REMHI - CAPUA

Analysis of ERA-Interim driven COSMO-CLM simulations over MENA-CORDEX area.

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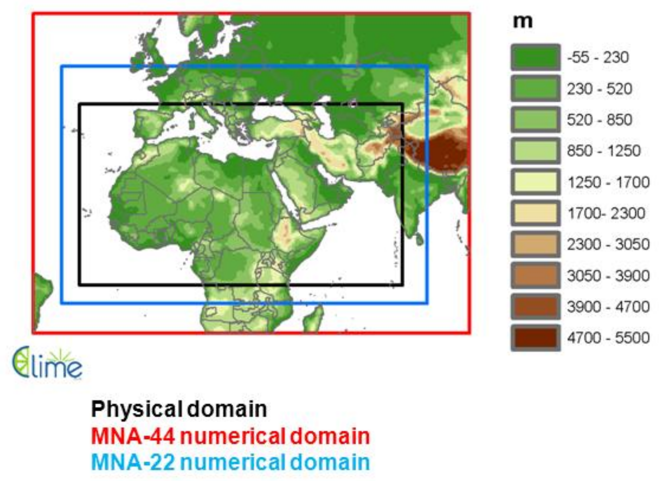
1. Introduction

The Middle East-North Africa (MENA) is one of the official CORDEX domains: it offers considerable challenges due to its large size, complex topography and great climate variability. One of the most important climate systems of the area is the West African Monsoon (WAM), which is an exciting issue for climate models; it consists in a seasonal change in atmospheric circulation associated to high variability in precipitation: this system is driven by a complex interaction among atmosphere, ocean and land surface.
In this study, the capabilities of the regional climate model COSMO-CLM in reproducing the main climate features of this area have been assessed. Two ERA-Interim driven simulations were performed, respectively at 0.44° (MNA-44) and 0.22° (MNA-22) spatial resolution for the period 1979–2011, to investigate the effects of increasing spatial resolution on the quality of results. In fact, higher spatial resolution in a RCM may not always provide higher quality results especially for precipitation.

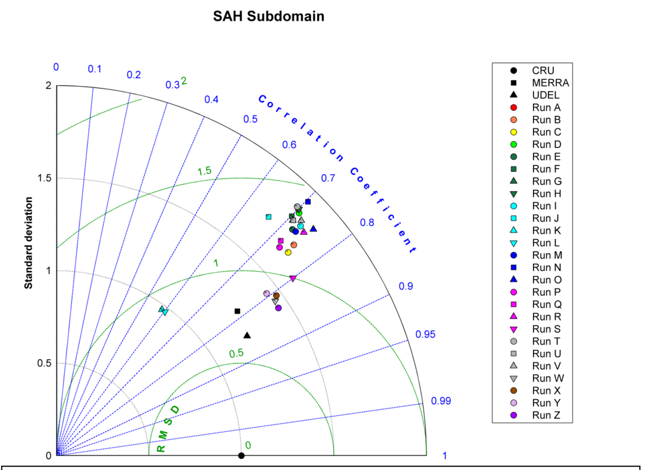


2. Model configuration and observational data

Model configuration was optimized with a sensitivity analysis aimed to ascertain model performances with respect to changes in physical and tuning parameters. It was found that parameterization of albedo derived from MODIS data gives a significant contribution to the improvement of the model performances. The NASA-GISS AOD distributions were also adopted, since they provide a more accurate spatial and temporal distributions of aerosol.
Time integration is performed with a third order Runge-Kutta scheme. Tiedtke scheme is used for the convection parameterization.

Model response has been analyzed in terms of, 2-meter temperature and precipitation. Evaluation was conducted with respect to a combination of available ground observations, satellite products and reanalysis:

- CRU (resolution of 0.5°) version 3.21;
- MERRA (resolution of 0.66° by 0.5°) version 5.
- GPCC (resolution of 0.5°) version 6;
- GPCP (resolution of 2.5°) version 2.2;
- UDEL (resolution of 0.5°) version 3.01.

