Jordan 3rd National Communication on Climate Change

Provision of regional climate projections using CORDEX

Technical report – final version

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1 Introduction

Within the framework of the preparation of the Third National Communication on climate change (TNC), Jordan needs to update its knowledge on climate change impacts, vulnerability and and risks assessment. The objective is to work at a national level, but also to focus on a pilot area selected within the Zarqa River Basin.

The starting point of a climate change vulnerability assessment is a better understanding of the future climate conditions at a regional level. This task was entrusted to TEC, using an innovative approach and set of regionalized data derived from the CORDEX Programme.

So as to get the best information available, the expert team, gathered by IUCN ROWA and the UNDP needed :

- some constant interaction with the TEC team, so as to discuss all technical choices (temporal horizons, spatial domains, socio-economic scenarios, downscaling techniques), which potentially strongly impact the final results. Such an effort of transparency in quite rare;

- some tailored indices and some innovative visualization tools, able to describe the key variables influencing Jordan's future climate, including for instance some indices of droughts;

- some metrics of uncertainty, based on the processing of a multimodel ensemble. Indeed, there would be a great risk to base a climate change vulnerability assessment on a single climate projection, which would not represent the range of possible futures and may lead to ''adaptation error''.

These three conditions (interaction, tailoring, uncertainty analysis) formed the basis of the PROCLIM offer, developed by TEC (www.pro-clim.org). Such an approach was made possible by the availability of CORDEX projections, as a result of a huge multiannual research effort of the climate community. It was also made possible by our continuous efforts to increase the accessibility and understanding of rough model outputs, so as a growing number of stakeholders can benefit from the advancement of research in the field of climate variability and change.

The following is the final report of the "Provision of regional climate projections using CORDEX" assignment, granted to TEC by UNDP. Section 2 (Methods) contains some important information on the methodological framework applied for the study, in particular as it concerns the understanding of our visualization tools,. Section 3 (Results) starts from Global trends as modeled by IPCC, then gradually focuses on Jordan and on the pilot areaarea retained for the TNC V&A Assessment. Both classical indices (mean temperature, cumulated precipitations….) and more aggregated indices (consecutive dry days, standardized precipitation indexes…) are presented. It then ends with a tentative analysis of extreme events.

2 Methods

Overall perspective

CORDEX (Coordinated Regional Climate Downscaling Experiment), coordinated by the World Climate Research Program under the auspices of WMO-IPCC and UNFCCC, is the most global ambitious effort of climate downscaling undertaken so far. It provides, for sub domains covering most of habited lands, large ensembles of projections coupling the most recent and most observation fitted Global Climate Models (GCM) with all the Regional Climate Models (RCM) available (such as RCA4 from Sweden or the French Aladin).

Jordan is covered by 4 CORDEX sub-domains (EUROCORDEX, MEDCORDEX, MENA CORDEX and AFRICA CORDEX). CORDEX offers:

- some in-depth uncertainty assessment. Projections in CORDEX are driven by best GCMs and all Representative Concentration Pathways (RCPs, the IPCC AR5 socio-economic scenarios). It allows to develop ensemble projections with associated metrics, thus avoiding taking wrong directions, and therefore avoiding maladaptation and non-robust strategy;
- the provision of daily datasets of various parameters, allowing to calculate tailored climate indexes adapted to users, such as those selected by the Jordanian sectoral experts;
- above all, a tremendous improvement of the understanding of local climate systems, from regional circulation, such as cold fronts and heavy precipitation or Sirocco periods, to local orography details. Elements like the coupling and feedbacks within the Mediterranean and the land are accounted for; besides, the run-offs of river like the Jordan River are modeled (in particular in Med Cordex). This is absolutely out of the scope of GCMs, and therefore of GCM statistical downscaling.
- Moreover, a resolution of 50kmx 50km provides 43 grid points for the whole country, a resolution of 20 km X 20 km provides more than 150 grid points and about 600 with a resolution of 11 X 11 km (0.44, 0.22 and 0.11 degrees are the three basic resolutions of CORDEX.

According to recent research papers, high resolution regional models do not avoid all GCM biases. But their added-value is to improve the representation of spatial contrasts, such as irregular relief and mountainous area (the Jordan rift).

The Jordan's Third National Communication on Climate Change (TNC) project is one of the first applied project aiming at translating CORDEX datasets into usefulinformation accessible to policy makers. This required a rigorous methodology, with the constant supervision of high profile climatologists, and a strong effort of research and development, under very tight deadlines.

Data preparation and processing

Choice of data sets

Domain

The CORDEX database evolves very quickly and is expected to expand further in the course of 2014. Many projections are under development amongst the various contributing research teams. For most of them, the validation step is on-going. **As far as Jordan is concerned, the country is covered by four domains :** EUROCORDEX, MEDCORDEX, MENA CORDEX and AFRICA CORDEX. Each domain has its own specificities, such as spatial resolution, boundaries, number and type of models, RCPs available, etc. (see Table 1).

The choice of the most suitable domain for the study resulted from a trade-off between data policy, resolution, geographical position of the country within the domain and the size of available ensemble of projections (GCM, RCM, RCP). The data policy excluded MEDCORDEX, given that this domain is restricted to non commercial use. The very lateral position of Jordan in the domain excluded also EUROCORDEX, despite high resolution (0.11°) and a reasonable ensemble size. Indeed, Jordan being at the very East of the domain (with a small part of the country missing), some border effects (visible with simple data visualization tools) could introduce clear biases in the data. This point was highlighted at the CORDEX

2013 conference (Brussels, November 2013). A third domain, MENACORDEX, was then considered given the good location (right at the center) of Jordan. However, the limited number of GCM (3) and RCM (1) limited the interest of the ensemble.

Altogether, after some interactions with IUCN, UNDP Jordan and the expert team, AFRICACORDEX was selected for this study. The location in the domain is good. The resolution of 0.44° is good compared to the current state of the art, even though it is the lowest available in the CORDEX Programme. It offers a good ensemble : 8 GCM coupled with SMHI (Sweden) regional model, + 1 GCM coupled with DMI (Denmark) regional model, which is 9 projections by RCPs. RCP 4.5 and RCP 8.5 are available, those are the most important for future vulnerability assessment.

	Data policy	Resolution	Data Center (one RCM)	Number of GCM	RCP
MENA CORDEX	All uses	0.22 ° (~ 25km)	SMHI(Sweden)	2	8.5
		0.44 ° (~50 km)	SMHI(Sweden)	3	2.6 4.5 8.5
MEDCORDEX	Restricted to non commercial use	0.44°	CNRM (France)	1	4.5 8.5
		0.11°	CNRM (France)	1	4.5 8.5
EUROCORDEX	All uses	0.11 ° (~12 km)	SMHI (Sweden)	5	2.6 4.5 8.5
			DMI (Denmark)	1	4.5 8.5
		0.44 °	SMHI (Sweden)	9	2.6 4.5 8.5
			DMI (Denmark)	1	4.5 8.5
AFRICA CORDEX	All uses	0.44 °	SMHI (Sweden)	8	4.5 8.5
			DMI (Denmark)	1	4.5 8.5

Table 1: Cordex data availability as of March 2014.

Representative concentration pathways (RCPs)

RCPs are the reference socio-economic scenarios governing climate projections in IPCC reports. They replace SRES (A2, B2, etc.) scenarios previously used by IPCC. Maps, graphs and analysis will take RCPs 4.5 and 8.5 as references. RCP 4.5 depicts a scenario where the GHG atmospheric concentration would be limited by some efforts in climate policy, while RCP 8.5 depicts the consequences of low restrictions in the emissions of global anthropogenic emissions. The RCP 2.6, also of interest for the TNC, would illustrate the impact on a severe global reduction of GHG. It is judged very even unrealistic, and is therefore unfortunately neither included in SMHI or in DMI datasets. It will be treated, in a separate box/section (so as not to extend the range of climate futures somehow artificially), using the results of IPCC AR5, WG1 and WG2 reports.

Time horizons

After interaction with IUCN, UNDP and the expert team, the following time horizons were selected:

- 1980-2010 as a reference period (corresponding also to the best availability of observational data)

- 2020-2050, 2040-2070, 2070-2100 for future projections (maps…). In particular, the 2020-2050 horizon, centered around 2035, is sufficiently far from now (20 years or so), to start seeing a climate change signal emerging from the background noise of inter-annual variability.

Beyond that, most of indicators represented in graphs use a moving average of 30 years, and therefore alternative time horizons will be available (see description of visualizations).

Station data

Any bias correction or further downscaling requires a reference dataset of observational data, if possible at a daily scale. The "official" station data of the Jordan Meteorological Department was, at the time of the study, only available at a monthly scale. Therefore, alternative options had to be pursued:

- The Jordan expert team finally got 258 local station data, for several parameters, from the Ministry of Water and Irrigation (MWI) network. After an analysis and station selection by Dr Mohammed Qinna, 60 stations for precipitations and 14 for temperature (tmin and tmax) only were used for bias correction and projection at the station level and interpolation, as the only ones covering the period 1980-2010 with less than 10% of missing values. Dr Qinna estimated for the Jordan expert team the absolute error for rainfall data for the two closest stations to compare between the data obtained from MWI and Meteorological Department (MED). The first was AGRO0008 (MED) and AE0002 (MWI) for Irbid with only 652.2m distance between the two stations, the associated average monthly absolute error was only 3.3mm from the period between January 1980 till December 2005. The other stations were Rain0037 (MED) and AM0001 (MWI) with 625.8m apart. The associated absolute error was found 8.5mm. These results are good enough to indicate the low variability between the two data sets, and therefore the possibility to use the MWI data base. This MWI data is used for the geostatistical downscaling and four our attempts of quantile-quantile correction.
- Still, the MED stations were used partly for the key step of model selection, when the model values for the reference period were compared with observations. Indeed, we assumed that the model outputs were built (e.g temperature at 2m high), so as to fit the best with the measurement method of international standardized weather stations managed by the MED.

A cartography of these stations (see Figure 1) shows a good coverage,of Jordan main human settlements, and in particular, a quite dense network of stations in the pilot areaarea selected for the TNC.

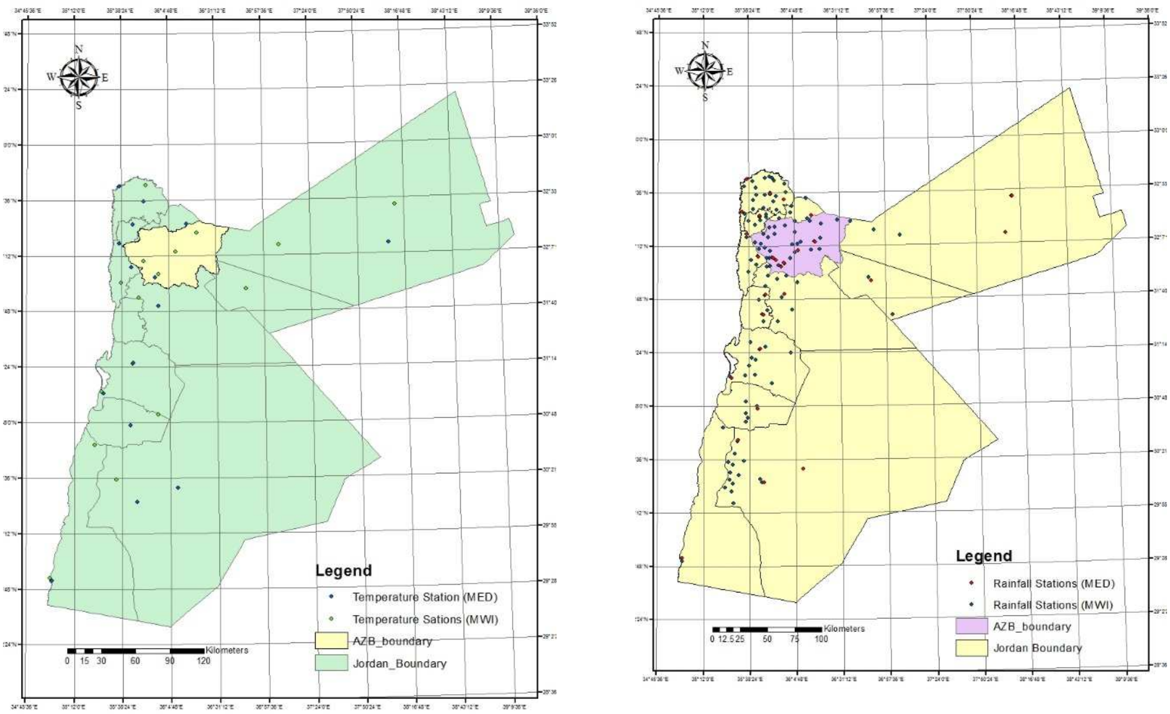


Figure 1: Maps of stations used in the study. The pilot area (AZB) is highlighted in both maps

Model selection

TEC policy is to produce information of future projections using multi-model ensembles, so as to provide the wider knowledge of uncertainty. It is also to highlight a “reference model”, so as to be a reference for decision making. Indeed, this need of a reference is an understandable need from stakeholders and decision makers, for obvious communication purpose. Moreover, a “reference model” allows illustrating not only means but also the inter-annual variability of climate, through annual values.

This reference projection, however, must be selected using a strict procedure. In short, the reference projection must be a reference corresponding to the objective of this study, i.e. the assessment of future climate conditions, with a preference to long term time horizons (2050 being often cited in the literature as an important horizon).

The reference projection was selected using a three-step procedure:

1. We first plotted on a delta-temperature / delta precipitation graph, for 2 time horizons (2035-2065, 2070-2100), the average changes in annual temperature and annual cumulated precipitation, compared to the 1975-2005 period. The choice of slightly different time slices, is due to the availability of observations. For each of these graphs, we also represented the median of our ensemble of projections. This was achieved for RCP 4.5 and RCP 8.5.
2. We chose the three models that, across RCPs and time-horizons, were most frequently the closest to the median. Indeed, this proximity to the median corresponds to an ability to represent well the ensemble. 3 models emerged : SMHI – NCC-NorESM-LR, SMHI – ICHEC-EC-EARTH, SMHI – MIROC-MIROC5 (see Figure 2)
3. These three models were evaluated regarding their capacity to model past climate. For the four model grid points located close to meteorological department stations (grid points ID83, 95, 101, 108), we compared the annual average temperature and the cumulated average annual temperature, of the period 1975-2005 (the time slice available for the Meteorological department data). The important discrepancies existing between model data and observations are not due to model bias, but to the fact that we compare two phenomena of very different nature. Indeed, while the station data describe a punctual phenomenon (local rain of temperature), the model gridded data is the average of a 0.44° by 0.44° surface values. Therefore, depending on the local features of the station, the difference can be

positive or negative, and would only match by chance. However, given that this discrepancy is the same for all model, their individual “error” to observation can still be compared to make a choice. Altogether, it is still difficult to compare the model result with observations, in the absence of gridded observation products, or reanalysis products, such as ERA40. That is another reason why we favor the position to the median of future projections in the choice of the reference models.

From this analysis, the “SMHI – NCC-NorESM-LR” projection emerged as our reference projection. This projection is a combination between Norvegian Eearth System Model as global climate model, and Swedish SMHI regional climate model.

- The SMHI – NCC-NorESM-LR projection is the closest to the median for future climate, and is close to the median of the nine models for the comparison with observations for temperature. It does not present abnormal or outlier values when compared to the ensemble of models for precipitations.
- This reference projection is highlighted in all our graphs together with the multimodel range of projections (see below)
- This is also the one used for maps.

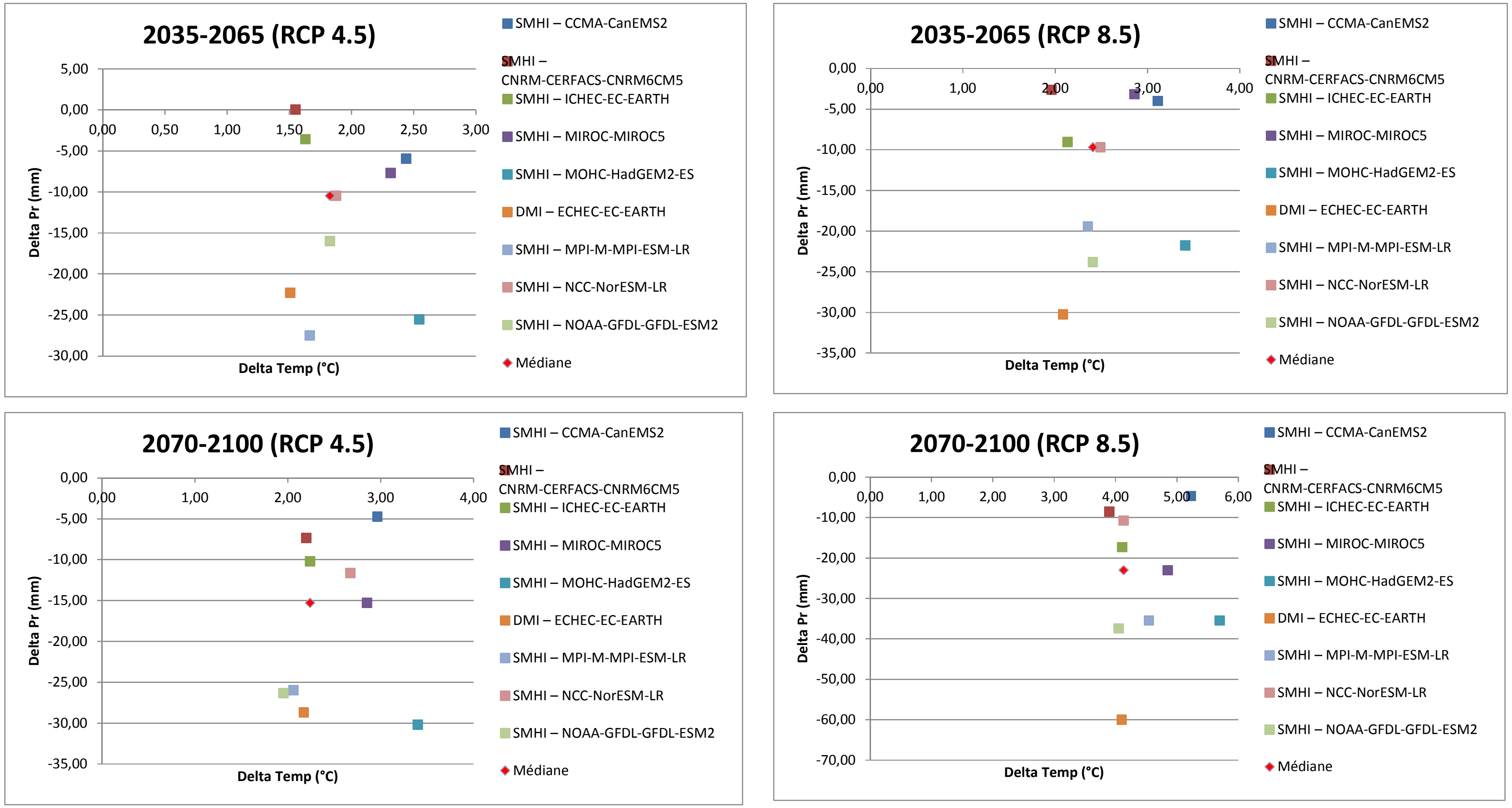


Figure 2 : Changes in temperature (˚C) and precipitation (mm) over Jordan, for 2035-2065 and 2070-2100 time-horizons

Indices selection

Table 2below present the state indices requested by the expert team and TEC's comments.

Climate index	Description	Unit	Time Period requested (Month/Season/Year, other)	Geographical scale (National, Local, both)	Note	Sector specific analysis	Comments
T2m_mean	Mean temperature at 2m height	°C	Day / Month / Season/ Year	Both	Daily will return to TX	All sectors	**ok**
T2min	Mean daily minimum temperature at 2 m height	°C	Day / Month / Season/ Year	Both	Daily will return to TN	All sectors	**ok**
T2max	Mean daily maximum temperature at 2 m height	°C	Day / Month / Season/ Year	Both	Daily will return to TG	All sectors	**ok**
RR	Precipitation sum	mm	Day / Month / Season / Year	Both		All sectors	**ok**
R10 mm	Heavy precipitation days (> 10mm)	days	Month / Year	Both		Urban	**ok**
Maximum no of consecutive dry days (CDD)	Maximum no of consecutive dry days (RR<1mm)	days	Month / Year			Biodiversity	**ok**
6-month Standardized Precipitation Index **(SPI6)**	6-month Standardized Precipitation Index SPI is a probability index based on precipitation. It is designed to be a spatially invariant indicator of drought. SPI6 refers to precipitation in the previous 6-month period		Seasons / Year	Both		Climatology	**ok**

3-month Standardized Precipitation Index (SPI3)	3-month Standardized Precipitation Index		Quarter / Seasons / Year	Both		Biodiversity and Agriculture	**ok**
Potential EvapoTranspiration **PET**	potential evapotranspiration as calculated by the Penman-Monteith parametrization	mm	Day / Month / Year	Both		Climatology, Agriculture, and Water	Available in SMHI dataset but not for DMI.
Maximum value of daily maximum wind gust (FXx)	Maximum value of daily maximum wind gust	M/s	Day / Month / Year	Both	Daily will return to FX	Urban, Health, Climatology	ok Available in SMHI dataset but not for DMI.
DD	Wind direction		Day / Month / Year	Both		Climatology	The datasets includes a U and V vectors, which includes several potential calculations. We will provide a breakdown of winds(% or number of days with dominants wind) per quarter
Mean of daily mean relative humidity (RH)	Mean of daily relative humidity	%	Day / Month / Year			Agriculture, Health and Biodiversity	Ok
Mean of daily snow depth (SD)	Mean of daily snow depth	cm	Day / Month / Year			Urban	Ok
visibility index	Dust Days		Day / month / year	Both		Urban	The data sets do not include parameters allowing calculating visibility index. **This index is therefore abandoned**

Table 2 : Requested indices

Downscaling

Downscaling methods

Stakeholders often ask climate data at very high resolution, both in numeric formats and in visualization products like maps. Although this need is understandable, climatologists tend to answer it with caution. Indeed, climate models have some limitations that should not be hidden by impressive maps. Some techniques might neglect the reality of the field (relief, etc.) and create the illusion of a “perfect” information, that will never be attainable in the field of climate change.

Actually, the “downscaling” term covers several meanings:

1. Dynamical downscaling, with the coupling of Global climate models (GCMs), with Regional climate models (RCMs), as achieved in the Cordex programme. The AFRICACORDEX 0.44 dataset used here is already resulting from the downscaling of global climate models. Stakeholders might need, however, some higher resolutions data.

2. Statistical downscaling, using methods such as :
   a. weather generator, or analogues methods, can help going further, starting from GCMs of from GCMxRCMs results. They are however not affordable for this assignment (time and computing resources, availability of tools). These methods try to generate the variability of a future climate, owing to local features as described in observations;
   b. statistical projections at the stations level, e.g. using the “delta method”;
   c. bias correction of model gridded data with observations, so as to improve the quality (distribution….) of the model data. Even though the resolution is not improved here, the information ‘contained’ in observations in somehow integrated in the model, and this can be assimilated to some downscaling.

3. Simple statistical and cartographic interpolation (e.g. smoothing, kriging), which can lead to any resolution (e.g. 1 km per 1 km), but with limited benefit. This could let readers think that climatologists modeled the future climate at such a high resolution, although this is not the case.

4. Geo-statistical interpolation, using information like altitude or land use (DEM). Such a geostatistical interpolation is recommended for zooms at high resolution, and provided local datasets are available.

