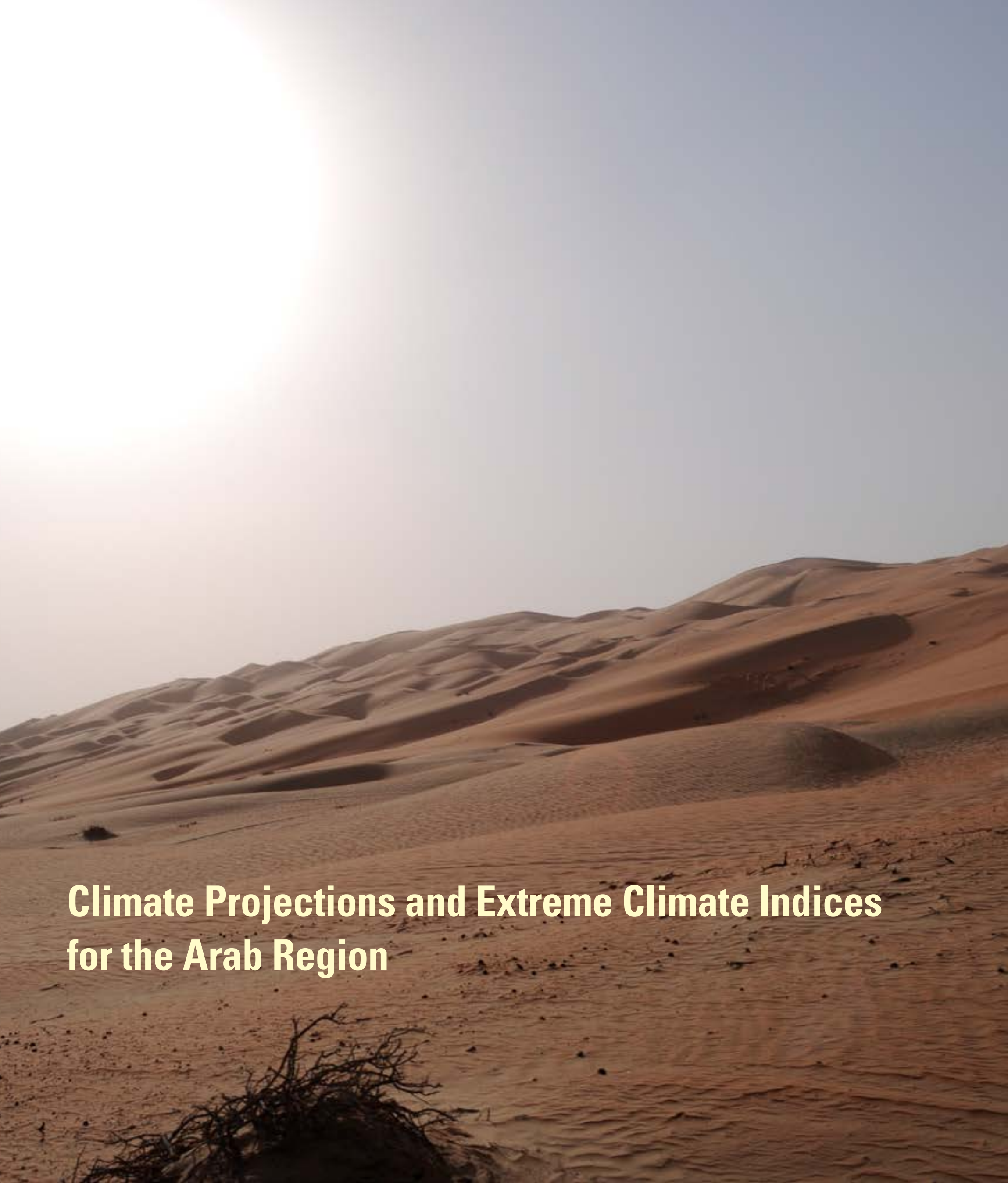

Climate Projections and Extreme Climate Indices for the Arab Region

UNITED NATIONS

League of Arab States

Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR)

E/ESCWA/SDPD/2015/Booklet.2

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15-00436

Background

The Regional Initiative for the Assessment of the Impact of Climate Change on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) is a collaborative regional initiative between the United Nations and the League of Arab States implemented at the request of Arab member States that is jointly implemented by 11 regional and international partner organizations as well as three contributing climate research institutions.

The initiative is coordinated by the United Nations Economic and Social Commission for Western Asia (ESCWA) and implemented in partnership with the League of Arab States, Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Food and Agriculture Organization (FAO), Swedish Meteorological and Hydrological Institute (SMHI), United Nations Environment Programme (UNEP), United Nations Educational, Scientific and Cultural Organization (UNESCO) Cairo Office, United Nations Office for Disaster Risk Reduction (UNISDR), United Nations University Institute for Water, Environment and Health (UNU-INWEH), and the World Meteorological Organization (WMO). Three climate research institutes have also contributed to the initiative, namely the Center of Excellence for Climate Change Research at King Abdulaziz University (KAU/CECCR), King Abdullah University of Science and Technology (KAUST), and Climate Service Center (Germany). The initiative is funded by the Swedish International Development Cooperation Agency (Sida) and the German Federal Ministry for Economic Cooperation and Development (BMZ), as well as through the in-kind contributions of the RICCAR partners.

