Comparative evaluation of climate simulation results with COSMO-CLM under the frameworks of Med-CORDEX and CORDEX-MENA

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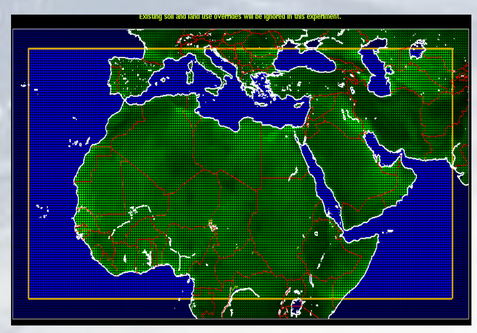
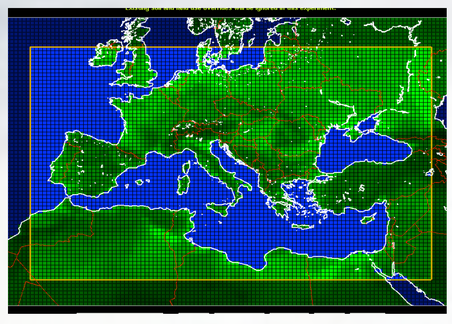
CORDEX-MENA



MED-CORDEX



Introduction

In this analysis we discuss the results of regional climate downscaling (RCD) simulations with COSMO-CLM using two model domains (Med-CORDEX and CORDEX-MENA) (Panel 1). The Med-CORDEX domain covers the MR and neighboring areas (30°-50°N, 10°W-45°E), whereas the MENA-CORDEX includes also a significant part of North-Africa, southern Europe and the whole Arabian Peninsula. Both domains (MED-CORDEX and CORDEX-MENA) employed are typically used in regional climate downscaling (RCD) studies over the MR.

The aim of the study

The aim of the study is two-fold. The first aim is to determine an optimal CCLM configuration for the climate research in the MR. The second aim is to estimate the relative contribution of internal and external (for the MR) effects in the Mediterranean climate.

The methodology of analysis

In this evaluation we assume, that the use of the two MED and MENA domains allows an indirect estimation of the role of the external (for the MR) effects (including tropical moisture exports) in the RCD runs. To estimate the role of the second factor (internal MR processes) in the formation of the climate conditions in the MR, we perform RCM simulations employing different spatial resolutions (0.44° and 0.22° [i.e. 50 and 25 km]) and three model set-ups differing by the intensity of the laminar heat flux over sea surface.

The COSMO-CLM model (http://www.cosmo-model.org) (COSMO-CLM version 5, hereafter CCLM) is employed. The experiments are performed using the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim reanalysis (Uppala et al,. 2008; Dee et al., 2011) (horizontal resolution of 0.703125°) as the initial and driving data. The CCLM configuration adopted includes the use of optimized data on the soil albedo derived from Moderate resolution Imaging Spectro-radiometer (MODIS) quite accurately reproducing the reflectivity of the Earth's surface, especially over arid zones and new NASA-GISS aerosol maps. The vertical coordinate (40 levels) as well as the soil model (9 levels) remain identical for all cases, with the upper-most layer set at 30 km above sea level. To keep the simulation towards analyzed data, spectral nudging is applied to the horizontal wind components (U,V).

The sets of RCD experiment performed include

(1) a RCD simulation of the MR climate during the period from 1 to 30 November 1994 (initiated at 00 UTC of November 1 , 1994) performed with 50 km and 25 km spatial resolutions; and

(2) RCD simulation of the MR climate from 1 January 1989 to 31 December 1994 performed with 50 km spatial resolution.

To allow an evaluation of the contribution of the regional (MR) processes on the accuracy of the RCD MR climate representation with the CCLM, in addition to the two CORDEX domains experiments, representing the role of non-regional effects, these (1989-1994) simulations employ three sets of the model set-up parameters differing by the Rat_sea values (20, 10, 1), which represent the laminar heat flux over sea surface (the results for the first year are considered as those affected by the spin-up process and are not included into the analysis).