In order to improve the resolution of the information contained in the CORDEX dataset, and to limit the biases contained in model outputs, our team had to tackle different issues:

- On one hand, the need to take into account the high contrasts of Jordan geography and climate highlight a need of further downscaling. Even though the signal of climate change is contained in the model data, the visual representation of this data might be rough, if parameters like altitude are not used. This is particularly true since the 0.44°C CORDEX resolution is used here. On the other hand, 0,44°C (cerca 50km) is already a good resolution with regards to the state of the art. Past effort of downscaling relied on Global climate models with a 200kmx 200 km grid, then abruptly downscaled at the station level, which appeared particularly risky. The coupling in CORDEX of a RCM with a GCM is clearly an added value, and limits the necessity of a further downscaling.

- The desire of the expert team to use 1km x 1km gridded data for the pilot area, particularly challenging. However, there is no difference between a work for entire Jordan and a work focusing on the pilot area. In the absence of very high resolution data sets, on land cover for instance, no higher resolution will be reached for the pilot area. Should a high resolution be reached, it would be made available for the entire country.

- Given the willingness of the Jordan team to work on extremes, a correction of model biases would be interesting. Indeed, if uncorrected datasets are very usable to assess means (annual, seasonal, monthly…), they are less accurate as soon as one wants to study indices including thresholds, such as intense precipitations or length of drought. Therefore, a correction (quantile-quantile methodology) had to be tried

It was therefore decided to combine:

- a further downscaling of CORDEX dataset for the parameters for which observational datasets on the long term were available (temperature and precipitations) was implemented. A "delta" method (i.e. applying at the station level the difference of models outputs between a given horizon and the reference period) was applied. A very novel approach developed here was to implement between the stations a geostatistical interpolation (described above). This was applied only for the reference model, in order to improve the cartography of key parameters.

- for other parameters, a simple interpolation (kriging) was implemented for maps;

- a tentative correction of model biases (for all models) was developed, using the "quantile-quantile" methodology in particular for the pilot area. The specificity of Jordan climate and its observations however limits its use. Therefore the results of this correction is not used in this report. Some methodological points are presented in annex.

These points are developed in the following.

Methods for temperature and precipitation : delta method and geostatistical interpolation

Interpolation

For temperatures and precipitations, an innovative geostatistic tool has been used. It is developed by French National Centre for Scientific Research (CNRS). The tool aims to explore the dependence between the variable of interest and deterministic factors at different scales. It contains the following sources of information: local temperatures or local precipitations (observed data of the ministry of water and irrigation (MWI) + virtual stations) and variables derived of digital terrain model (DEM) at 1 km spatial resolution: altitude, orientation, slope, roughness, encasement (the DEM was provided by the Jordan team)…

Virtual stations correspond only to points of the climate model which are remote from observed data to minimize the influence of the model. The virtual station is located on the grid point or on a pixel near the point (= average altitude of the mesh).

Regressions are systematically conducted on the datasets, with temperatures or precipitations as the dependent variable, and each of the other data layers as the independent variables. The results indicated that each explanatory variable a specific contribution to changes in temperatures or precipitations. The explanatory variables are crossed through multiple regression. Coefficients are considered mapping operators to produce the continuous field of the variable of interest. Two types of regression are tested: overall regression and local regression. For overall regression, only one regression is applied using the corpus available (*n* stations). For local regression, *n* nearest stations of each pixel of the study area are sought, then the pixels attached to the same stations are grouped within a polygon for which regressions (identification of best regressors and multiple regression) and kriging are made.

For this study, the spatial distribution of temperature and precipitation was carried out in 3 steps:

- step 1: it corresponds to the estimated values by multiple regression

- steps 2: the residue is calculated by cross-validation and is estimated by kriging

- step3: it corresponds to the sum of the two previous estimates

The results of cross-validation i very satisfactory for rainfall (coefficient of determination > 0.92, low standard deviation of the residuals) and temperatures (R^2 > 0.80, low standard deviation of the residuals).

Delta method

Once the interpolation formula is developed, it is applied to future climate. First, a delta is calculated for each grid, for the chosen horizons, with regards to the reference period (modeled future minus modeled reference period). Then this delta is downscaled using the techniques described above.

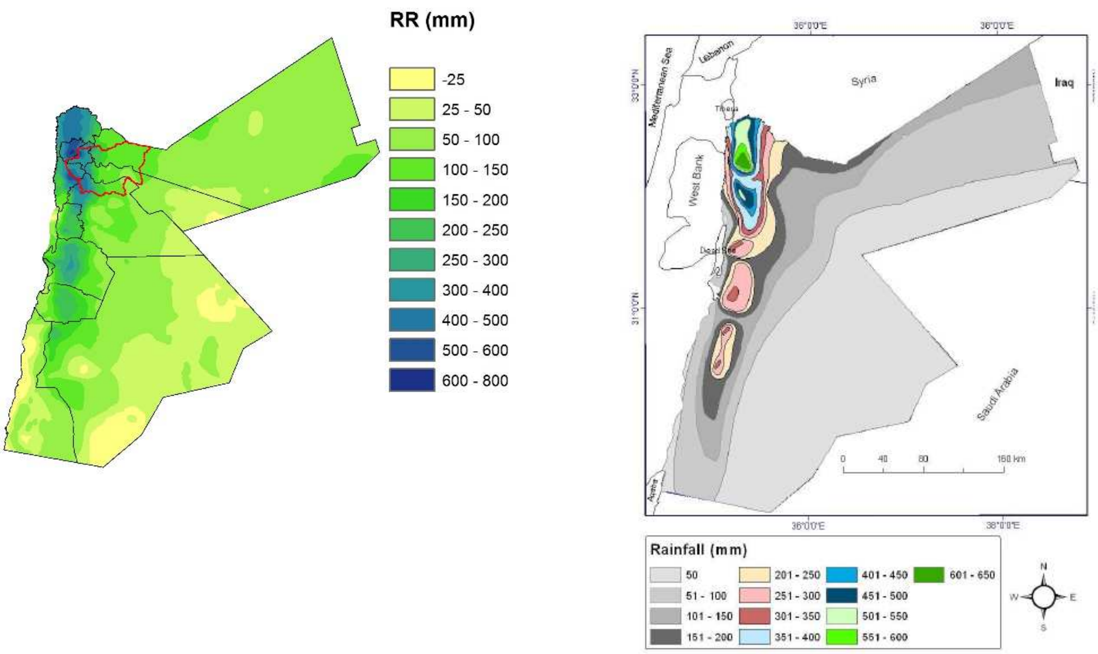


Figure 5 : Comparison of the historical observed precipitations (right) and of the modeled data (left) for the 1980-2010 period. The geostatistical interpolation and projection at the station clearly allow a better representation of the effect of topography on precipitation.

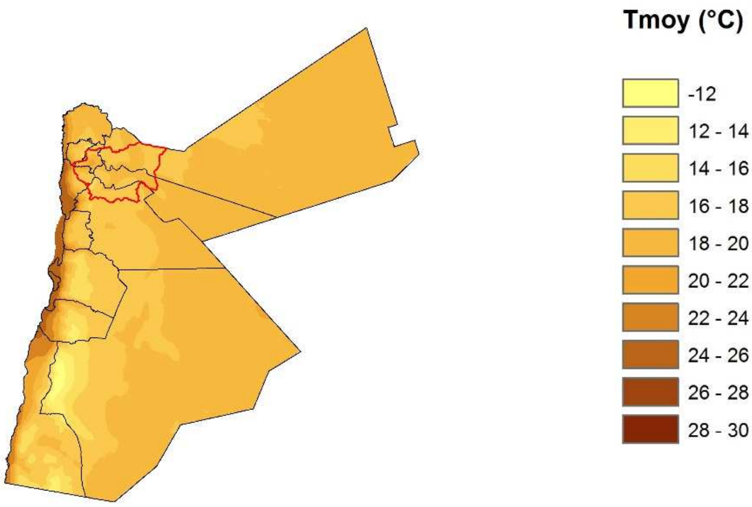


Figure 6 : Average temperature, 1980-2010, reference model, results of a geostatistical interpolation and projection at the station

Methods for other parameters

Observed values or model values (at grid points coordinates), are interpolated using a simple technique of smoothing (ordinary kriging), given the absence of long term validated observations, but also the difficulty to correlate parameters like evapotranspiration or humidity with geographical parameters (slope, altitude etc., as it was achieved for temperature and precipitations).

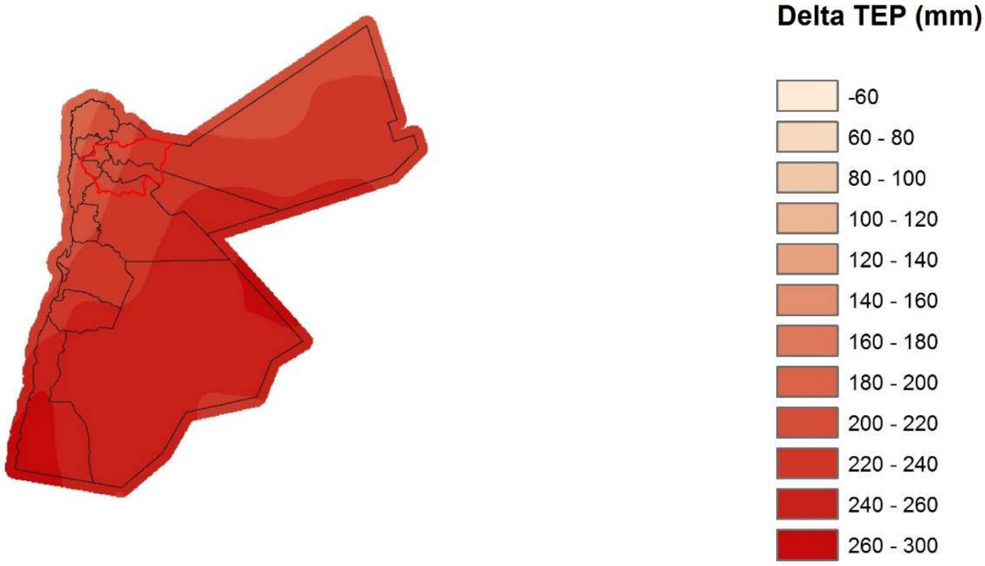


Figure 7: Changes evapotranspiration in Jordan, reference model, 2070-2100 compared to 1980-2010

Parameters not suitable for cartography

Given the low values of snow and the 0.44x0.44 grid, it did not seem realistic to map snow depths for the entire country. This information was developed for the pilot area only, with numerical trends rather than cartography.

Due to the absence of reliable long term observations and the strong influence on relief on the wind, it was also decided not to map this parameter.

Specification of deliverables

A comprehensive set of deliverables is annexed to this report : graphs and excel files, maps in various forms (absolute values, changes over periods and RCPs), netCDF files with various modes of calculation. Overall, this accounts for a 2 Go database.

Graphs and maps

End users can easily get drown in climate data. In order to facilitate the interpretation of results, we developed a limited set of graphs and maps, providing highly synthetic information.

How to read our synthesis graphs?

For each indice, the same graph was built (see Figure 8 for an example), containing the following common information

- The most important information is the trend for Jordan. This is represented by the dark green (central) line, which is the median of the 9 GCMxRCM ensemble, using a moving average over 30 years, to avoid inter-annual variability. This gives a clear and readable trend. In the example below, the annual cumulated precipitation tend to decrease regularly, until a value of -18% in 2100. The reader can refer to any date to see what will be the situation of the country, for instance the 2070 value refers to the 2040-2070 average, the 2035 the 2005-2035 average;

- The information on the range of uncertainty is given by the “min” and “max” values, which are the minimum and maximum values of the 9 GCMxRCM ensemble of projections, for each year, again on a 30 years moving average. In the example below, while the trend is to a gradual decrease of precipitations, some models still tend to predict a slight increase in precipitations, even up to 2085. Therefore the trend is uncertain, and the range between min and max, fist quite narrow, tend to increase from 2035. The min value gives here the most pessimistic scenario, with a potential loss of more than 20% of rain over the entire country.

- Though important, this information of multiannual means (moving average) do not translate the potential inter-annual variability of climate, which can have more severe impacts than means. That’s why, in addition to the 3 previous parameters (median, min and max), the individual annual values (without moving average) of the reference model are also represented. Here we can see that even in a context of decreasing precipitation, years of intense precipitation might still occur at the end of century. For indices, like temperature, this info on inter-annual variability is of particular importance : exceeding a given threshold, even one year out of 20 or 30, might destroy ecosystems or cause some severe health problems (as illustrated by the 2003 European heat wave, that killed some 15 000 people, only in France). Therefore this curve also gives information on extremes.

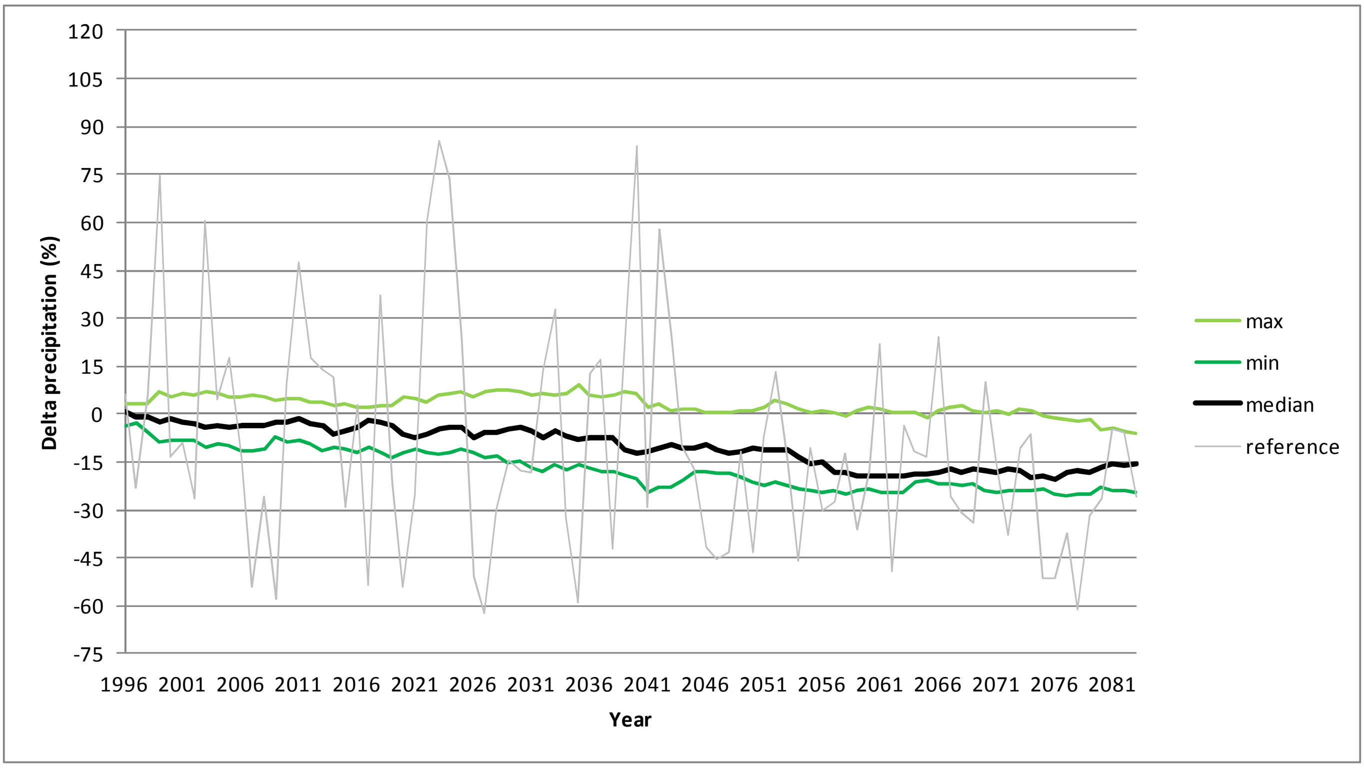


Figure 8: Changes in cumulated annual precipitations over Jordan, 1995-2085, RCP 4.5

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

How to read the maps ?

For each indices:

- a series of 6 maps is provided : for each RCP (RCP4.5 and RCP 8.5), the reference model (and only it) is mapped for the three time horizons chosen (2020-2050, 2040-2070, 2070-2100), with homogenous scales and color codes, so as to avoid errors in interpretation;

- the information on dispersion is given in the corresponding graph illustrating the trend over the period 2005-2095 (see above);

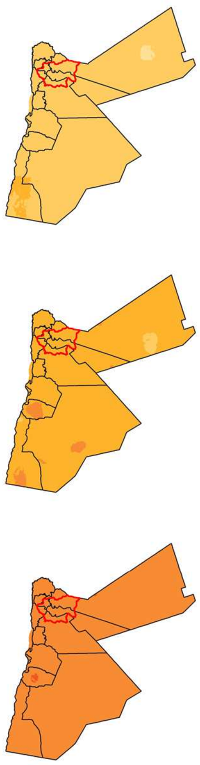
- maps represent the changes in temperature, precipitations and other values. Indeed, the models tend to represent better the evolution than the absolute value. Moreover, given the scarcity of observations, one could not compare easily the model data for the reference climatology with similar observations. This is all the more true that maps visualizing model data represent average values on surfaces (e.g. average precipitations in a 50km x 50 km box), while observations data represent punctual values, which can vary a lot depending on the local features of the station. Therefore, maps presenting changes in the report, but maps with absolute values are also provided in the annexes.

RCP 4.5	RCP 8.5
Anomaly 2020-2050	Anomaly 2020-2050
Anomaly 2040-2070	Anomaly 2040-2070
Anomaly 2070-2100	Anomaly 2070-2100

Table 3: Structure of map sheets

RCP 4.5

RCP 8.5



2020 - 2050

Δ Tmean	4.5	8.5
med	+1.2°C	+1.6°C
ref	+1.2°C	+1.6°C

2040 - 2070

Δ Tmean	4.5	8.5
med	+1.7°C	+2.6°C
ref	+1.8°C	+2.6°C

2070 - 2100

Δ Tmean	4.5	8.5
med	+2.0°C	+4.0°C
ref	+2.5°C	+4.0°C

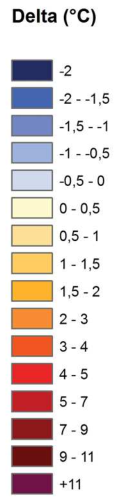


Figure X : Evolution of annual mean temperature (°C) over Jordan for 2050, 2070 and 2100 ti-mes-horizons and for RCP 4.5 and 8.5

The two RCPs predicts a clear rise in mean temperature for all of the country, up to 3°C for 4.5 and 5°C for the 8.5. Note that the increase is homogeneous for the RCP 4.5. The 8.5 shows a stronger one for the east and the south.

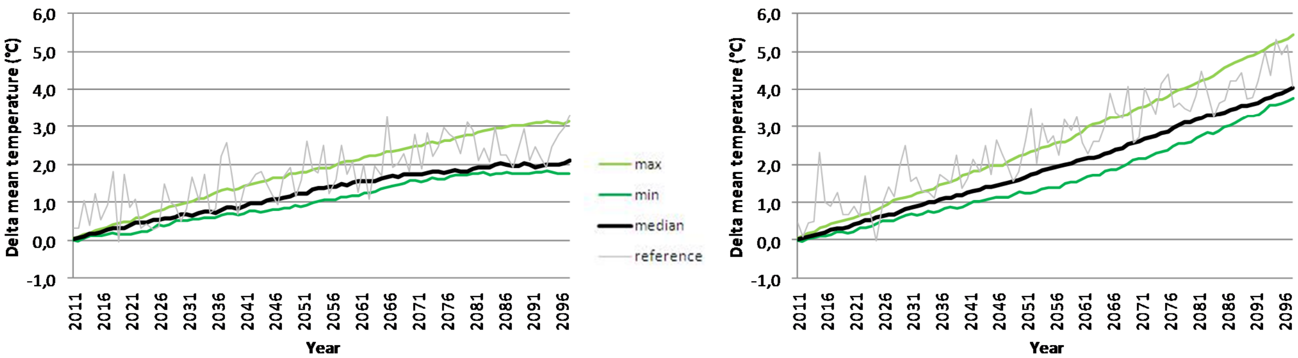


Figure X : Evolution of delta mean temperature (°C) over Jordan for RCP 4.5 and 8.5

The two RCPs show a clear rise in mean temperature.
For the RCP 4.5, maximum temperature rises up to +3.1°C and +2.1°C for the mean. After 2080, minimum temperature is unchanging until +1.70°C in 2100. The median values are closer to the minimum ones and deviate from maximum ones in time. The reference model gives a positive inter -annual a variability of 2°C, sometimes exceeding of more than 1°C the maximum average and is always positive.
The RCP 8.5 shows a higher rise, up to +5.5°C for the maximum temperature, +5°C for the median and + 3.8°C for the minimum in 2100. The median is closer to the minimum average and deviates from maximum one too. The inter-annual variability reaches 2°C, sometimes over the maximum average and is purely positive.

Figure 9: Example of "Indicator sheet"

Datasets

The “data” subfolder of the annex provided to UNDP and ICUN is organized as such:

Subfolders

The main subdivision is by indice.

Organisation of variable subfolder

The files are labelled with the following code :

Example 1: pr_cum_sais_30ans_nat : cumulated precipitation (pr_cum), seasonal time slice (_sais_), moving average over 30 years (30ans), for all Jordan (_nat)

Example 2: tas_moy_ann_30ans_ponct : Mean temperature (tas_moy), annual values (_ann), moving average 30 years (30ans), individual values of each grid points (_ponct)

Parameters

pr_cum = cumulated precipitation

tas_moy = mean temperature

tas_min = minimum temperature

tas_max = maximum temperature

pr_cpt_sup_10 = heavy precipitation days

pr_max_sec = consecutive dry days

evspsblpot = evapotranspiration

huss = humidity

snd = snow depth

wsgsmax = Maximum value of daily maximum wind gust

wd = wind direction

Time slices

ann = annual values

sais = seasonal values (DJF, MAM, JJA, SON)

mens = monthly values

day = daily values

Geographicale scale

Nat = Jordan mean (whole country, 43 grid points averages)

Ponct = Individual values of grid points (43 grid points with Lat/ Lon coordinates)

Rp = Pilot area (New pilot area (ID95 and ID96)

Labelling of models and RCPs

Each subfolder contains per parameter 18 files, each of them representing the result of one model. Files are labelled as such:

Example : Africa_pr_DMI_ECHEC-EC-EARTH_rcp45

Africa = AFRICACORDEX

Pr = precipitation

DMI, SMHI = DMI or SMHI regional model

ECHEC-EC-EARTH = global climate model

Rcp45 : Rcp 45 or 85

Miscellaneous

- The moving average is given for the 30 years preceding the date (for instance 2040=2011-2040 average)
- The files are in NetCDF format
- Temperature data is Kelvin
- Humidity data is in fraction of 1 (in % if multiplied by 100)
- Precipitation data and evapotranspiration data are in mm/s, it should in the current state of files :
    - be multiplied by 24*3600*365 for annual values (in “30 years” files only)
    - 24*3600 only for seasonal and monthly time frames (no need to multiply by 90 or 30 days) to reach the cumulated value of any other period (day, month, seasonal)

3 Results

Synthesis

The following synthetize the main results at the national level. The colors give the level of confidence on trends and values (green = strong, yellow = medium, orange =low, red= very low), as an expert judgment, based on the convergence of evidences from different sources (global climate models and regional climate models, different indices), the convergence of model results, and our knowledge on model skills with regard to some specific parameters. Figure are given either for the median of the 9 models or for the reference model when specified. Number under brackets [x-y] are the minimum and maximum value of the ensemble.