RICCAR assesses the impact of climate change on freshwater resources in the Arab region through an integrated assessment methodology that combines climate change impact assessment with socio-economic and environmental vulnerability assessment. The impact assessment component is based on the generation of dynamically downscaled regional climate modeling projections covering the Arab/MENA Domain and a series of associated ensemble outputs. The projections were then linked to two regional hydrological models to specifically analyze the impact of climate change impacts on the region's freshwater resources, including several shared river basins. These outputs were in turn used as inputs into a regional vulnerability assessment that is identifying climate change vulnerability hotspots across the Arab region. More information on RICCAR is available at: www.escwa.un.org/RICCAR.

Mandate

RICCAR activities and the generation of climate change projections for the Arab region is mandated by Arabs States through resolutions adopted by the Arab Ministerial Water Council (AMWC), the Council of Arab Ministers Responsible for the Environment (CAMRE) and the Arab Permanent Committee for Meteorology (APCM).

The regional climate modeling work being undertaken by RICCAR is specifically referenced in the following strategies and action plans, namely the:

- *Arab Strategy for Water Security in the Arab Region to Meet the Challenges and Future Needs for Sustainable Development 2010-203*0 and its Action Plan – adopted by the AMWC in 2012 and 2014, respectively.
- *Arab Framework Action Plan on Climate Change* – adopted by CAMRE in 2012.
- *Arab Strategy for Disaster Risk Reduction 2020* and its Implementation Plan – adopted by CAMRE in 2010.

The regional initiative is also supportive of work to be carried out in support of the Arab Strategic Framework for Sustainable Development, which was adopted by CAMRE in 2014. The Board of Directors of ACSAD comprised of Arab Ministers of Agriculture as well as the ESCWA Ministerial Session and the ESCWA Committee on Water Resources have also mandated the work being conducted under RICCAR. RICCAR findings and outputs are also informing and complementing work being undertaken by GIZ under its Adaptation to Climate Change in the Water Sector in the MENA Region (ACCWaM) project, the FAO under its Regional Water Scarcity Initiative (WSI), and other activities being coordinated by the League of Arab States.

The analysis of climate change impacts and extreme climate events is a key element of RICCAR's regional climate modeling, hydrological modeling and vulnerability assessment components. Generating regional climate projections on temperature, precipitation as well as a series of extreme climate indices aims to foster dialogue between policy-makers, stakeholders and researcher engaged in the climate change and disaster risk reduction communities throughout the Arab region.

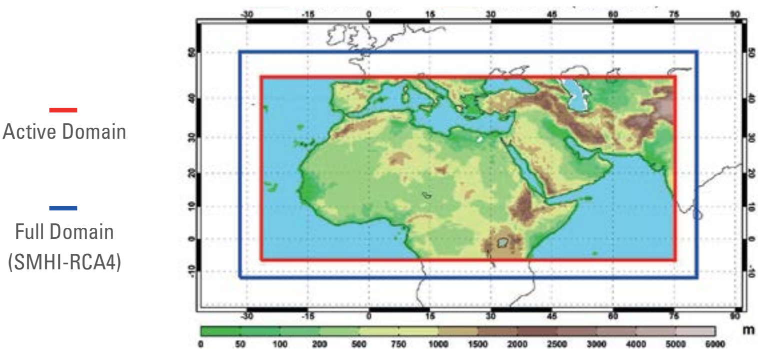
Methodology

Within the impact assessment component of RICCAR, an Arab Domain was established for framing the application of regional climate models (RCMs) in accordance with guidelines put forth by the Coordinated Regional Climate Downscaling Experiment (CORDEX) of the World Climate Research Programme, which is supported by the WMO.

Climate change projections conducted within the framework of the RICCAR are based on two of the four representative concentration pathways (RCPs) developed by the Intergovernmental Panel on Climate Change (IPCC) for informing global and regional climate modeling work presented in its Fifth Assessment Report (AR5). The regional climate projections presented in this document are based on RCP 4.5 (moderate case scenario) and RCP 8.5 (worst case scenario). These scenarios are named in accordance with their expected radiative forcings expressed in watts per square meter (W/m^2). The outputs presented herein were generated at a 50 km x 50 km scale.

