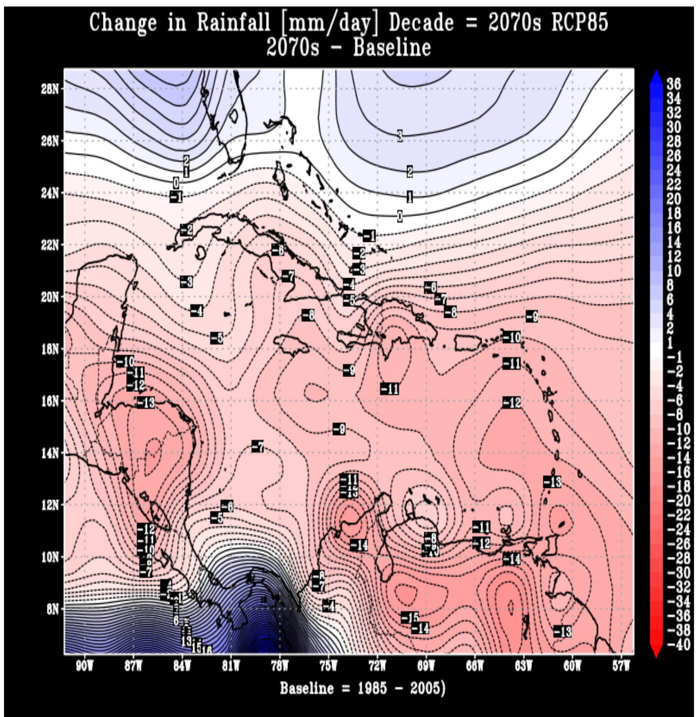


Mean Rainfall

RCP 8.5

2070s



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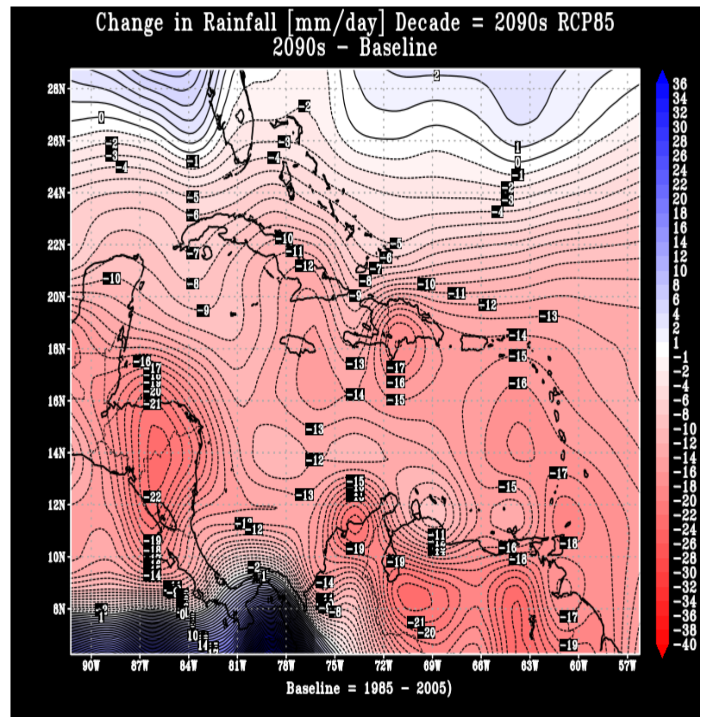
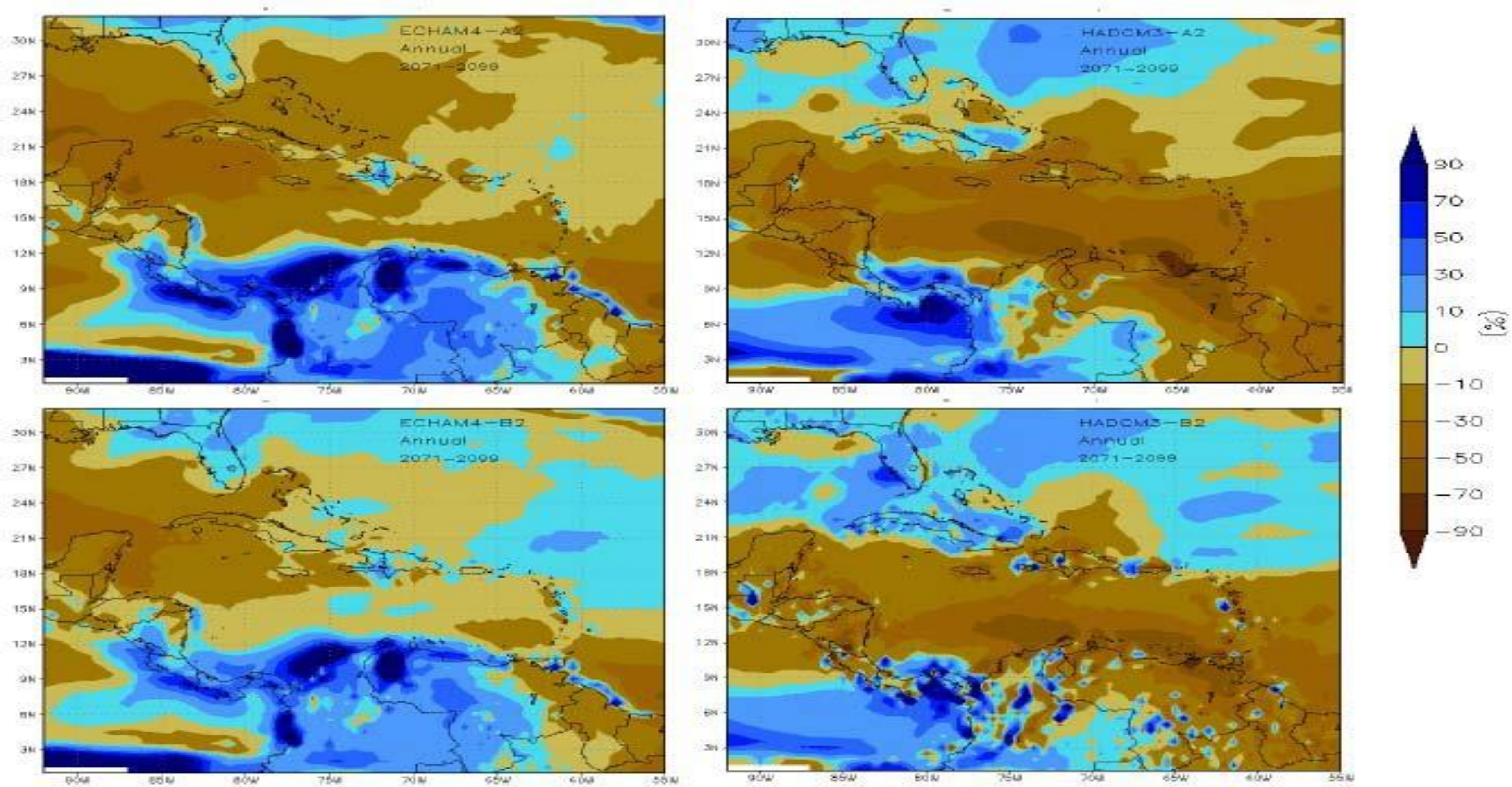


