# Dynamical downscaling in the Eastern Mediterranean and the Middle East using PRECIS Regional Climate Model

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Keywords: dynamical down-scaling, climate change, feedbacks

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The Eastern Mediterranean and the Middle East (EMME) are likely to be greatly affected by climate change, associated with increases in the frequency and intensity of droughts and heat waves. Since the region is socio-economically diverse and extreme climate conditions already common, the impacts will be disproportional. The variable topography (land alternating with major water bodies) and steep orography (from deserts to mountains several Km high) make the EMME a complex region hard to be well represented in the current Atmosphere-Ocean General Circulation Models (AOGCM) resolutions. In addition, this part of the world is an atmospheric circulation crossroad (influenced by North Atlantic and South Asian flows) so it is essential to create simulations using mesoscale-regional models of finer resolution, where local weather features can be simulated more realistically.

We performed simulations using the PRECIS (Providing Regional Climates for Impact Studies) regional climate model, based on the United Kingdom (UK) Met Office Hadley Centre HadRM3P model (Jones et al. 2004) for the 20th and 21st centuries. PRECIS is freely available and has been ported to run on a PC (under Linux) with a simple user interface, so that experiments can easily be set up over any region of the globe. It applies the same formulation of the climate system as its parent AOGCM, HadCM3 (Collins et al. 2005), which is also used to provide the lateral boundary conditions, and is driven by the IPCC SRES A1B emissions scenario. PRECIS accounts for the radiative forcing by changing concentrations of greenhouse gases, including ozone, and sulfate aerosols, and for interactions with the surface and deep soils. Results presented here are obtained from a PRECIS run over the period 1950–2099, applying a horizontal resolution of 0.22° latitude and longitude (about 25 km) and 19 vertical levels (Figure 1).

In this paper we briefly present some of the future climate projections from our simulation with focus in temperature and precipitation. Moreover, trying to understand better the feedback mechanisms that may contribute to these regional climate changes we have explored the role of soil moisture in the warming of the region.

We evaluate the model output with meteorological observations from the Climatic Research Unit (CRU) TS3.0 data (http://badc.nerc.ac.uk/data/cru/). This dataset offers the most complete, consistent and updated compilation of gridded precipitation and temperature data at the global scale in general and for the Middle East in particular (Tanarhte et al 2011). The 0.5° resolution data cover the period 1901-2006. The monthly time series of various climate variables include air temperature, precipitation, and vapor pressure, interpolated from surface observations.

A comparison between the PRECIS and CRU 30-year (1961-1990) climatology is presented in figures 2 and 3. The upper panels of figure 2 show the mean summer (JJA) maximum temperature (TX). In general, the model represents sufficient the CRU climatology. PRECIS overestimates summer TX mostly in the Arabic peninsula. The lower panels depict the mean winter (DJF) TN for the 1961-1990 period. Again the spatial patterns of the model and the observational dataset are

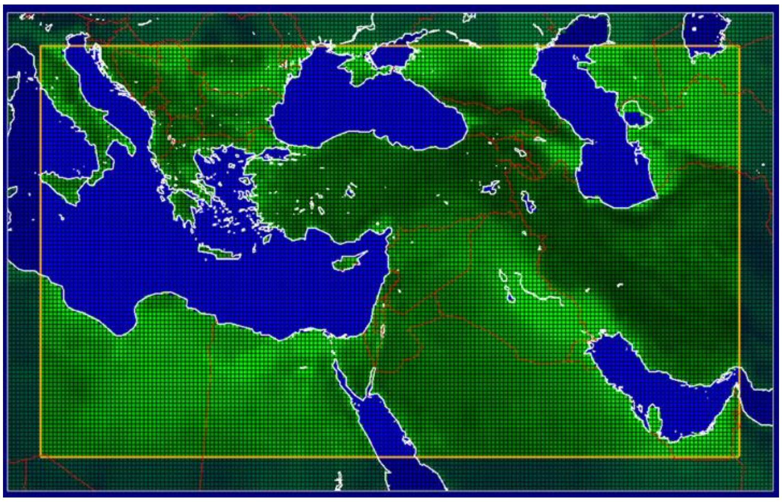

Figure 1. Geographic area and 0.22° latitude/longitude grid coordinates of the PRECIS regional cimate model, applied for the period 1950–2099. The outer eight rows of grid cells are a “buffer zone” (not included in our analysis) to circumvent inconsistencies between the global and regional modelsThe EMME domain

very similar. Though, a small underestimation of the model for winter TN is observed in the Arabian Peninsula.