Selection of these two RCPs and the associated scale applied for generating the RCM outputs corresponds with efforts being pursued by CORDEX to encourage collaboration and exchange of information on regional climate modeling within and across endorsed regional domains based on a common set of scenarios and data protocols. The Arab Domain is referred to as the MENA Domain in CORDEX and when downloading data from the Earth System Grid Federation (ESGF), which hosts several of the regional climate modeling projections generated by CORDEX members. It is also noted that the Comoros, while an Arab State, is not included in the Arab Domain given its geographic location. The Comoros can be studied drawing on high-resolution global climate models or regional climate modeling outputs covering the Africa Domain.

Figure 1. CORDEX MENA/Arab Domain (50 km)



Outputs

The results presented in this booklet are based on the regional climate modeling outputs generated by SMHI using RCA4 nested in three driving global climate models (GCMs), namely EC-Earth, CNRM and GFDL-ESM. An ensemble of outputs was produced for RCP 4.5 and RCP 8.5 for a variety of climate parameters through the end of this century at a 50 x 50 km scale. Additional projections generated at the 25 x 25 km scale will be available on the RICCAR regional knowledge hub.

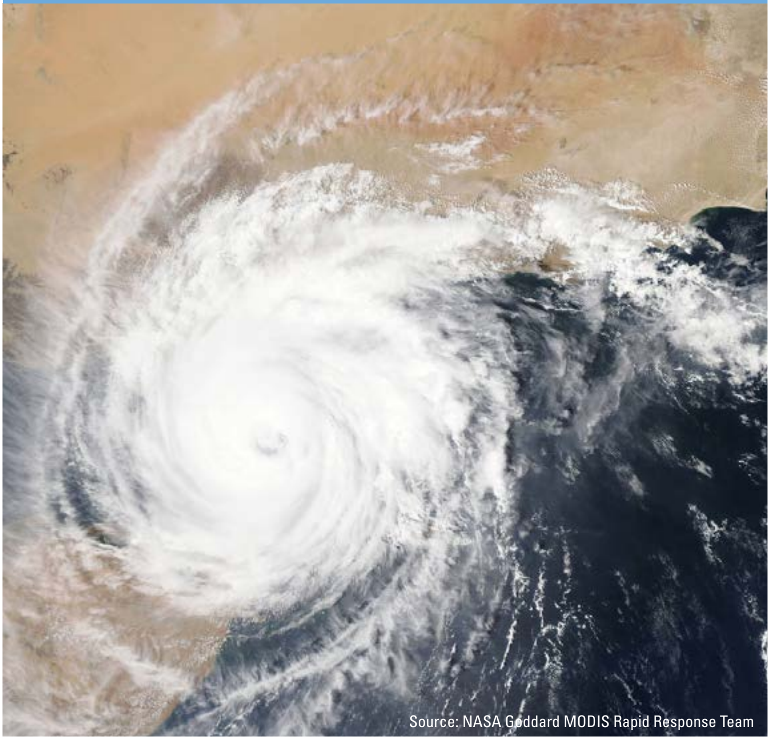
The projected temperature and precipitation results are shown in Figures 2 to 5. The results are presented as the change projected between the twenty-year time periods of 2046-2065 and 2081-2100 with reference to the baseline time period of 1986-2005.

The extreme climate indices listed in Table 1 are illustrated for the Arab Domain and the projected extreme climate parameters are shown in Figures 6 to 10. The results are presented as the change projected in the twenty-year time period of 2081-2100 with reference to the baseline time period of 1986-2005.

Graphical representation of changes over time for a series of sub-domains delineated within the Arab Domain are available upon request and will be made available on the RICCAR regional knowledge hub. Complementing the regional findings, information on these sub-domains is intended to support climate change dialogue at smaller scales of analysis, including shared water basins and distinct topographic areas, such as the Atlas mountains, the Southern Mediterranean coastline and the Eastern coast of the Arabian Peninsula.

It is noted that the results shown herein are bias corrected outputs produced by SMHI with respect to a thirty year reference period (1980-2009). Distribution-based scaling (DBS) was used for the bias correction of the regional climate modeling results in order to make them suitable for hydrological climate change impact assessment, which was also conducted under RICCAR. This means that the regional climate modeling outputs presented herein differ from the raw RCM outputs that are generated under CORDEX or accessible from the Earth Grid Federated System.

Cyclone Chapala Approaching Landfall in Yemen, November 2015



Source: NASA Goddard MODIS Rapid Response Team

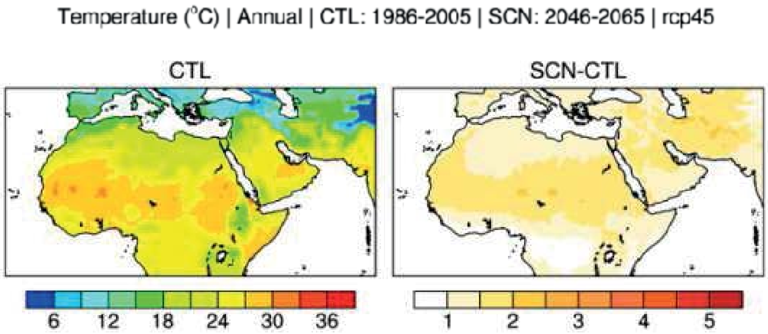
The international climate modeling community is increasingly turning to the use of bias corrected results to inform climate change analysis. More information on DBS tools is available at: http://www.smhi.se/en/research/research-departments/hydrology/dbs-1.30310.