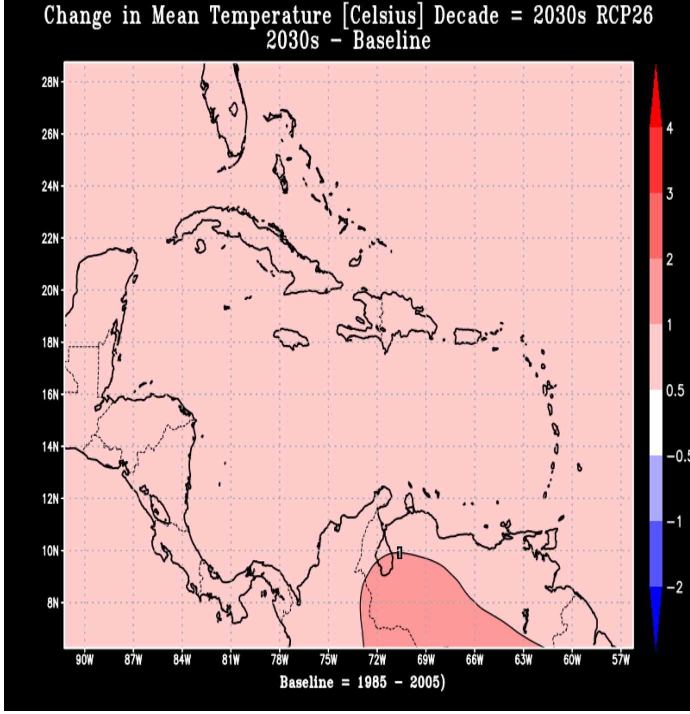
Projected Mean Annual Rainfall Change in The Caribbean



- 25% -30 % less mean annual rainfall by end of Century.
- Drying far exceeds natural variability → drier wet seasons

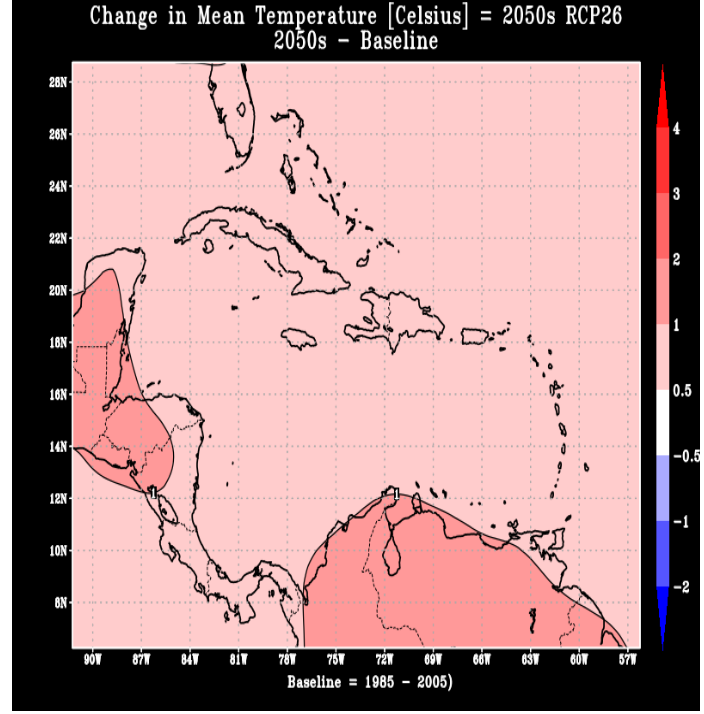
(Taylor, 2011)

2030s



Mean Temperature

RCP 2.6



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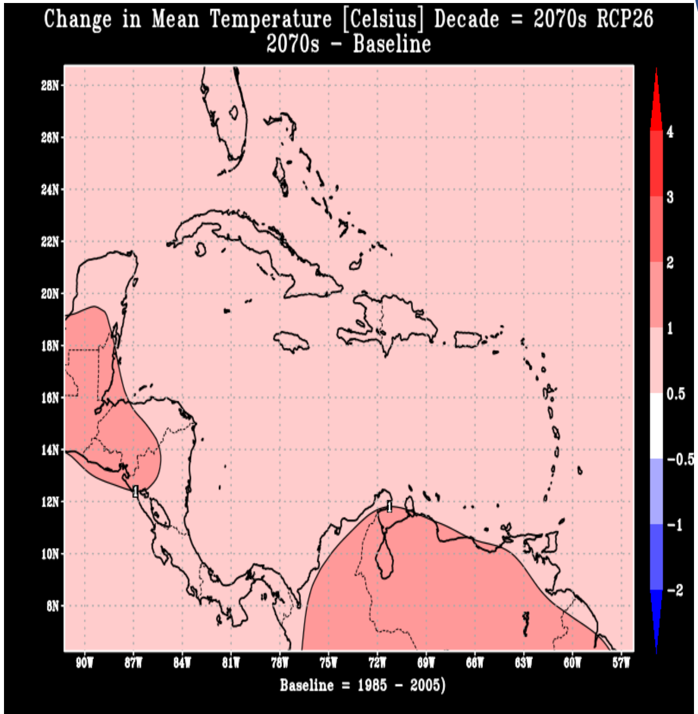

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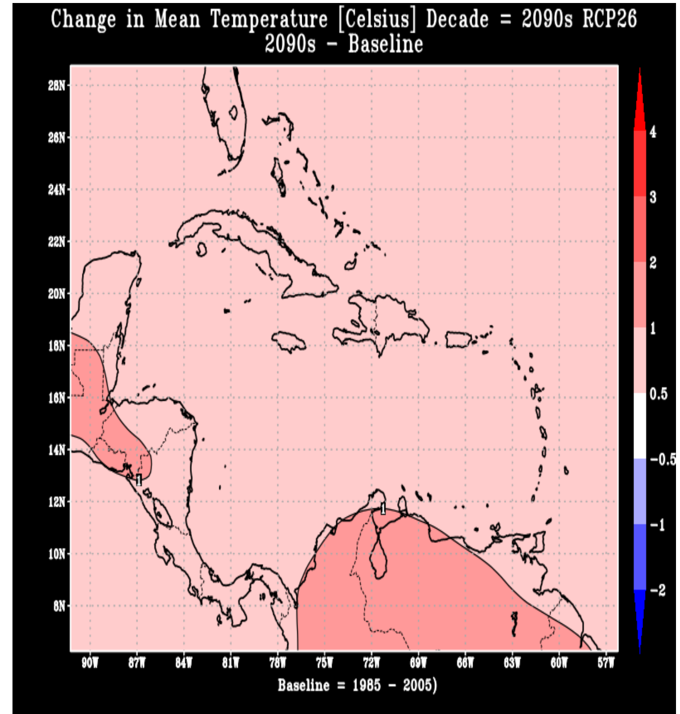

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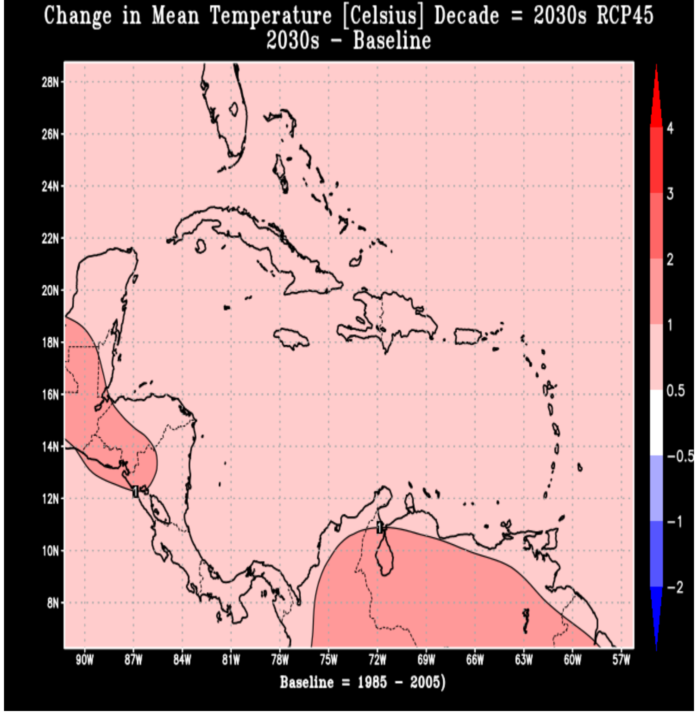