The horizontal grid with resolution of 50 km is adopted as specified by the CORDEX-MENA protocol: thus, the model domain uses a grid of 257 points from West to East and 141 points from South to North. A time step of 240 s is used in these experiments. For the high-resolution run (25 km), the number of grid points increases to 513 x 281, and the time step is reduced to 120 s. In the case of the CORDEX-MED series, the model domain has a grid of 114 points from West to East and 79 points from South to North. A time step of 240 s is used. For the high-resolution run (0.22 deg.), the number of grid points increases to 227 x 157, and the time step is again reduced to 120 s.

Justification of the choice of the RCD time period

The choice of the periods for the simulations (1-30 November 1994 and January 1, 1989 - December 31, 1994) has been motivated by the following considerations. The time period included the Vaison La Romaine, 22 Nov. 1992 with ~300 mm in 24 hours (>50 deaths, 1 billion € damages, Sénési *et al*, 1996), Piedmont case, 4-5 Nov. 1994 with ~300 mm in 36 hours (> 60 deaths, 12 billion € damages, Buzzi *et al,* 1998), torrential cloudbursts, reported to be the worst experienced in 80 years at some locations, causing severe, widespread flooding and landslides in southeast France, Corsica and northwestern Italy during the four-day period in early November 1994" Obasi (1997), heavy floods in Israel and Egypt during the same time period (Krichak and Alpert, 1998). It has been hypothesized that the extreme climate event (understood here as a precipitation anomaly of monthly scale) of November 1994 apparently was a consequence of the activity of hurricane Florence (2-8 November 1994) (Krichak et al. 2014). The hurricane developed from a low-pressure system that formed at the end of October along a stationary frontal band about 1000 nautical miles to the east-southeast of Bermuda. The process initiated by the hurricane formation has clearly contributed to the intensification of the synoptic processes and tropical moisture export over a large area including the MR.

Observational datasets employed

To evaluate the performance of the model vs independent data, we employ a combination of available gridded ground data and reanalysis: the Climatic Research Unit (CRU, University of East Anglia), the E-OBS, and NCAR-NCEP reanalysis dataset.

Results

In the following section we discuss the results of the simulations for Sea Level Pressure (SLP), Precipitable water (PW), near surface air temperature (T2m), and total precipitation amount (Tot Prec).

The panels (2-5) present results of the CCLM simulations for 1-30 November 1994 (for the Eastern Mediterranean region only).

In the upper row of panel 2 presented are the actual SLP patterns at 00 UTC of 2 – 5 November 1994 (i.e. the time period with heavy floods in Israel and Egypt (Krichak and Alpert, 1998) and intense PW intrusions in the form of atmospheric rivers (panel 3). The middle and lower rows of the panel present the corresponding results of the 50 km resolution CCLM hindcasts for 24, 48, 72 and 96 hrs (i.e. valid at 00 UTC of November 2-5) calculated with the CCLM using the Med-CORDEX and CORDEX-MENA. Results of the hindcasts demonstrate a reasonable accuracy of the model ability to represent the actual synoptic processes of the time period with an advantage for the CCLM with the Med-CORDEX domain. No significant changes in the SLP hindcasting have been obtained in the model simulations with 25 km resolution (not presented).

Panel 4 presents patterns with the actual amount of the four days (1-5 November 1994) precipitation (according to E-OBS) (left pattern) and the CCLM results obtained in the MENA and MED experiments employing 50 km and 25 km resolution, respectively, demonstrating a certain advantage for the CCLM-MENA version employing 25 km spatial resolution.

The conclusion on a better accuracy of the model representation with the MENA-25 km model version of the actual extreme synoptic processes of the November 1994 appears to be confirmed by the patterns given in the Panel 5 presenting the observed and model simulated total monthly precipitation.

Panels 6-11 present the data for the 5-year (1990-1994) mean T2m, Tot Prec and PW (Prec Wat) patterns based on the results of the CCLM-MENA and CCLM-MED RCD simulations (1989-1994) with 50 km resolution.