Trend	Details
A warmer climate	All models converge to increase in temperature, and AFRICACORDEX results are consistent with IPCC. In 2070-2100, average temperature increase could reach for RCP 4.5, +2,1°C [+1,7 to +3,2°C], and +4°C [3,8- 5,5°C] for RCP 8.5
A drier climate	Compared to the 2nd national communication that used CMPI3 results, CMIP5 results coupled with regional climate models in CORDEX give a more consistent trend to a drier climate. In 2070-2100. The cumulated precipitation could decrease by 15% [-6% to -25%] in RCP 4.5, by - 21% [-9% to -35%] in RCP 8.5. The decrease would be more marked in the western part of the country
Warmer summer, drier autumn and winter	The warming would be more important in summer, and the reduction of precipitation more important in autumn and winter than in spring, with for instance median value of precipitation decrease reaching -35% in autumn in 2070-2100
More heat waves	The analysis of summer temperature, monthly values and the inter-annual variability reveal that some thresholds could be exceeded. For instance, in pessimistic but possible projections, for a summer month, the average of maximum temperature for the whole country could exceed 42-44°C.
More droughts, a contrasted water balance	The maximum number of consecutive dry days would increase in the reference model of more than 30 days for the 2070-2100 period. In contrast, annual values still show possible heavy rainy years at the end of the century. More intense droughts would be (partly) compensated by rainy years, in a context of a general decrease of precipitation. Evapotranspiration would increase. The occurrence of snow would strongly decrease. This will complicate water management.
No trend for intense precipitations or winds	The number of days with heavy rain (>10 mn) does not evolve significantly, nor does the maximum wind speed or the direction of winds

Jordan current climate

Jordan is characterized by a predominant Mediterranean climate, with hot and dry summers and wet and cool winters. January is the coldest month and august is the hottest one. The two intermediate seasons are short. Temperatures are very variable depending on the area. Globally, it rises north to south and west to east, but decreases with altitude. The major part of the country (90%) is arid to semi-arid, characterized by very low annual precipitation averages less than 200mm. The rain season begins in October and ends in May, but 80% of the seasonal rainfall occurs between December and March, with a maximum in January.

There is three main climatic regions: the Gore Region, below the sea level, which is the Jordan Valley, at the west of the country, north to south. Then, marking out the valley at the east, north to south, the Highlands Region, that is mountainous area, about 1150m high in the North and 1500m in the South. At the east, the rest of the country is Badia and Desert region, formed by a semi-arid to arid plateau. The southeast area is true desert.

These regions correspond to three different types of climate, as we can see in the map below.

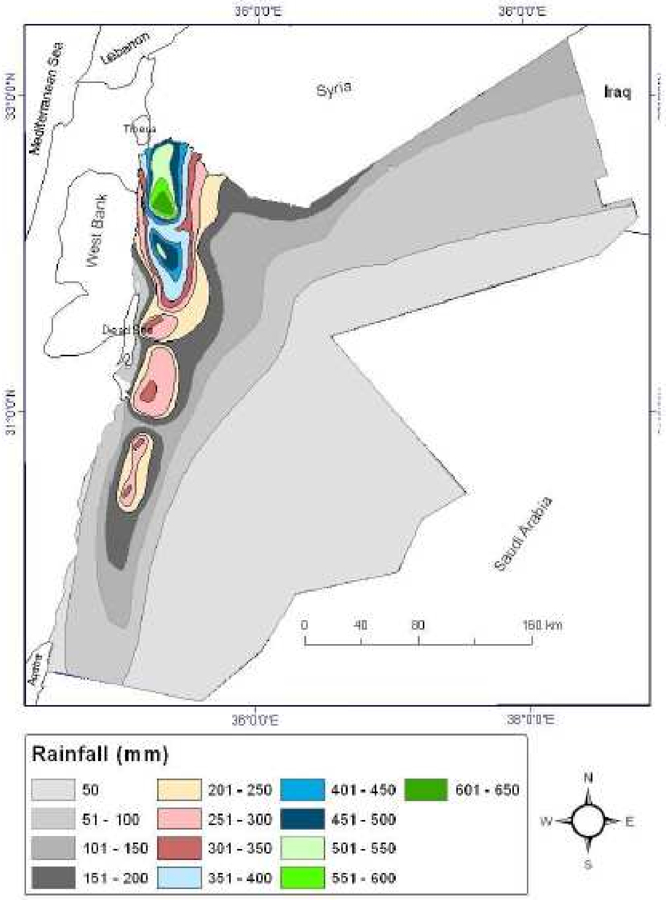
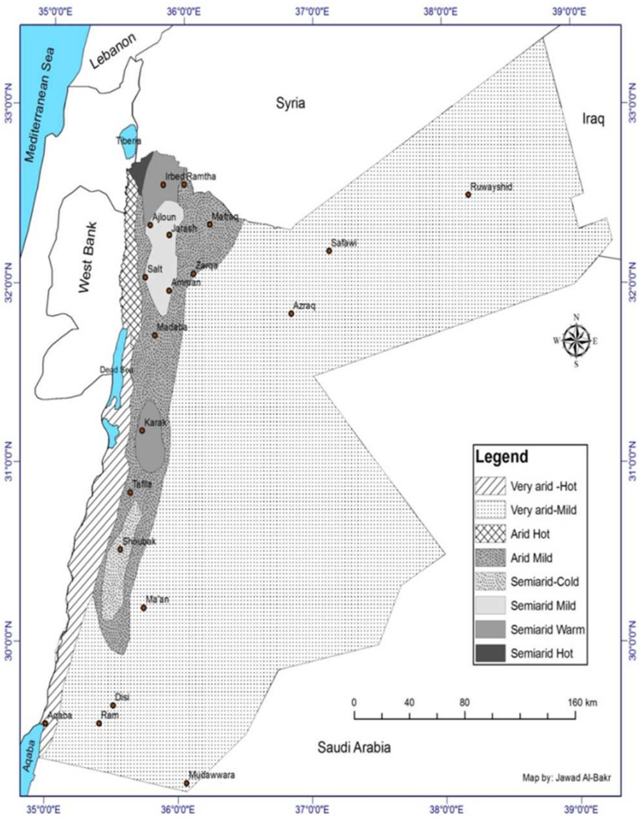


Figure : Mean annual rainfall over Jordan

In the Gore Region, conditions are quite pleasant, summers are hot, the mean daily maximum temperature is 39°C and winters are clement with a mean daily minimum temperature of 9°C. Therefore, frost is rare. In general, annual precipitation is less than in the mountains, between around 400mm in the North, decreasing to 70mm in the South. In the Highlands region, winters are colder and frost and snow are more common. The mean daily minimum temperature is 4°C and maximum ranges between 26 and 30°C. Usually, it is the rainiest region, above 500mm in the north, decreasing gradually southward up to 300mm. In the Badia region temperatures vary between a maximum of 36-39°C in summer and a minimum of 1-4°C in winter. Frost is ordinary. Temperatures increase to the east and to the south. Annual mean rainfall is very inconsistent. It is below 200mm and decreases to the east and to the south. In the southeastern part of the country, it rains less than 35mm annually.

So globally, Jordan faces arid conditions. The aridity index allows identifying the same three distinct climate zones described. In the report, we refer to those three types.



Aridity index (Emberg classification) over Jordan

In the Second National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), trend analysis were made on different 1961 to 2005 indices and some are significant. Maximum, minimum and mean temperatures rise in almost all the stations and this is the minimum ones that have the greatest increase. In the major part of the stations, a reduction of annual precipitation is noticed, but some register a rise. This lack of rainfall in certain parts of the country is consistent with evidences observed in the recent years like drying up of some streams or underground water table fall. Climate is only part of the cause, with water management, but it worsens the tense context. In addition, extreme weather conditions such as flash floods during winter or heat waves in summer seem to be more frequent. Even if it has no direct connection with climate change yet, we can quote the snowstorm Alexa that hits Middle East in December 2013. This is an extreme weather event of a rare intensity.

What says IPCC for future climate ? Lessons from Global climate models

Before presenting the CORDEX results for Jordan, we present the results of IPCC fifth assessment report, which provides a global benchmark to our results. The report of IPCC Working group 1 of the 5th assessment report (AR5) was published in September 2013. It is based on the result of the CMIP5 Programme (Climate Model Intercomparison Programme), which involved the global climate science community for years, with a high level of validation, expertise, consensus, and the use of the most up to date visualization and metrics.

CMIP5 provides some multimodel ensemble projections, using most of the available Global climate models (GCMs). GCM typical resolution range from 150x150km to 300x 300km. They do not allow a local perspective, which does not mean, however, that their skill in the simulation of present and future climate at large scale is worse than that of Regional climate models (RCMs).They allow a comparison of RCMs results with CMIP5, and also the analysis of more socio-economic scenarios. In particular, RCP 2.6, a (unfortunately) very unrealistic scenario, in which the world would be wise enough to reduce GHG emissions very quickly, was seldom used in CORDEX. CMIP5 gives an outlook of such hypothesis.

IPCC did for AR5 an effort of regionalization, with the provision of supplementary data by region (see ipcc.ch). We retained here temperature and precipitation data.

What is RCP2.6 and what would be its consequence ?

RCP 2.6 describes a situation where human induced radiative forcing would pear at 3 w/m^2 before 2100 then declining to 2.6 w/m^2. In order to reach such a situation, a very aggressive mitigation policy would be needed: global emissions would peak before 2020, then decrease very quickly, until a carbon neutrality (= zero emission in 2080, see Figure 10). Such a situation is quite unrealistic, still it remains a political reference within UNFCCC framework, that is why it is evoked here.

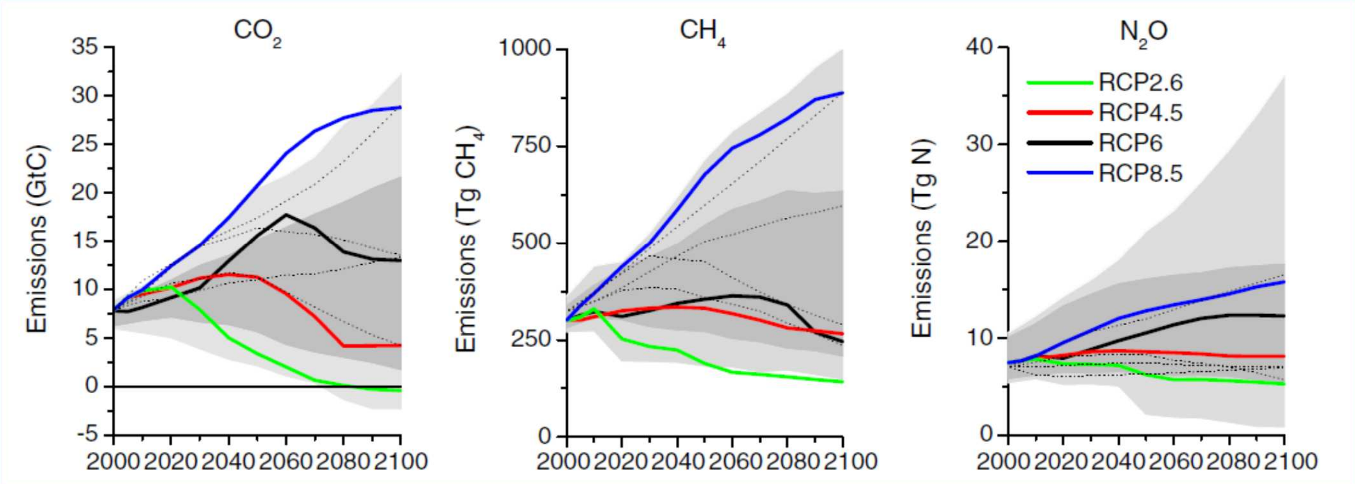
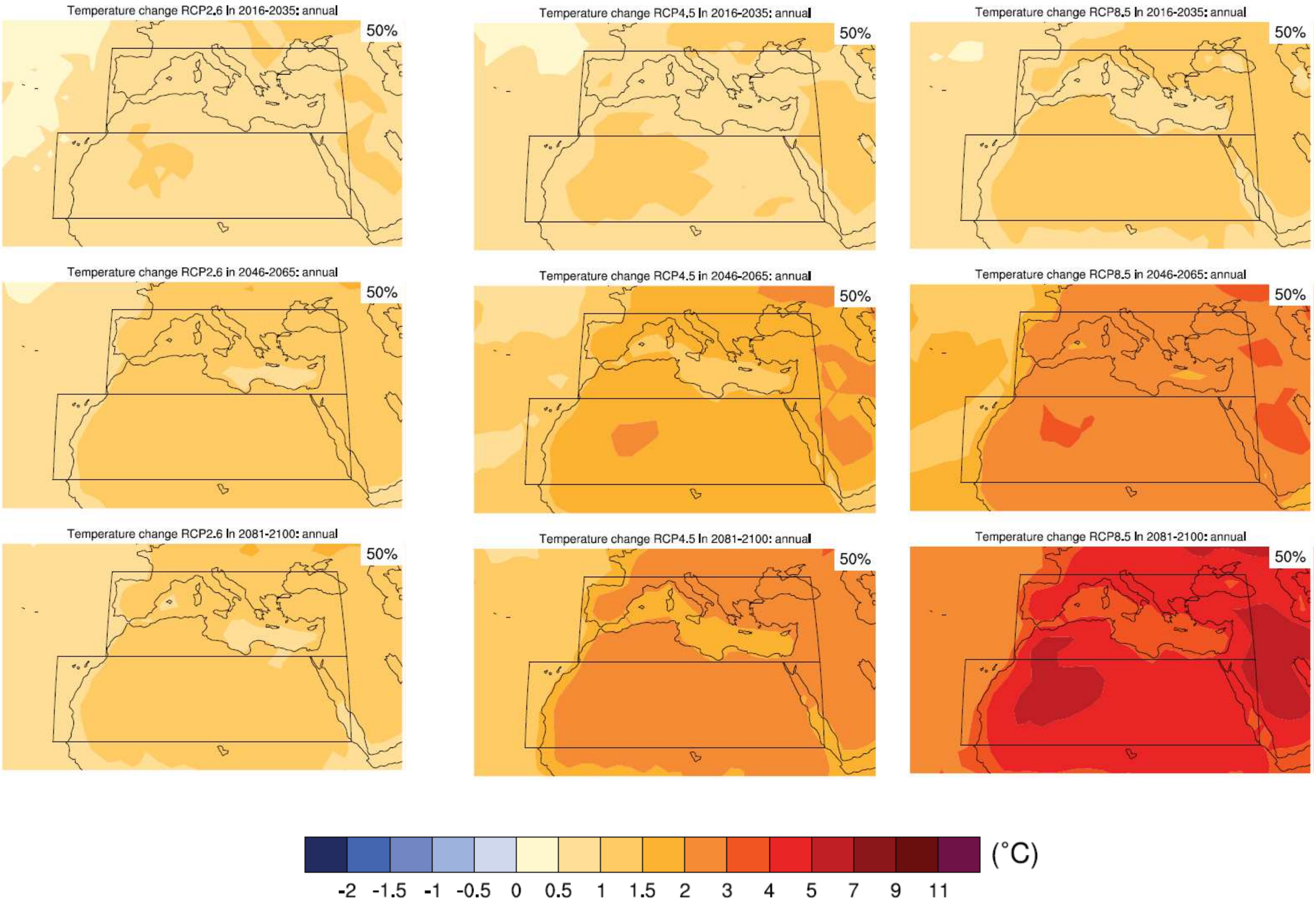


Figure 10 : Emissions of main greenhouse has across RCPs

For temperature, RCP 4.5 and RCP 8.5 gives a median value of warming ("50%" in Figures 11 and 12) of + 1,5 to 2°C for RCP 4.5, 2 to 3°C for RCP 8.5, in 2046-2065 period. For the 2081-2100 period, this would reach around +3°C and around + 5°C for RCP 4.5 and 8.5. This is a bit warmer, though consistent, with the AFRICA CORDEX results we present in the following. In RCP 2.6 the warming would be limited to +1 to 1,5°C in the Jordan region.

RCP 2.6 RCP 4.5 RCP 8.5



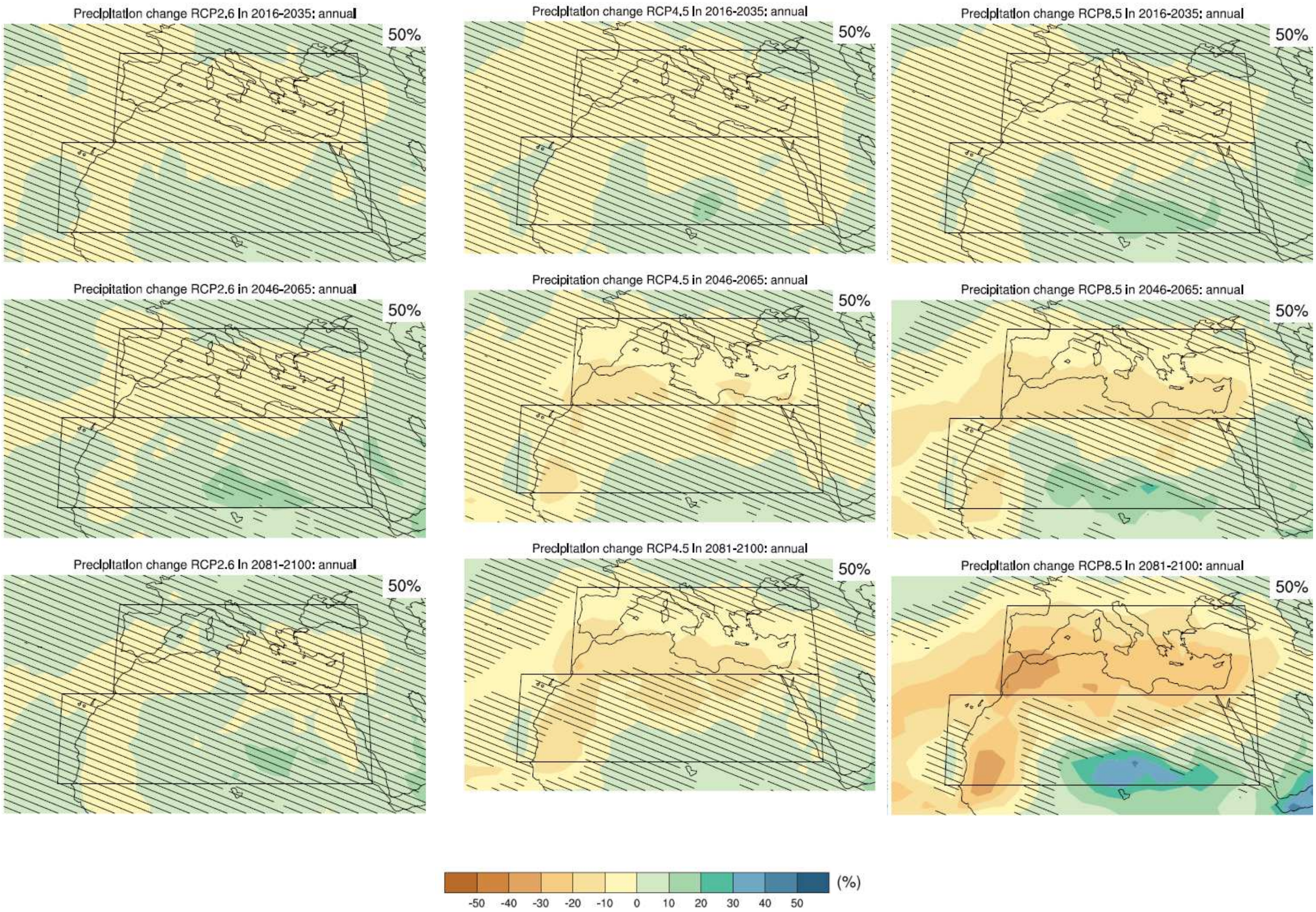
(Below) Maps of temperature changes in 2016–2035, 2046–2065 and 2081–2100 with respect to 1986–2005 in the RCP4.5 scenario. For each point, the 25th, 50th and 75th percentiles of the distribution of the CMIP5 ensemble are shown; this includes both natural variability and inter-model spread. Hatching denotes areas where the 20-year mean differences of the percentiles are less than the standard deviation of model-estimated present-day natural variability of 20-year mean differences.

Figure 11 : Maps of temperature change in 2016-2035, 2046-2065, 281-2100 with respect to 1986-2005, in the RCP 2.6, 4.5 and 8.5 scenarios

For precipitation, the A5R tends to present a reduction of cumulated precipitation by 0-10% for RCP 4.5, and a little below -10% for RCP 8.5 for the 2046-2065 period. The range would be similar in 2081-2100 for RCP 4.5, and the diminution could go below -20% in the western part of Jordan for RCP8.5. Again, this is consistent with the AFRICA CORDEX results presented in the following.

In RCP 2.6 the diminution would be more moderate, and some increase of precipitation could be even observed in the eastern part of the country.

RCP 2.6 RCP 4.5 RCP 8.5



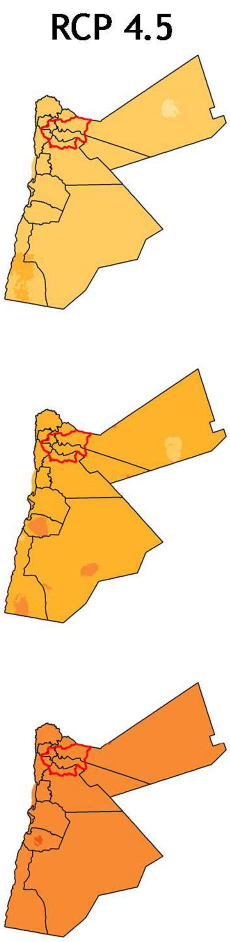
(Below) Maps of precipitation changes in 2016–2035, 2046–2065 and 2081–2100 with respect to 1986–2005 in the RCP4.5 scenario. For each point, the 25th, 50th and 75th percentiles of the distribution of the CMIP5 ensemble are shown; this includes both natural variability and inter-model spread. Hatching denotes areas where the 20-year mean differences of the percentiles are less than the standard deviation of model-estimated present-day natural variability of 20-year mean differences.

Figure 12: Maps of precipitation change in 2016-2035, 2046-2065, 281-2100 with respect to 1986-2005, in the RCP 2.6, 4.5 and 8.5 scenarios

Main trends of regional climate

Mean temperature

The two RCPs predict a clear rise in mean temperature for all of the country, up to 3°C for 4.5 and 5°C for the 8.5. Note that the increase is homogeneous for the RCP 4.5. The 8.5 shows a stronger one for the East and the South.



2020 - 2050

Δ Tmean	4.5	8.5
med	+1.2°C	+1.6°C
ref	+1.2°C	+1.6°C

2040 - 2070

Δ Tmean	4.5	8.5
med	+1.7°C	+2.6°C
ref	+1.8°C	+2.6°C

2070 - 2100

Δ Tmean	4.5	8.5
med	+2.0°C	+4.0°C
ref	+2.5°C	+4.0°C

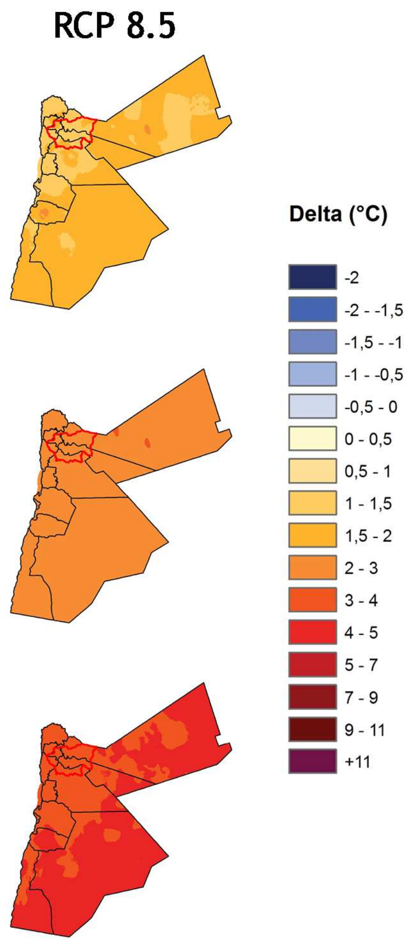


Figure 13 : Changes in annual mean temperature (°C) over Jordan, reference model, for 2035, 2055 and 2085 times-horizons and for RCP 4.5 and 8.5

For the RCP 4.5, the mean temperature (Figure 14) could rise up to +3.1°C (maximum value, moving average 30 years) and +2.1°C for the median. After 2060, minimum increase in mean temperature is unchanging until +1.70°C in 2085. The median values are closer to the minimum ones and deviate from maximum ones in time. Generally, the reference model gives an inter-annual variability (i.e. difference between two consecutive years) of around 1°C, up to nearly 2°C, sometimes exceeding the maximum of the model ensemble (light green line in the graph) by more than 0.5°C. It is always positive after 2000.