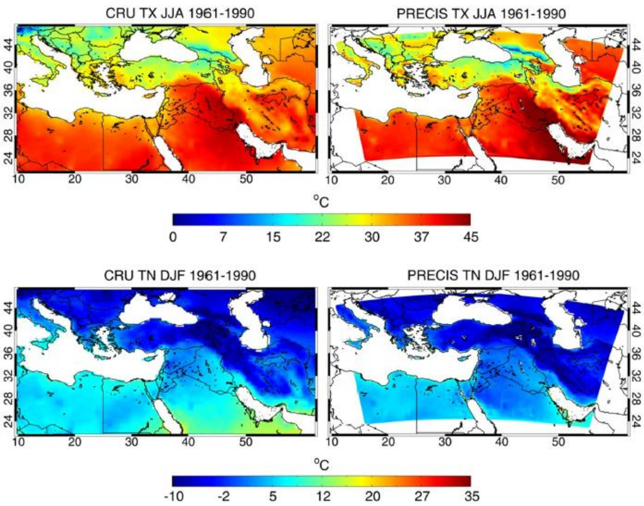


Figure 2. Patterns of the mean summer maximum (JJA, top) and mean winter minimum (DJF, bottom) temperatures. TX and TN respectively. The left panels are based on CRU data and the right panels on PRECIS output (Lelieveld et al 2012a)

Average winter and summer precipitation (RR) are presented in figure 3. During winter PRECIS is wetter than CRU. Because of the paucity of rain gauge data in many mountainous regions, however, it is not certain to what extent PRECIS overestimates RR. For most of the region summers are dry. Only in some continental locations in the Balkans and the Caucasus convective storms in summer contribute significant amounts of rain. In the southern part of the domain, rainfall deficits and summer droughts are commonplace.

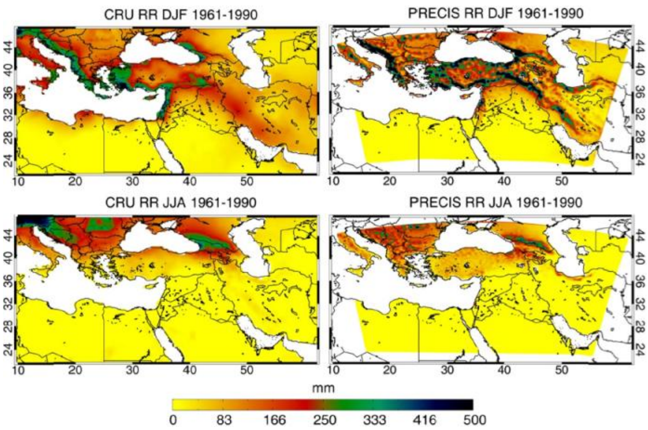


Figure 3. Patterns of the mean summer (JJA, top) and mean winter (DJF, bottom) precipitation (RR). The left panels are based on CRU data and the right panels on PRECIS output (Lelieveld et al 2012a)

More extensive comparison of the PRECIS output against point observations in the EMME and ensemble model output for the European part of the domain, with a focus on temperature, precipitation and weather extremes can be found in Lelieveld et al. 2012a and 2012b.

Future climate projections from PRECIS model are presented in the following figures. Summer TX warming ranges from 3-5°C in the mid-century period (2040-2069) to 3.5-7°C by the end of the century (2070-2099). Winter TN warming is less in this region with a maximum 3-4°C by the end of the century. In each period, this warming is more spatially uniform for winter TN, while for TX it is most pronounced at latitudes north of 36°-38°N (reaching 6-7°C in the Balkans, Turkey and the Caucasus by 2070-2099) and weaker in the southern EMME (~3.5°C in Libya, western Saudi Arabia and southern Iran).

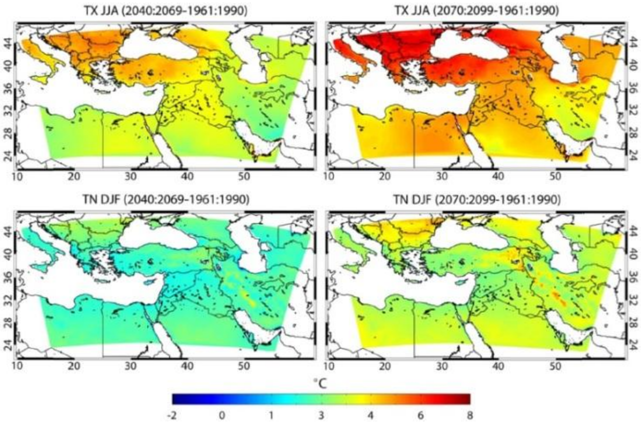


Figure 4. Patterns of changing mean summer maximum and mean winter minimum temperatures, TX (top) and TN (bottom), respectively. The left panels show the mean changes for 2040-2069 and the right panels for 2070-2099 relative to the 1961-1990 control period (Lelieveld et al 2012a)

The modeled changes in precipitation exhibit a large variability in space (Figure 5). The strongest drying is projected around the eastern Mediterranean, the coastal Levant and North Africa (–10% to –25% in 2040-2069 and –25% to –35% in 2070-2099). Another notable feature is the projected, statistically significant, strong increase in precipitation throughout the southeastern part of the domain, related to the northward expansion of moisture from the tropical rain belt. Note, however, that these relative changes should not be over-interpreted since rainfall during the control period in the southern EMME is minor.