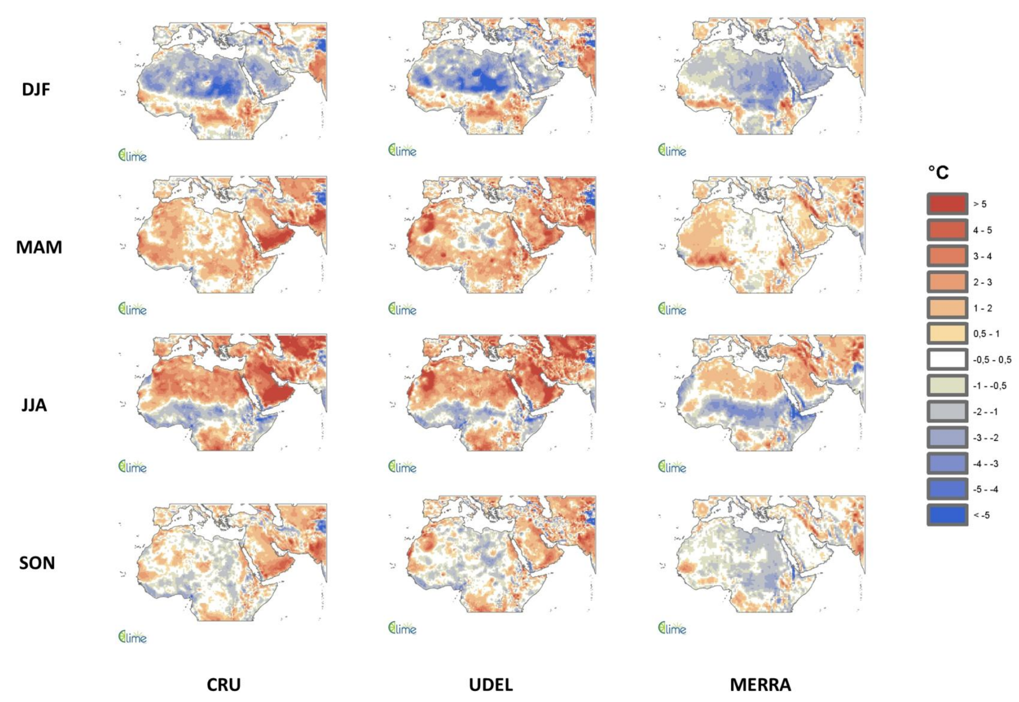


T2m Taylor diagram for the configurations tested in the sensitivity analysis, Sahel subregion.

