Performance evaluation of COSMO-CLM over Italy and climate projections for the XXI century

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Outlook

- Introduction
- The domain simulated
- The COSMO-CLM setup
- Validation of simulations driven by different forcing sets
- Assessment of climate change up to 2060 with the RCP4.5 scenario
- Conclusion and future work

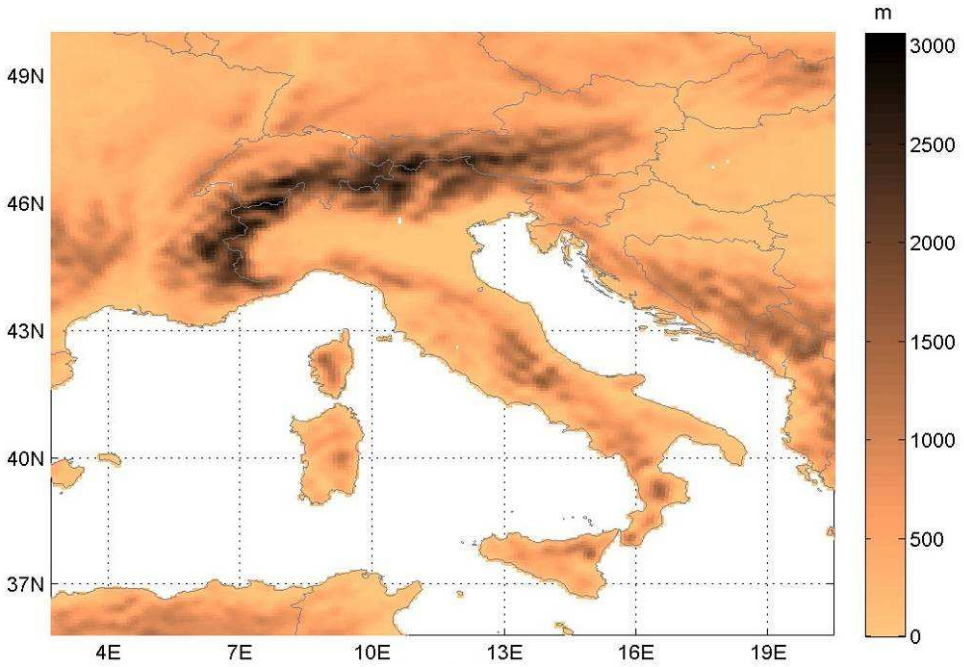
Introduction

Italy is located in Southern Europe and belongs to the Mediterranean area, affected by the arid climate of the North-Africa and by the temperate and rainy climate of central Europe (Giorgi and Lionello, 2008).
It is characterized by a very complex and heterogeneous topography, ranging from high mountain chains, such as Alps and Apennines, to several coastal areas, being Italy almost totally surrounded by the Mediterranean Sea.

Given this complexity, a high horizontal spatial resolution is needed for climate projections.

GEMINA project funded by the Italian Ministry of Research: the main aim is the growth and consolidation of the Euro-Mediterranean Center on Climate Change.

Orography of the domain and COSMO-CLM setup

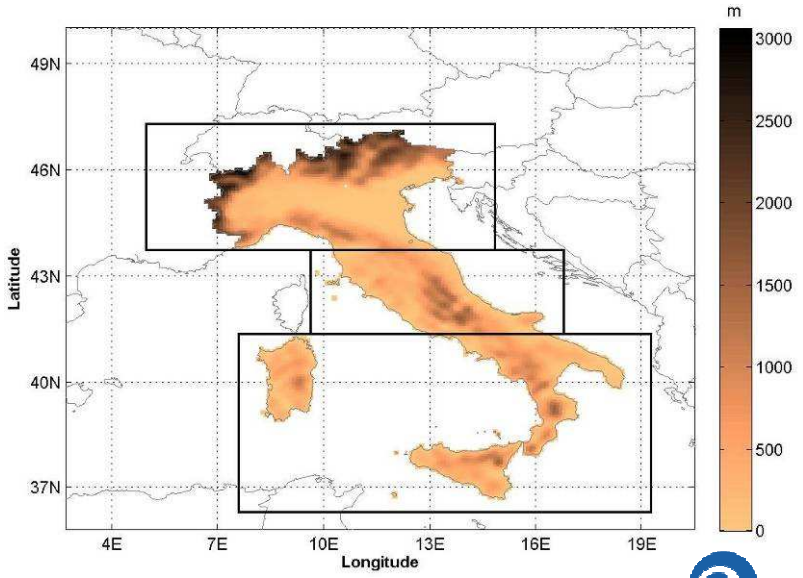


Simulated domain: (3-20E; 36-50N)

