High-resolution projection of climate change over Israel with COSMO-CLM

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Outlook

- Introduction
- COSMO-CLM Configuration and experiment set-up
- Model Evaluation using also detailed Israeli observation data
- Analysis of climate projections over 1981-2070 under IPCC RCP4.5
- Conclusions

Reference papers:

- Hochman A. Bucchignani E. Gershtein G. Krichak SO. Alpert P. Levi Y. Yosef Y. Carmona Y. Breitgand J. Mercogliano P. Zollo AL. Evaluation of regional COSMO-CLM climate simulations over the Eastern Mediterranean for the period 1979 – 2011, *International Journal of Climatology*, 2017. DOI: 10.1002/joc.5232
- Hochman A. Mercogliano P. Alpert P. Saaroni H. Bucchignani E. High-resolution projection of climate change and extremity over Israel using COSMO-CLM, *International Journal of Climatology*, 2018. DOI:10.1002/joc.5714

Introduction

- The main purpose of this study is to employ the COSMO-CLM model in dynamically downscaling the CMCC-CM global model to an 8 km grid resolution over the region of Israel, in order to project average and extreme changes in precipitation and temperature until 2070.
- Climate projections under IPCC RCP4.5 are provided, in terms of average values and extreme events.
- Regional downscaling within the MENA-CORDEX domain is driven by several needs, such as the assessment of impacts on water resources and consequent socio-economic and environmental vulnerability.
- Two reasons motivated our focusing on the south-eastern Mediterranean (Israeli) area: the region is expected to become too hot for humans by 2070; it is characterized by quite frequent torrential rain events and floods, so it is important to prove that the model is able to reproduce the phenomenon.

Simulations over MENA-CORDEX domain

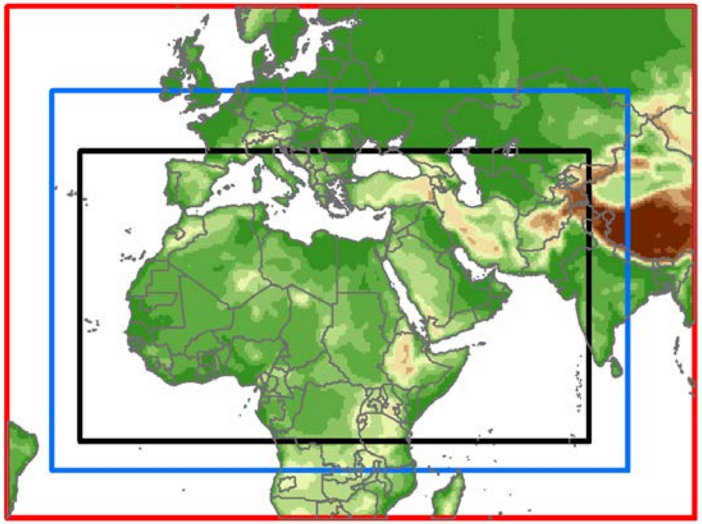
- **COSMO-CLM resolution**: 0.44° (time step 240 s)
  . 0.22° (time step 120 s.)

- **Domain:** 26.40W - 75.24E; 6.60S - 44.88N

- **Validation period**: (1979 spin up) 1980-2011
- **Scenario**: IPCC RCP4.5 2006-2100

- **Forcing data**: - ERA-Interim (resolution of about 80 km)
  - GCM CMCC-CM (res. of about 80 km)

- **Validation with 5 different datasets**:
  - ✓ CRU (resolution 0.5°)
  - ✓ MERRA (resolution 0.66° by 0.5°)
  - ✓ GPCC (resolution 0.5°)
  - ✓ GPCP (resolution 2.5°)
  - ✓ UDEL (resolution 0.5°)