Extreme weather events can have severe impacts on human health, built infrastructure, the natural environment, the transport sector and the economy at large. It is therefore necessary to develop and apply seasonal forecast, climate prediction and climate projection modeling tools and capacities in the Arab region to enable scientists to provide the information needed to inform policy-making and decision-making on climate change adaptation and measures to enhance resilience across the Arab region.
The results on extreme climate indices presented in this booklet are informing analysis being conducted by Arab Meteorological Services to this end.

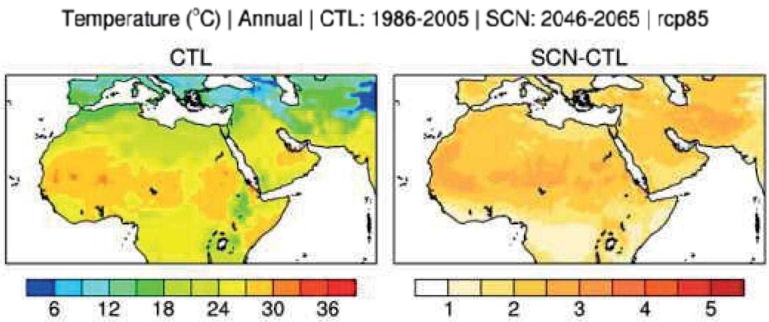
Change in Temperature: Mid-Century

Figure 2. Change in Temperature for the time period 2046-2065 from the baseline 1986-2005 for RCP 4.5 and RCP 8.5

RCP 4.5



RCP 8.5

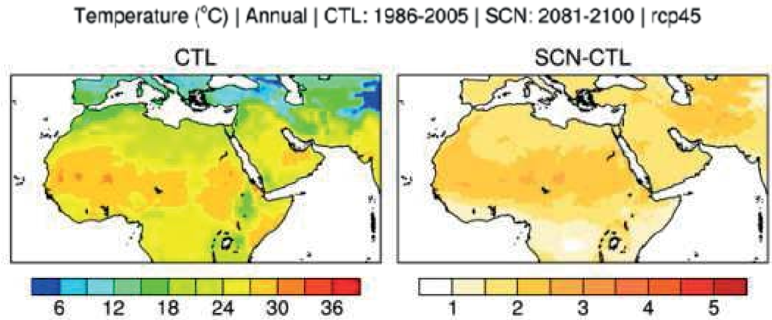


The general change in temperature to the middle of the century shows an increase varied between 0.3 and 2.4°C in RCP 4.5 and from 1.1 to 3.4°C under RCP 8.5. The higher increase is shown in the non-coastal areas, with the greatest increases projected in the Sahara desert.

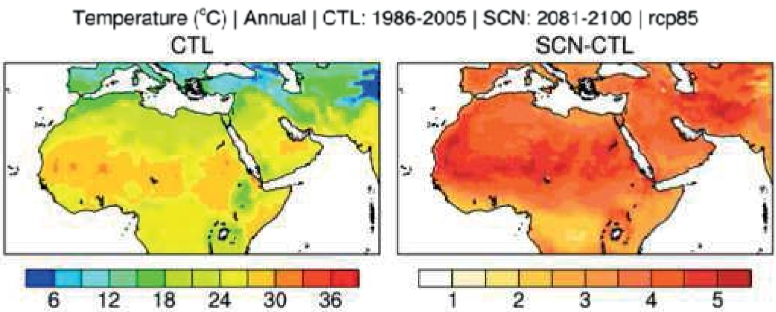
Change in Temperature: End-Century

Figure 3. Change in Temperature for the time period 2081-2100 from the baseline 1986-2005 for RCP 4.5 and RCP 8.5.

RCP 4.5



RCP 8.5

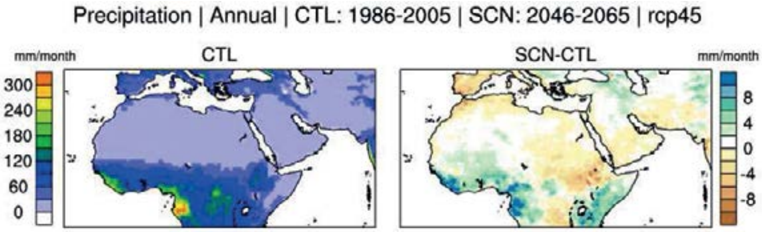


The general change of temperature towards the end of the century shows an increase between 1 to 3°C in RCP 4.5 and from 2 to 5°C with RCP 8.5. The areas showing higher increase are in the Sahara area in North Africa and East Africa, including Morocco and Mauritania. The increasing change in temperature becomes much more evident throughout the region by the end of the century. The increasing temperature signals along the westerns shores of Yemen and Saudi Arabia under RCP 8.5 are also stronger than under RCP 4.5 in comparison with the rest of the Arabian peninsula.