The RCP 8.5 shows a higher rise, up to +5.5°C for the maximum increase in mean temperature, +5°C for the median and + 3.8°C for the minimum increase in 2085. The median is closer to the minimum average and deviates from maximum one too. The inter-annual variability is under 2°C, sometimes over the extreme averages and it is purely positive after 2000.

The reference model is one model amongst other, and models will never predict a given date, but this is an illustration of the situations Jordan could potentially face.

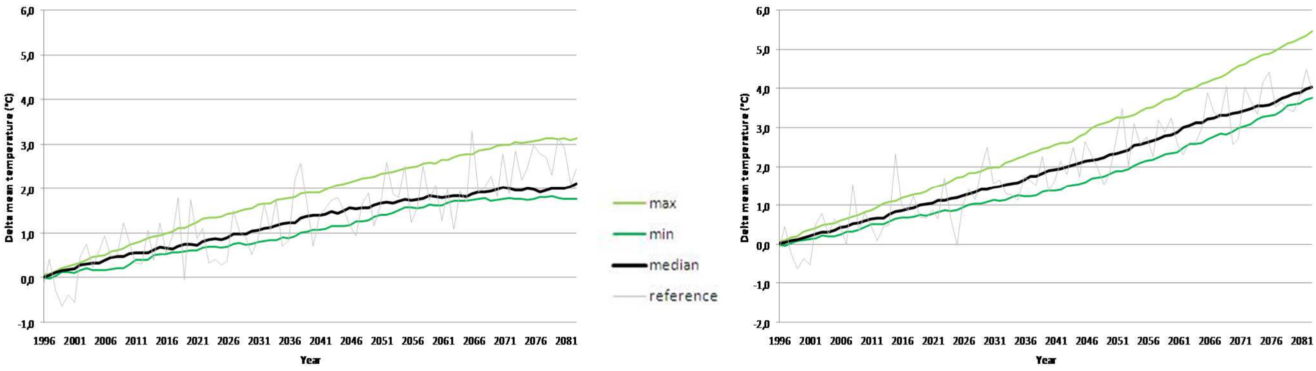


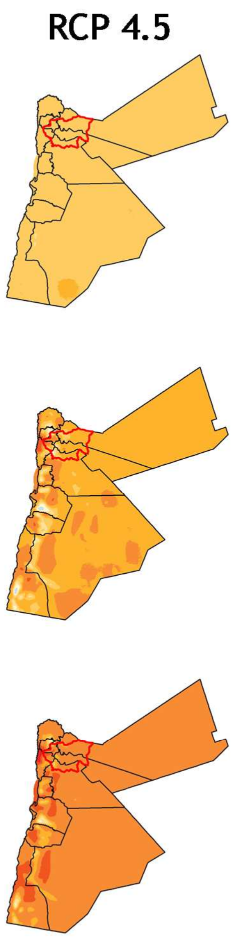
Figure 14 : Changes in mean temperature (°C) over Jordan for RCP 4.5 and 8.5

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

Minimum temperature

The RCP 4.5 shows (Figure 15) a homogeneous rise in minimum temperature up to 2050. After, the rise is globally of +3°C, with local variations in the west, there are even small areas in mountains with increase or at least no evolution. The stronger increase, impacts the north-western part of Al Balqa' up to +5°C.

The RCP 8.5 shows a stronger rise, not homogeneous on the rift and the mountains too. There are some localised decreases only up to 2050 in the mountains. In 2100 the rise reaches +5°C on the East and is between +1°C and +9°C on the west.



2020 - 2050

Δ Tmin	4.5	8.5
med	+1.1°C	+1.6°C
ref	+1.2°C	+1.6°C

2040 - 2070

Δ Tmin	4.5	8.5
med	+1.6°C	+2.5°C
ref	+1.8°C	+2.6°C

2070 - 2100

Δ Tmin	4.5	8.5
med	+2.0°C	+4.0°C
ref	+2.5°C	+4.0°C

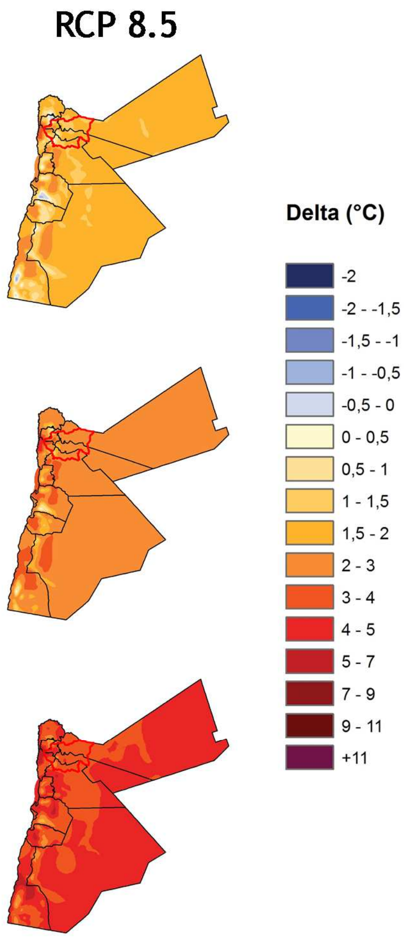


Figure 15 : Delta annual minimum temperature (°C) over Jordan, reference model, for 2035, 2055 and 2085 times-horizons and for RCP 4.5 and 8.5

The RCPs show (Figure 16) an increase in minimum temperature and globally a positive inter-annual variability.

For the RCP 4.5, temperature rises up to +2°C in 2085. This median value ranges between +1.7°C and +3°C. The inter-annual variability given by the reference model can reach more than 1.5°C. It is positive after 2000 and it exceeds maximum averages some years.

For the RCP 8.5, the median temperature rises up to +4°C in 2085. Maximum average reaches +5.3°C and minimum +3.7°C. The inter-annual variability is positive after 2000 and can reach 1.5°C, it can exceed extreme averages.

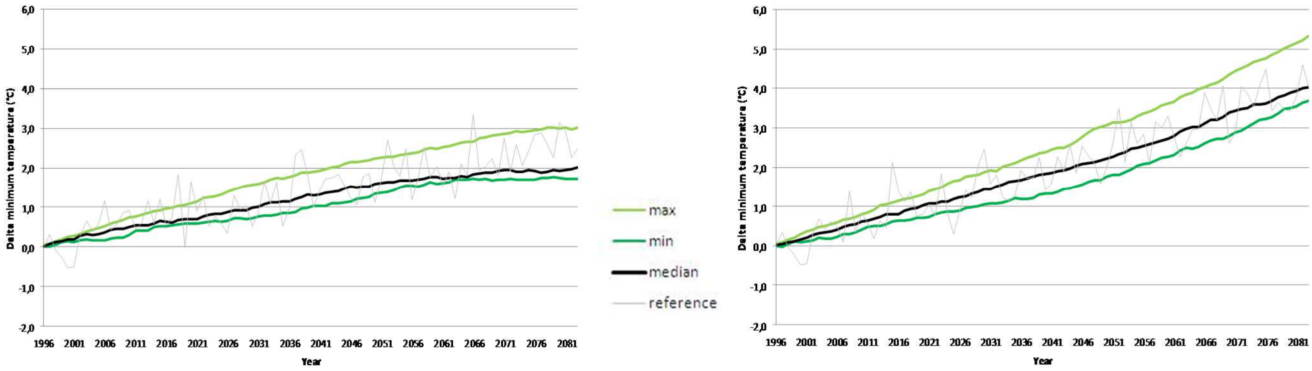
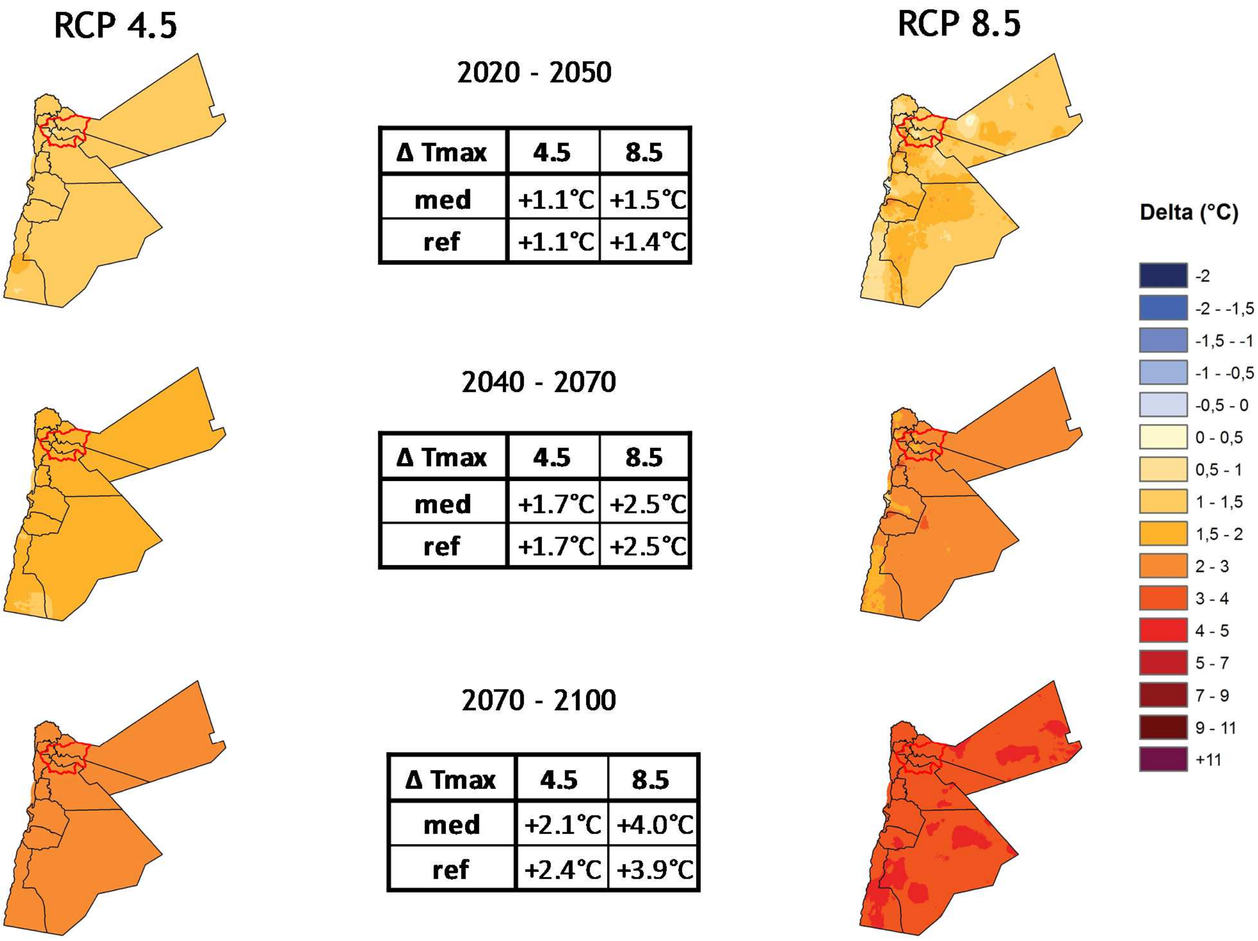


Figure 16 : Changes in delta minimum temperature (°C) over Jordan for RCP 4.5 and 8.5

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

Maximum temperature

The RCP 4.5 shows (Figure 17) a homogeneous and gradual rise in maximum temperature up to +3°C in 2100. The RCP 8.5 shows an increase too, stronger than but spatially, not as consistent as the 4.5. The strip along the southwest frontier is less impacted until 2070. However, in 2100, all the country suffers from a rise between +3 and +5°C.



2020 - 2050

Δ Tmax	4.5	8.5
med	+1.1°C	+1.5°C
ref	+1.1°C	+1.4°C

2040 - 2070

Δ Tmax	4.5	8.5
med	+1.7°C	+2.5°C
ref	+1.7°C	+2.5°C

2070 - 2100

Δ Tmax	4.5	8.5
med	+2.1°C	+4.0°C
ref	+2.4°C	+3.9°C

Figure 17: Changes in annual maximum temperature (°C) over Jordan, reference model, for 2035, 2055 and 2085 times-horizons and for RCP 4.5 and 8.5

For the RCP 4.5, temperature rises by 2.1°C in 2085, this median value is between +1.7 and +3.2°C. The inter-annual variability is globally positive except some years before 2025. It can exceed the extreme average by 0.5°C. For the RCP 8.5, the median temperature increases up to +4.1°C in 2085 and is between +3.7° and +5.5°C. The inter-annual variability is always positive after 2000. It can be more of nearly 2°C over the maximum average.

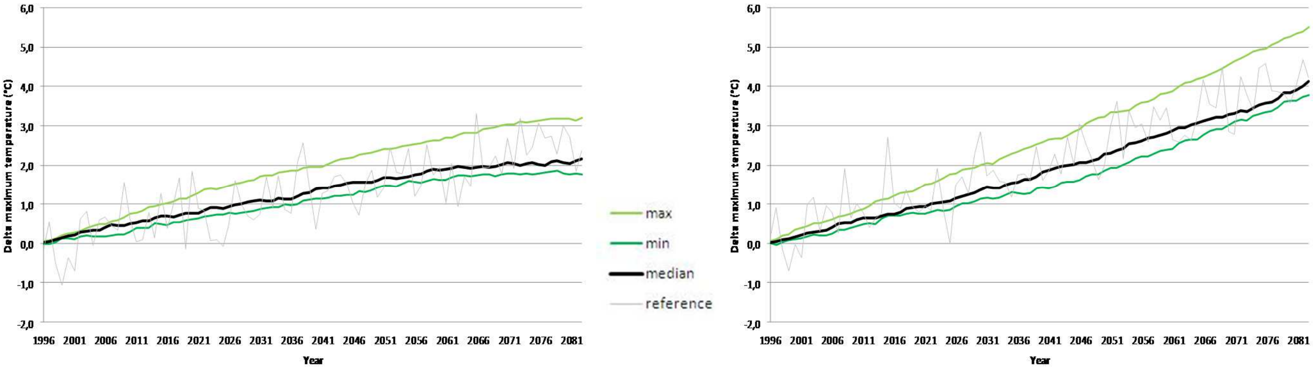


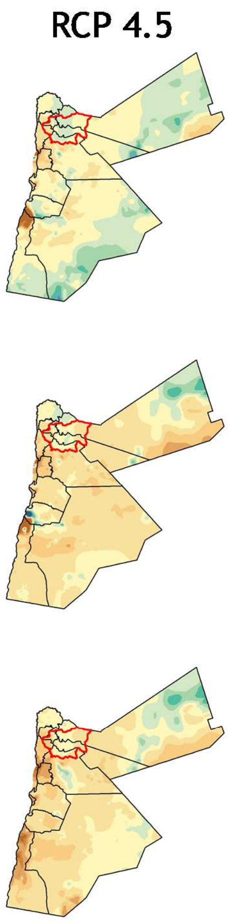
Figure 18 : Changes in maximum temperature (°C) over Jordan for RCP 4.5 and 8.5

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

Precipitation

For RCP 4.5, globally (Figure 19), there is a increase up to 2050 on the East and South, and a decrease one for the rest of the country, which is less than 50% in the North of Al'Aqabah. Until 2100, the decrease of rainfall extends to the whole country, except the northeaster part.

For the RCP 8.5, precipitation decreases everywhere in 2050 except in two small areas in the mountains and in the rift. The North of Al'Aqabah is the most affected region too. A positive anomaly extends along the southeast frontier up to 2100.



2020 - 2050

Δ P	4.5	8.5
med	-8.1%	-12.8%
ref	-3%	-12.8%

2040 - 2070

Δ P	4.5	8.5
med	-15.4%	-15%
ref	-15.4%	-12.8%

2070 - 2100

Δ P	4.5	8.5
med	-13.5%	-21.8%
ref	-11.9%	-14.8%

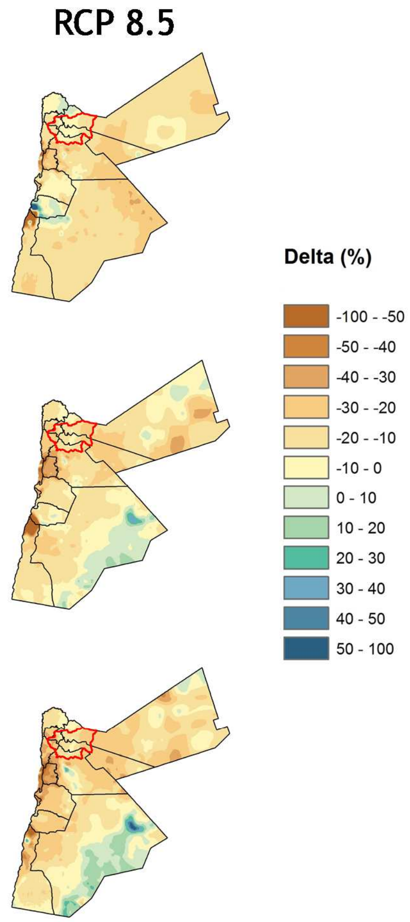


Figure 19 : Changes in annual precipitation (mm) over Jordan, reference model, for 2050, 2070 and 2100 times-horizons and for RCP 4.5 and 8.5

For the RCP 4.5, the median values (Figure 20) decrease until -20% in 2055. After, precipitation decrease is quite constant and up to -16% in 2085. The maximum values show more precipitation until 2040, then it is similar to the reference period. The minimum values decrease steadily until 2040 and then more irregularly until -24% in 2085. The reference model shows a large inter-annual variability between -60 and +85%: if very wet years would still be possible at the end of the century, the overall trend is still clearly towards a decrease in precipitation. Note that the median is closer to the minimum values, especially after 2055, so maximum values are to be interpreted with more cautions.

For the RCP 8.5 the median values decrease until -21%. The minimum values reduce until -38%. The maximum values show a rise until +11% in 2025 then decrease up to -9% in 2085. The reference model shows a great variability between -60 and +75%, with an extreme year at +112%. Again, wet years are still possible at the end of the century, but also very dry ones (see for instance the hypothetical dramatic series of drought, with 3 consecutive years with less than -50% rainfall compared to the reference climatology, around 2075, for the reference model).

Figure 20: Changes in precipitation (%) over Jordan for RCP 4.5 and 8.5

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

Seasonal perspective

The two RCPs show a gradual rise in seasonal mean temperature. The rise is the strongest in summer, and the smallest in winter, which could increase further the negative impact of climate change.

For the RCP 4.5 in 2050, the rise is around +1.2°C for each season. In 2070, the increase is nearly of +2°C, except for winter, it is smaller at around +1.5°C. In 2100, temperature rises up to +2°C in winter, exceeds +2.5°C for the other seasons with the maximum of +2.6°C in summer.

For the RCP 8.5, the difference among the seasons is more important. The rise is between +1.1°C in winter and +1.6°C in summer in 2050. In 2070, it ranges between +2°C in spring and 2.6°C in summer. The evolution until 2100 is the largest. It reaches +3.2°C in winter and +4.3°C in summer.

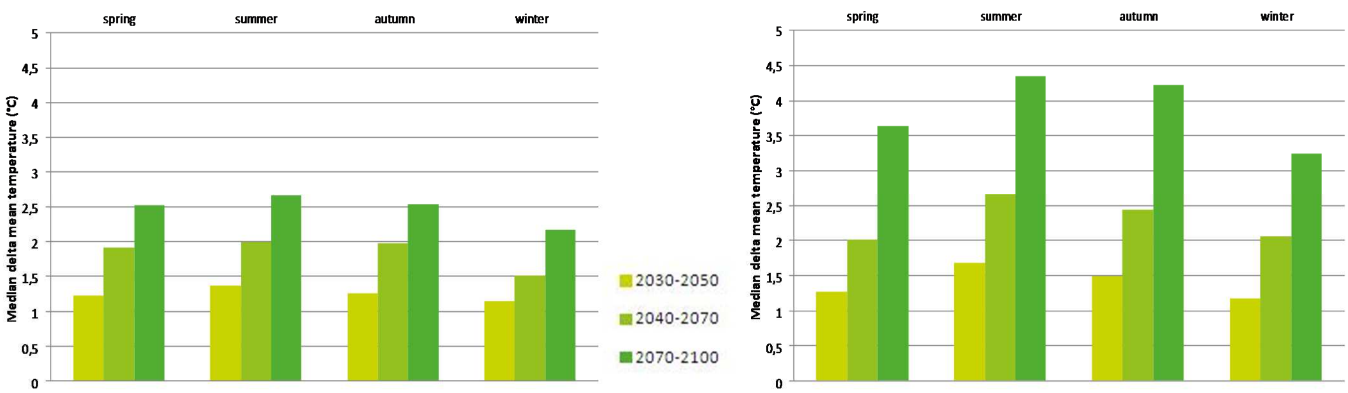


Figure 21: Changes in seasonal mean temperature (°C) over Jordan for 2035, 2055 and 2085 times-horizons and for RCP 4.5 (left) and 8.5 (right). Median of multimodel ensemble

For precipitation, for the RCP 4.5, in 2050, the stronger fall is in summer with nearly -10%, thus affecting a time of the year where there is nearly no rain. This can explains the summer precipitation in 2070, which presents no decrease compared to the reference period. Because it concerns very scarce rainfall, the evolution represents few rains. For the other seasons, in 2070 the fall is more substantial, with an important loss during the rainy season of -20% in autumn and -16% in winter. In 2100 the decrease does not change much, except for summer with -16%.

For the RCP 8.5, in summer, there is a small increase in 2050 and then it stabilizes at around -10%. In autumn, the fall exceeds -22% in 2050 and reaches -35% in 2100. The changes in spring and winter rainfall is gradual and reach respectively -16% and -25% in 2100. So in 2100, during the rainy season, the precipitation falls dramatically.