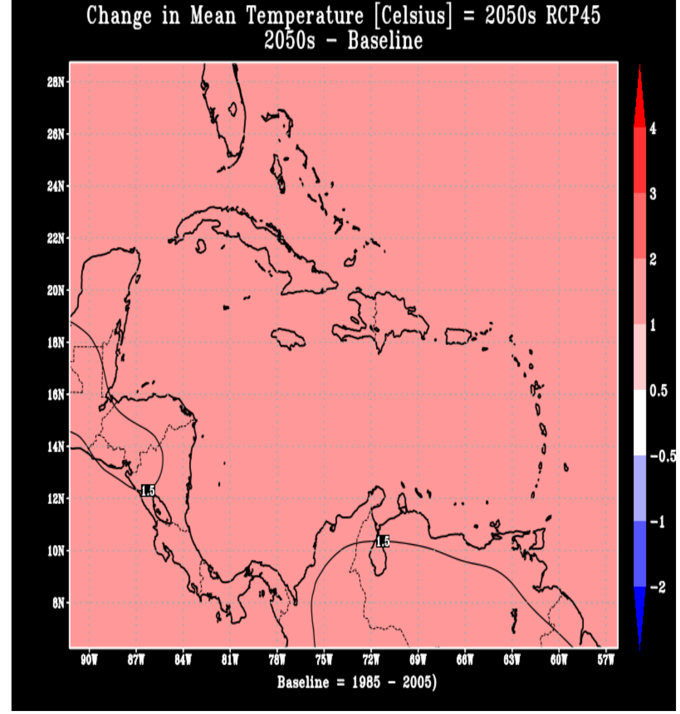

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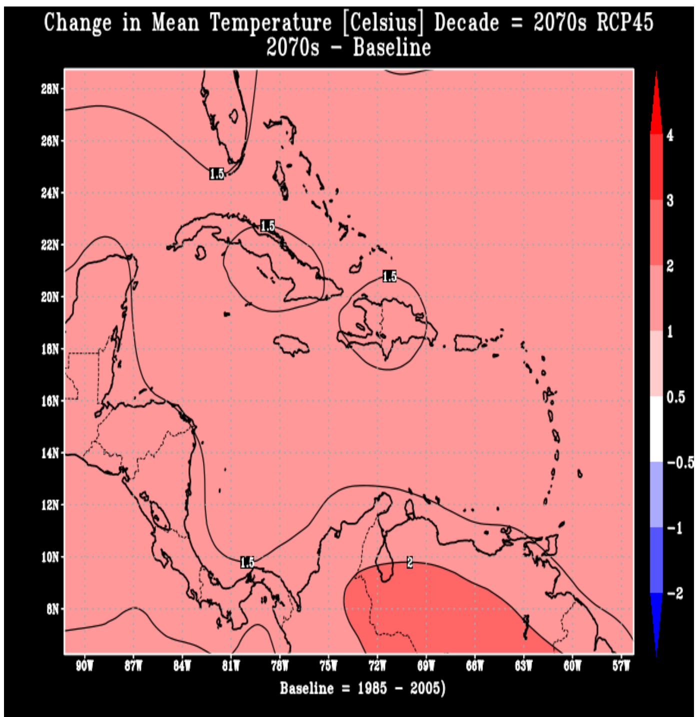

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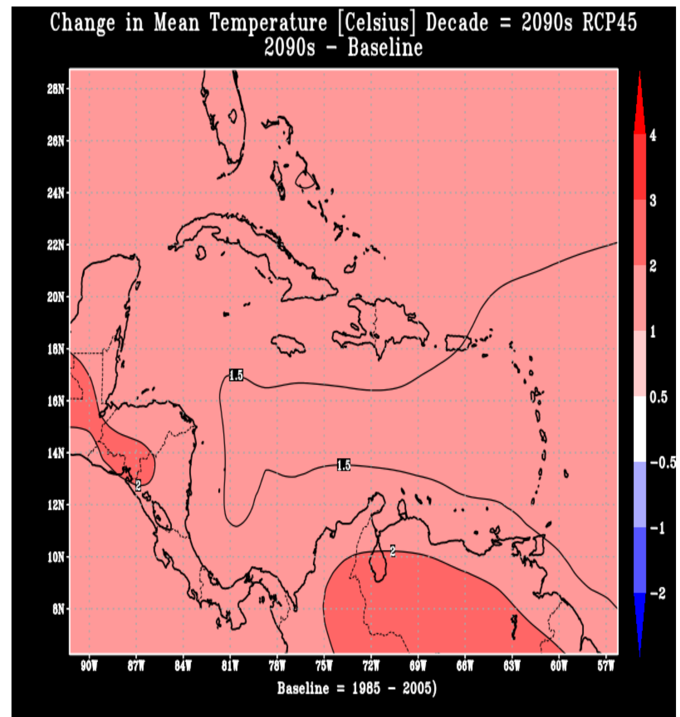

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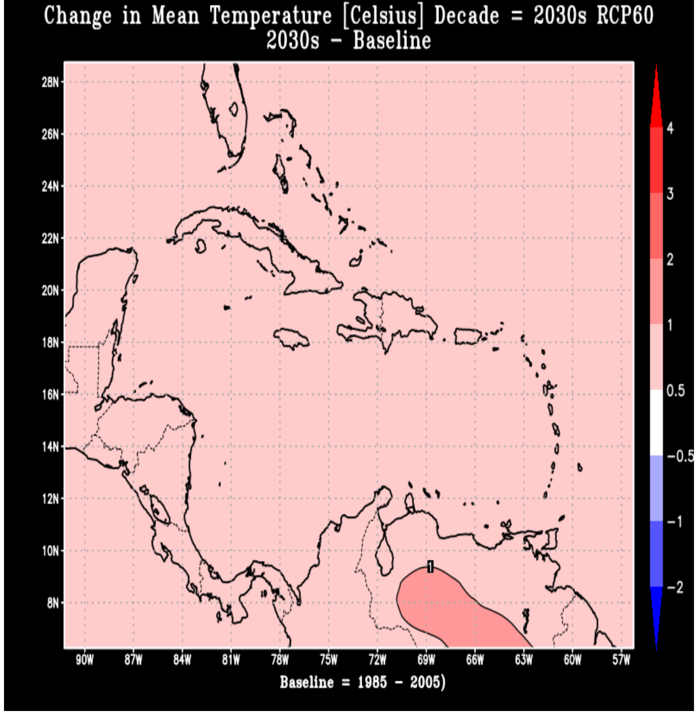

Mean Temperature

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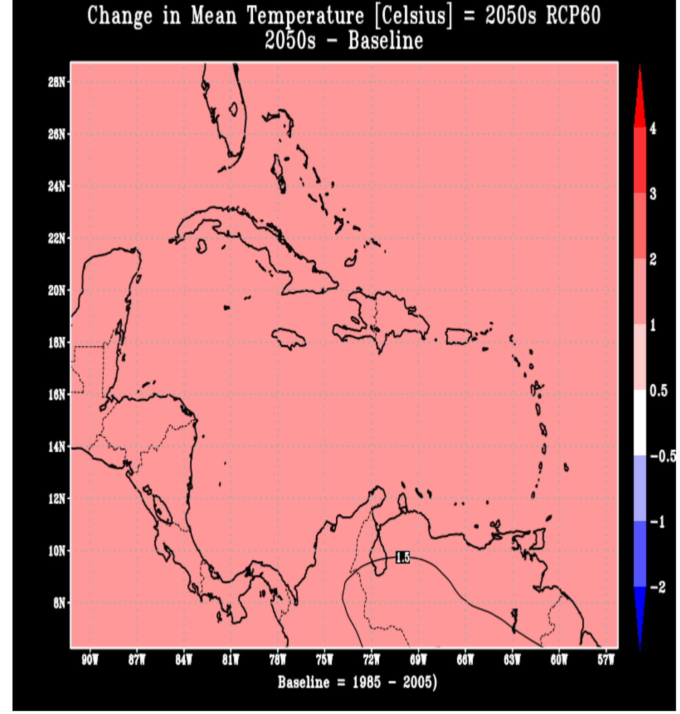