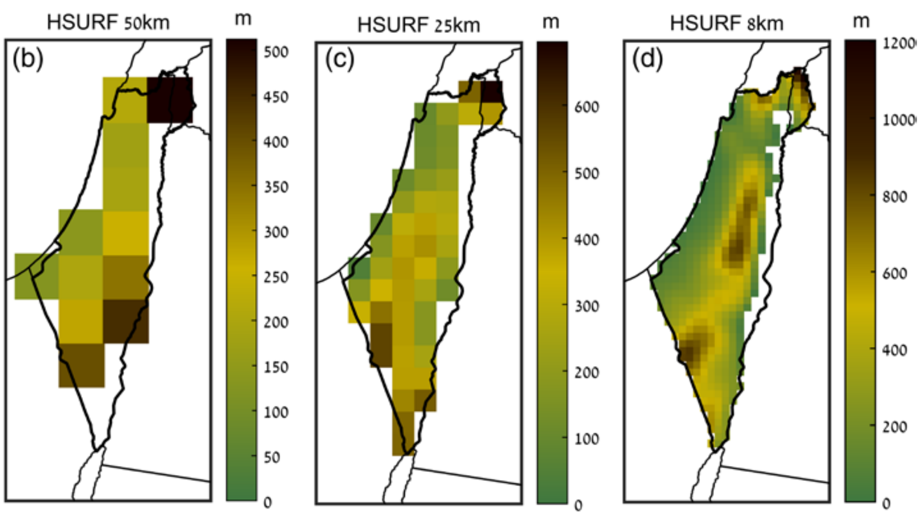


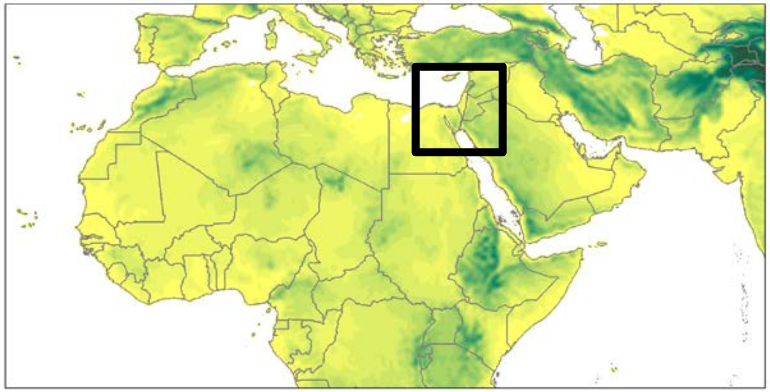
Official MENA physical domain
0.44° computational domain
0.22° computational domain

Results were presented in previous CLM Assemblies

Simulations over Israel

- **COSMO-CLM resolution**: 0.0715° (161 x 161 points; 40 vertical levels)
- **Domain:** 28.10E – 39.45E; 24.01N – 35.45N





- **Hindcast simulation*:** (1979 spin up) 1980-2011
- **Historical simulation**:** (1979 spin up) 1980-2005
- **Scenario RCP4.5** 2006-2070

- **Forcing data**:
  * MENA-CORDEX simulation at 0.22° forced by ERA-Interim
  ** MENA-CORDEX simulation at 0.22° forced by CMCC-CM

Model configuration

Model configuration was optimized with a sensitivity analysis evaluating a set of 26 model runs, testing several parameters. The optimized configuration uses:

- Parameterization of albedo derived from MODIS data.
- NASA-GISS AOD distributions.
- Third order Runge-Kutta scheme for time integration.
- Tiedtke's parameterization convection scheme.

Model version (simulations performed in 2015):

- int2lm_1.19
- cosmo_4.21_clm2

List of extreme indicators (EWI) considered

ETCCDI has defined a set of descriptive indices of extremes, to sample a wide variety of climates. They can be derived from daily values of maximum and minimum temperatures and daily precipitation amounts.

	Label	Description	Unit
PRECIPITATION	**SDII**	Simple Daily Intensity Index – mean precipitation on wet days (> 1 mm)	mm/day
	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
	R10	Number of days with precipitation ≥ 10mm/day	days/year
	R20	Number of days with precipitation ≥ 20mm/day	days/year
	99p	99th percentile of daily precipitation considering only the wet days (> 1 mm)	mm/day
	90p	90th percentile of daily precipitation considering only the wet days (> 1 mm)	mm/day
TEMPERATURE	**ID**	Ice days - Annual count of days when the daily Tmax is below 0°C	days/year
	SU	Summer days - Annual count of days when the daily Tmax is above 25°C	days/year
	90p tmax	90th percentile of daily Tmax	°C
	TXx	Annual maximum value of daily Tmax	°C
	FD	Frost days - Annual count of days when the daily Tmin is below 0°C	days/year
	TR	Tropical nights - Annual count of days when the daily Tmin is above 20°C	days/year
	10p tmin	10th percentile of daily Tmin	°C
	TNn	Annual minimum value of daily Tmin	°C

All the ETCCDI indices were calculated on a yearly basis and then averaged in order to obtain a climatological mean. On the contrary, percentiles were calculated from the distribution representing the whole period.

Observational datasets used for validation

- **<u>APHRODITE</u> dataset (0.05°)**

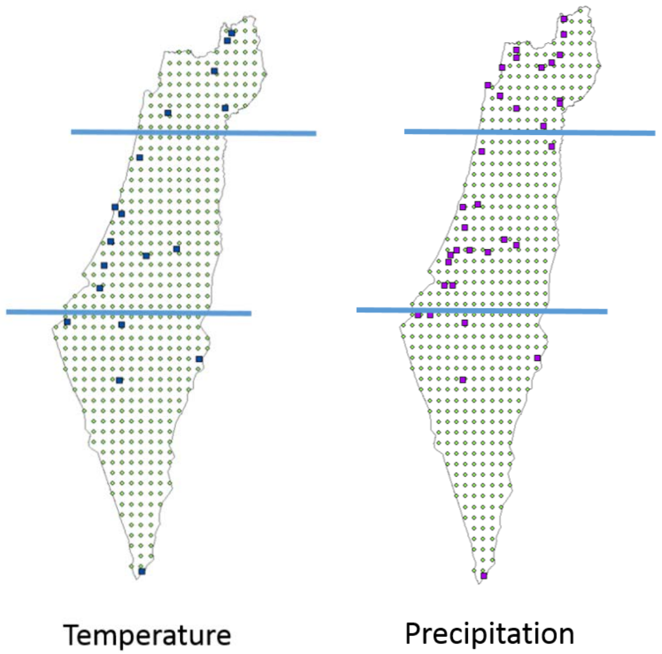
  APHRODITE is a gridded dataset characterized by daily values of precipitation over the EM region. Over Israel the database has a high spatial resolution (around 5 km) and it covers the period 1980-2004. It is based on a dense network of rain gauges in the Middle East.