Validation of the simulations: 1980-2011

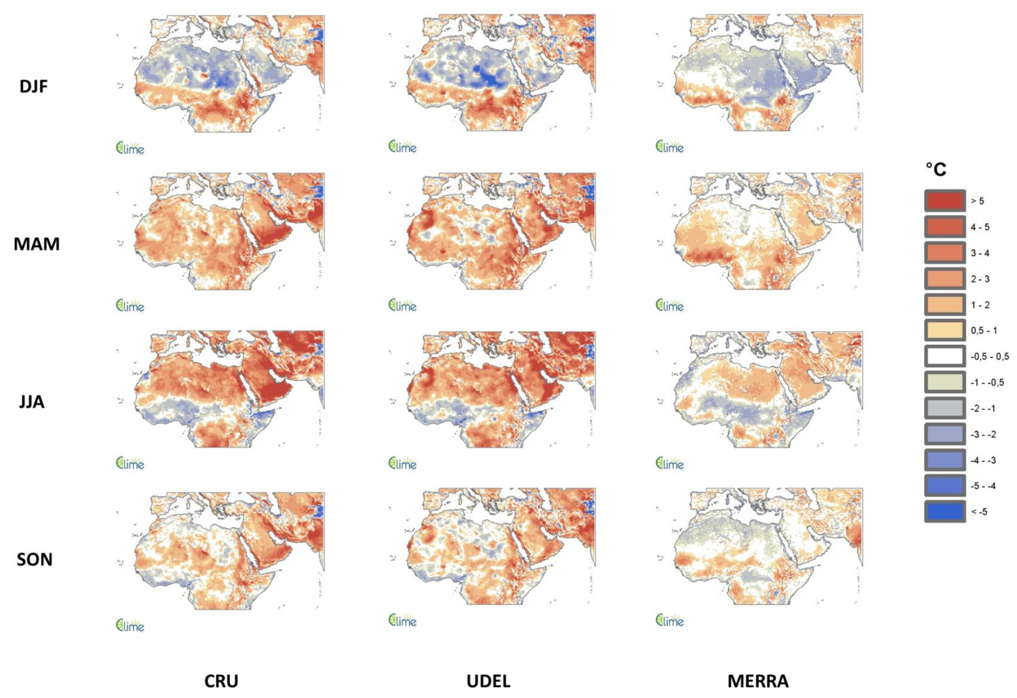
TEMPERATURE BIAS DISTRIBUTION

0.44°



This figure shows the mean T2m bias distribution (°C) of COSMO-CLM at 0.44° resolution against CRU, UDEL and MERRA for the four seasons. In DJF a strong cold bias is observed in the central part of the domain, while warm biases are observed in the southern and eastern part of the domain; in MAM almost the whole domain is affected by a warm bias (3-4°C) in JJA the domain shows a dipole, characterized respectively by a warm bias in the northern part of the domain and a cold one in the southern part. In SON a good agreement is registered over almost the whole domain, with a bias generally lower than 1.5°C in absolute value.

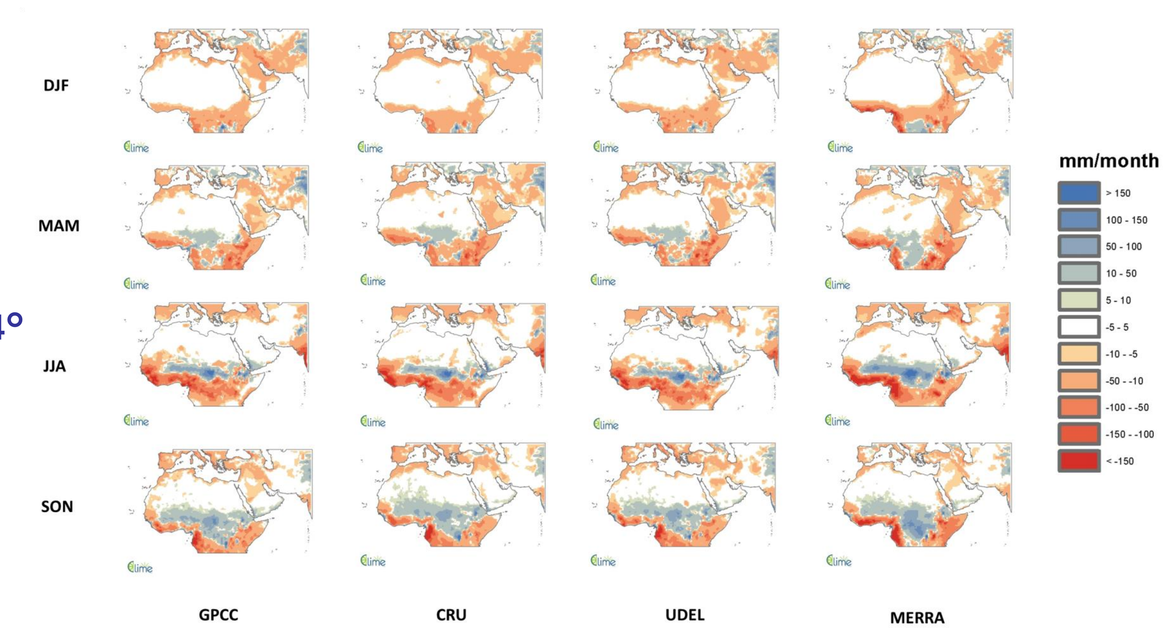
0.22°



This figure shows the same maps, but related to the higher resolution simulation (MNA-22): in DJF a reduction of the cold bias is registered against all the three datasets, suggesting that this kind of bias could be related with the resolution, but in the other seasons bias maps do not show remarkable changes with those related to MNA-44.