Panel 6 present the graphs for the actual (E-OBS) [black curve] and the model simulated (with the MENA and MED domains) [green, red, blue curves for the results employing the values of model nudging parameter for the laminar heat flux over sea surface (Rat Sea) equal to 20, 10 and 1 respectively] monthly-mean T2m and Tot Prec values in the Western Mediterranean (Madrid), Central Mediterranean (Rome), north-eastern Mediterranean (Ankara) and south-eastern Mediterranean (Bet-Dagan station, in Israel), demonstrating a conflicting sensitivity of the RCD results to the Rat_Sea determination in the southeastern Mediterranean (with the optimal value of Rat Sea (1)) and the other parts of the MR, more notable during the intermediate seasons of year.

Panels 7 and 8 present the seasonal (DJF, MAM, JJA, SOM) 5-year mean patterns with the biases of the Tot Prec and T2m produced in the CCLM MENA and CCLM MED model runs with Rat Sea = 10. The patterns demonstrate a tendency to a notable positive bias for precipitation and negative bias of the T2m over the northern and most of western parts of the MR in expense of the southeastern part of the region (especially notable in the patterns for DJF and SON).

The patterns with the differences between the seasonal mean Tot Prec and T2m produced in the CCLM MENA and CCLM experiments given in Panel 9 additionally confirm the above conclusion with a clear advantage to the CCLM MENA version.

The result appears to be an indication of a certain inability of the CCLM employing MED-CORDEX domain to accurately account for the moist air intrusions during the extreme synoptic events (which for some areas of the MR represent the major part of the annual precipitation amount) which may be associated with an insufficient amount of water vapor in the model atmosphere. To provide information for testing the hypothesis in panels 10 and 11 we present the multiyear seasonal mean values of precipitable water (PW) according to the NNRP data archive and the differences between the PW as produced in the RCD CCLM simulations with the MENA and MED domain, indicating a notable advantage of the MENA based model version to provide higher amounts of water vapor necessary for a more reliable representation of the MR climate conditions.

Conclusion

Results of the evaluation demonstrate the existence of similar systematic deficiencies of the seasonal scale climate conditions in the Mediterranean region simulated with the CCLM using the both MENA and MED CORDEX domains. The results produced with the use of the CORDEX-MENA domain appear to be more accurate than those produced with MED-CORDEX domain in respect to extreme precipitation events in the western and eastern parts of the region.

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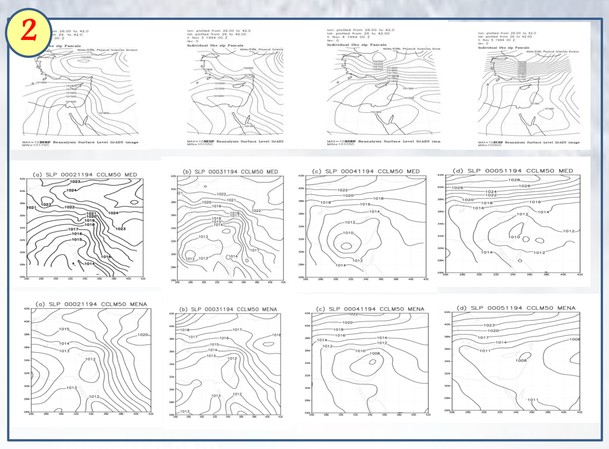

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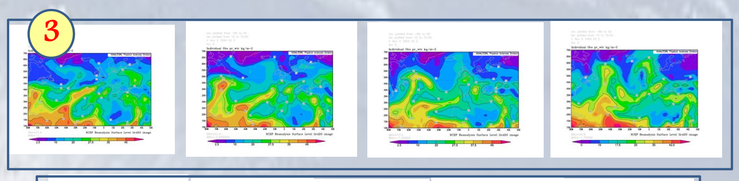

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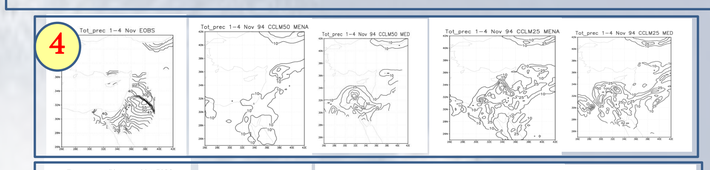