- **<u>E-OBS</u> v.14 (0.25°)**

  E-OBS (from the EU-FP6 project ENSEMBLES) is a widely used gridded dataset of precipitation and temperature at 0.25° spatial resolution available for the period 1980–2011. It has been designed to provide the best estimate of grid box averages to enable direct comparison with RCMs

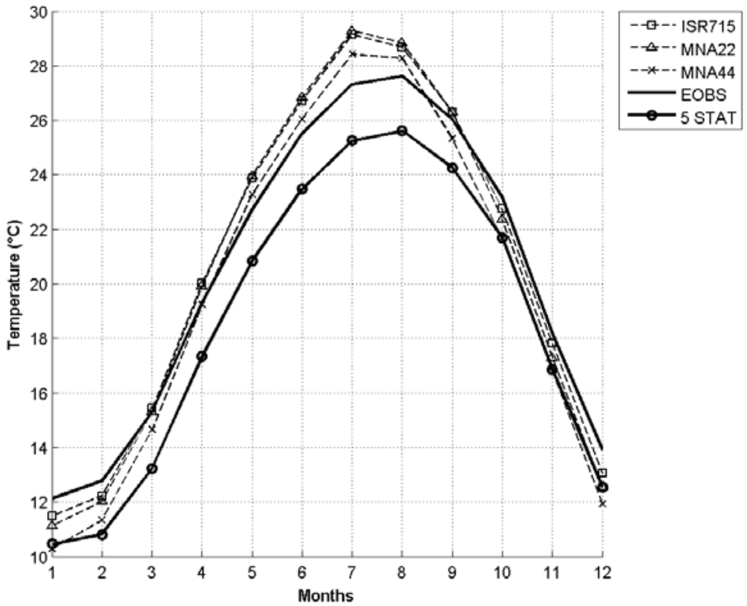
- **<u>IMS (Israel Meteorological Service)</u> dataset**

  Collection of 34 precipitation and 18 temperature stations, covering the period 1980–2011 (https://ims.data.gov.il/).

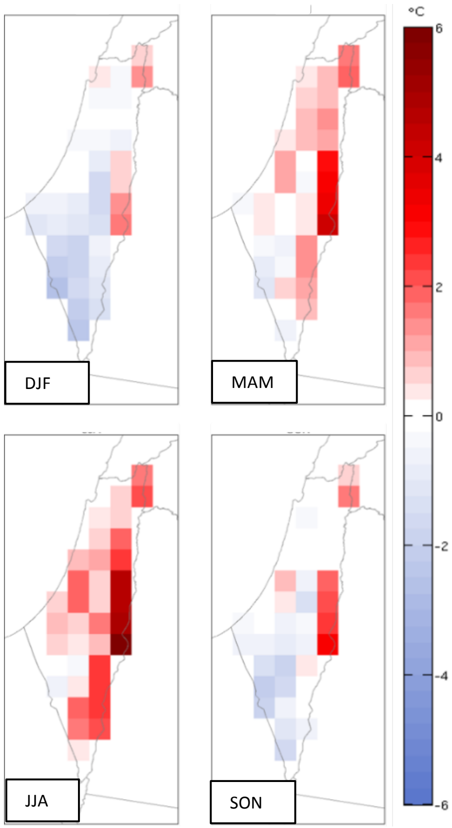


Distribution of available IMS station data for temperature and precipitation, super-imposed over the COSMO-CLM computational grid.
Identification of North, Center and South Israel.

ERA-Interim driven simulation: temperature bias



Annual cycle of temperature averaged over the period 1980-2011. compared also with coarser resolutions and with IMS 5 stations homogenized national average.

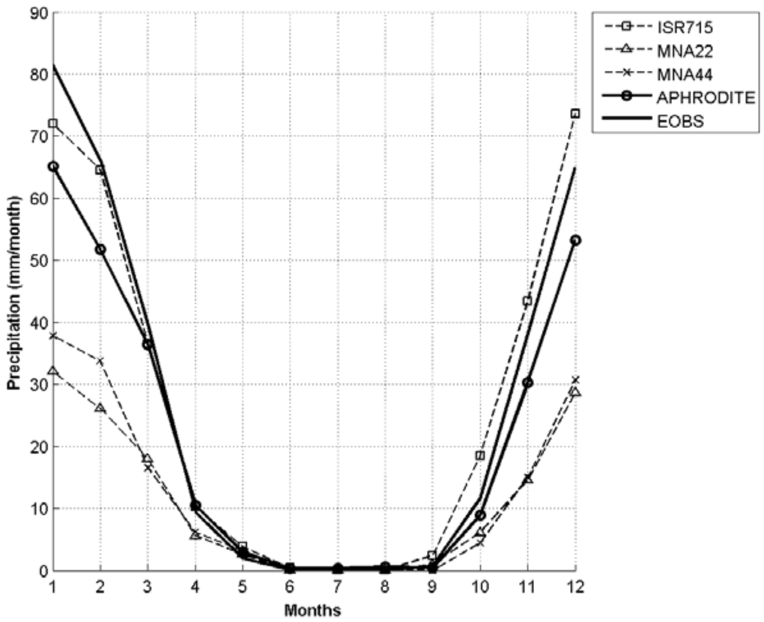


Seasonal bias of temperature (° C) against E-OBS, 1980-2011.