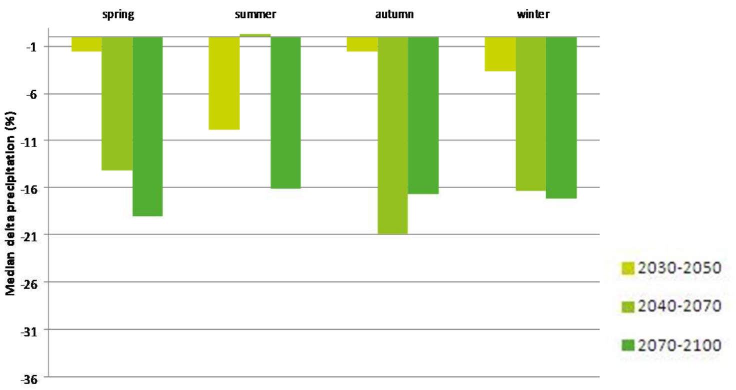
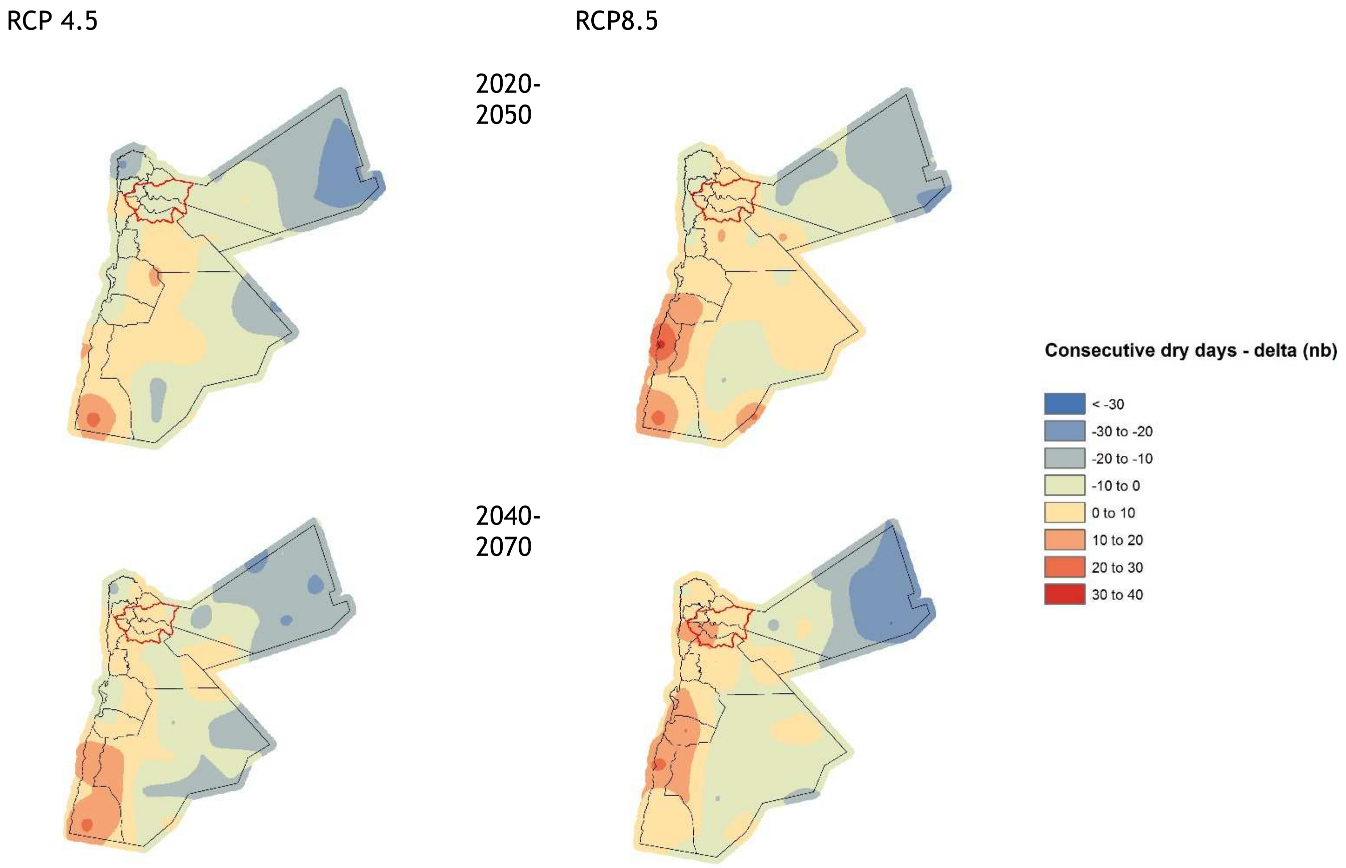


Figure 22 : Changes in seasonal precipitation (%) over Jordan for 2035, 2055 and 2085 times-horizons and for RCP 4.5 (left) and RCP 8.5 (right) . Median of multimodel ensemble

Specific indices

Consecutive dry days

Both RCPs show an increase in the maximum number of consecutive dry days.



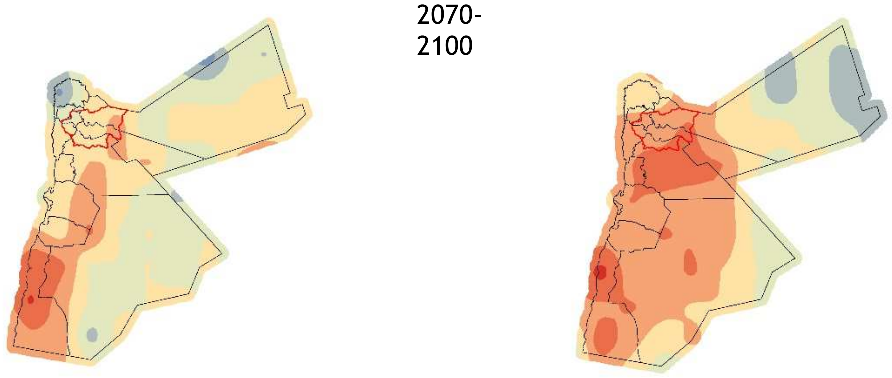
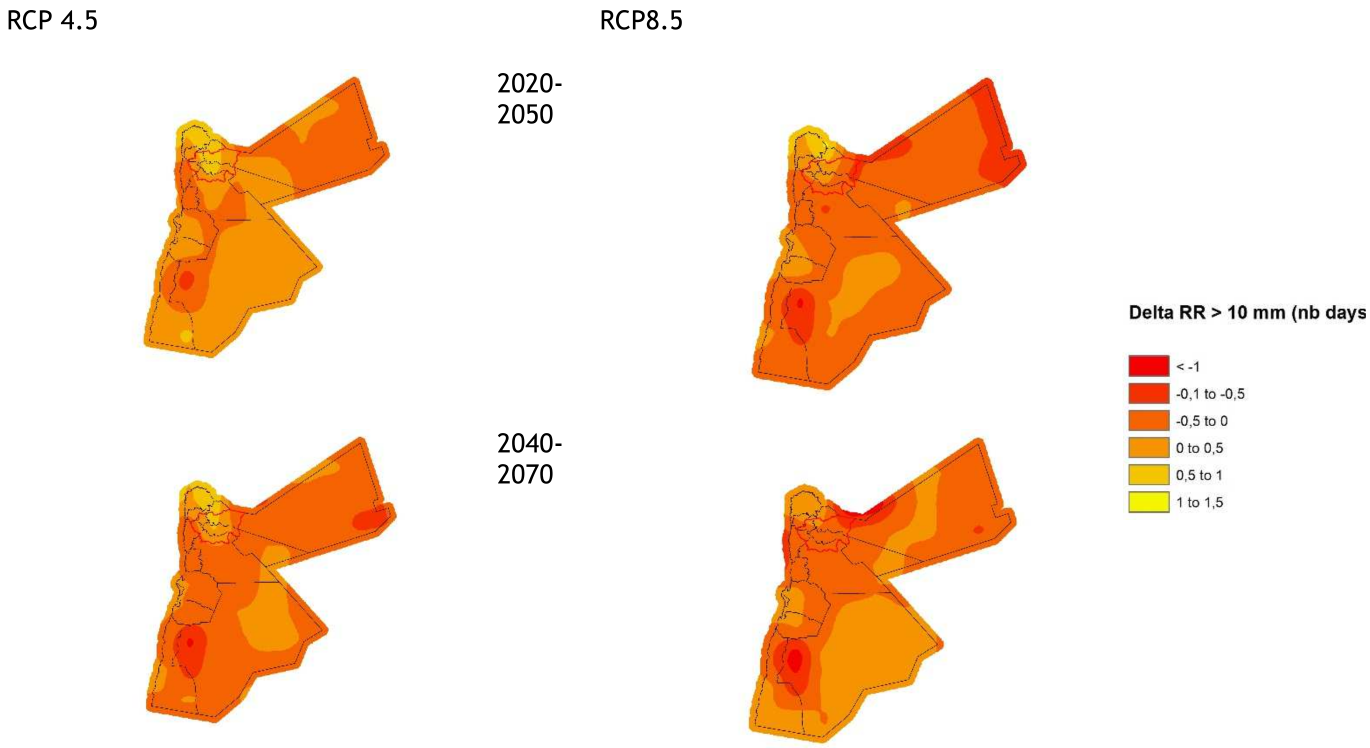


Figure 23: Changes in annual consecutive dry days in Jordan, reference model

Heavy precipitation days

The analysis of the annual number of heavy precipitation days (>10 mm) does not reveal a clear signal (positive or negative), nor a trend or a clear spatial distribution of events. First the absolute values are low and range from 0 to 5-6, given the aridity of Jordan. Second, models are known for representing badly heavy rains, as all extremes. Altogether, one can provisionally say that there does not seem to be an increase of heavy precipitation events over the country.



2070-
2100

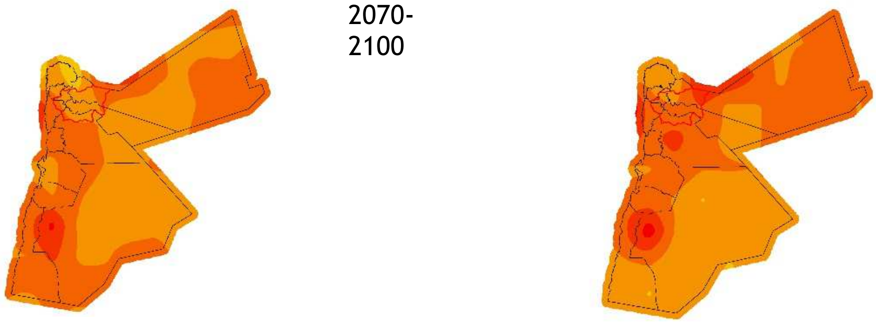


Figure 24 : Changes in number of precipitation days >10 mm, reference model

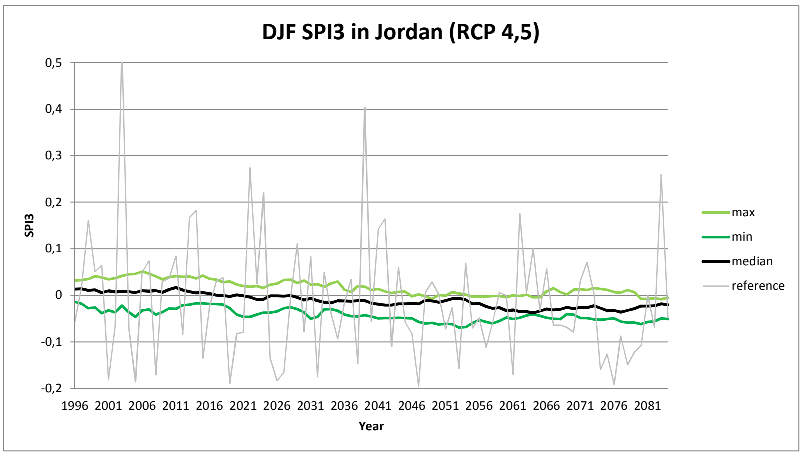
Standardised precipitation indexes (SPIs)

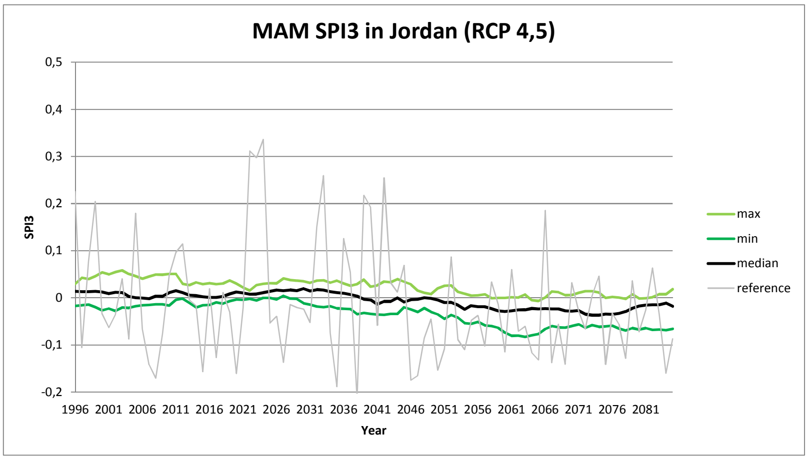
"The SPI is an index based on the probability of recording a given amount of precipitation, and the probabilities are standardized so that an index of zero indicates the median precipitation amount (half of the historical precipitation amounts are below the median, and half are above the median). The index is negative for drought, and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive" (NOAA).

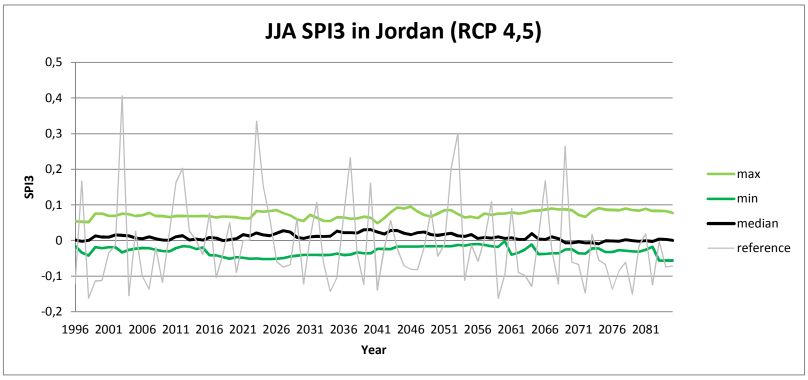
The SPIs are calculated here with reference to the 1980-2100 period. Therefore, given the overall decrease of precipitation over Jordan in this period, the values start above average (i.e. wet years, compared to the 1980-2100 average), while the end below average (i.e. dry years).

Given the low values of summer precipitations, the graphs (Figure 25 and 26) for JJA (June, July, August) must probably interpreted with cautions. Other seasons show a progressive trend towards an intensification of droughts, more visible in winter (DJF) and spring (MAM) than in autumn (SON). The droughts are more intense in RCP 8.5.

The impact on the water balance should be all the more important that the evapotranspiration (see next indice) tends to increase.







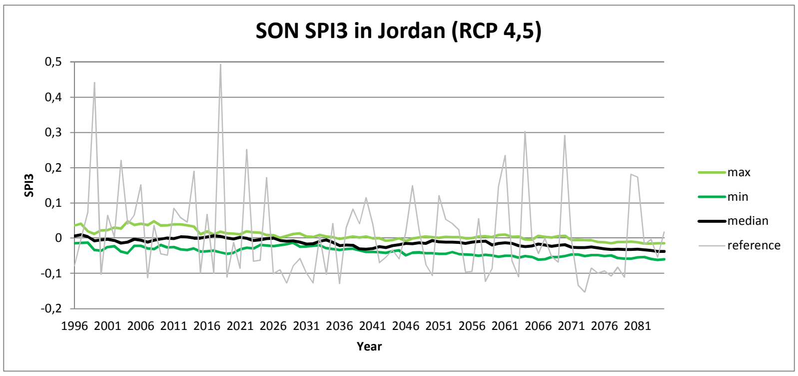
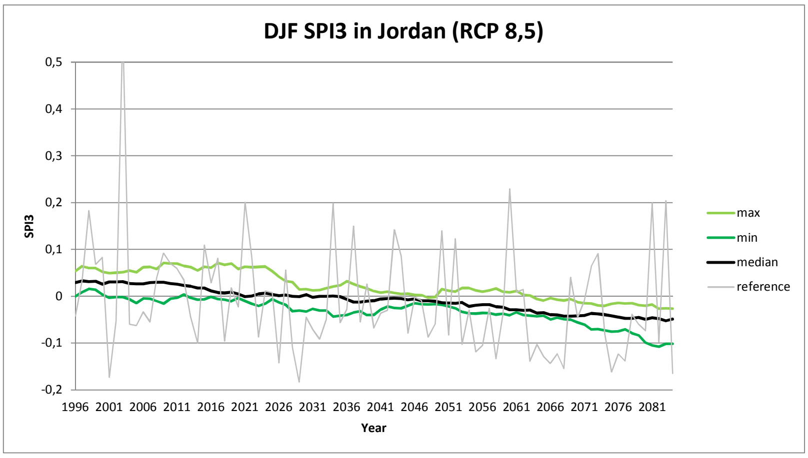


Figure 25: seasonal SPI for RCP4.5, Jordan



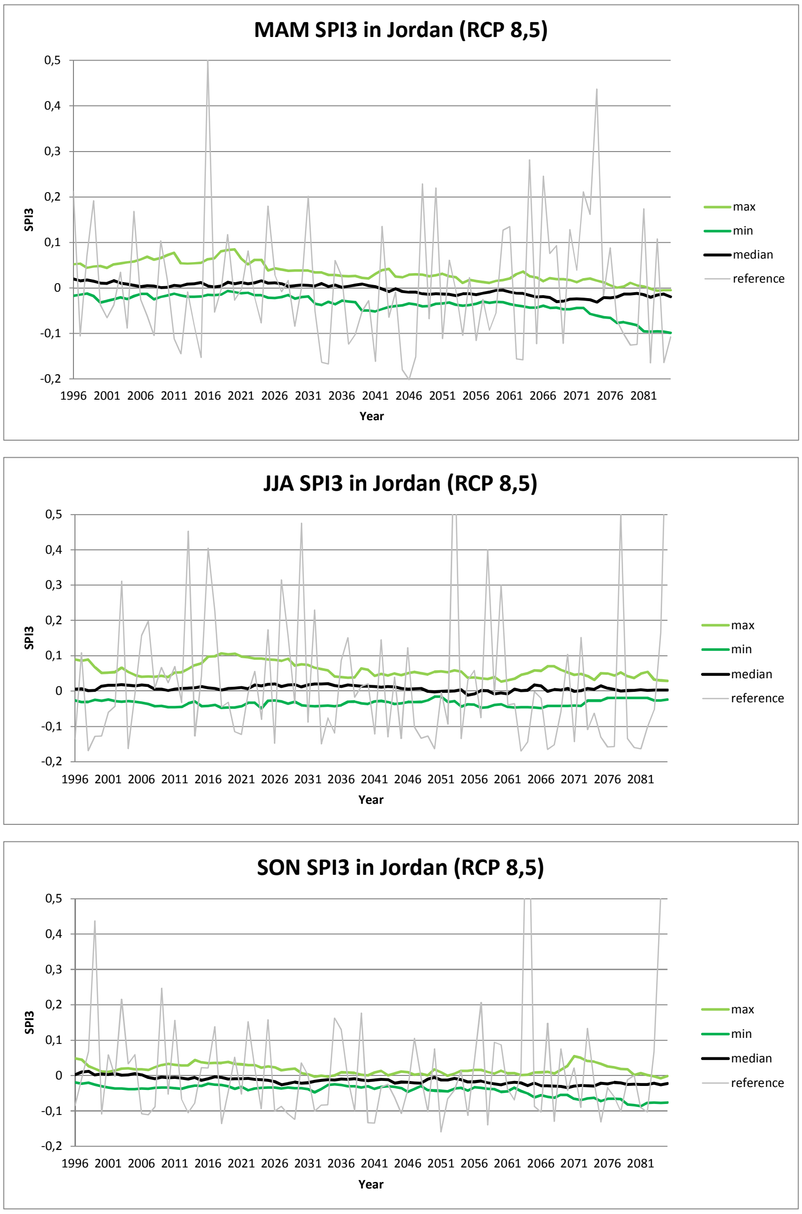


Figure 26: seasonal SPI for RCP8.5, Jordan

Evapotranspiration

For the two RCPs and for the whole country, potential evapotranspiration (PET) exceeds 1800mm in 2100, with a gradual decrease.

For the RCP 4.5, in 2050 there is two parts (Figure 27): the North and a small strip in the South that are between 1700 and 1800mm, the rest of the country has a PET between 1800 and 2000 mm. In 2070 the south band disappears and the north area under 1800mm reduces. In 2100, the North area more downsizes and two areas (extreme West-South and along the East frontier) exceeds 2000mm of PET.

For the RCP 8.5, in 2050, all the country has a PET between 1800 and 2000mm, except the area in the North that is just below. In 2070, two areas exceed 2000mm in the extreme South-West and on the East along the frontier. In 2100 those two parts extend.

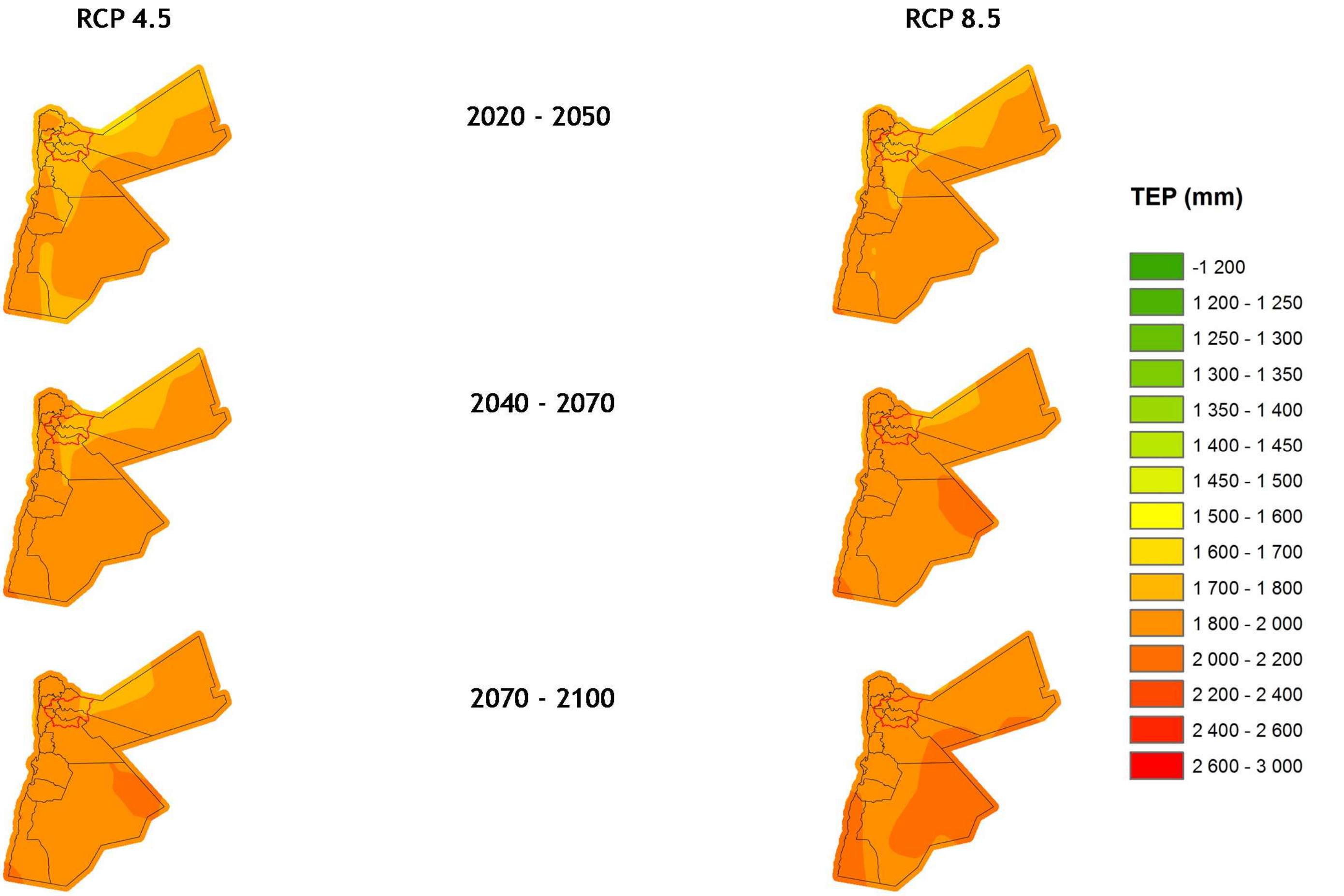
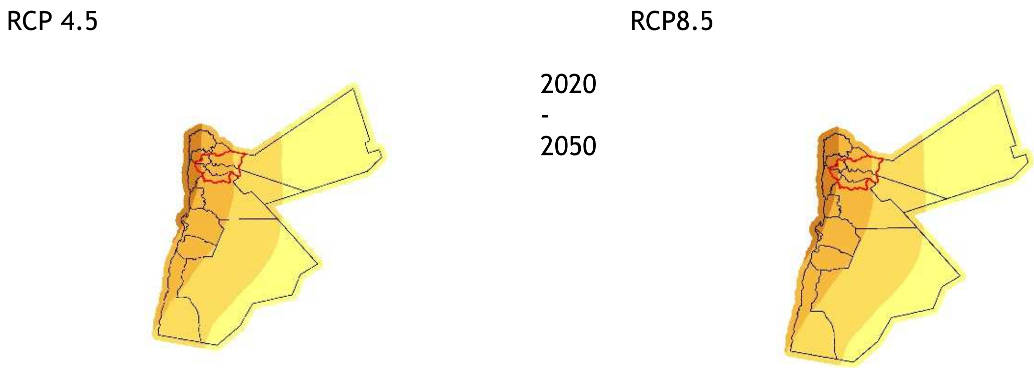


Figure 27: Potential annual evapotranspiration (mm) over Jordan, reference model, for 2035, 2055 and 2085 times-horizons and for RCP 4.5 and 8.5

Specific humidity

The two RCPs show an increase in specific humidity, more important for RCP 8.5. Both absolute values (represented in maps) and deltas are higher in the western part of the country, with a gradient form North-West to South-East.