Investigated areas:

- NORTH: (5.62-15.62E; 43.87-47.12N)
- CENTRE: (5.62-15.62E; 43.87-47.12N)
- SOUTH: (5.62-15.62E; 43.87-47.12N)

Horizontal resolution	8 km
Num. of grid points	224 x 230
Model versions	INT2LM: 1.10_clm2 / COSMO: 4.8_clm19
Num. of levels	40 vertical and 7 soil
Time step	40 s
Configuration	CORDEX



The numerical simulations

Three numerical simulations at about 8 km of horizontal resolution:

- The first is driven by ERA40 reanalysis, to assess the model performance with “perfect” boundary conditions, for the period **1971-2000**
- The second is driven by the GCM CMCC-MED, whose atmospheric component is ECHAM5 (horizontal resolution of 80 km), for the period **1971-2100**, considering the RCP4.5 emission scenario (up to now 2067)
- The third is driven by the GCM CMCC-MED for the period **2006-2100**, considering the RCP8.5 emission scenario (up to now 2018).

The validation has been performed by using:

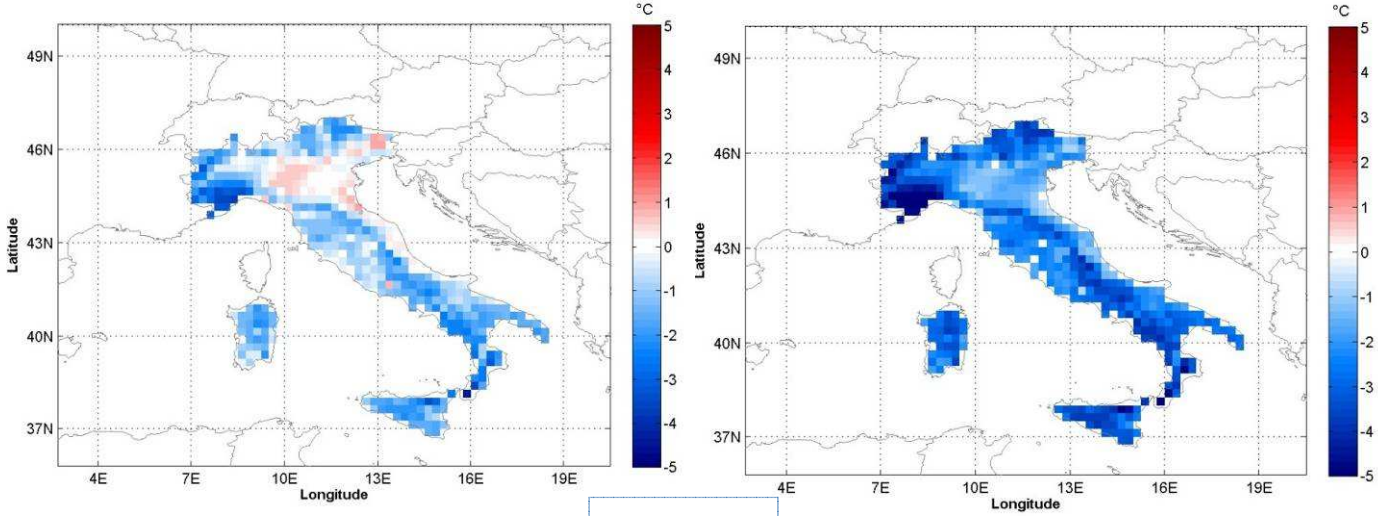
- the **EOBS** dataset for the temperature and the precipitation.
- the **ERA-Interim** for the total cloud cover and the geopotential (500 hPa and 850 hPa)