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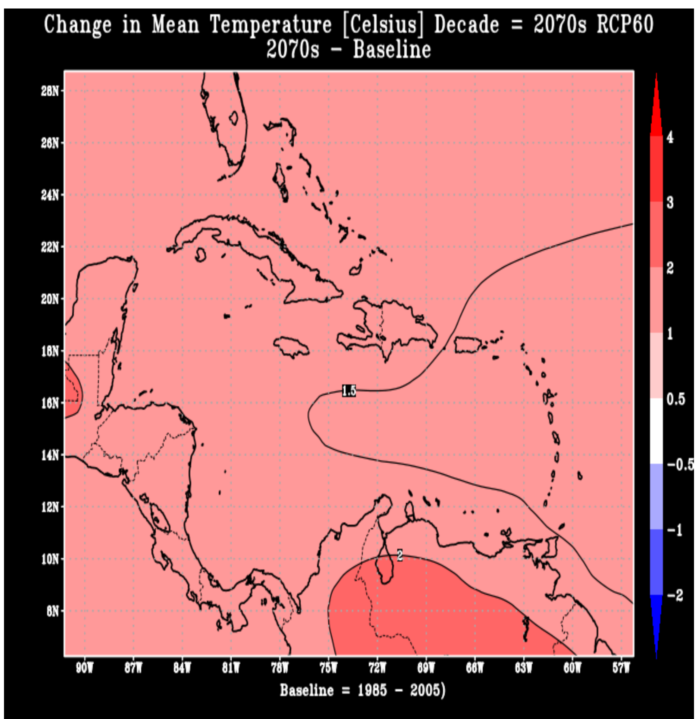

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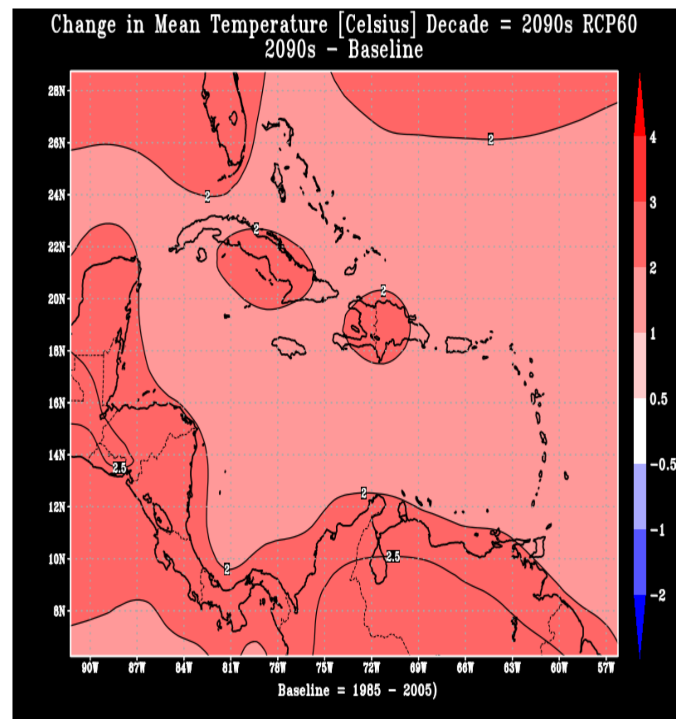

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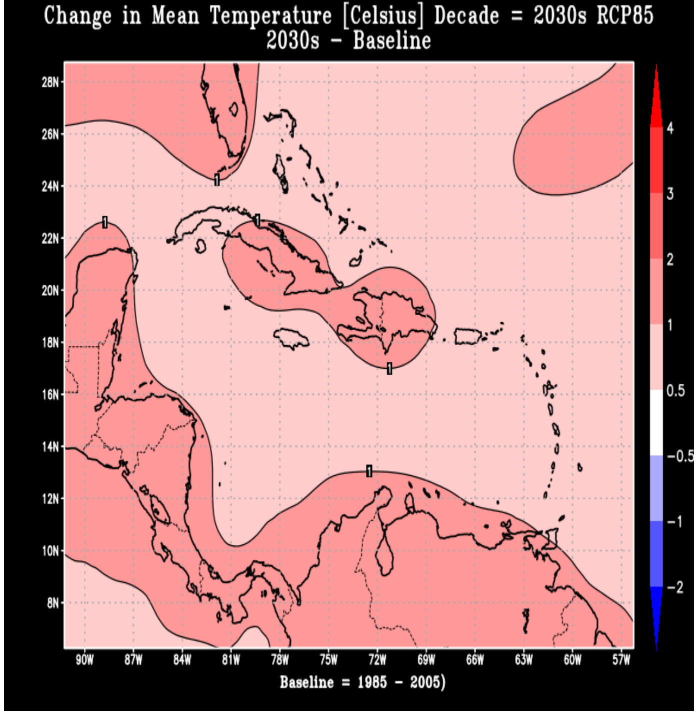
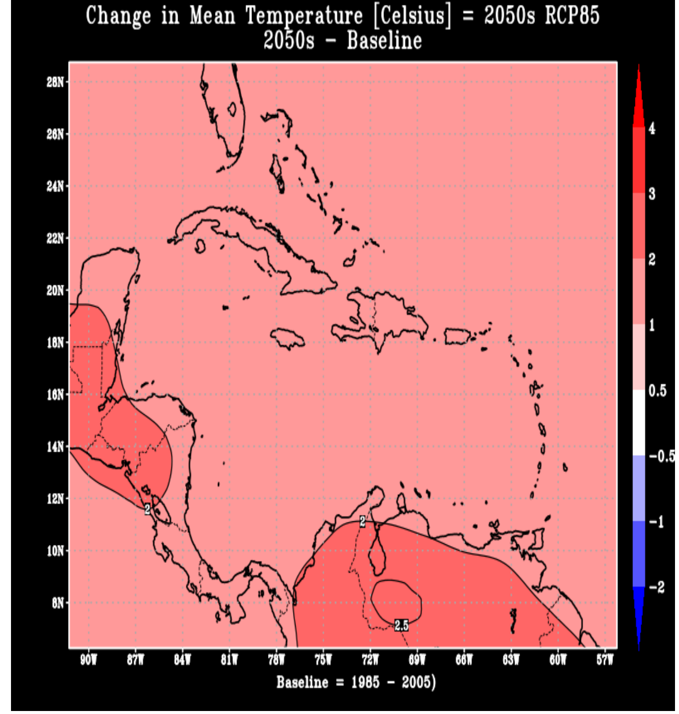


