Comparison of 3km and 8km-resolution climate simulations with COSMO-CLM for the recharge zone of the Western Mountain Aquifer until 2070

Key findings

- Seasonal temperature changes (increase of up to 2.2 °C in winter and fall) show minimal differences in distribution and magnitude between the ISR3 and ISR8 data.
- Projected seasonal changes in precipitation show up to 59% (ISR3) and 42% less precipitation (ISR8) in fall.
- The extreme indicators for temperature show similar distribution patterns for ISR3 and ISR8 with more apparent changes in the ISR3 data.
- The extreme indicators for maximum and mean precipitation show strongly divergent distribution patterns between the ISR3 and ISR8 data.

Motivation

The Western Mountain Aquifer (WMA) is one of the most important groundwater resources for Israel and the West Bank. It has been intensively used for decades due to continuous population growth, industrial progress, and extensive agricultural production. The WMA's recharge zone is spatially restricted to the eastern part of the aquifer area along the north-south striking mountain ranges. The climate is characterized by extremely low precipitation in the hot summer months and a highly variable geographical distribution of precipitation, with 700 mm per year in the north and 200-300 mm in the south. Investigations of potential climatic changes in the recharge zone could provide indications of the long-term recharge capacity of the WMA. High-resolution climate projections for Israel have been published by Hochman et al. (2018). These showed an increase in temperature of up to 2.5°C in winter and a decrease in seasonal precipitation for the northern and central regions of up to 40% in fall. In addition to these initial studies, higher-resolution climate projections were prepared as part of the MedWater project specifically for the recharge zone of the WMA.

Methodology

To evaluate future climatic conditions of the WMA's recharge zone, two sets of daily climate data (1981-2070, IPCC RCP4.5) with resolutions of 0.0025° (about 3km) (ISR3) and 0.0715° (about 8km) (ISR8) were provided by the Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC). The data are based on the Coordinated Regional Downscaling Experiment Middle East North Africa (MENA-CORDEX) (Bucchignani et al., 2018) and have been produced by the regional climate model COSMO-CLM (Rockel et al., 2008). For the period 2041-2070, several indicators of seasonal climate change and extreme events (Table 1) were determined for the ISR3 and ISR8 data and compared to a 1981-2010 hindcast period. The calculation was based on the Expert Team on Climate Change Detection and Indices (ETCCDI) indicators. The parameters used for calculating the indicators were average (T_{2m}), minimum (T_{min}), and maximum (T_{max}) temperature 2m above the surface, and precipitation (P). Data was processed with the programming language Python. The generated raster files were evaluated for the recharge zone using the Zonal Statistics Tool in QGis.

COSMO-CLM

The COSMO-CLM (Consortium for Small-scale Modelling model in Climate Mode) is a unified model system for numerical weather prediction (NWP) and regional climate modeling (RCM) used by various national weather services. It is employed at a spatial resolution between 1 and 50km. The model was originally developed by the German Meteorological Service (DWD) and the COSMO consortium. Later, a climate mode (CLM) with the extensions necessary for climatological applications was provided by the CLM community.

MedWater – Sustainable management of politically and economically highly relevant water resources in hydraulically, climatically, and ecologically dynamic carbonate aquifers of the Mediterranean.
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MedWater

Table 1: List of ETCCDI indicators calculated with precipitation and temperature data

Indicator	Description	Units
Precipitation		
R10	Number of days with precipitation ≥10 mm/day	days/year
R20	Number of days with precipitation ≥20 mm/day	days/year
CDD	Maximum number of consecutive dry days (<1 mm)	days/year
CWD	Maximum number of consecutive wet days (>1 mm)	days/year
Rx1day	Maximum of daily precipitation	mm/day
SDII	Mean precipitation on wet days (>1 mm)	mm/wet day
Temperature		
SU	Summer days—annual count of days when the daily T_{max} >25 °C	days/year
TR	Tropical nights—annual count of days when the daily T_{min} >20 °C	days/year
TNn	Annual minimum value of daily T_{min}	°C
TXx	Annual maximum value of daily T_{max}	°C