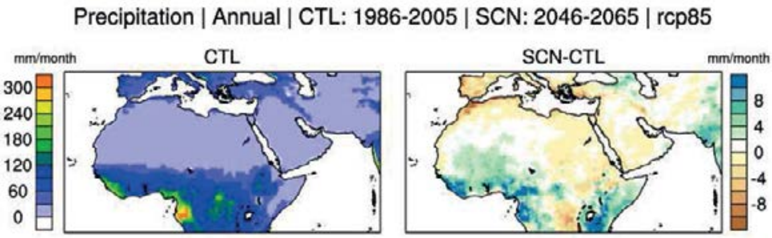
Change in Precipitation: Mid-Century

Figure 4. Change in average monthly Precipitation for the time period 2046-2065 from the baseline 1986-2005 for RCP 4.5 and RCP 8.5.

RCP 4.5



RCP 8.5

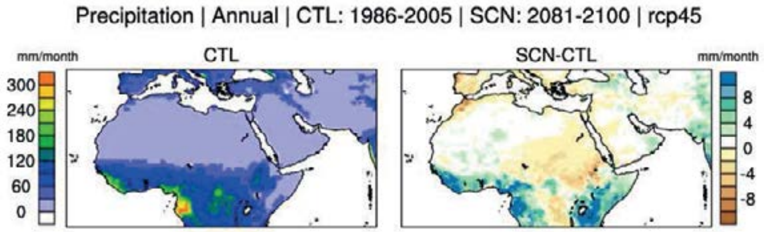


Decreasing trends can be seen in most of the Arab region. The figure shows a reduction of 8 mm in average monthly precipitation for the Atlas Mountains for RCP 8.5.

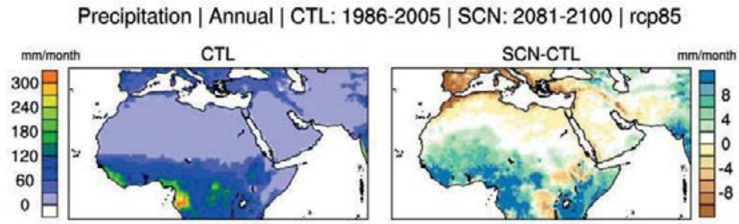
Change in Precipitation: End-Century

Figure 5. Change in average monthly Precipitation for the time period 2081-2100 from the baseline 1986-2005 for RCP 4.5 and RCP 8.5.

RCP 4.5



RCP 8.5



Both scenarios show a reduction of the average monthly precipitation reaching 8-10 mm in the coastal areas of the domain, mainly around the Atlas Mountains in the west and upper Euphrates and Tigris river basins in the East.

Extreme Climate Indices

The selected and constructed climate change indices presented in Table 1 are based on those formulated by the Expert Team on Climate Change Detection and Indices (ETCCDI), which is a joint working group of the Commission for Climatology, World Climate Research Programme and the Joint Technical Commission for Oceanography and Marine Meteorology, which are all convened under the auspices of the WMO.

These indices were used to assess historical climate trends in the Arab region in the journal article by Donat et al. "Changes in extreme temperature and precipitation in the Arab region: long-term trends and variability related to ENSO and NAO" published in the *International Journal of Climatology* (2013), which was prepared in cooperation with Arab Meteorological Offices. Based on the analysis of the findings and the work conducted under RICCAR, two additional climate change indices have been formulated and presented in the table above, namely SU35 and SU40. This is in order to better reflect regional specificities associated with warmer temperatures in the Arab region, as the indicator for summer days adopted by ETCCDI was limited to measuring the number of summer days when the daily maximum temperature exceeds 25°C.

Table 1. Climate Change Indices

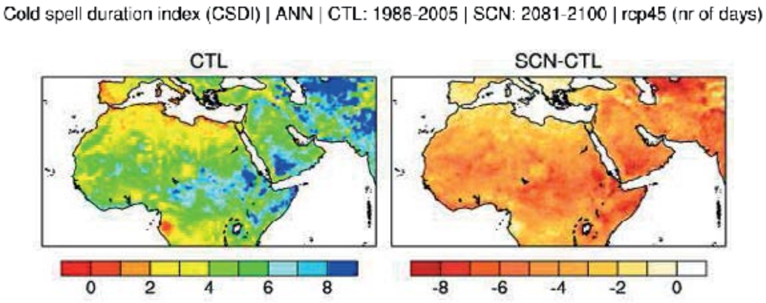
Indices	Code	Definition
Changes in Temperature Indices		
Cold spell duration index	CSDI	Annual number of days with at least 6 consecutive days when Tmin < 10th percentile
Summer days with Tmax > 35°C	SU35	Annual number of days when Tmax > 35°C
Summer days with Tmax > 40°C	SU40	Annual number of days when Tmax > 40°C
Tropical nights	TR	Annual number of days when Tmin > 20°C
Changes in Precipitation Indices		
Maximum length of dry spell	CDD	Maximum annual number of consecutive dry days (i.e. when precipitation < 1.0 mm)
Heavy precipitation days	R10mm	Annual number of days when precipitation ≥ 10 mm)
Very heavy precipitation days	R20mm	Annual number of days when precipitation ≥ 20 mm)