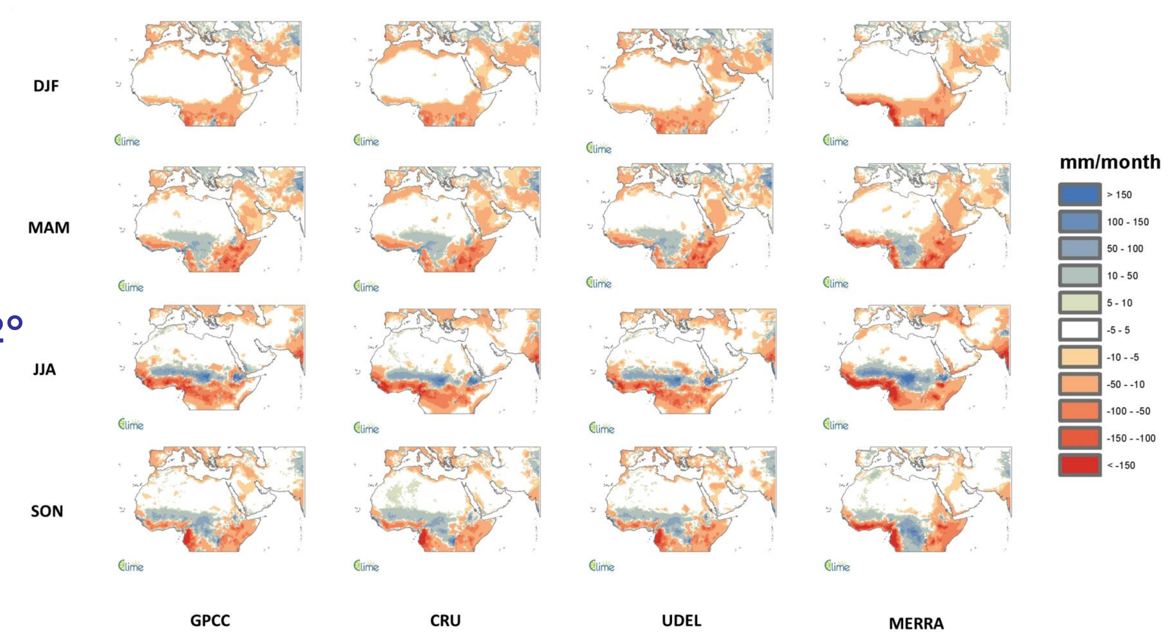
PRECIPITATION BIAS DISTRIBUTION

0.44°



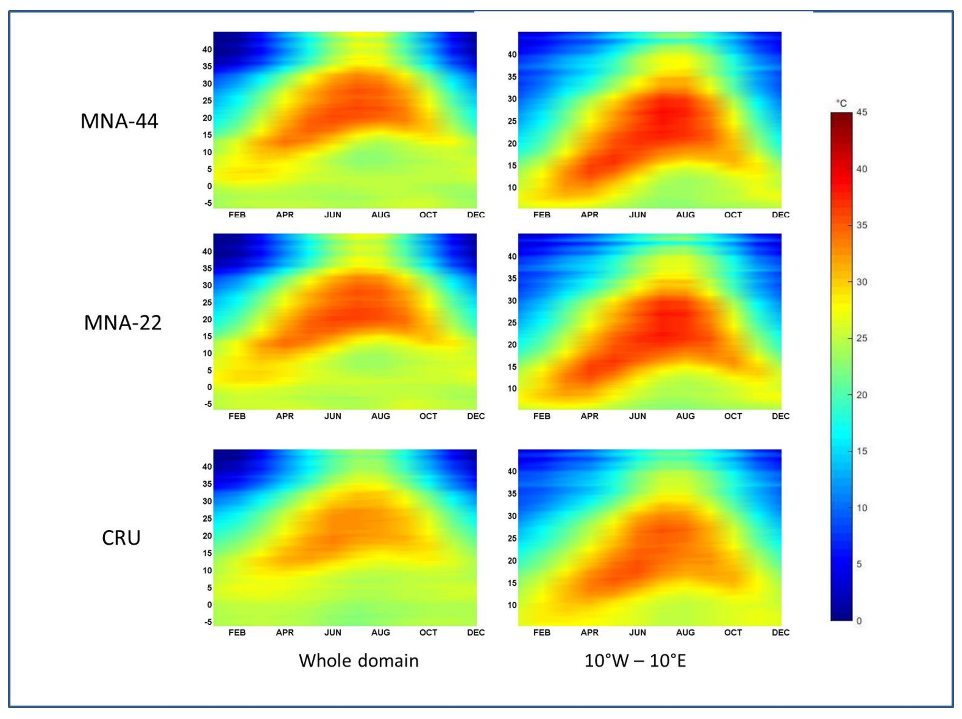
This figure shows the precipitation bias distribution (mm/month) of COSMO-CLM at 0.44° resolution against GPCC, CRU, UDEL and MERRA for the four seasons. In DJF an agreeable representation of the precipitation pattern is registered over north Africa. In JJA, rainfall associated with West African Monsoon (WAM) is at its maximum; COSMO-CLM generally underestimates the strength of WAM, locating the