Results

The following results represent a selection of seasonal parameters and indicators that provide important information on climate change in the WMA's recharge area. The ISR3 and ISR8 data show siginificant differences in the distribution and magnitude of calculated indicator values. Evaluation of the average seasonal temperatures shows for both the ISR3 and ISR8 data a general temperature increase of up to 2.2°C in winter and fall (Figure 1a). For the average seasonal precipitation, the ISR3 projection shows a significant precipitation decrease of up to 59% in the fall compared to 42% in the ISR8 projection (Figure 1b). Deviations are seen in the maximum number of TR with 58 days per year (ISR3) as opposed to 45 days (ISR8) in the northern part (Figure 1c). The CDD in winter is on average 1 day higher in the ISR3 data than in the ISR8 data. Large deviations between the ISR3 and ISR8 data occur for the Rx1Day. Figure 1d shows a projected change in the maximum value for RX1Day of 55 mm/day as opposed to 0.5 mm/day (ISR8) and in the minimum value of -31 mm/day as opposed to -14 mm/day (ISR8). The SDII for the ISR3 data shows projected changes in the maximum value of up to 2mm/wet day, whereas no positive change is predicted for the ISR8 data, and projected changes in the minimum value with -3.6 mm/wet day (ISR3) as opposed to -1.6 (ISR8).

Application

The high-resolution ISR3 projection shows an even more accurate trend of climate change for extreme indicators of temperature and precipitation and predict extreme precipitation events not simulated in the ISR8 data. The changing future precipitation patterns, longer dry spells, and higher temperatures in the precipitation-rich months, with consequently higher evaporation rates, demonstrate the need for action. With the incorporation of ISR3 data into the groundwater models developed in MedWater, accurate recharge rates can be projected in the long-term. In addition, groundwater pumping can be adjusted in scenario analyses to show the response of the WMA with respect to changes in groundwater levels and thus develop long-term management strategies.

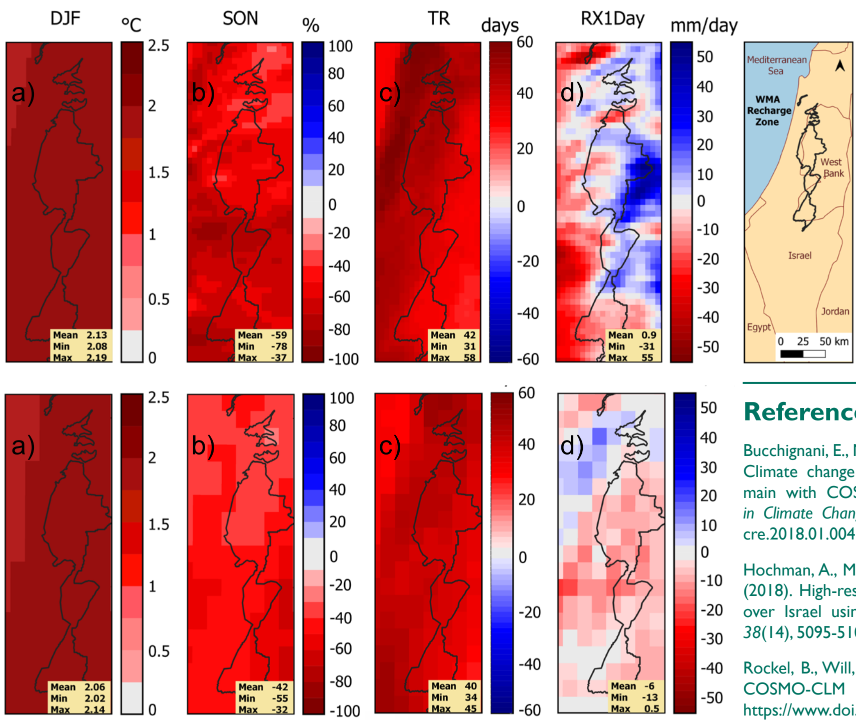

Figure 1: ISR3 (upper row) and ISR8 (lower row) projections for change in seasonal mean temperature and precipitation and extreme indicators, 2041–2070 minus 1981–2010. a) shows the average temperature change in winter (Dec-Jan-Feb), b) the average precipitation change in fall (Sep-Oct-Nov), c) the number of tropical nights (TR), and d) the maximum of daily precipitation (Rx1Day).

References

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