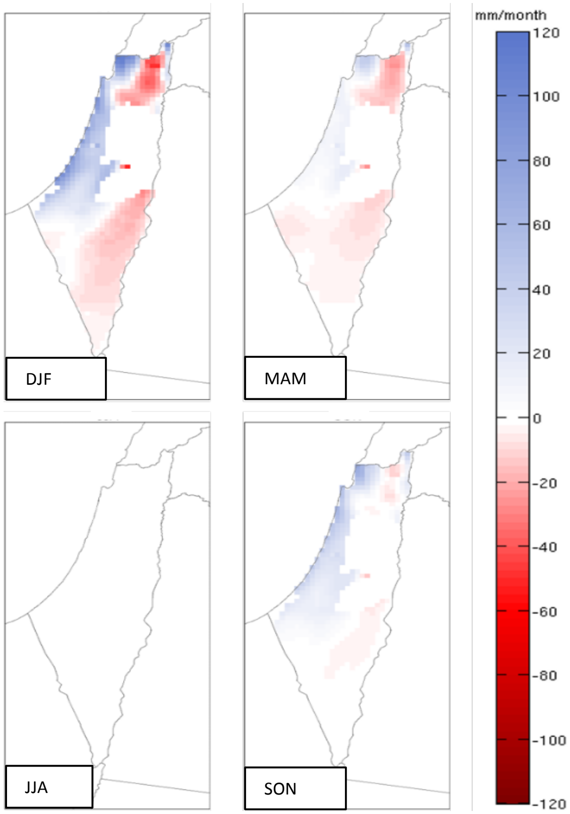
The high-resolution simulation over Israel is not able to improve the performances achieved at lower resolutions. The temperature is generally overestimated, especially in summer months.

General warm bias in the four seasons. A cold bias is recorded in the left part of the domain.

ERA-Interim driven simulation: precipitation bias



Annual cycle of precipitation averaged over the period 1980-2004, compared also with coarser resolutions.

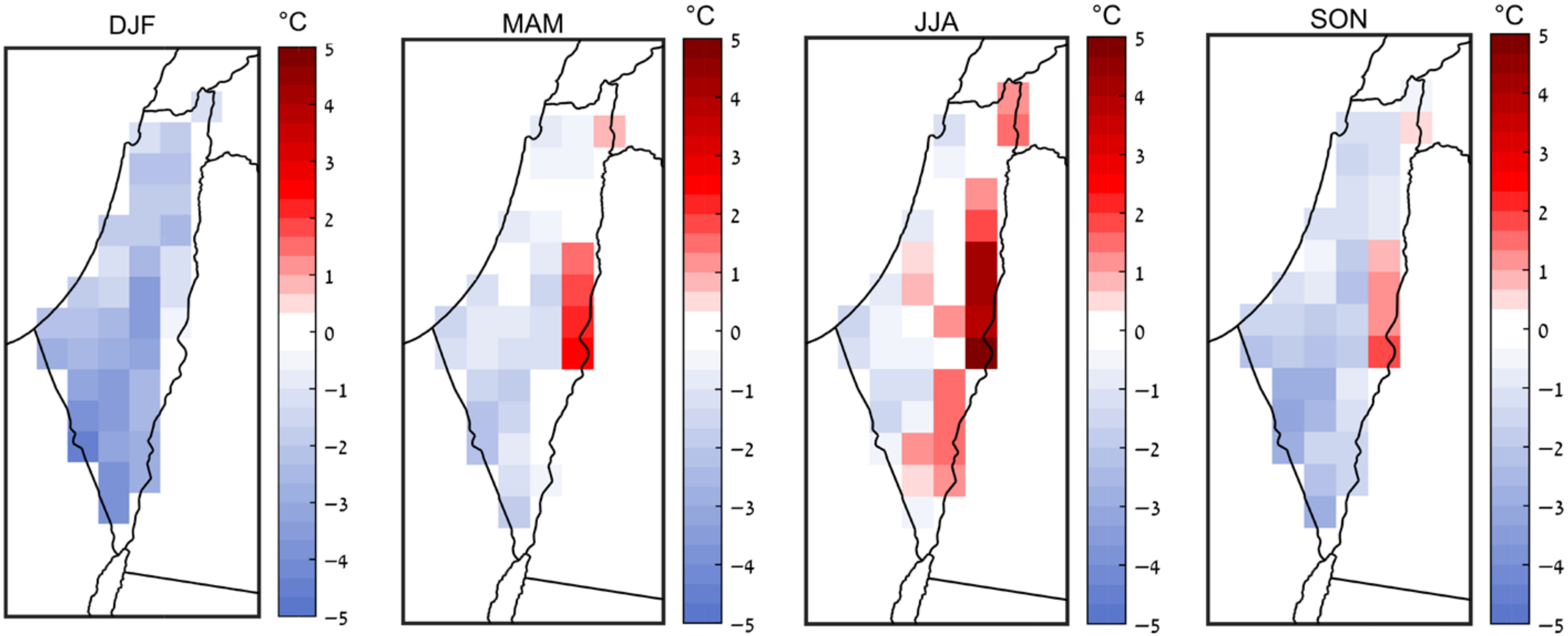


Seasonal bias of precipitation (mm/month) against APHRODITE dataset, 1980-2004.

The high-resolution simulation over Israel provides an excellent agreement with observations, exhibiting a significant improvement with respect to the lower resolution simulations.

Very good agreement, especially in JJA. Small overestimation over the coastal area. Large biases in DJF (most of precipitation occurs in this period).