Source: *Based on work conducted by the WMO Expert Team on Climate Change Detection and Indices (ETCCDI). 2009. ETCCDI/CRD Climate Change Indices: Definition of the 27 core indices. Available at: http://etccdi.pacificclimate.org/list_27_indices.shtml.*

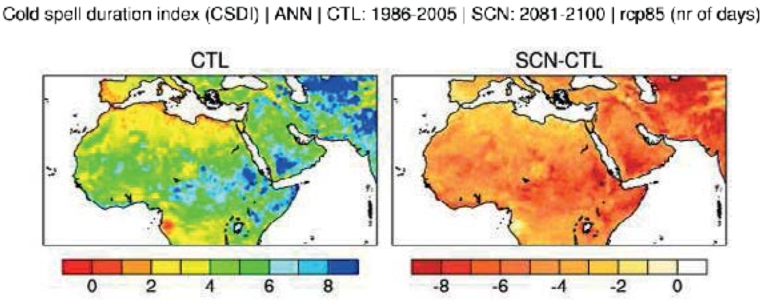
Changes in Extreme Temperature

Figure 6. Change in the Cold Spell Duration Index (CSDI) for the time period 2081-2100 from the baseline period 1986-2005 for RCP 4.5 and RCP 8.5.

RCP 4.5



RCP 8.5

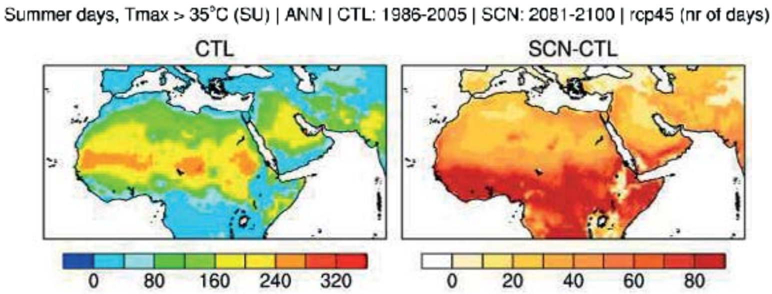


The results show decreasing trends in the cold spell in the entire Arab region. There is a larger decrease for RCP 8.5 with maximum values at the south western region of the Arabian Peninsula and at the headwaters of the Nile and Tigris and Euphrates river basins.

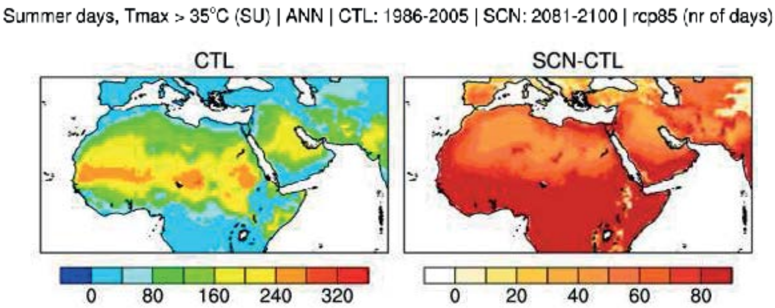
Changes in Extreme Temperature

Figure 7. Change in the Summer Days with Tmax> 35°C (SU35) for the time period 2081-2100 from the baseline period 1986-2005 for RCP 4.5 and RCP 8.5.

RCP 4.5



RCP 8.5

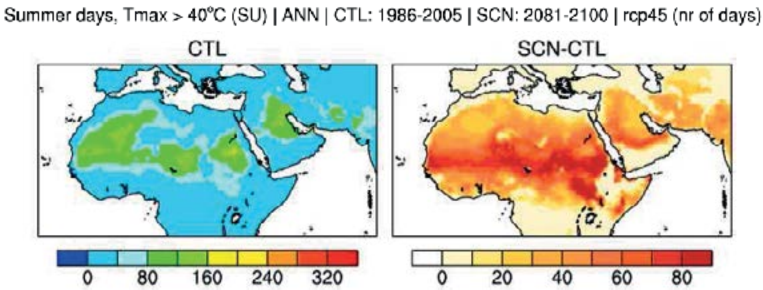


The results show significant warming trends for both scenarios reaching up to 80 days in the southern Arabian Peninsula and the western coast of Africa for the RCP 8.5.