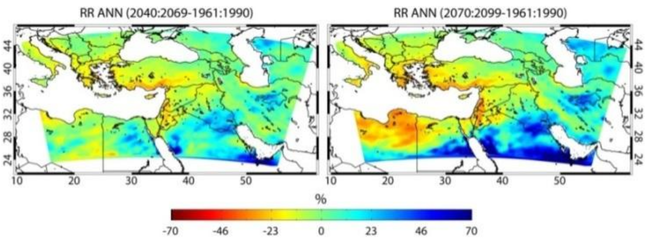


Figure 5. Same as figure 4 for mean annual precipitation (Lelieveld et al 2012a)

The annual number of days with less than 1 mm precipitation for the 1961-1990 period exceeds 300 over the southern and eastern part of the domain (not shown), demonstrating the near-absence of rainfall. In future (figure six – right panel) this is not expected to change much apart from a small decrease in the number of dry days (up to ~10 days/year) around the Persian Gulf. In the northern EMME, mainly in the Balkans, Turkey, Cyprus, Lebanon and Israel, the number of dry days may increase (10-20 days/year).

The number of days with heavy precipitation (>10 mm/day) is expected to decrease in the high-elevation areas of the EMME (figure 6 – left panel).

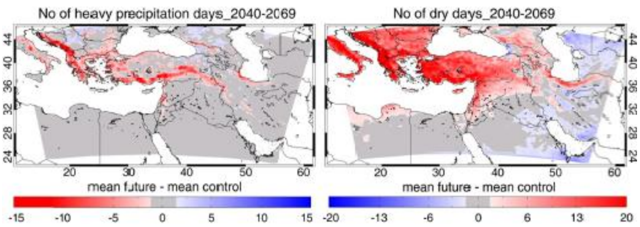


Figure 6. Patterns of changing number of days per year with heavy precipitation (RR>10mm, left panel) and number of dry days (RR<1mm, right panel), calculated from PRECIS output, showing the mean changes for 2049-2069 relative to the control period 1961-1990 (Lelieveld et al 2012a)

Trying to attribute the north-south gradient of climate warming (figure 4 – top panels) we explored the connection between soil moisture and temperature. Regions of higher warming concur with regions of more pronounced drying considering precipitation amounts (not shown) and not percentages. Such regions occur in northern EMME. A well-known type of feedback involves soil moisture – atmosphere interactions. When the soil water content and evapotranspiration are decreased, as our projections suggest for north EMME, near surface air temperatures may be enhanced due to reduced evaporative cooling.

We present here a common diagnostic of the land-atmosphere coupling, the correlation coefficient between evapotranspiration (ET) and near surface air temperature (Seneviratne et al. 2010; Jaeger and Seneviratne 2011). When ET is controlled by soil moisture a strong anti-correlation is expected. On the other hand, when there is abundant soil moisture and evaporation is controlled by atmospheric conditions the correlation is positive. Low correlations indicate no coupling. Figure 7 depicts the correlation coefficients between summer ET and TX for the 1951-2000 period. Significant negative correlations that indicate strong connection are found in the regions that may experience higher warming (Italy, Balkans, Anatolia, Caucasus).

In addition, we created composite maps of TX (figure 8) trying to highlight the effect of extreme dry and wet years. The mean TX difference for the ten driest minus the ten wettest years has high positive values again in the northern part of our study area indicating there that during years of soil moisture deficits TX is enhanced.

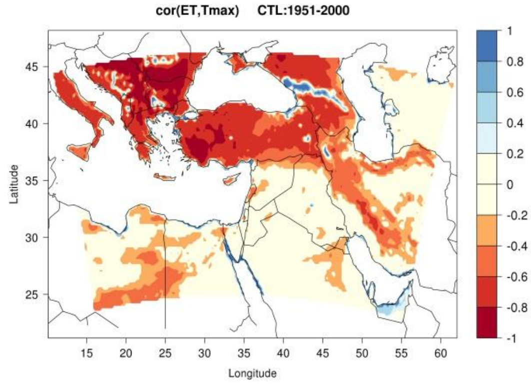


Figure 7. Correlation coefficients between maximum temperature and evapotranspiration for the 1951-2000. Significant correlations (95% confidence level) are colored red and blue (Zittis et al 2012)

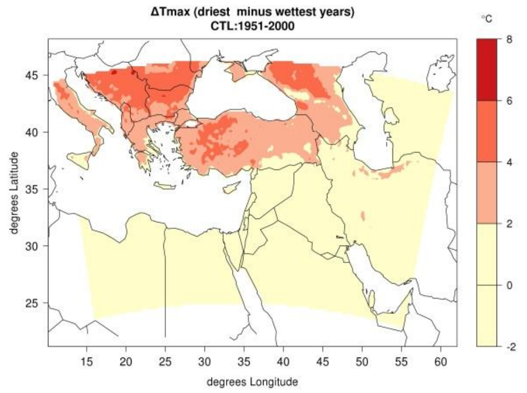


Figure 8. Composite analysis of TX. The difference between the ten driest and ten wettest years is shown for the period 1951-2000 (Zittis et al 2012)

**Acknowledgements.** The research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Programme (FP7/2007-2013) / ERC grant agreement n° 226144 (C8 Project).

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