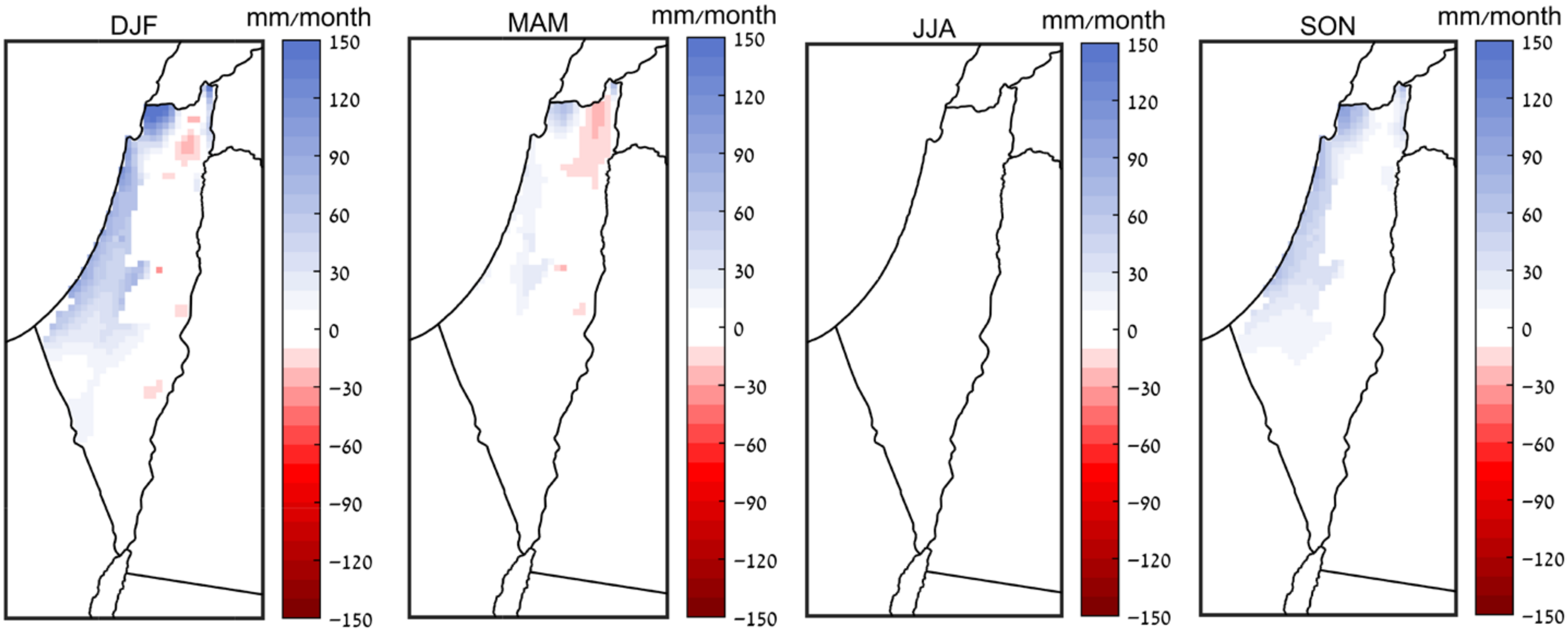
CMCC-CM driven simulation: temperature bias



Seasonal bias for T2m against ***E-OBS dataset****, 1980-2011*

General cold bias in DJF and SON, inherited from the driving GCM. Tendency to overestimation in MAM and JJA. Because the maximum daily T2m during the summer is governed by the Etesian winds together with the sea–land breeze circulation, it is speculated here that the 8 km simulation does not adequately represent the cool sea–land breeze winds, thus producing overestimations, which are smoothed out in the mean daily temperatures.

CMCC-CM driven simulation: precipitation bias



Seasonal bias for precipitation against ***APHRODITE dataset****, 1980-2004*

Generally, a west–east pattern of overestimations in the coastal plains and underestimations in the mountainous regions is found, especially in the winter months (most of precipitation occurs in this period). Furthermore, for the summer season (JJA), in which no significant precipitation events occur, simulations do not show any bias, indicating their good skill.

A verification against **E-OBS** highlights a bias distribution qualitatively similar with the exception of an underestimation in DJF in the eastern part.