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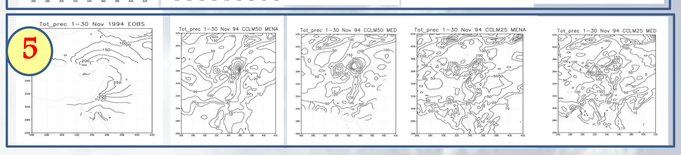

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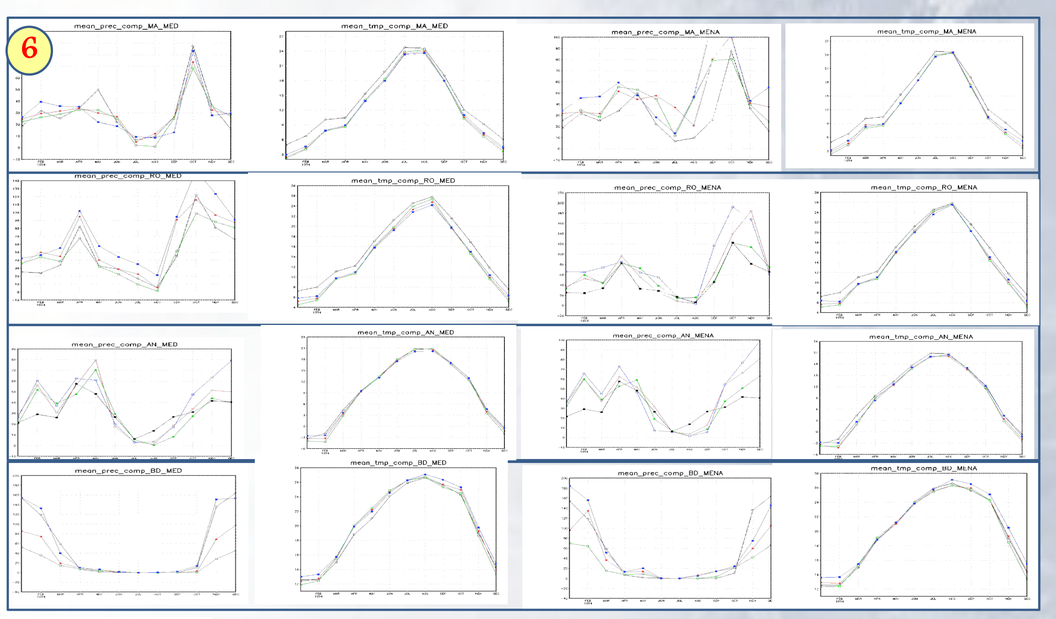

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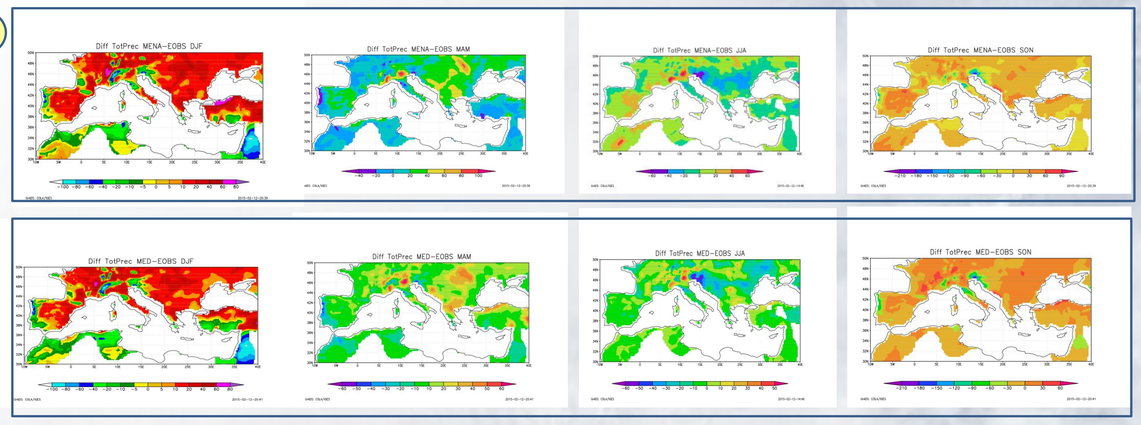