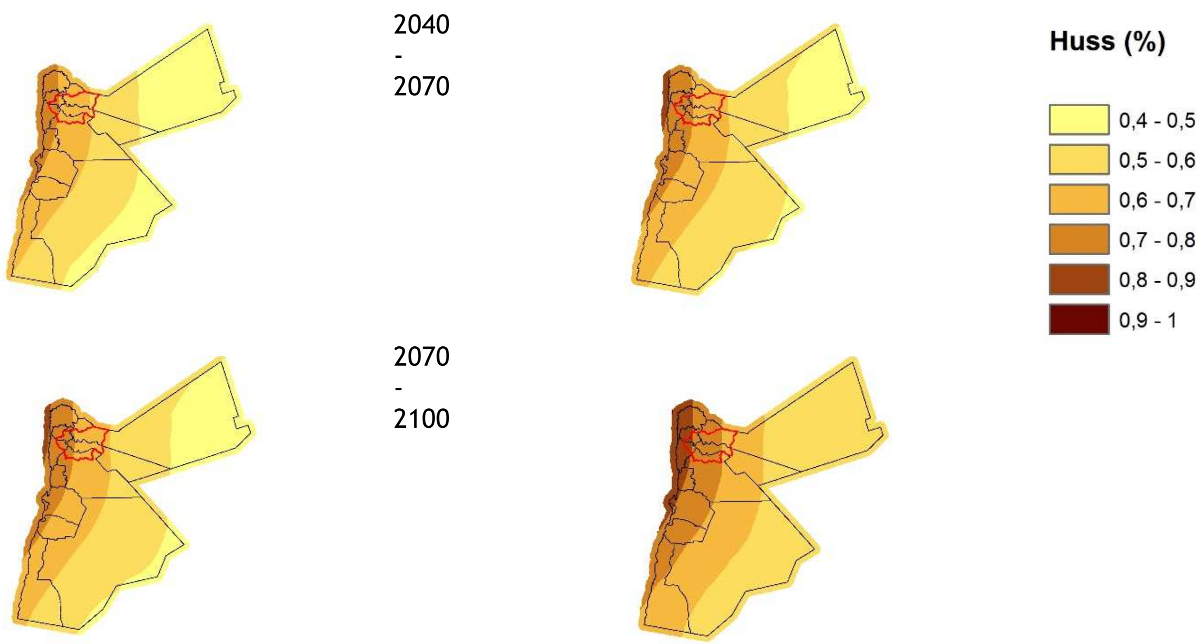


Figure 28 : Specific humidity of air, absolute values in % of water in air, reference model

Wind

Wind direction

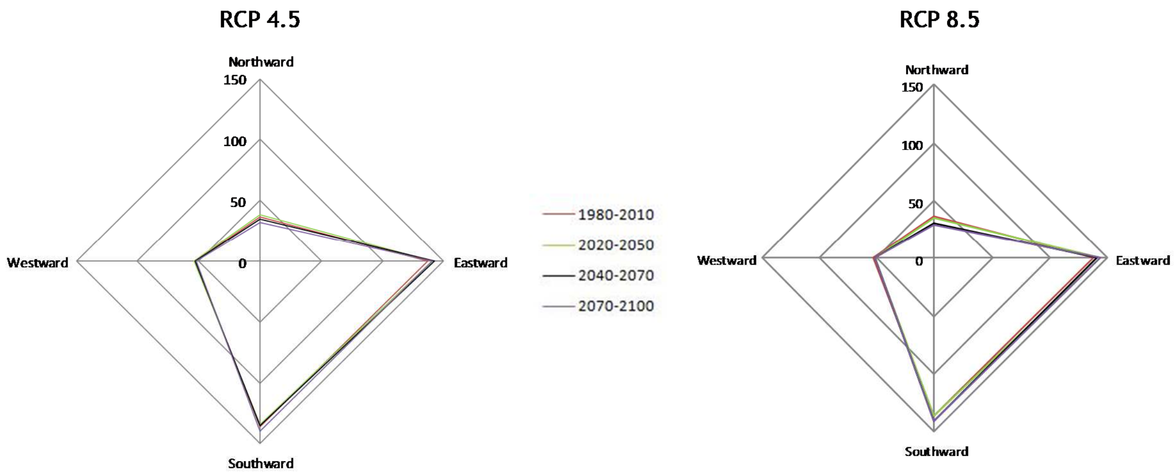


Figure 29 : Number of wind days for each direction in Jordan, for the reference period and the 2035, 2055 and 2085 time horizons and for the RCP 4.5 and 8.5

For the two RCPs the main wind directions are eastward and northward and there is no significant evolution over time.

Snow depth

Due to the low values of snow depth over the country, this indice was only represented for the pilot area.

Climate of the pilot area

This visualisation represents the processing of data for the ID95 and ID96 grid points for the model of reference. For temperature and precipitation maps, model outputs are downscaled and projected at the station using real and virtual stations, in order to reach a 1km x 1km resolution (see methods).

Overall, we can note that the changes in the pilot area is similar to that of the whole country.

Mean temperature

The cartography at 1km x 1 km resolution, using some geostatistical interpolation associated to the delta method (see section 2) does not reveal some strong geographical differences. The detailed numerical values can be extracted from the GEOTIFF maps, for instance for hydrological or agriculture modelling. The future projected values for the stations belonging to the pilot area, are also provided in the database.

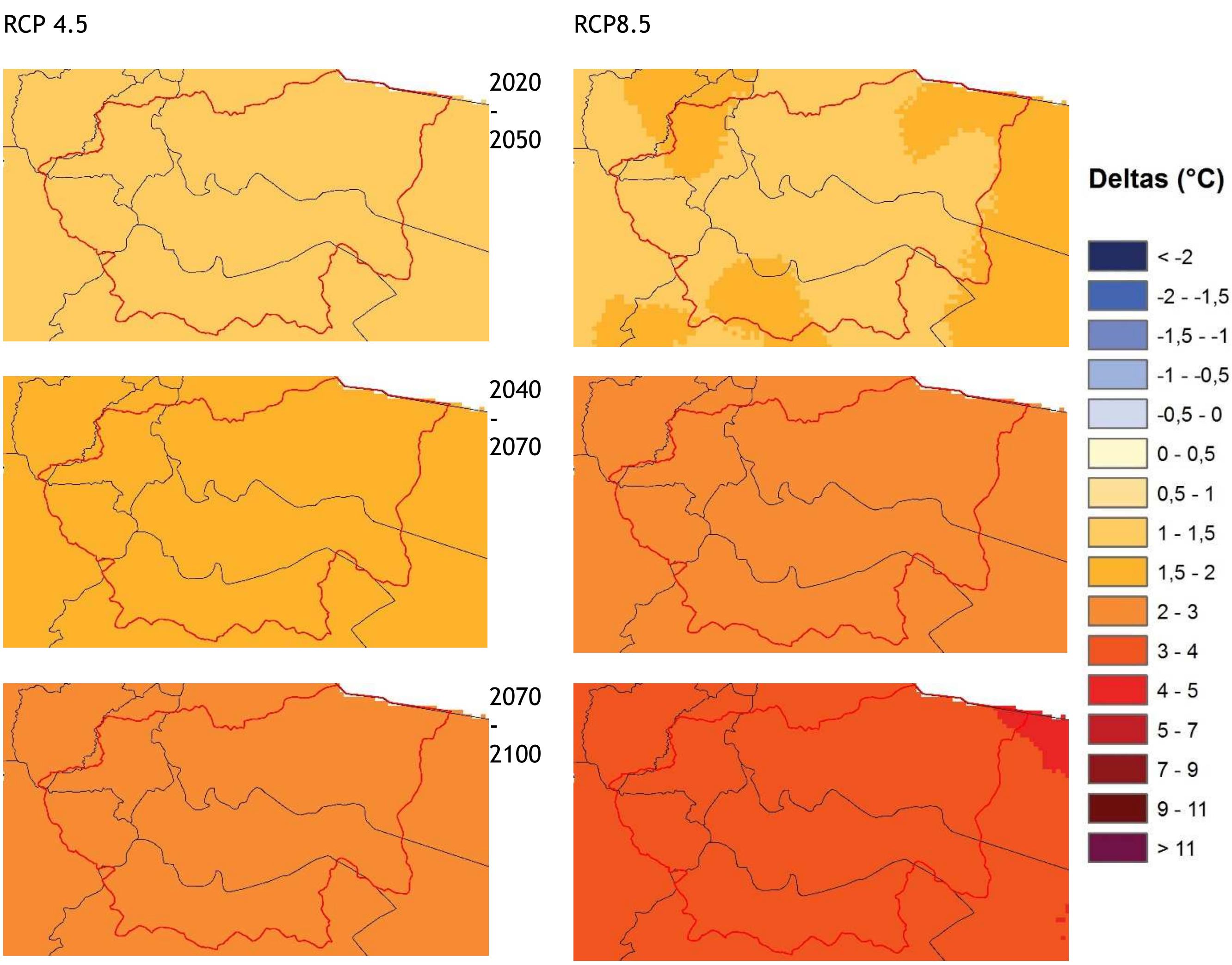


Figure 30: Changes in mean temperature of the pilot area, reference model

For the RCP 4.5, median values increase up to +2°C, +3°C for the maximum and +1.7°C. The inter-annual variability (i.e. difference between two consecutive years), illustrated by the reference model, can be around 2°C, exceeding the maximum and minimum ensemble averages some years. It is always positive after 2030.

The RCP 8.5 projects a stronger increase, between +5.3°C and +3.6°C, with a median value of +3.8°C. Reference model inter-annual changes could reach 2°C and are purely positive after 2015, exceeding the extreme averages some years too.

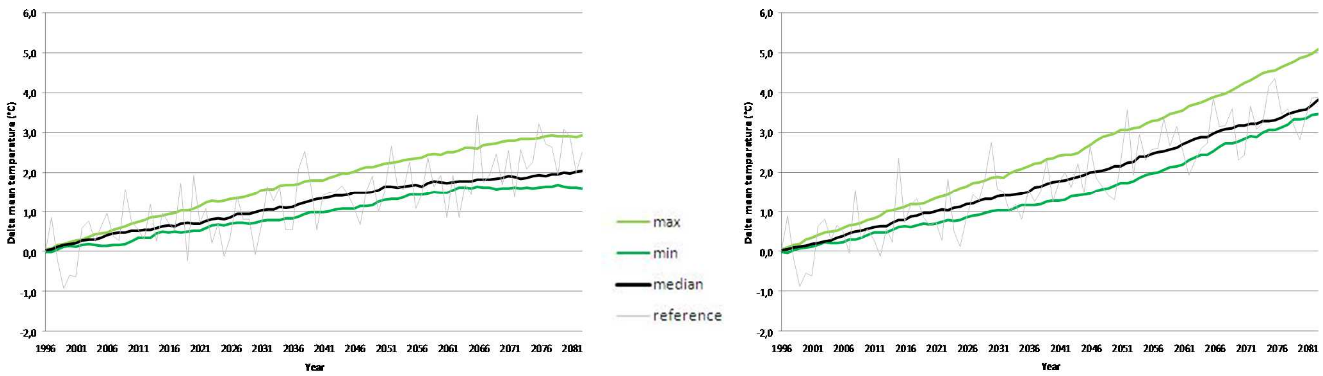


Figure 31 : Changes in delta mean temperature (°C) over pilot area for RCP 4.5 and 8.5

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

Minimum temperature

For the two RCPs, minimum temperature increase.
For the RCP 4.5, the rise is between +1.8°C and +3°C, with a median value of +2°C. The inter-annual variability of the reference model is up to 2°C, exceeding the extreme averages some years.

For the RCP 8.5, temperature ranges from +3.5°C to +5°C, with a median of +3.6°C. The inter-annual variability is still positive after 2015 and reaches 2°C. It exceeds regularly minimum average and sometimes maximum one.

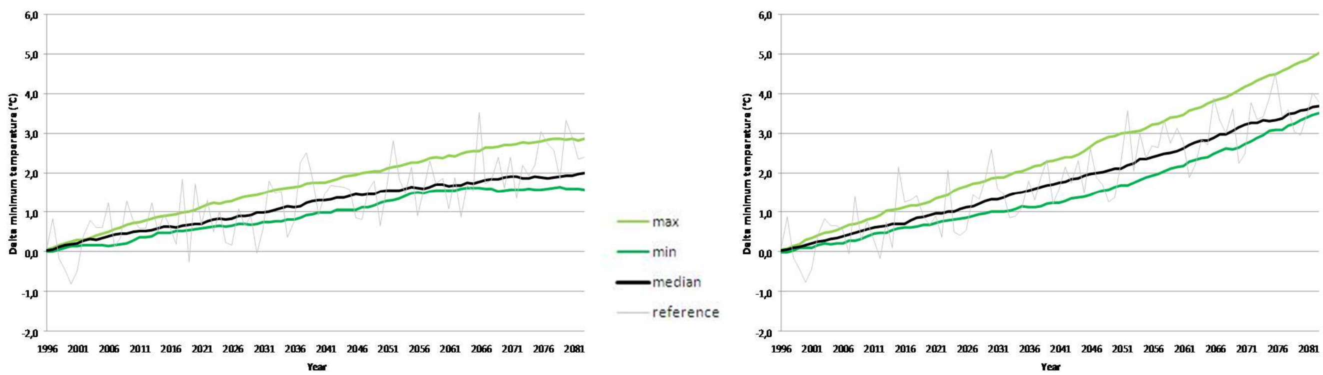


Figure 32: Changes in delta minimum temperature (°C) over pilot area for RCP 4.5 and 8.5

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

Maximum temperature

For the two RCPs, maximum temperature increase. For the RCP 4.5, median values increase up to +2.1°C in 2085, and ranges between +1.7 and +3.1°C. The inter-annual variability is sometimes over 2°C. It can largely exceed extreme averages. It is always positive after 2030. For the RCP 8.5, median temperature reaches +4.1°C in 2100 and is between +3.6 and +5.4°C. The inter-annual variability is always positive after 2025 and can exceed extreme averages.

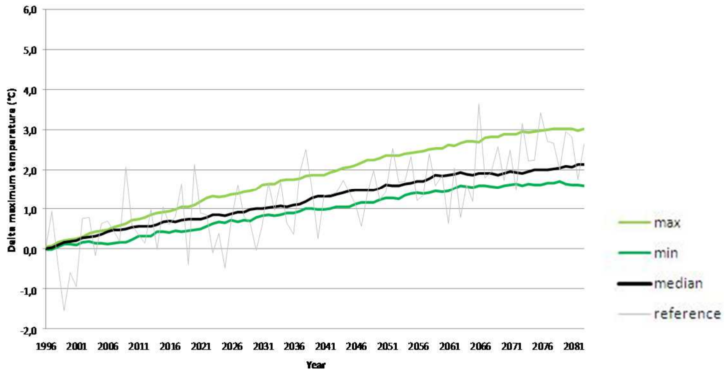
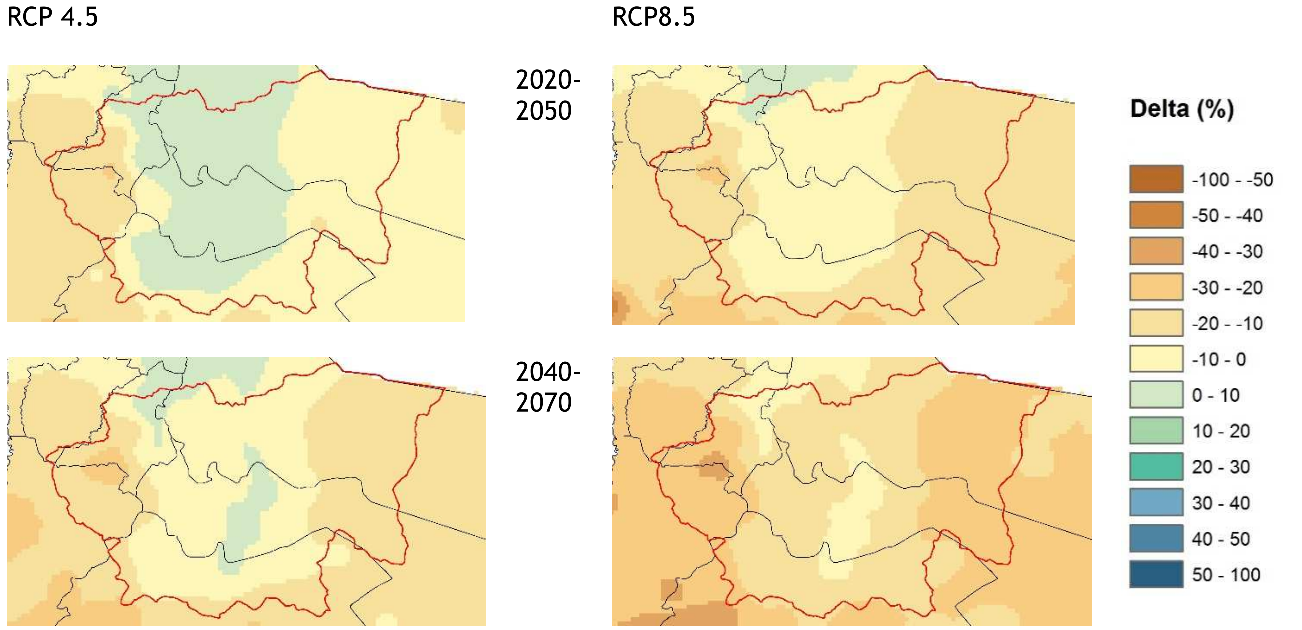


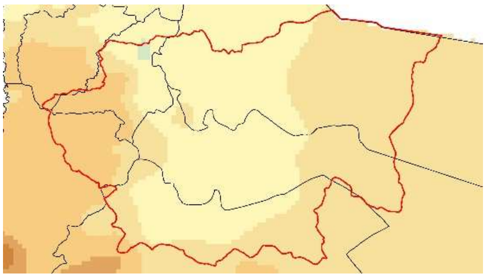
Figure 33 : Changes in maximum temperature (°C) over pilot area for RCP 4.5 and 8.5

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

Precipitation

The cartography at 1km x 1 km resolution, using some geostatistical interpolation associated to the delta method (see section 2), reveals some contrasted evolutions. Both RCPs show a trend to a growing diminution of precipitation, with more important evolutions in the eastern and western part of the basin, and more moderate evolutions in the central part. RCP 4.5 shows for 2020-2050 and 2040-2070 periods still some positive changes in precipitations in the central part, while values are almost all negative for all horizons for RCP 8.5. The detailed values can be extracted from the GEOTIFF maps, for instance for hydrological or agriculture modelling. The future projected values for the stations belonging to the pilot area, are also provided in the database.





2070-
2100

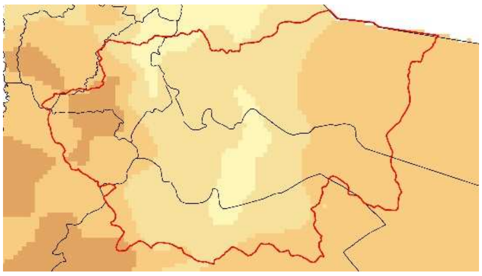


Figure 34 : Changes in annual precipitation of the pilot area, reference model

The two RCPs show a decrease in precipitation, stronger with the 8.5. For the RCP 4.5, median precipitation does not decrease before 2020, and reaches -15% in 2085. The minimum values reduce up to -23%. The maximum values predict positive changes around +5% until 2070, and then a decrease up to -7% in 2085. The inter-annual variability given by the reference model is between +55% and -55% with two peaks of +76 and +98%. For the RCP 8.5, the median values decrease up to -25% in 2085 and -42% for the minimum ones. The maximum values are positive until 2035 and then decrease up to -10% in 2085. The inter-annual variability is between +65% and -55%, with two extreme anomalies of +95 and –70%. So, even if the trend show a relative decrease, extreme years, positive or negative, are still likely.

RCP 4.5

RCP 8.5

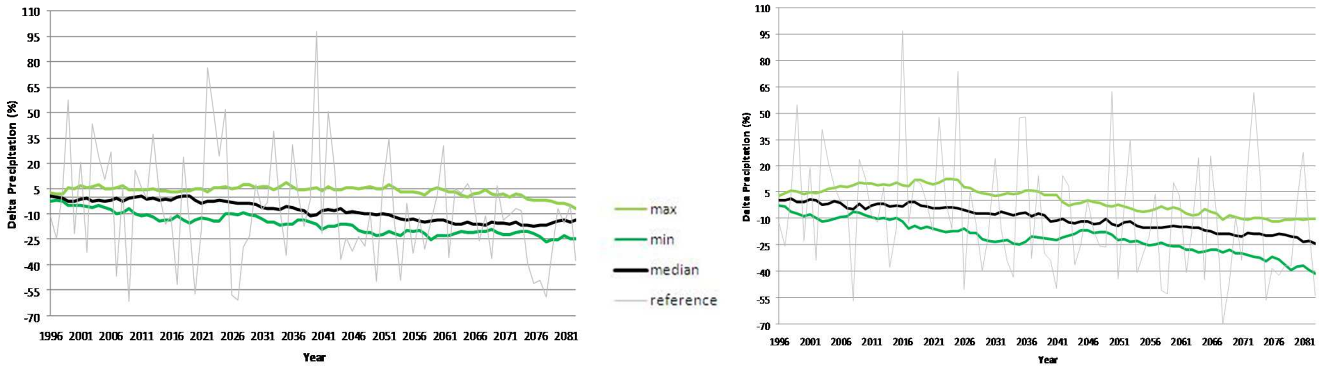


Figure 35 : Changes in delta precipitation (%) over pilot area for RCP 4.5 and 8.5
Min: Minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

Climatographs

The following graphs compare the climatology of the reference period (1980-2010), with that of the 2070-2100 horizon. This illustrates the stronger decrease of precipitation in Autumn and Winter than in Spring. It also shows the average monthly temperature that could be reached by the end of the century, with an increase likelihood of heat waves. Indeed, the average temperature of July and August would exceed 30°C. Both trends are more marked for RCP 8.5.