Mean Temperature



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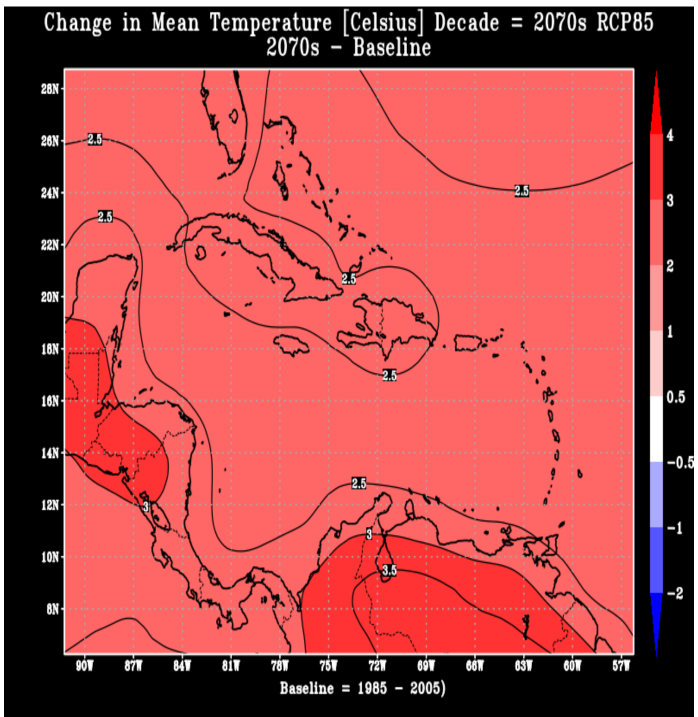

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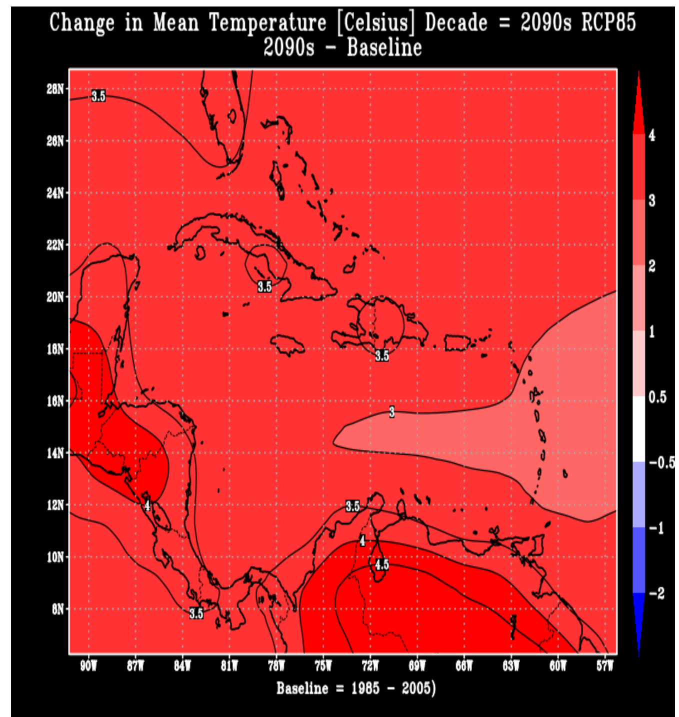
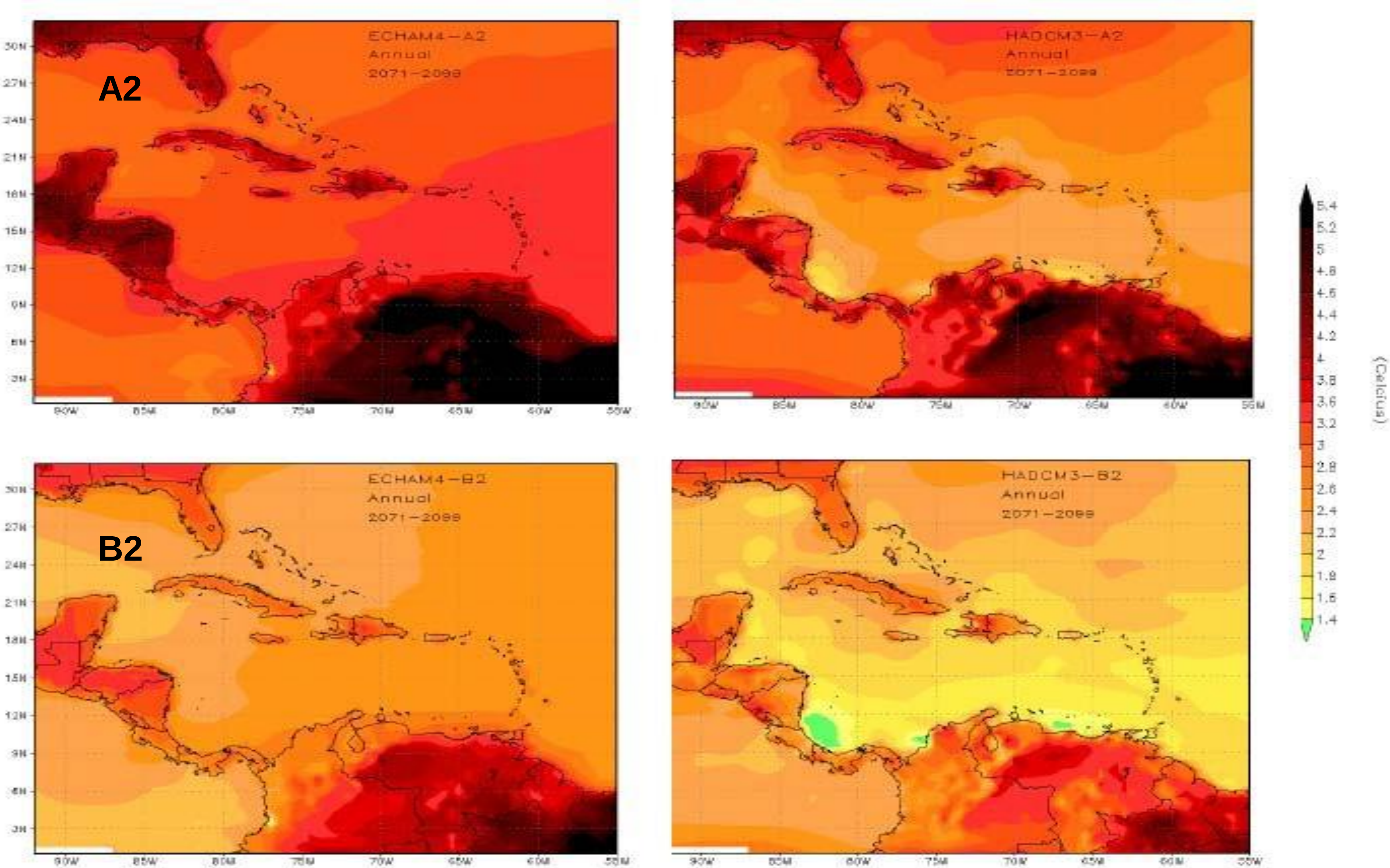