Bias of temperature (COSMO-EOBS) (°C): 1972-2000

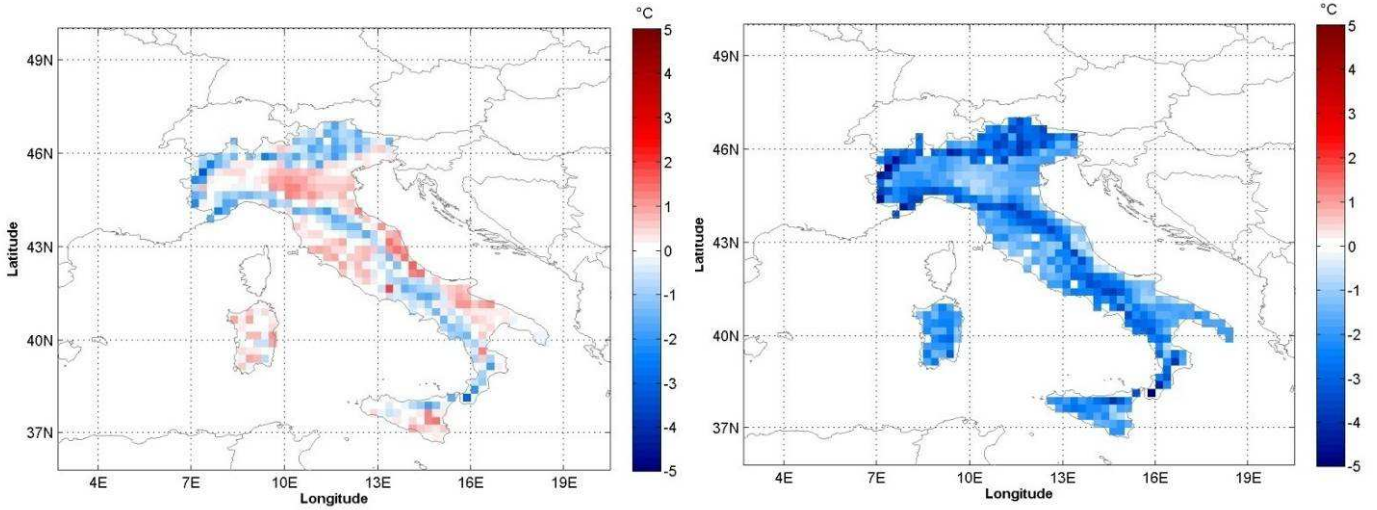
ERA40 driven

CMCC-MED driven

DJF



MAM



Apennines and Alps are characterized by a higher underestimation than other regions, especially in DJF.

In the ERA40 driven simulation, the spring temperature is well reproduced (bias less than 1.5°C).

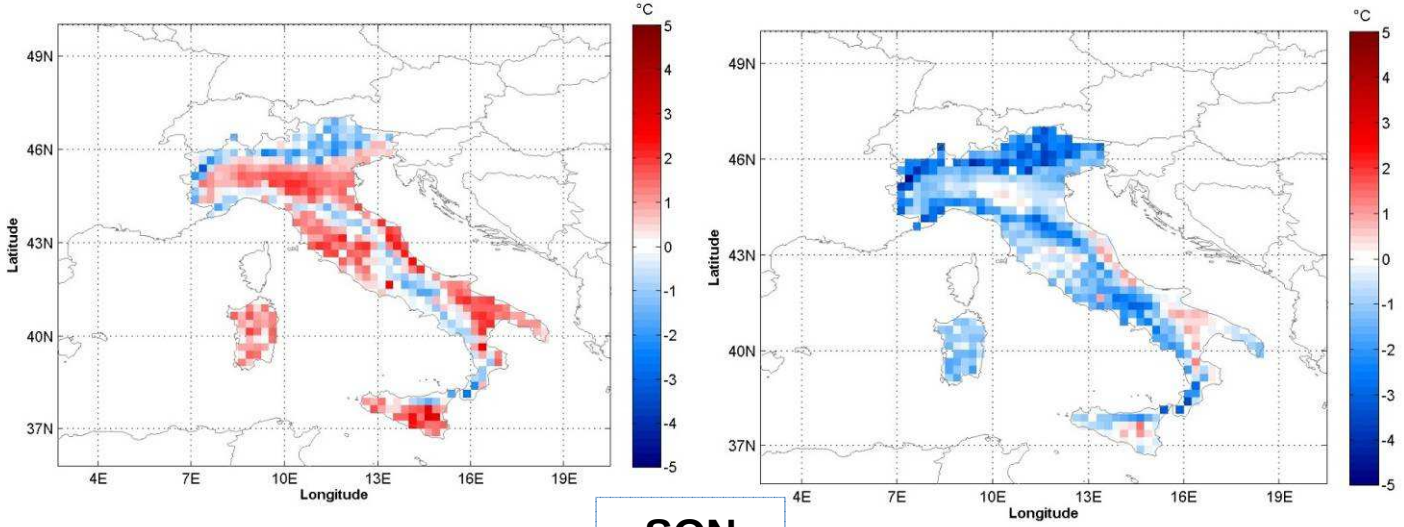
The simulation driven by CMCC-MED is strongly colder than the one driven by ERA40.