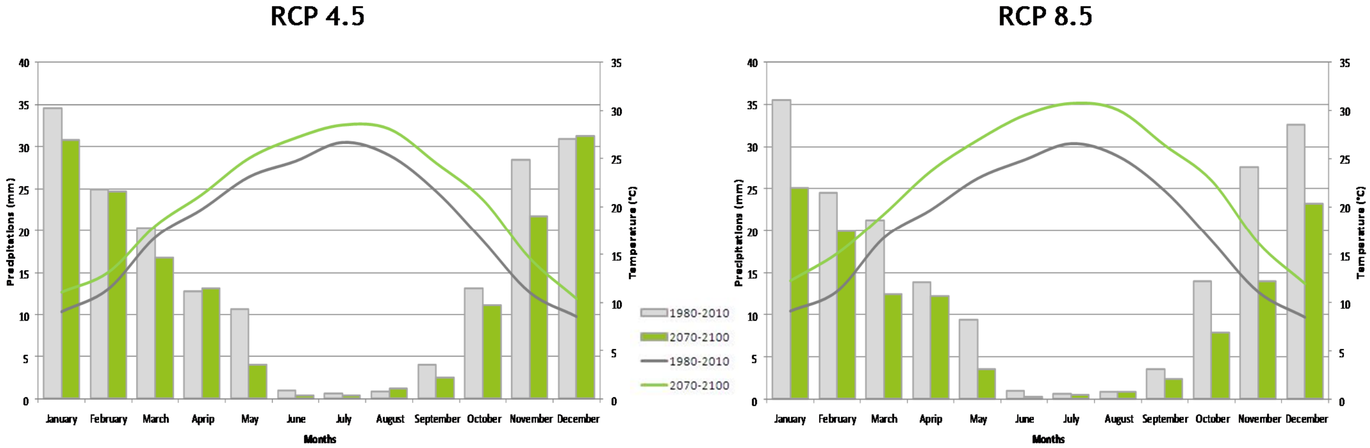


Figure 36: Climatograph of pilot area for RCP 4.5 and 8.5

Line : temperature, Bars : precitations. Note that the slight differences between 1980-2010 periods for the two RCPs are due to the difference in initial conditions of model runs

Evapotranspiration

The two RCPs show an increase in PET until 2085 and median average and reference model are closer to the maximum values.

For the RCP 4.5 the median values increase until 2060 and then are quite steady around 1780mm. The minimum average increases up to 1700mm in 2085. The maximum one rises more and more slightly up to 1840mm in 2085. Some years, the inter-annual variability nearly reaches 200mm and it often exceeds the maximum average with, for example, two extremes above 1900mm around 2070.

For the RCP 8.5, evapotranspiration increases steadily. From 1996 to 2085, median values rise up to 1880mm, it means an increase of more than 200mm. Minimum ones evolve more slightly from up to 1770mm, and the maximum reaches 1950mm. The inter-annual variability sometimes exceeds 200mm. It is often above the maximum average: some years exceed 1900mm as soon as 2030.

This evapotranspiration increase will affect the vegetation growth and also the agricultural sector.

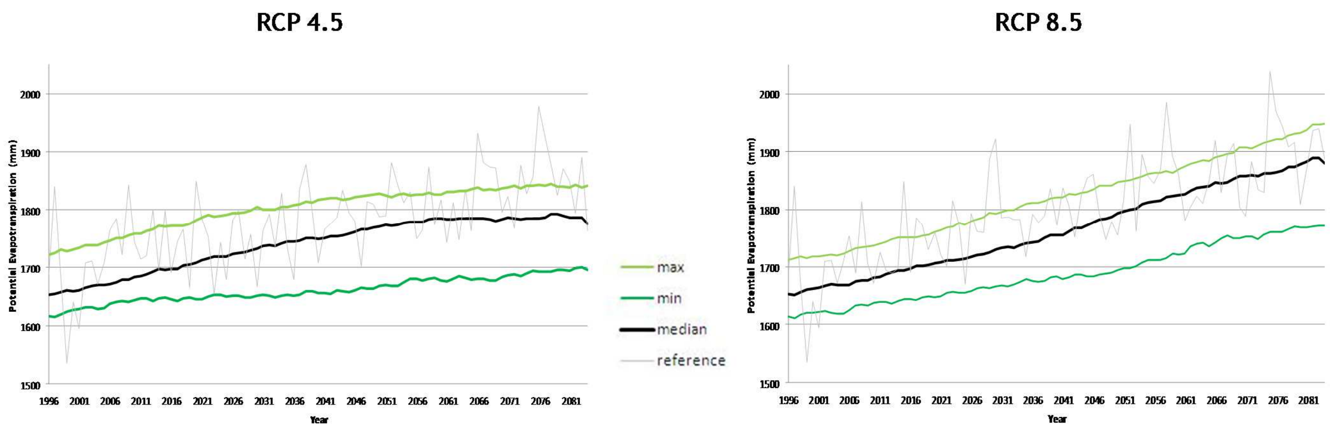


Figure 37 : Changes in potential evapotranspiration (mm) over pilot area for RCP 4.5 and 8.5

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

Snow

Values are very low because there are averaged on a yearly basis. So, this graph cannot be interpreted easily because a year with snow can reflect many different situations, from several small snowfalls to one important snowfall.

For the two RCPs, the snow thickness decreases and globally becomes a rare event: there are just over ten years with snowfalls.

For the RCP 4.5, minimum average reaches 0 before 2025. Median values are very close to 0 in 2085. Maximum average is more irregular and falls up to around 0.0001m in 2085.

For the RCP 8.5, the decrease is greater. Median values come close to 0 as soon as 2050. The minimum average is around 0 for the whole time period and maximum values are irregular and decrease and nearly reach 0 in 2085.

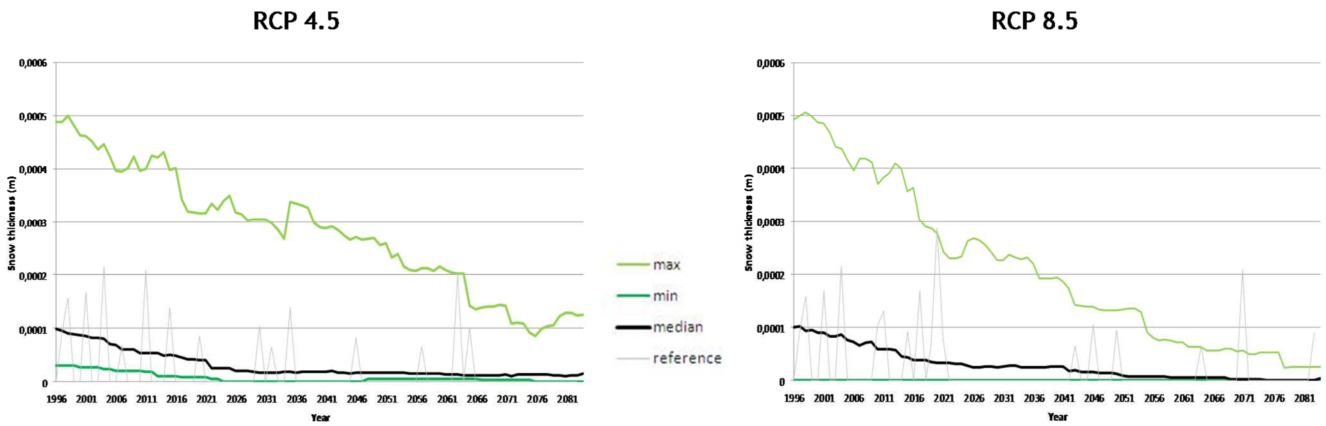
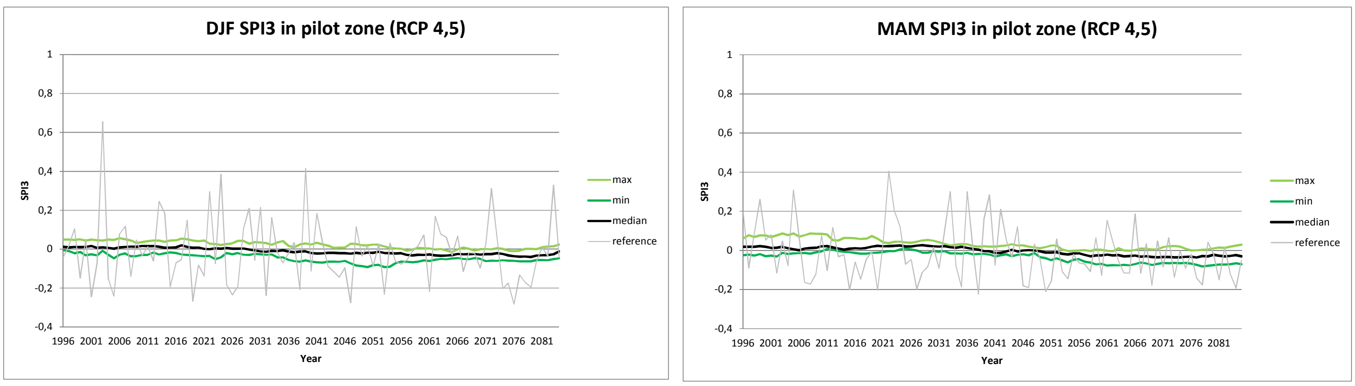


Figure 38 : Changes in snow thickness (m) over pilot area for RCP 4.5 and 8.5

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

Standardized precipitation indexes (SPIs)

The SPIs give a normalized value of cumulated precipitations for a given period (3 months for SPI3, 6 months for SPI6), compared to the reference of a period. It therefore indicates droughts, and general water availability. Trends shows a decrease (more droughts), in particular in winter, spring and autumn. Individual values of the reference model illustrates the fact that if some years of relative abundance can still occur, they are more and more rare. The trend is stronger for RCP8.5 than for RCP 4.5. The significance of such values will have however to be interpreted further by the Jordan team.



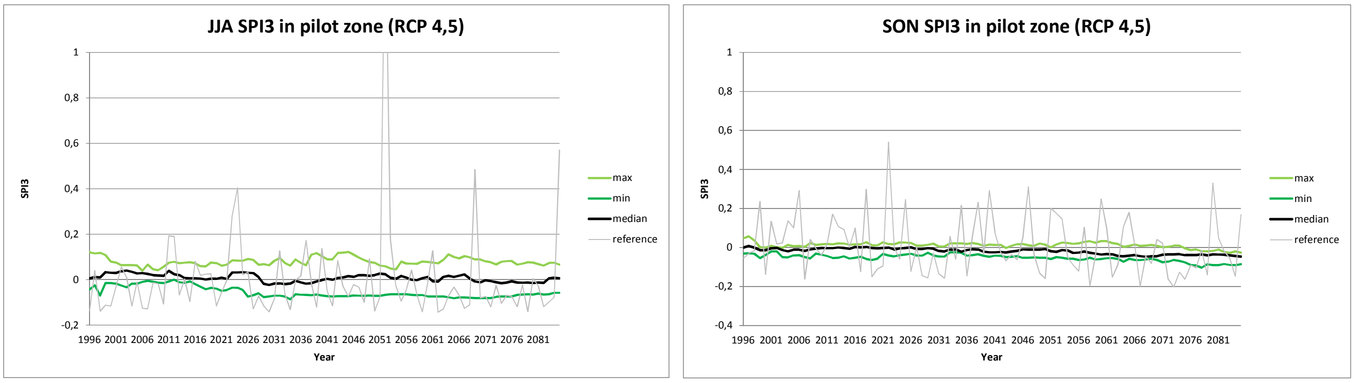


Figure 39 : seasonal SPI for RCP4.5, pilot area

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Mediane: Mediane values of the 9 GCMxRCM ensemble of projections. Min, Max and Mediane for moving averages over 30 years periods. Ref : annual individual values of the reference model.

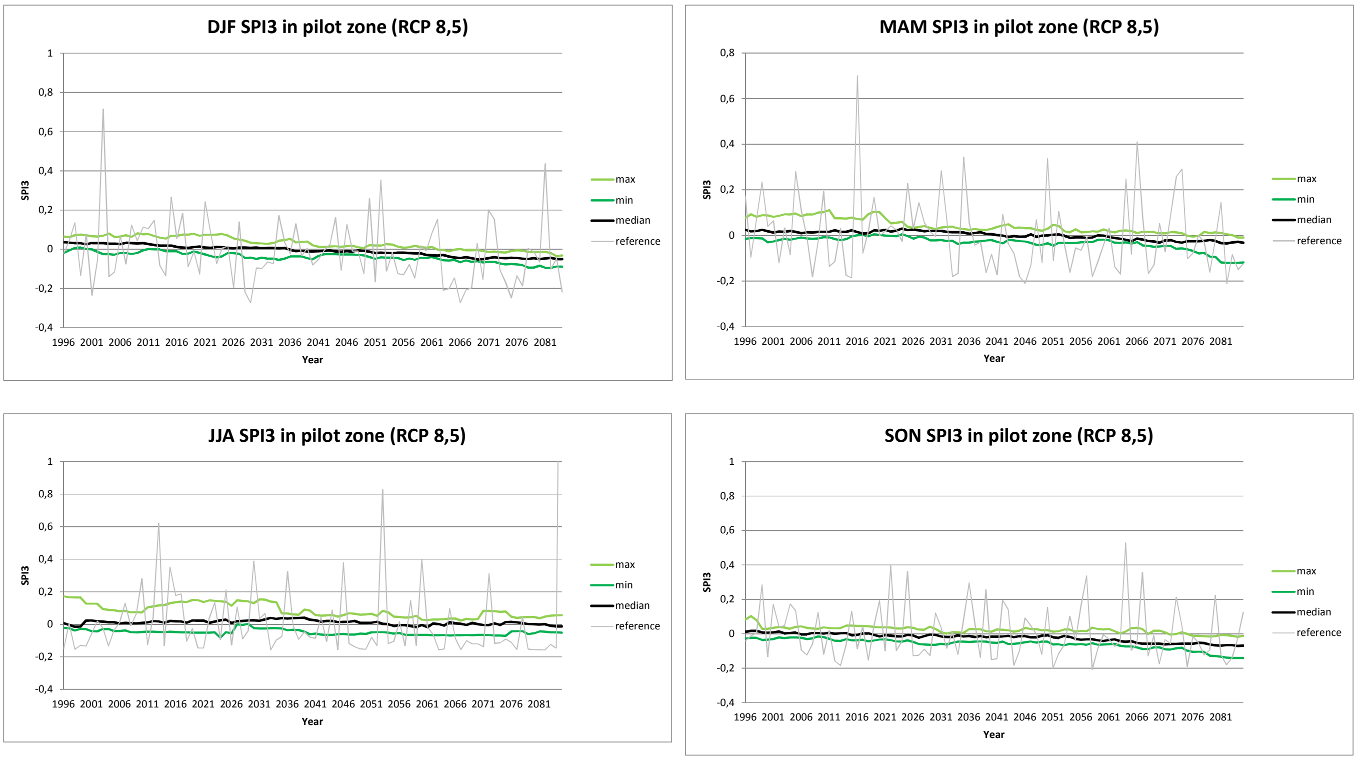


Figure 40: seasonal SPI for RCP8.5, pilot area

Min: minimum values of the 9 GCMxRCM ensemble of projections, Max : minimum values of the 9 GCMxRCM ensemble of projections, Median: Median values of the 9 GCMxRCM ensemble of projections. Min, Max and Median for moving averages over 30 years periods. Ref : annual individual values of the reference model.

Humidity

For the two RCPs the specific humidity (fraction of water vapour in a unit mass of moist air,) increases and the inter-annual variability is closer to the minimum average and does not exceed maximum one.

For the RCP 4.5, the median values rise up to 0.0073 in 2085. The minimum average rises up to 0.0068, in 2065, and then is steady. The maximum average increases up 0.0084. The inter-annual variability is around the median average but is sometimes below the minimum one.

For the RCP 8.5, the three averages rise steadily. The median values increase up to around 0.0083 in 2085, 0.0073 for the minimum and 0.0093 for the maximum. The inter-annual variability can exceptionally reach 0.001. It is around the median, and sometimes under the minimum average.

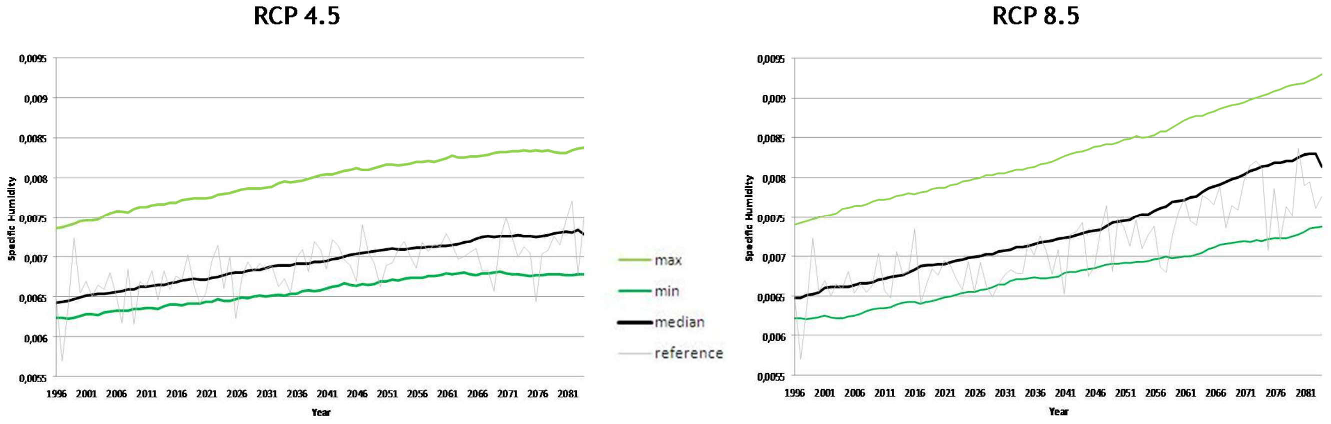


Figure 41: Changes in specific humidity (water kg/humid air kg) over pilot area for RCP 4.5 and 8.5

Wind

Wind speed

For the two RCPs, there is no significant changes in maximum of daily maximum wind speed of gust (DMWS).
For the RCP 4.5, the median value is around 23m/s, the minimum ranges between 22 and 23m/s and the maximum is around 24m/s. However, the inter-annual variability is more important and can reach 6m/s. The DMWS given by the reference model are around the median average but exceeds most of the time the maximum and minimum values, with two extremes of 19 and 27m/s.The RCP 8.5 is very similar to the 4.5. The averages are steady too, around 23m/s for the median, 22m/s for the minimum and 24m/s for the maximum. The inter-annual variability is a bit less important until 2060 and globally ranges between 21 and 25m/s. After there are some peaks closer to 19m/s.

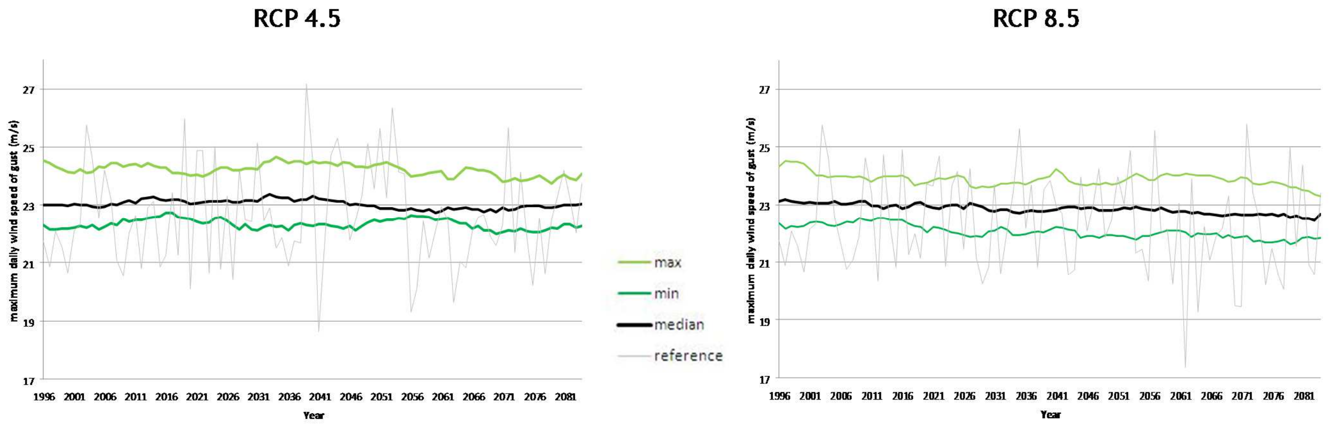


Figure 42: Changes in maximum value of daily maximum wind speed of gust (m/s) over pilot area for RCP 4.5 and 8.5

Wind directions

For the two RCPs, the main wind direction in the pilot area is eastward, northward is the lower. There is no significant changes in the number of wind days over time.

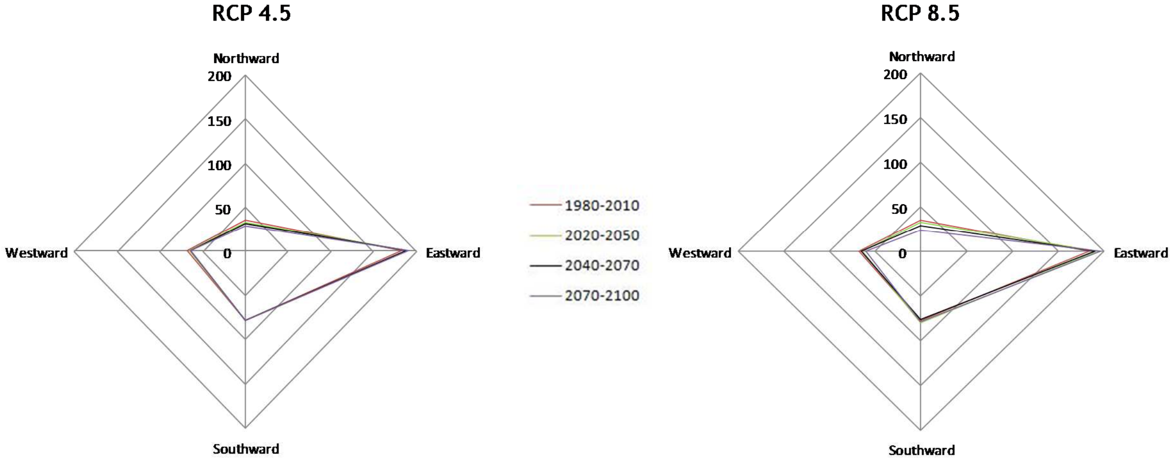


Figure 43 : Number of wind days for each direction in the pilot area, for the reference period and the 2035, 2055 and 2085 time horizons and for the RCP 4.5 and 8.5

A tentative approach of extreme events

Context

In order to provide comprehensive information on the future climates of Jordan, some data on climate extremes can be of interest. Indeed, if some sectors are first dependent on mean values – e.g. the cumulated precipitation in the past 3 or 6 months for agricultural yields – the occurrence of extremes can matter at various extents for some specific activities. For instance, exceeding a threshold of temperature, even one month out of ten years, can cause severe casualties to populations, or create some irreversible loss of biodiversity. In the same order, extreme rains can obviously create flash floods, and extreme droughts can be lethal for the livestock.

It's generally the combination of intensity (positive or negative: heavy rainy event, of length of drought) and low occurrence, that defines a climate extreme. Those two notions raise some serious challenges to climatology. Indeed, if climate models reasonably represent mean values, in particular at broad scale and long time slices, they notably perform less in the representation of the margins in a distribution. Model have systematic biases, either inherent to their physics (absence of convective phenomena), or linked to the way they represent the climate (with areal mean rather than with punctual values as measured by stations). The higher the spatial and temporal resolution is (for instance for one grid point with infra-days values), the worse the results are.

One possibility to answer to these limitations is to run adapted downscaling methods. In particular, the quantile-quantile correction that was tented for the pilot area could allow a better representation of first and last percentiles of the distribution, therefore providing a better understanding of indexes as consecutive dry days or heavy precipitations days. Some practical limitations (see methods) did not make it feasible, however. To go further, some sophisticated (and costly) methods exist, like weather generators. They, however, go far beyond the possibility of this assignment, and meanwhile are also subject to criticism.