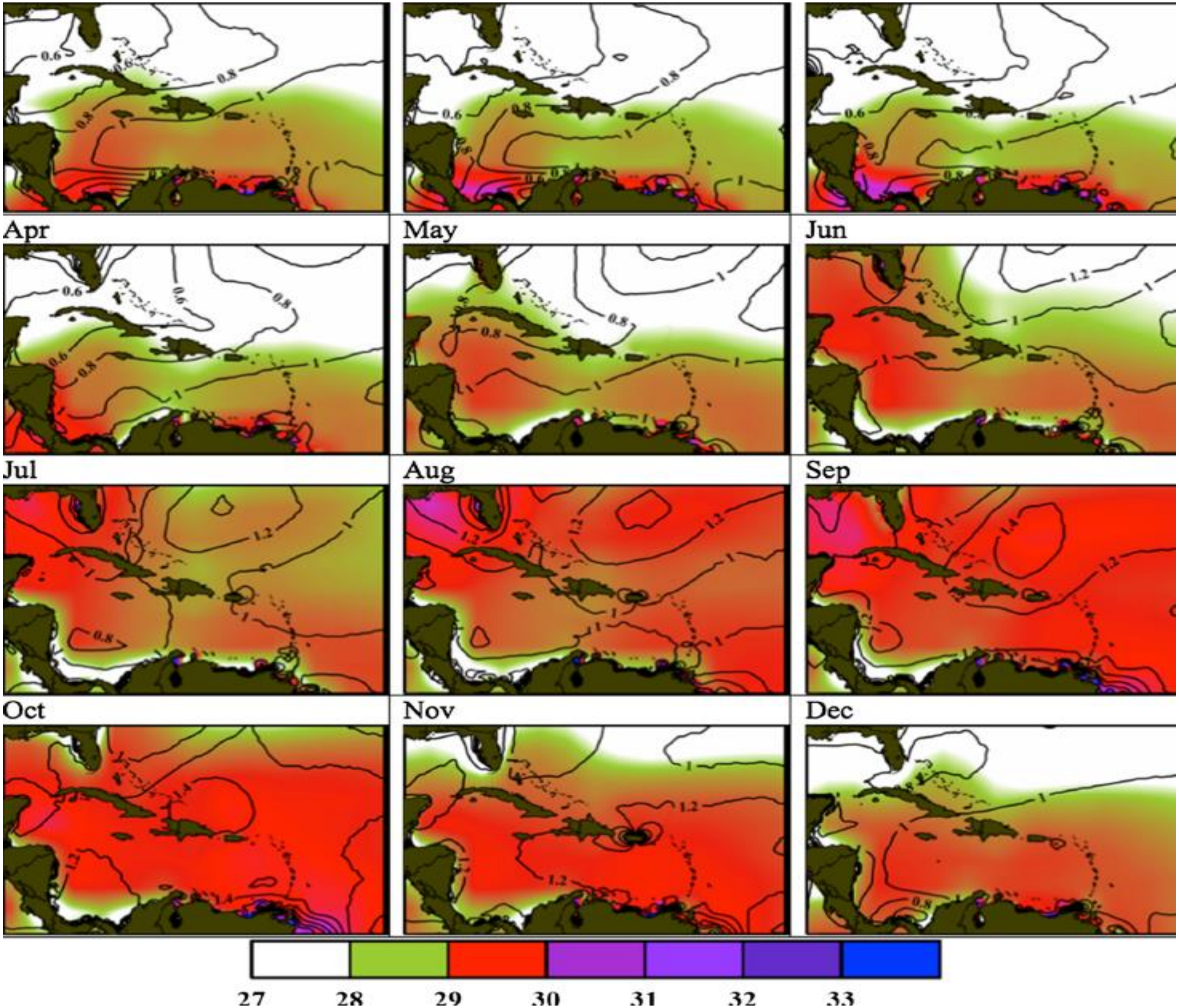
2090s

1^{0} C – 4^{0} C Warming (relative to 1960-1990 mean) Projected by End of Century

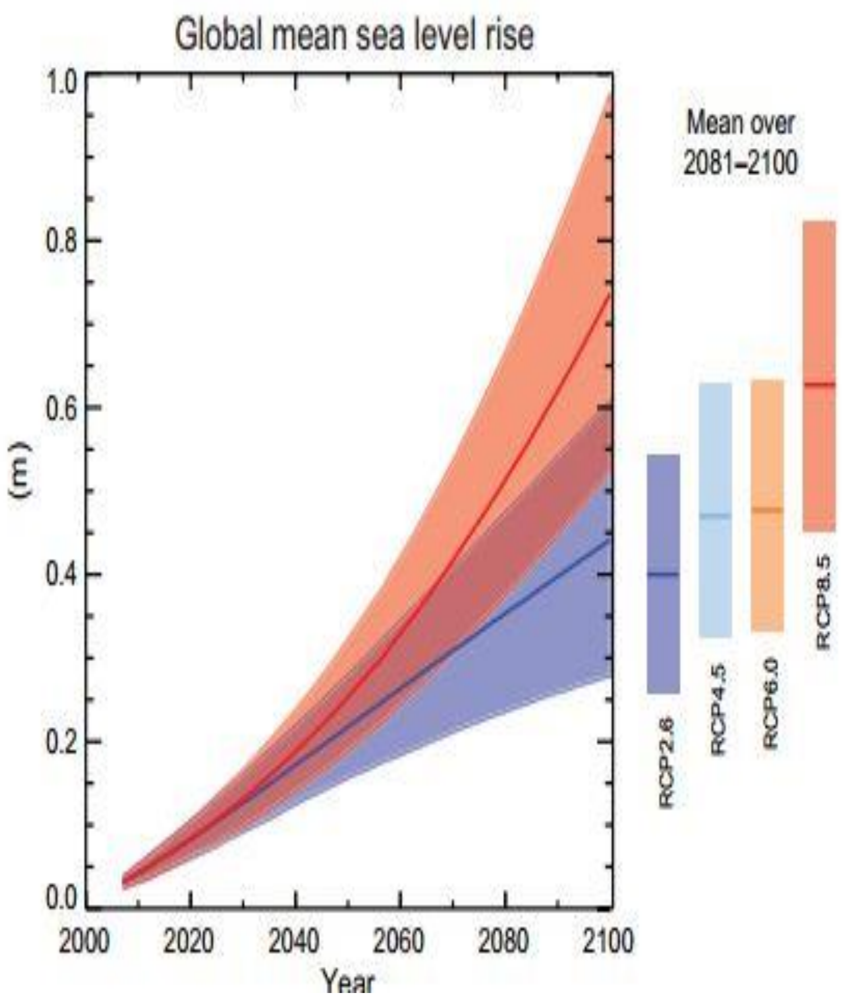


Caribbean Sea Surface Temperature Projections

(Nurse & Charlery, 2015. *Theoretical and Applied Climatology*, 2014, DOI: 10.1007/s00704-014-1346-1)