T2m climate projections RCP4.5: 2041-2070 vs 1981-2010

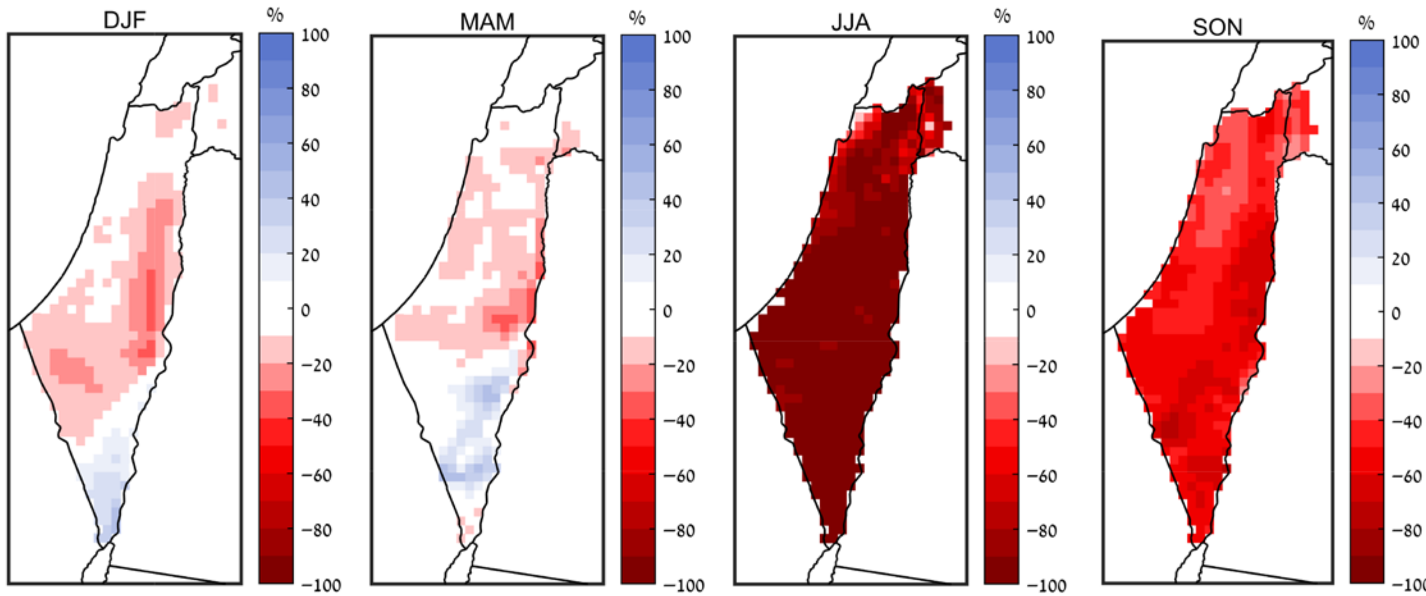
TEMPERATURE

A pronounced increase in the mean temperature is predicted throughout the entire domain with peaks of up to 2.5° C.
In spring a west–east gradient is found showing larger temperature increases in the eastern part of the domain, a trend seen also for the autumn, and partly for the winter.

Earlier GCM and RCM projections suggested that the strongest increase in mean temperature will take place in the summer. Anyway, the 8 km resolution better reproduces the maximum temperature, due to better simulation of the sea–land breeze, especially in summer. This might explain the slightly smaller increase in temperature during the summer, when the sea–land breeze is most effective.

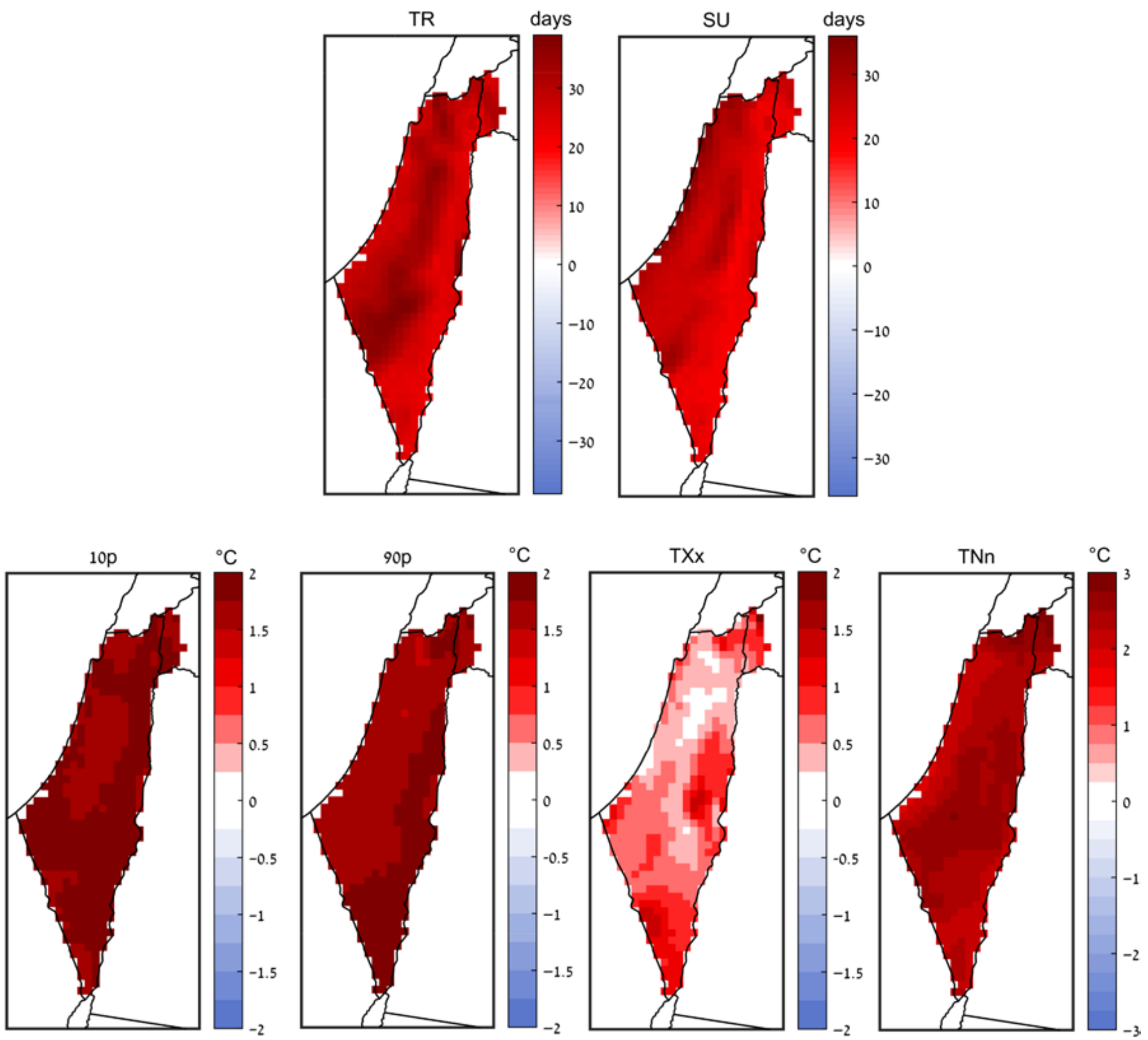
Precipitation climate projections RCP4.5: 2041-2070 vs 1981-2010