Methods

Our approach of extremes had to be achieved with caution, bearing in mind the limitation of current climatology and of the EUROCORDEX datasets.

It relies on :

- the processing of specific indices, as requested by the TNC team. Indices as heavy precipitation days (>10 mm), consecutive dry days, standardized precipitation indexes (SPI), maximum wind gust, Snow, give, even in the way they are presented in the previous sections, some key information on extreme events causing severe impacts (floods, droughts, damages of wind to vegetation, blockage by the snow). Key results are recalled in the following.

- the processing of some requested indices in a different manner. For instance, the maps and figures presented above insist on means and trends, with a preference given to 30-years moving average, so as to limit the noise of inter-annual variability. But the data can be also processed differently, insisting on annual (or monthly) individual values rather than on 30-years smoothed means; on min and max values (i.e. minimum and maximum values of the ensemble of models) rather than on the median value.

Doing this, we however remind the following principles :

- the nature of climate models and the low frequency of climate extremes make it difficult to assess the long term variability of such extremes. The studies of the links between low probability-high impact hydro-meteorological events such as Alexa, belong to research fields and might lie outside the scope of this study. Given that this science is still at its infancy, any results presented should be interpreted with great caution;

- we generally present, rather than a trend, the possibility of occurrence of some events during the next century (e.g. the possibility of one month with average maximum temperature exceeding 40°C);

- we stayed apart of daily values, which biases can be more important than monthly, seasonal or annual values;

- we did not zoom spatially excessively, since the resolution increase the risk of errors.

Results

Will floods be more important ?

Heavy precipitation days (>10 mm)

Nationally in the current state of data, no trend shows an increase in the number of heavy precipitation days (>10 mm), nor an increase of mean values.

In the pilot area, the two RCPs present very similar values of median number of heavy precipitation days and there is no significant trend over time. RCP 8.5 predicts a small decrease of 0.3 day in December until 2100.

RCP 4.5 RCP 8.5

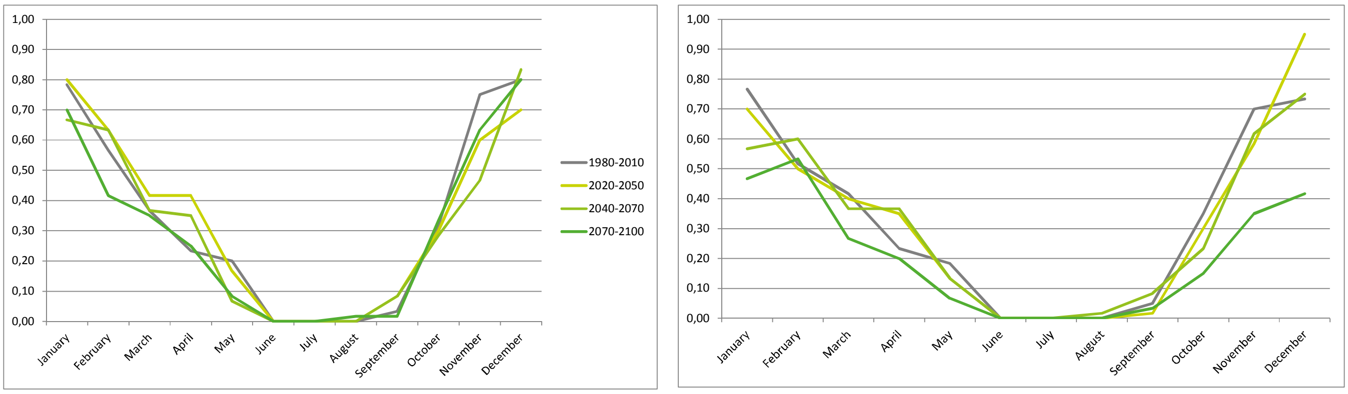


Figure 44 : Median number of heavy precipitation days (> 10mm) for the RCP 4.5 and 8.5 over the pilot area. Median value of the nine models for each RCP

For the two RCPs, there is no trend over time for maximum number of heavy precipitation day, except a small decrease in august and values are similar. Maximum number of precipitation is nearly twice the median one. Even if there are rare (<0.5d/month) it predicts some (very hypothetical) days of heavy rain in summer and more than one day in December, January and February In 2100.

RCP 4.5 RCP 8.5

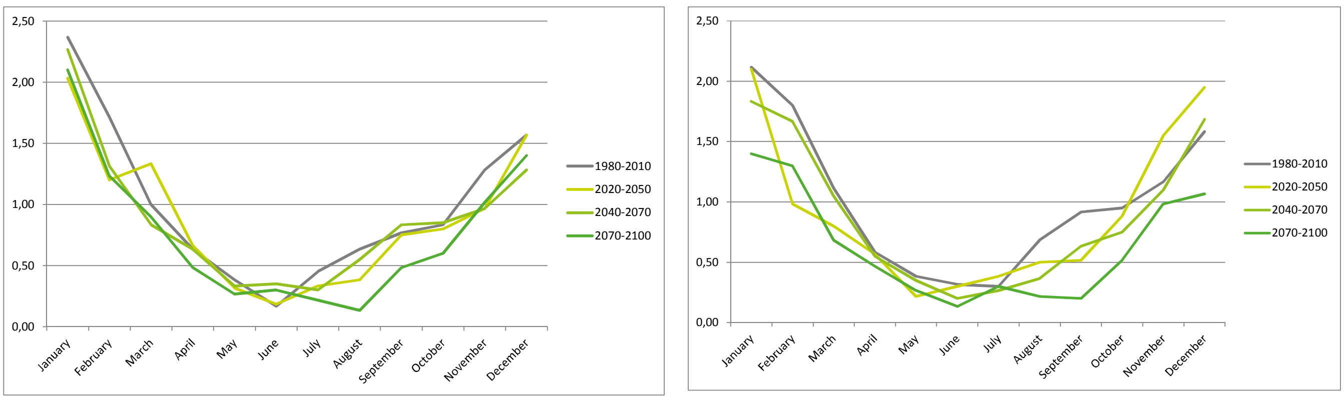


Figure 46: Maximum of number of heavy precipitation days (> 10mm) over the pilot area for the RCP 4.5 and 8.5. Maximum value of the nine models for each RCP/

Cumulated precipitations

The next graphs concern the extreme of precipitations. For each year, the monthly maximum value across the the nine models is taken (max all models, light green curve). For the same month, the median value of the nine models (both smoothened and unsmoothed, i.e. the median of the maximum month of a year,) as well as the value of the reference model are selected,. The four values are then compared in the graphs in order to see the average climatology (smoothen median), the likely inter-annual variability (reference model) and the possible extreme years (max all models). The median unsmoothed allows to check the reference model prediction.

The two RCPs present an important inter-annual variability of the maximum of all models (MAM). For the RCP 4.5, the median average increases a bit until 2035 but is nearly the same in 2085 than in 2011. The median unsmoothed presents an inter-annual variability between 10 and 35mm. The reference model has a more important inter-annual variability, globally between 6 and 35mm, but with two peaks around 50mm. The MAM is above the reference model and ranges between 20 and 100mm with important variations.

For the RCP 8.5 the median average is 15.5mm in 1996 and decreases to 8.1mm in 2085. The inter-variability of the median is between 20 and 35mm and decreases slightly until 2085 up to a range of 12 to 28 mm. The variability of the reference model is larger, between 6 and 50mm. The MAM is above the reference model and varies between 28 and 90mm.

This means that some exceptional years, during a month, the mean total precipitation of the country could reach 90 to 100mm. Depending on the spatial and temporal distribution, those extreme months can caused floods, for example. As for heavy precipitation days, and in spite of a diminution of precipitation around -16% and -21% (RCP 4.5 and 8.5) on an annual basis, there does not seem to be a reduction of intense precipitation periods. In short: droughts should be more intense (see next), and this will be partly compensated with intense precipitation month. This might cause serious challenges to water management (storage, dam capacity etc.)

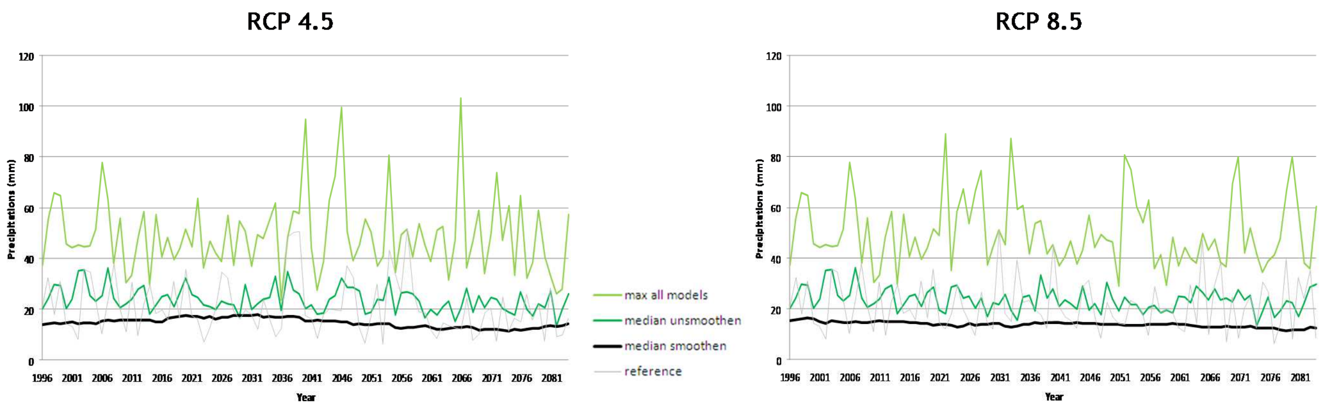


Figure 47 : Changes in monthly maximum precipitation (mm, annual value) over Jordan for RCP 4.5 and 8.5

Will droughts be more frequent ?

Standardized precipitation indexes

SPI3 show an intensification of drought (see supra)

Consecutive dry days

The following graph presents differently the values of the “maximum number of consecutive dry days” indice, requested by the TNC team. It compares the monthly distribution and its evolution over period (1980-2010, 2020-2050, 2040-2070, 2070-2100) of the median of this value, and then the “maximum of the maximum” (maximum value of the nine models).

Maximum number of consecutive dry days (CDD) is very similar for the two RCPs. There is no significant evolution except a slight increase in September, October and November.

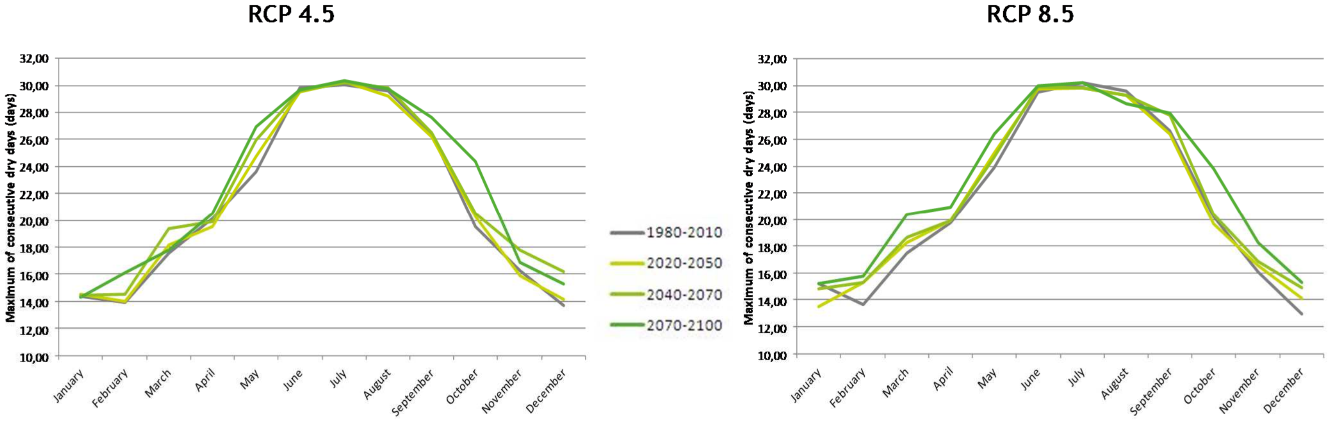


Figure 48: Changes in median of maximum number of consecutive dry days over pilot area for RCP 4.5 and 8.5

Concerning the maximum of maximum, the two RCPs present the same evolution, with an increase in number of CDD in October, November and December after 2070 and a smaller one in March and April. Globally the evolution is the same for the two RCPs and the major rises in maximum number of consecutive dry days could occur after 2100.

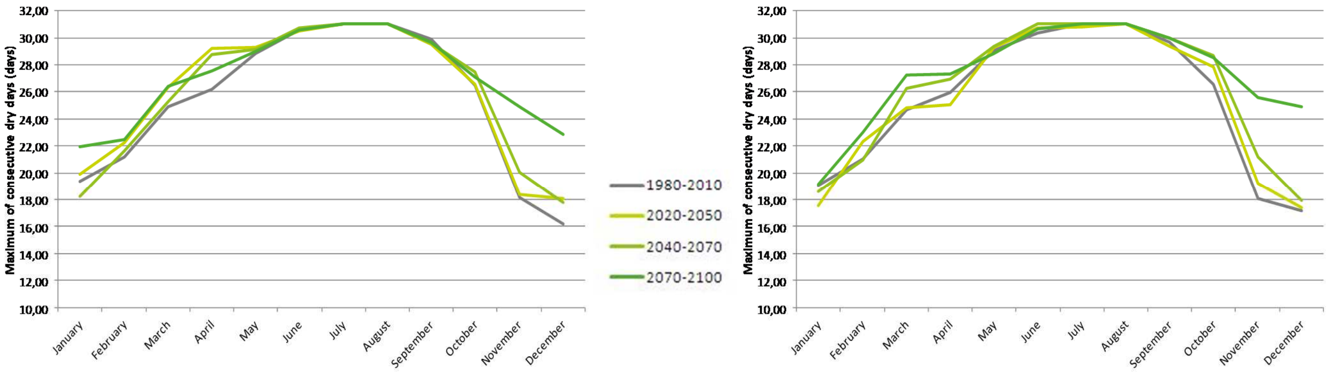


Figure 49: Changes in "maximum of maximum" number of consecutive dry days over pilot area for RCP 4.5 and 8.5

Will strong snow event go on affecting Jordan?

The trend presented for the pilot area reveals that the occurrence of snow (in term of cumulated with and number of years with snow) is decreasing gradually, to become virtually inexistent in the RCP 8.5, and very, very rate in RCP 4.5.

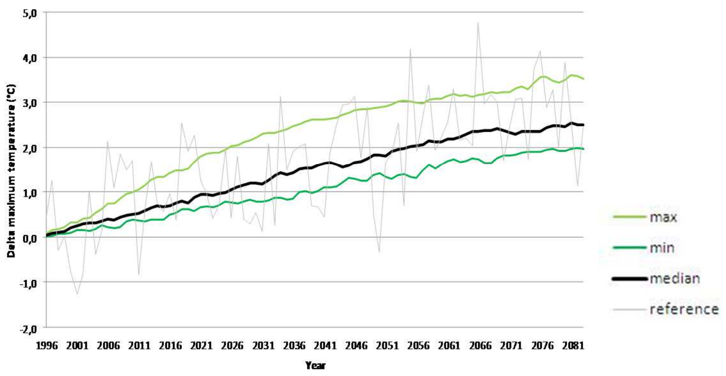
What will be the occurrence of temperature extremes?

Summer temperature

For RCP 4.5 the rise in 2085 is between +2°C and +3.5°C, with a median of +2.5°C. The inter-annual variability is significant, up to 3°C and can largely exceed the extreme averages. It implies some years with a summer temperature of +4°C.

The RCP 8.5 shows a stronger rise, between +3.2°C and +6°C and with a median of +4.7°C. The inter-annual variability can reach more than 3°C. It can exceed maximum averages and is positive after 2010.

RCP 4.5



RCP 8.5

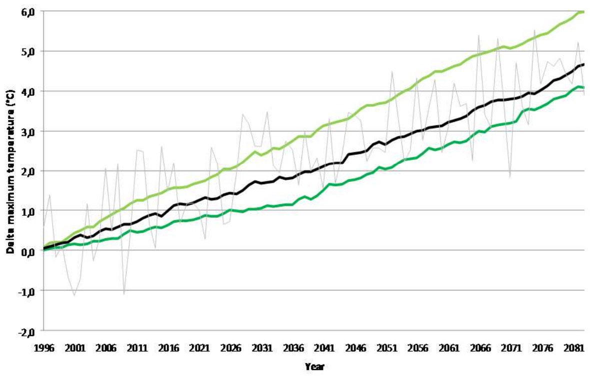


Figure 50 : Changes in summer maximum temperature (°C) over Jordan in summer for RCP 4.5 and 8.5

Monthly maximum temperature

The next graphs concern the extreme of temperatures. Monthly data are used. Maximums of each month are taken, for the nine models. For each year the month with the maximum value is chosen. For this month, the maximum value over the nine models is taken (max all models, light green curve), the median value of the nine models (unsmoothed, i.e. the median of the maximum month of a year) and compared with the monthly maximum value of the reference model, and with the 30-years median, to compare with the average climatology. So, these graphs give the changes in the median maximum, its inter-annual variability and the higher value of maximum that the ensemble of model predicts.

For the RCP 4.5, the median average of nearly 36°C in 1996 increases to 38°C in 2085. The inter-annual variability of the median maximums (unsmoothed) can reach 2°C. Near 2080, there are peaks above 39°C. The reference model is often mixed up with the MAM. Its inter-annual variability is more important and can reach 4°C. There are peaks around 42°C after 2060, up to 43°C. After 2040, some MAM exceeds 43°C.

For the RCP 8.5, the increase of the median average is even more important : above 40°C in 2085. The inter-annual variability of the median maximum is generally of 1°C but can reach 3°C. Around 2075, there are peaks of 41°C. The reference model is often mixed up with the MAM. Its inter-annual variability is higher and can exceed 4°C. Around 2075, there are peaks above 43°C. Some MAM exceeds 42°C after 2040, and 44°C after 2075.

So, it means that some years, for a month, the average of maximum temperature for the whole country can exceed 42-44°C. It implies that in some place, the temperature is even higher. Depending on the spatial and temporal distribution, those extreme months can cause problematical for agriculture, for example, and obviously for health, since it clearly depicts situation of major heat waves.

The two RCPs show an increase in the maximum of all models (MAM).

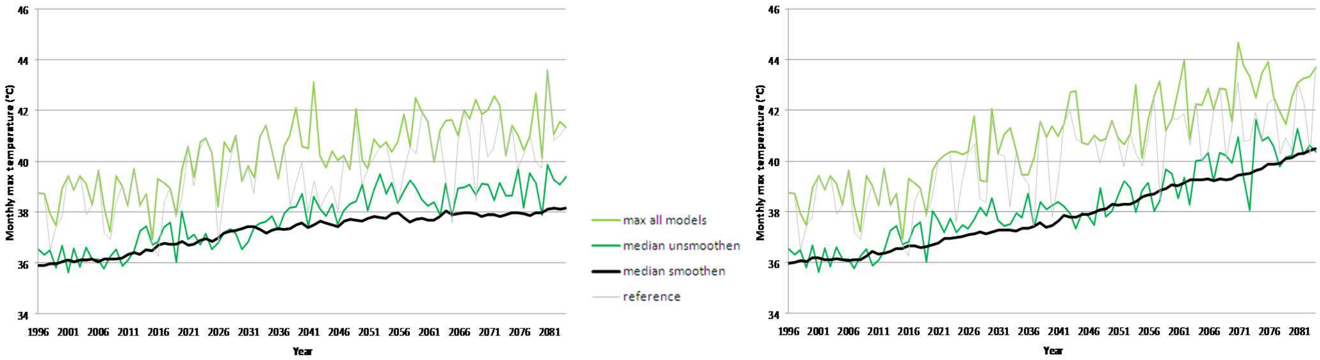
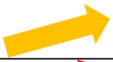
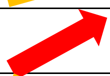
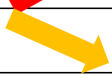


Figure 51 : Changes in monthly maximum temperature (°C) over Jordan for RCP 4.5 and 8.5

Will the wind create more damages?

There is no significant evolution of the maximum wind gusts in the pilot area.

Synthesis

Events	Trend	Degree of confidence
Intense precipitations and floods		Low
Droughts		Low
Heat waves		High
Snow event		High
Wind		Moderate

Annex 1 : Data correction

The quantile-quantile correction method

Simulated climate data, using model, tend to include systematic biases. For instance, the French Arpege climate underestimates intense precipitations and overestimates low precipitations days. These biases can be assessed comparing the historical part of a simulation with observations on the same period, and some correction can be undertaken. The most efficient technique is to compare the probability distribution functions of all series, and to correct the distribution quantile per quantile. In each grid point of the model, for each variable, a distribution in quantile (for instance 10, or 100), is calculated for both model and for observations (one of several stations located at a given distance of the grid point). Then the quantile of the model is corrected with the corresponding quantile of the observations. This method allows a correction of the main biases, relative to intensity of phenomena or occurrence of events. It is of particular interest to improve the reliability of results such as heavy precipitations days or number of consecutive dry days.

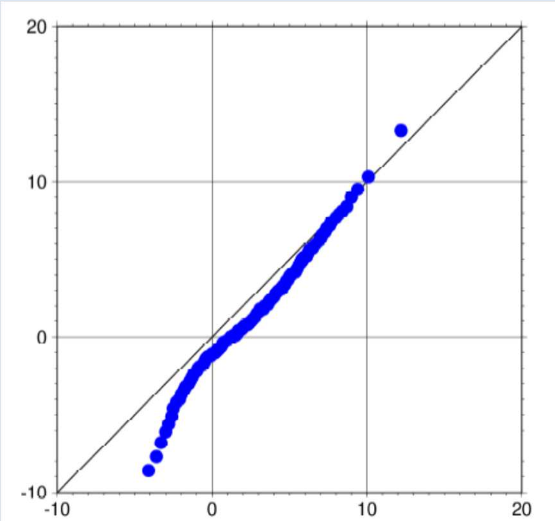


Figure 4: Example of quantile-quantile diagram for winter temperatures in Paris. Source: Meteo France

The quantile-quantile correction was implemented in the current assignment as a tentative approach. Its implementation in Jordan faced the following limitations :

- Due to the heterogeneity of observation dataset (14 stations for temperature, 60 for precipitations), and its concentration in some area of the country, all grid points of the models could not be corrected (some grid points did not have any stations located within the grid. Therefore no cartography or values at the country level could be obtained.
- Data correction is of particular interest for precipitation. Given the aridity of the country, however, the observation data sets (station data) only include a few days with precipitations over the year (on average, between 6 and 50 days with precipitation per year, depending on stations). This complicates the correction of distribution, since most of the daily values are equal to zero.

Therefore, the dataset and analyses provided in the results section do not use a corrected dataset. Some illustrations and methodological development are presented below.The quantile-quantile correction method (see box), after contacts taken at Meteo-France and at French INRA was implemented using the following rules :

- a grid point is corrected provided at least a station is included in a circle of 50km of diameter, which corresponds to the grid size.
- if several stations are included in this area, an “average station” is created, combining the information of all stations. The higher the number of stations, the higher the punctual measure of a station tends to converge with the areal mean of models, and therefore the more efficient the correction is;

Implemeting these rules, not all grid points could be corrected, due to the absence of observations in their neighborhood. For instance, only 19 out of 43 and 29 out of 43 could be corrected respectively to temperature and precipitation. Calculating mean over the whole country for an such 'hybrid' (i.e. mix of corrected and uncorrected dataset) could have introduced biases.

TEC will draw the conclusions of this experiment after the completion of the present assignment.