Bias of temperature (COSMO-EOBS) (°C): 1972-2000

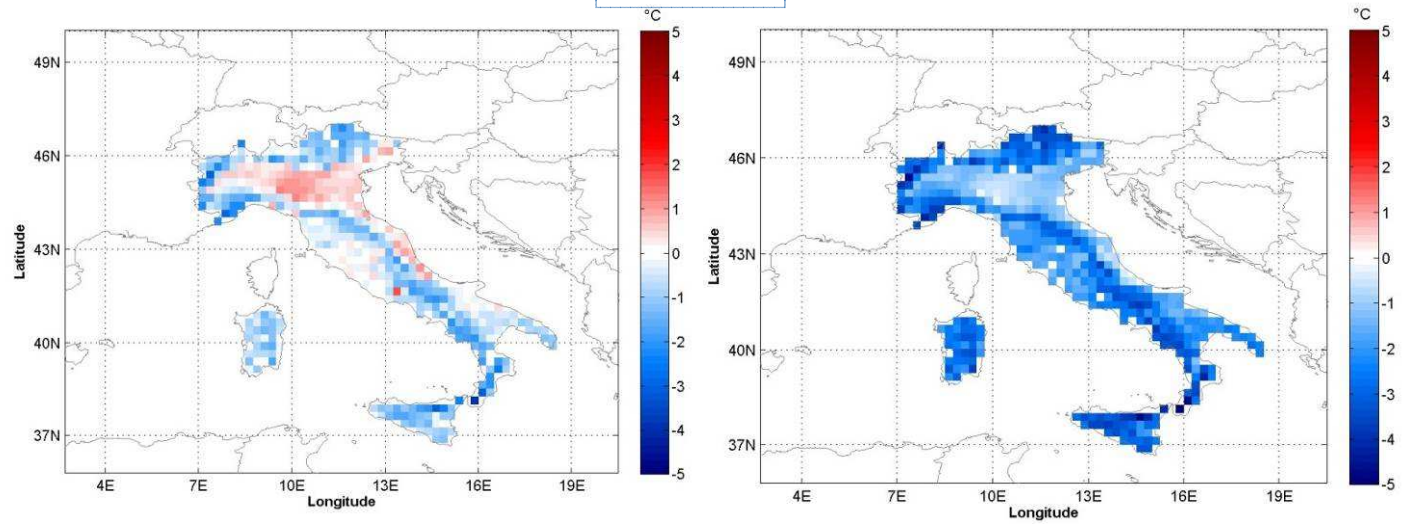
ERA40 driven

CMCC-MED driven

JJA



SON

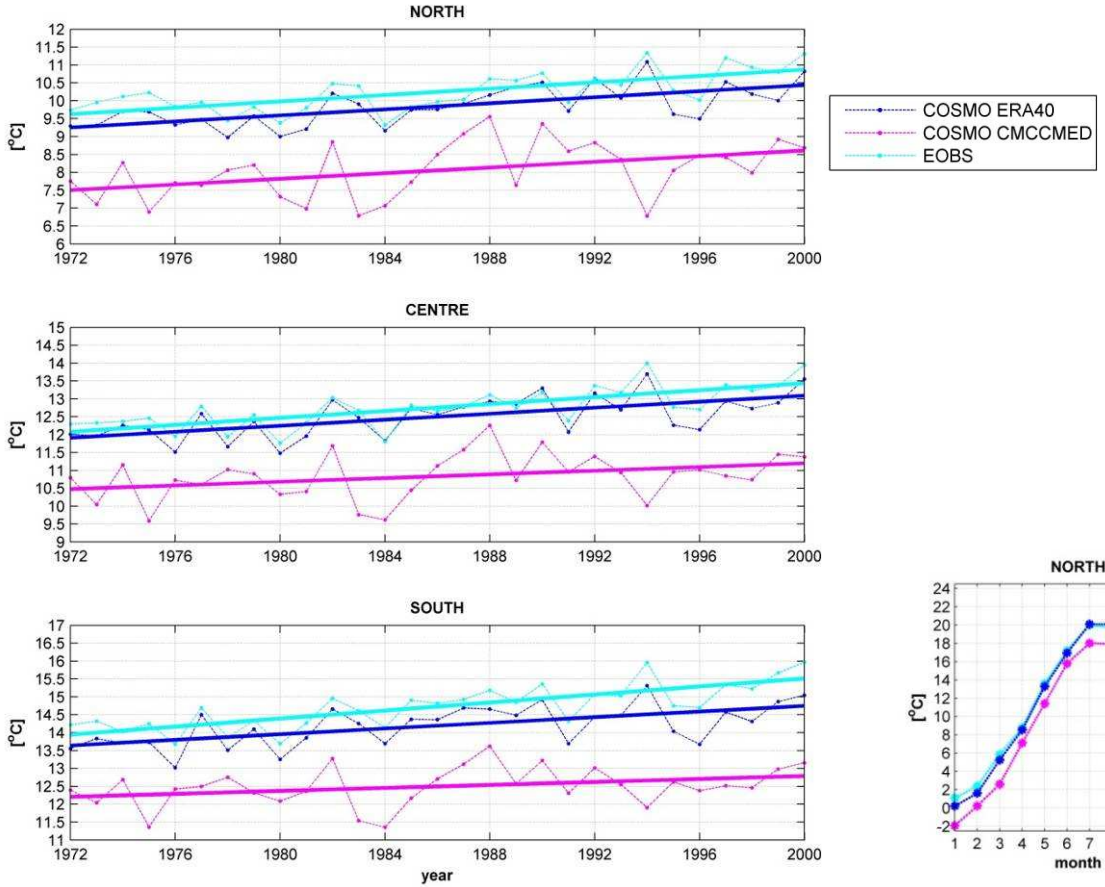


In JJA, the ERA40 driven simulation generally overestimates the temperature.