core of the rainbelt too far north and, as a consequence, precipitation over Gulf of Guinea is clearly underestimated. In MAM and SON, an overestimation is observed over Central Africa.

0.22°



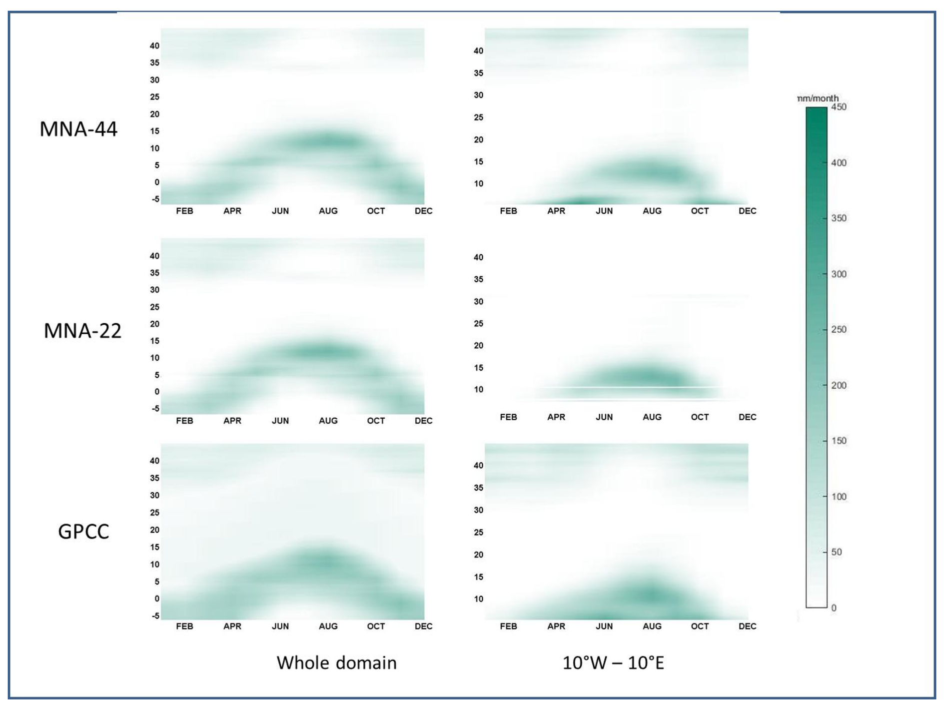
This figure shows the same maps, but related to the higher resolution simulation: they are qualitatively similar to the ones related to the coarser resolution simulation, with slight improvements registered in some areas (i.e., southern part of domain, Saudi Arabia) in all seasons.