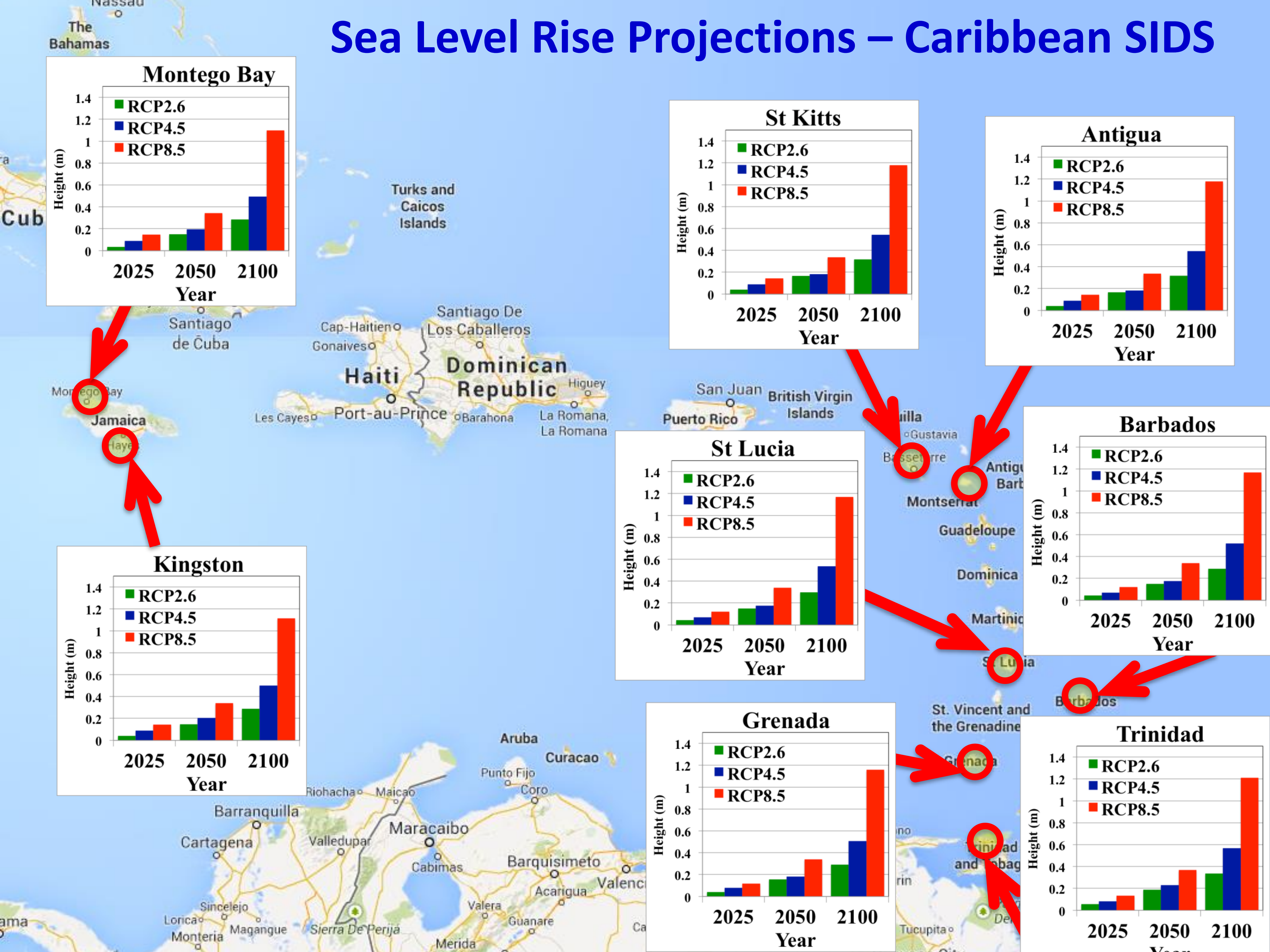


20th Century Observed SLR in SIDS Regions



- Tropical Western Pacific → rate of rise is almost 4 times the global average.
- Indian Ocean → rate of SLR as much as twice global average
- In **Caribbean** → rate of SLR generally higher than global average, ~ 1.8mm $^{yr-1}$.
- Guyana → observed mean rate of rise ~ 2.4 mm $^{yr-1}$.

Sea Level Rise Projections – Caribbean SIDS



Coastal & Marine Ecosystems : Role in Enhancing Resilience

- < 0.5 % coastal & ocean space covered by vegetated habitat → *mangroves, seagrasses, salt-marshes, macroalgae*

- Yet, they provide indispensable global services → habitat for fish & variety of organisms, wave energy attenuation, sediment entrapment, turbidity reduction, etc.

- These habitats account for *50% of all carbon sequestered in marine sediments*



Risks Factors for Seagrasses and Mangroves in Caribbean

Seagrasses

- Impacts mostly negative - *vary by species & environmental quality*
- Higher SSTs, UV-B radiation, CO_2 & sea level rise will likely lead to:

➢ Community redistribution due to competition among species and associated algal communities

➢ Reduced photosynthesis → increased metabolic stress due to production of UV-B blocking compounds within plant tissue

➢ Altered propagule formation and lower growth rates

➢ Species decline/loss ⟶ changes in reproduction & competition

Mangroves

- High sensitivity to SLR, air ^{0}T, SST, CO_2, rainfall , sedimentation

➢ Some species unable to keep pace with SLR → salinity & sediment changes

➢ Reduced rainfall → increased salinity and reduced sediment

➢ Changes in *species composition* and *phenology* → higher ^{0}T

➢ Non-climate risk factors, e.g. land-use changes & ‘*coastal squeeze*’ → restricts landward migration

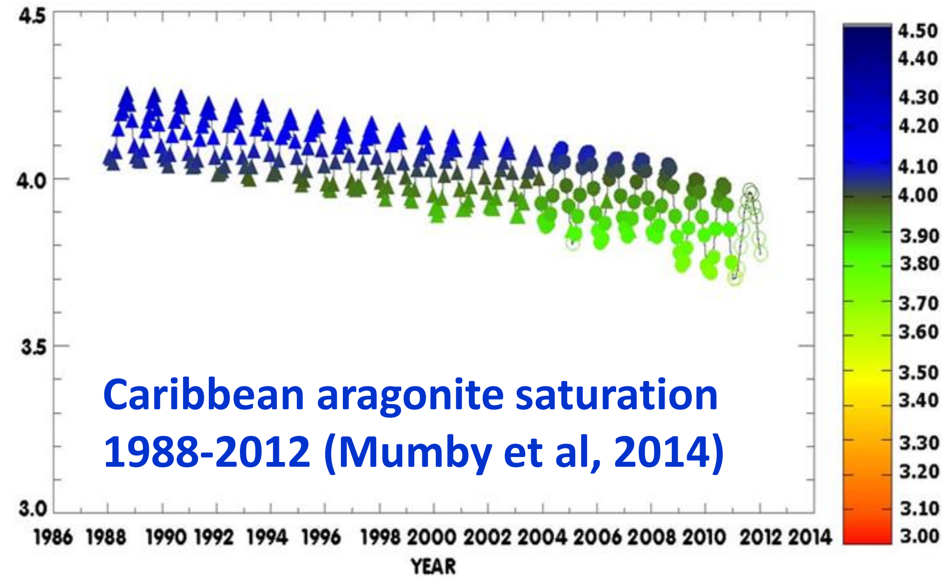
Climate Change Impacts and Coral Reefs in Caribbean: Evidence from Published Research

- In last 4 decades climate-related stressors have compounded the effects of human pressures → discharge of contaminants & poor H_2O quality, habitat damage, sedimentation, etc.
- Causal link between ocean warming, thermal stress & coral bleaching → major events in C'bean (e.g. '83; '97/'98; 2005/2006; 2009/2010) → SSTs ≥ 1^0 C above seasonal maximum.
- Direct, climate-induced changes in reef architecture - loss of complexity (*rugosity*) & coral cover → Jamaica, The Bahamas.
- No field evidence from Caribbean (or elsewhere) that corals can adapt to *unabated* thermal stress on *decadal timescales*.
- Research in the Caribbean suggests that in order to save 50% of the region's coral reefs, global mean ^{0}T would need to be limited to ≈1.2 °C relative to Pre-industrial.

Carbon Dioxide and Ocean Acidification

- CO_2 concentration in oceans positively correlated with higher atmospheric CO_2
- Atmospheric CO_2 rose from 287 ppmv in 1870 to > 400 ppmv in 2016
- Higher CO_2 → *higher ocean acidity* & *lower pH* → risk to survival of corals, other shell organisms & fisheries
- 14-30% decline in calcification projected by 2050
- Laboratory studies ⟶ at 560 ppm CO_2 → some corals cease growth