PRECIPITATION



The strong decrease shown in JJA is due to very low precipitation values in the past period.
In autumn, a general decrease is well noted over most parts of the domain.
Increases are noted in the most southern arid part for winter and spring.
The dominant reduction trend may be explained by the expected expansion of the Hadley Cell towards the Poles in a warmer climate, and by the increase in the occurrence of the positive phase of the NAO.

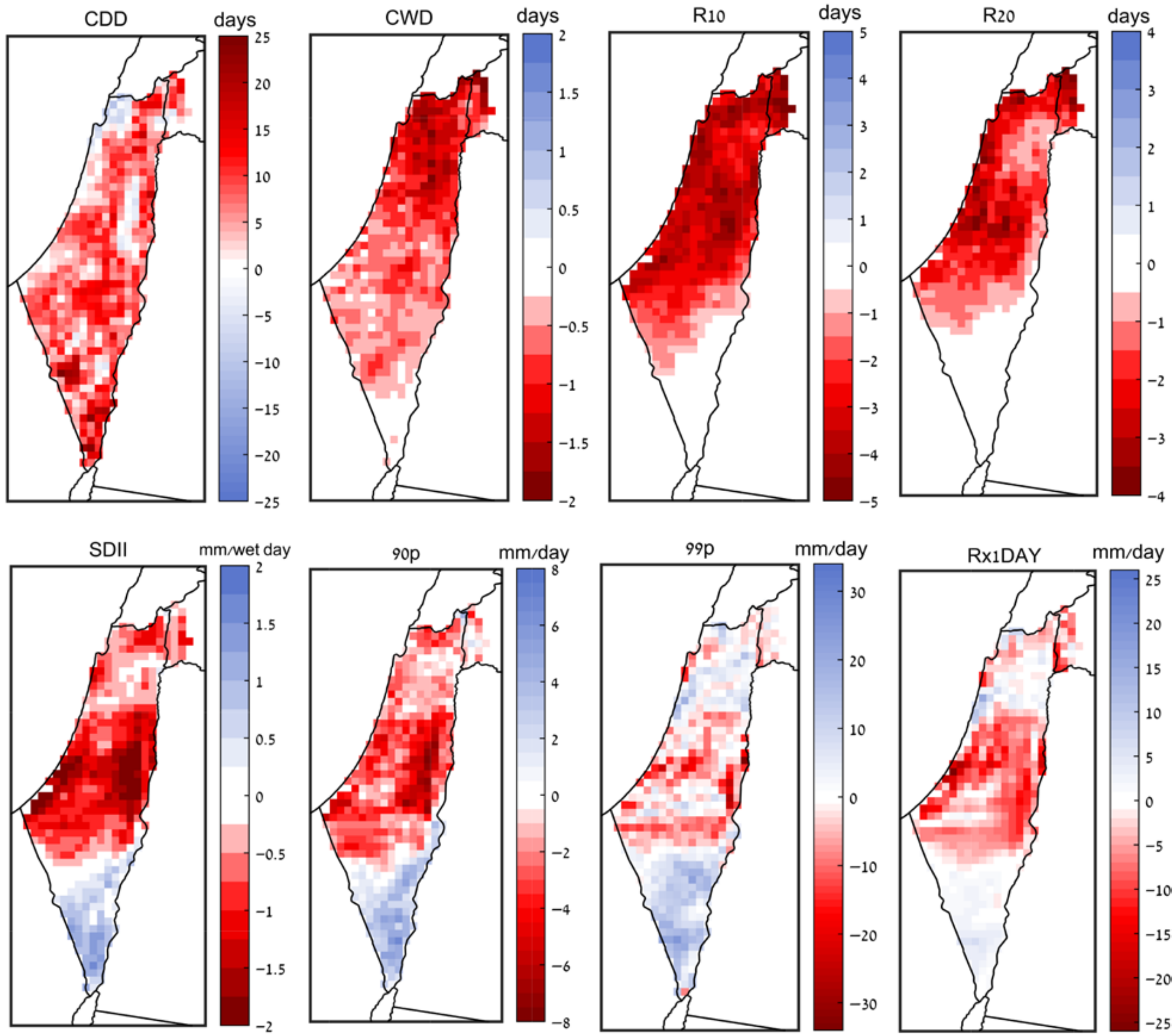
Temperature EWI projections RCP4.5: 2041-2070 vs 1981-2010



A pronounced increase is found in all ETIs. The increase in the annual minimum temperature (TNn) is larger than that of the annual maximum temperature (TXx).