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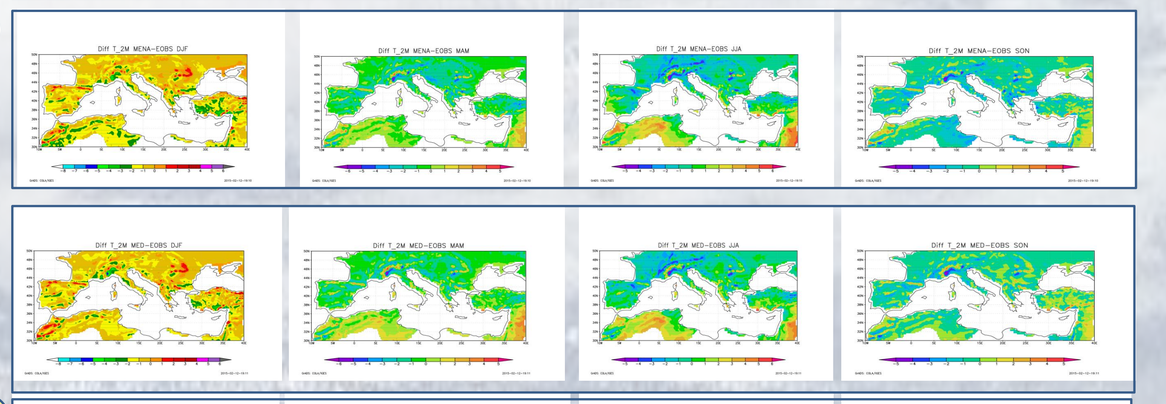

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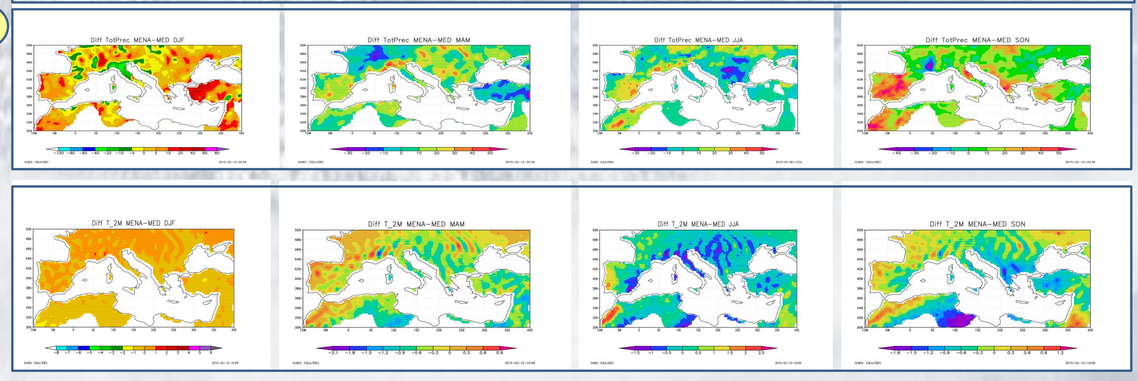

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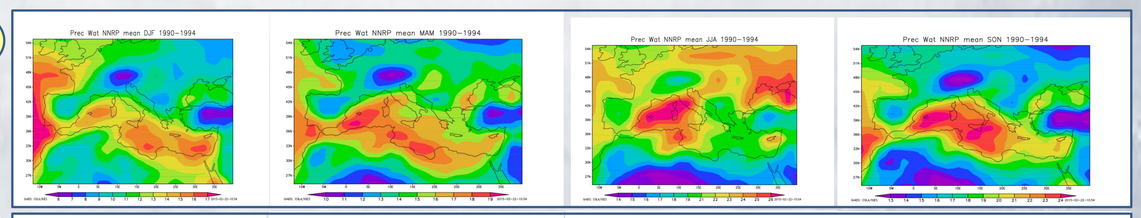

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