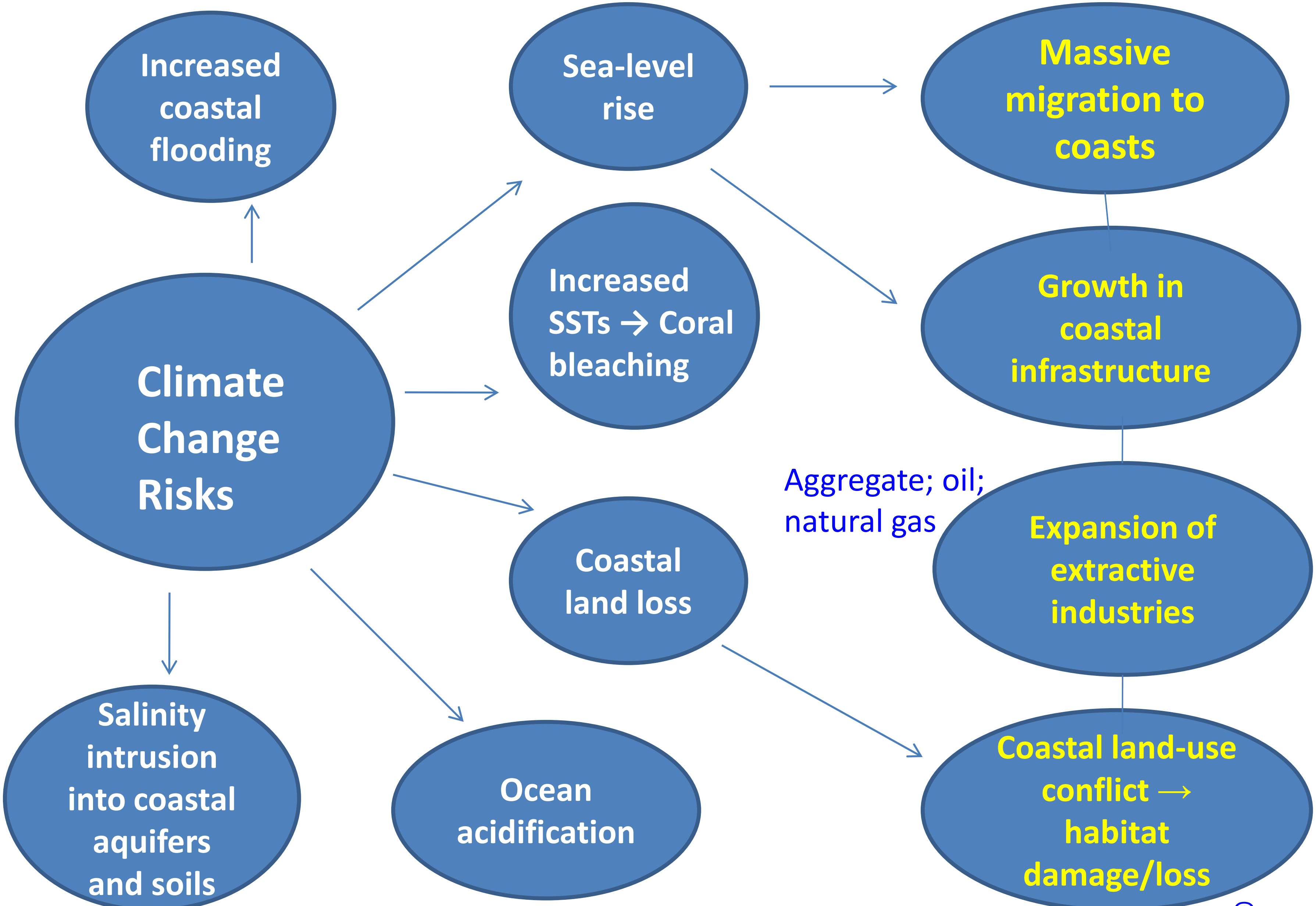
- *Aragonite* → form of $CaCO_3$ in corals & other marine organisms .
- The lower the *aragonite state* → more difficult for corals to form skeletons.
- 1988-2012 → lower ocean pH accompanied by sustained decrease in aragonite saturation in Caribbean.



Caribbean aragonite saturation 1988-2012 (Mumby et al, 2014)

- **Bonaire earns > USD 50 M/yr from recreational diver fees** (*Univ. of Amsterdam, 2013*).
- **Belize earned between USD 150 M-196 M from '*coral reef and mangrove-related recreation*' in 2007** (*Cooper et al, 2008*).

Climate Change – A Present and Future Risk Factor in Coastal Management in the Caribbean



Increased Rates of Beach/Coastal Erosion

- *Accelerated beach erosion* will be a major challenge in the Caribbean. While some present-day erosion is man-induced (*sand mining*, reef degradation, *etc.*), empirical studies show that sea level rise is a significant contributory factor.

  - Higher H_2O Levels → Higher Wave Amplitude → Increased Wave Energy = More Coastal Erosion

  - Vulnerability assessments in Barbados, Guyana & Grenada (CPACC) Project) show that elevated sea level amplifies coastal erosion.

Settlement and Infrastructure

- In the Caribbean more than half of the population lives within 1.5 km of the coast. Apart from settlement,
- Critical infrastructure, e.g. government offices, hospitals, businesses and utilities also tend to have coastal locations. Changes in sea level, and in the behaviour of storm events, are likely to have serious consequences for these facilities.
- With few exceptions, international airports are sited on or within a few km. of the coast. Similarly, the main road arteries often parallel the coast. While the severity of the threat will vary from country to country, air & seaport operations would be at serious risk.
- Threat to infrastructure & settlement from sea-level rise is amplified by storm surge that accompanies the passage of tropical cyclones (hurricanes).

Palisadoes Highway Protection - The Main Access to Norman Manley International Airport, Jamaica

Repeated damage from the passage of storms over many decades. In 2004 Hurricane Ivan caused > 300 m of shoreline erosion → complete shutdown of airport and isolation of adjacent communities. A decision was taken to raise road to 3.2 m amsl (formerly 0.6 -1.0 m amsl) and build a coastal revetment, at cost > USD 100 M.

Impact on Freshwater Supply

- Declining mean annual rainfall **+** More frequent longer dry spells **+** Higher ^{0}Ts & evaporation rates **+** saltwater intrusion

+

- Management failures
- Current & projected demand

Without adaptation (and augmentation) many Caribbean states will be unable to meet demand by 2050 $\rightarrow$ for some it could be as early as 2030’s.

Agriculture and Food Security

- Suite of factors will affect food security adversely:
- Reduced rainfall; more drought events
- Crop sterility above critical ^{0}T thresholds
- Higher soil & water salinity → sea level rise
- Change in *range* & *variety* of *pests* → insects, weeds
- Damage to critical fish habitat → coral reefs, mangroves, seagrasses

Forestry

- Many climate-related risks faced by Caribbean forests are similar to those in the crop agriculture sub-sector:
  - ➢ Reduced rainfall; higher evaporation; changes in *pest and disease behaviour* to which species will have to adapt
  - ➢ Altered *phenology*, *reproduction*, modes of *propagation*
  - ➢ Threat from *exotic invasive species* → may outcompete natives in changing environment
- Increased incidence of *forest fires*

Insect Damage - Belize Mountain Pine Ridge Forest Reserve

- Mountain Pine Ridge Forest Reserve (MPRFR) established in 1944 → protect & secure *endemism*, *biodiversity* and *natural regeneration*.
- Area >30,000 *ha* (300 *km*^{2}) → wide range of habitats & wildlife → Dominant species are Caribbean pine (*Pinus caribaea*) and ferns.
- Several attacks from southern pine bark beetle (*Dendroctonus frontalis*) → most severe infestation in 1999-2002 → estimated to have damaged 80% of the pine forest, killing 60% of the trees.



Efficacy of Ecosystem-Based Adaptation

- Explicitly recognizes linkages between people, livelihoods and their *natural life-support systems* (environment).
- By definition *ecosystem-based approaches* underpin the very notion of sustainable development:

◙ Contribute to achievement of multiple sustainable development goals → carbon stocks; biodiversity protection; sustained yields; resilience to hazards; food security and other livelihood support.

◙ Multi-sectoral and multi-disciplinary; operates at varying scales, spatially and temporally – offers opportunities for 'scaling up'.

◙ Can be combined with 'hard' engineering → *hybrid* approaches ⟶ integration of 'grey' and 'green' options.

Apply lessons from successful regional initiatives!

Coral Nursery and Restoration, Laughing Bird Caye, Belize

Mangrove Restoration Project, Guyana

Thank You

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