TEMPERATURE Hovmoller Diagram



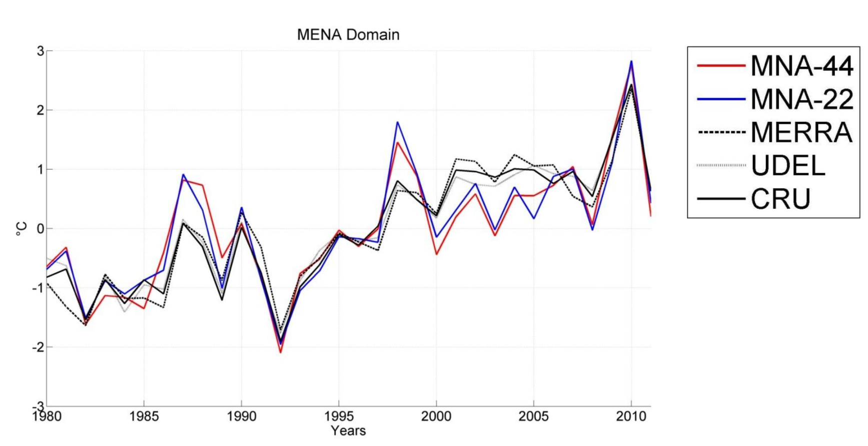
This figure shows the time-latitude Hovmoller diagram for temperature, averaged (left panels) over the whole longitude interval (27°W – 68°E) respectively for MNA-44, MNA-22 and CRU: the diagram shape is very well simulated, especially at low latitudes (< 10°N), but with a general temperature overestimation in the central part of the graphic. The same diagrams (right panels) have been tracked considering the reduced longitude interval (10°W – 10°E) including Sahel (located between Sahara Desert and the tropical rainbelt), in order to evaluate the model capability in tracking the position and shift of Saharan Heat Low, which is an important climate feature in West Africa; COSMO-CLM shows a good ability in reproducing the migration and intensification of SHL from the northern Sahel (April) to the Sahara (August).

PRECIPITATION Hovmoller Diagram



This figure shows the time-latitude Hovmoller diagram for precipitation, averaged (left panels) over the whole longitude interval (27°W – 68°E) respectively for MNA-44, MNA-22 and GPCC: a good agreement is observed between model and observations, with the exception of the intense rainfall area located between 10° and 15°N (from June to September) which results overestimated. The same maps have been tracked considering the reduced longitude interval (10°W – 10°E) including Sahel (right panels), in order to measure model skill in simulating WAM; it is apparent that COSMO-CLM is qualitatively able to capture the three distinct phases of WAM: the onset (March and April), the sharp discontinuity i.e., monsoon jump (June and July) and finally the southward retreat of the monsoon rain band (from September) with a consequent rainfall reduction over Sahel.

TEMPERATURE interannual variability



This figure shows the normalized interannual variabilities of T2m of both simulations, along with CRU, MERRA and UDEL data for the whole domain. Values have been calculated as anomalies with respect to the T2m mean, and normalized by the standard deviation. Both simulations generally quite well reproduce the main characteristics of T2m anomaly over MENA domain: better performances are registered in the first part of the period analyzed.

Conclusions

This study revealed that COSMO-CLM has a good capability in reproducing the basic climate features of the area considered. Low values of average biases have been registered, compared with other state-of-art RCMs. It is important to point out that the bias is partially due to low accuracy of observational datasets, related with the scarcity of the gauge stations over large areas, also confirmed by discrepancies among the different datasets. A comparison between 0.44° and 0.22° simulations revealed that no significant improvements are obtained with the resolution increase: progresses have been achieved for the T2m interannual variability and for monthly precipitation mean values.
Two possible explanations can be given: the first one is that the most important mesoscale phenomena (requiring high resolution to describe them) do not exist over this area. The second explanation is that these mesoscale phenomena are generally characterized by a higher spatio-temporal resolution with respect to the ones that can be analyzed by the two resolutions considered in the present work; therefore both simulations exhibit similar limitations to describe these phenomena.

References

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