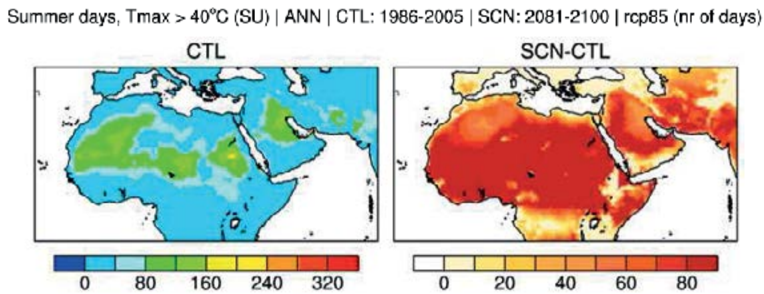
Changes in Extreme Temperature

Figure 8. Change in the Summer Days with Tmax> 40°C (SU40) for the time period 2081-2100 from the baseline period 1986-2005 for RCP 4.5 and RCP 8.5.

RCP 4.5



RCP 8.5

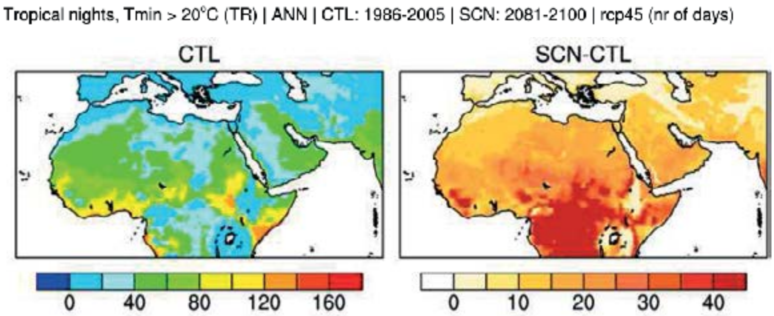


The results show strong projected warming in the Sahara and central Arabian Peninsula areas for RCP 8.5, indicating that the increase in the extreme temperature on the coastal areas would be lower than the central parts of the region for both scenarios.

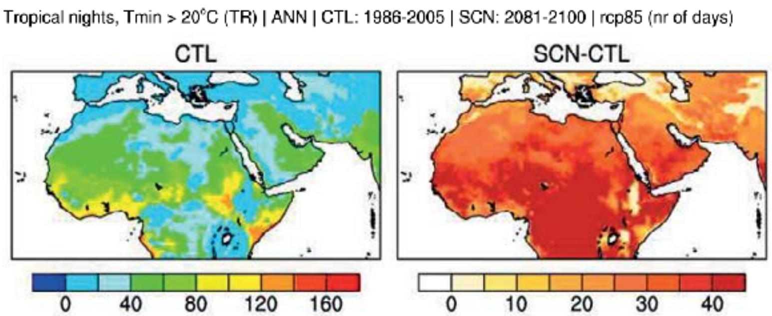
Changes in Extreme Temperature

Figure 9. Change in Tropical Nights (TR) for the time period 2081-2100 from the baseline period 1986-2005 for RCP 4.5 and RCP 8.5.

RCP 4.5



RCP 8.5

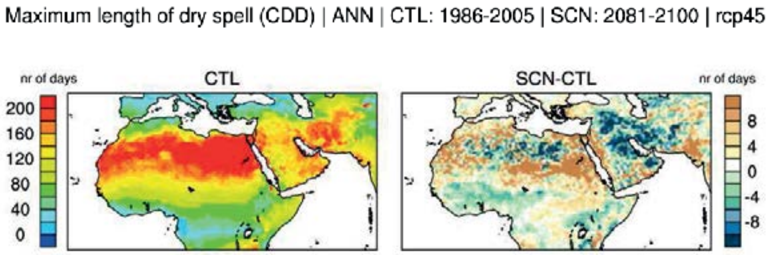


The results show significant warming trends with a projected increase in tropical nights mainly in central Africa and southern Arabian Peninsula regions particularly for RCP 8.5.

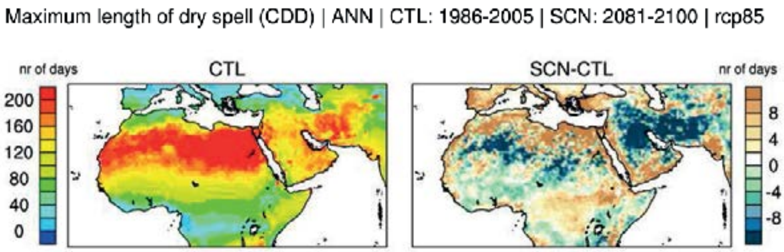
Changes in Extreme Precipitation

Figure 10. Change in the Maximum Length of Dry Spell (CDD) for the time period 2081-2100 from the baseline period 1986-2005 for RCP 4.5 and RCP 8.5.