The increase in the number of Tropical Nights and Summer days is larger than 20.

Precipitation EWI projections RCP4.5: 2041-2070 vs 1981-2010



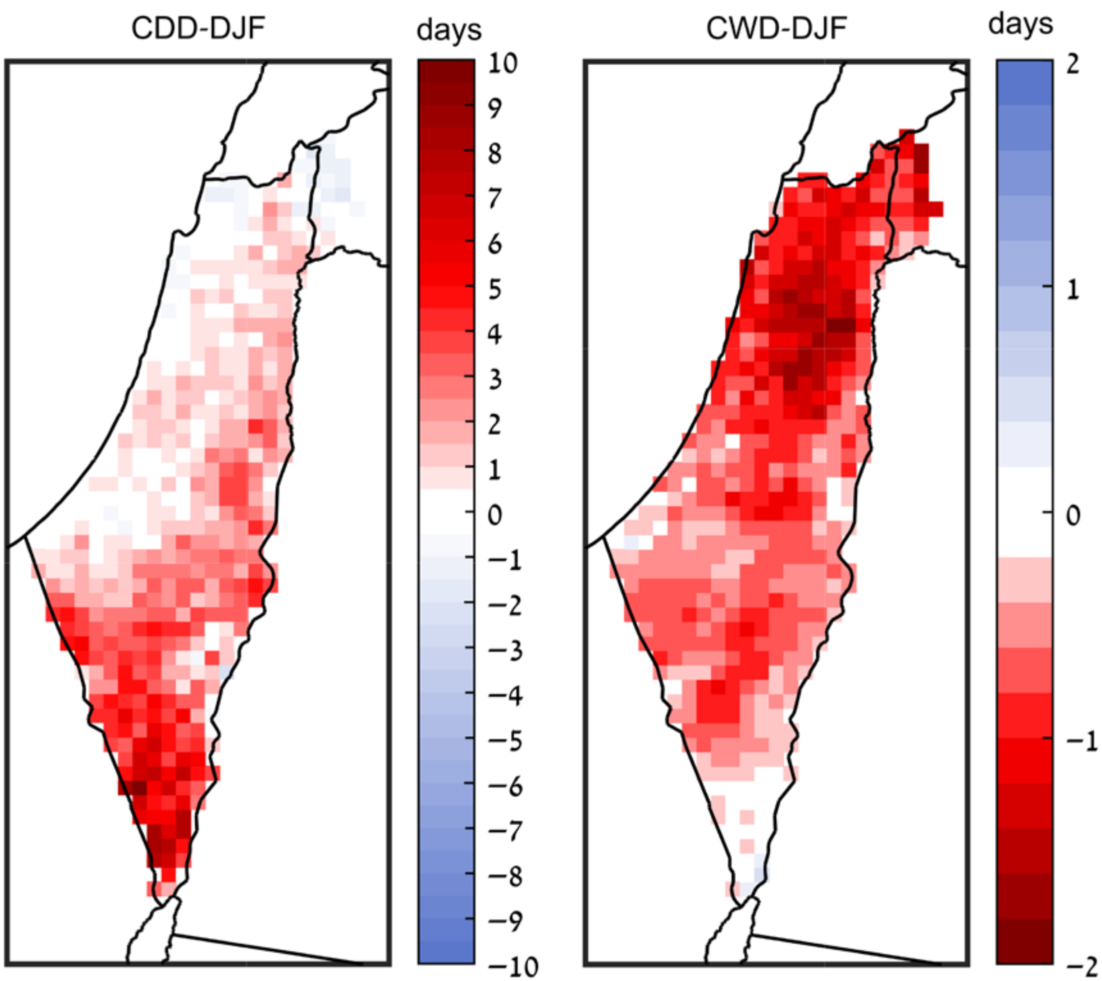
99p is projected to decrease in the center of the country, but to increase in the northern and southern parts.

Rx1day shows a similar spatial pattern as the 99p. A paradoxical increase in extreme daily precipitation is observed, in spite of decrease in total rainfall over the Mediterranean.

R10 and R20 are projected to decrease by 3–4 days.

CDD is projected to increase in most of the region, in accordance with the projection of a shorter winter and longer summer.

Projections for CDD and CWD (winter)



Focus on winter season, having more than two thirds of the annual rainfall.
A general increase in CDD is shown, which is strongest in the southern part of the domain.

For CWD the largest decrease is on the northern part and a slight increase at the southern tip.

This means that shorter wet spells and longer dry periods are projected for the winter season.

Conclusions

- Evaluation reveals a good capability of the model in reproducing the main climate features of the area, thanks to the high resolution and to the optimized model configuration.

- Increasing the spatial resolution from 50 km to 8 km improves the simulation of climate and climate extremes over Israel due to the better representation of topography and the location of land and sea in the model.

- COSMO-CLM is capable of reproducing the EPI with an average absolute bias of 13% for the whole region of Israel.

- Climate projections shows a warming trend leading to an average increase of about 2.5° C from 1980 to 2070. Precipitation are projected to decrease, especially in summer. .

- All extreme temperature indices project a significant increase with larger increase in the minimum temperatures as compared with maximum temperatures.

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Thanks

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