RCP 4.5



RCP 8.5

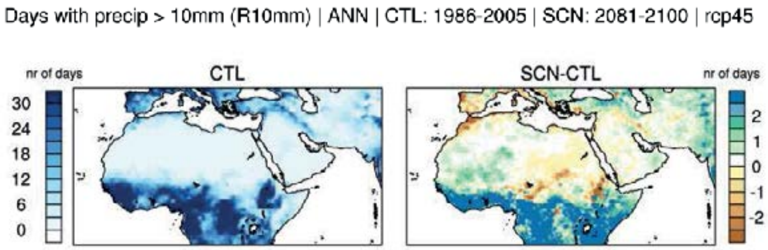


The projections show trends towards drier conditions with an increase in number of dry days specifically for the Mediterranean, as well as the western and northern parts of the Arabian Peninsula by the end of the century. This indicates that the dry season (summer) is extending in length especially in these areas.

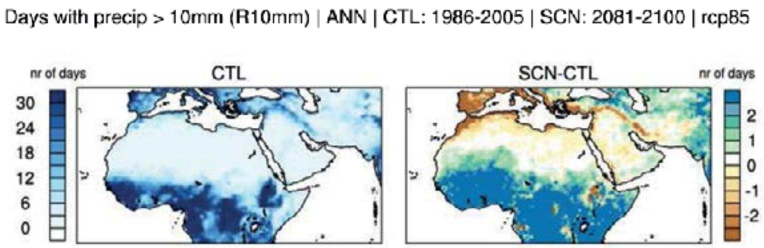
Changes in Extreme Precipitation

Figure 11. Change in Heavy Precipitation Days (R10mm) for the time period 2081-2100 from the baseline period 1986-2005 for RCP 4.5 and RCP 8.5.

RCP 4.5



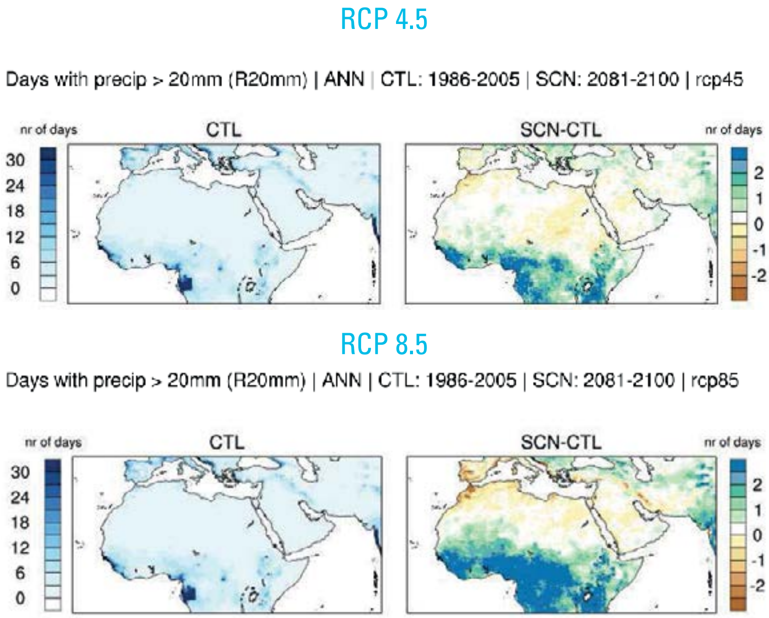
RCP 8.5



The figures show decreasing trends, indicating a projected overall reduction in rainy days with intensity greater than 10 mm for the Arab region.

Changes in Extreme Precipitation

Figure 12. Change in Very Heavy Precipitation Days (R20mm) for the time period 2081-2100 from the baseline period 1986-2005 for RCP 4.5 and RCP 8.5.



The results are similar to the R10mm showing decreasing trends and an overall reduction in rainy days with an intensity greater than 20 mm for the Arab region.

Conclusion

The analysis of the projected climate parameters and the extreme climate indices has shown:

- A consistent warming trend with a general increase in the frequency of warm days and longer summer periods across the Arab region.
- The precipitation trends are more variable than those related to temperature; drier conditions are more dominant in the northern Maghreb.
- The occurrence of extreme precipitation reflects a stronger spatial variability than those shown in the temperature extremes.
- Additional climate change indices can be developed to analyze maximum temperatures, heat waves, sandstorms, flash floods and other extreme climate conditions based on the outputs of regional climate models and hydrological models applied in RICCAR. This will improve the reflection of regional climate specificities of concern to the arid and semi-arid Arab region.
- Post-processing of regional climate modeling outputs using DBS tools corrects for biases and renders projections suitable for use in hydrological models.
- RICCAR outputs for the Arab Domain can be validated and complemented by regional climate modeling outputs generated for different modeling domains, such as the Africa Domain and the Mediterranean Domain, provided that care is made to compare between consistent outputs, i.e., raw RCM projections or bias corrected outputs.

RICCAR Partners

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- Climate Services Center (CSC) – *Germany*

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