The cold bias of the CMCC-MED driven simulation, instead, is lower with respect to the other seasons.

The temperature in SON is well reproduced by the ERA40 forced simulation.

Temperature: time series, trends and seasonal cycles

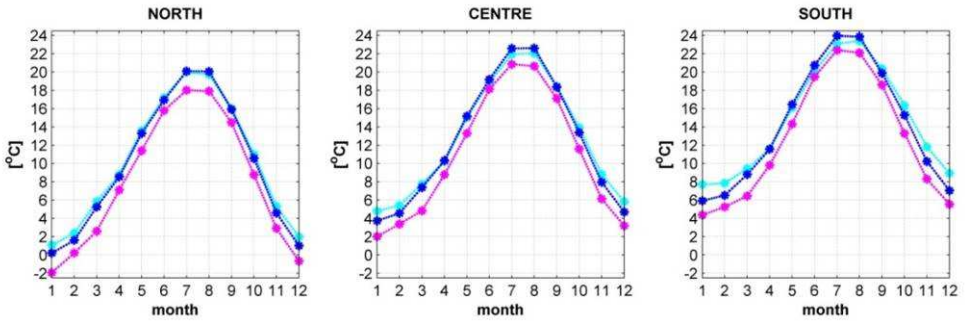
Time series



Trend (°C per year)

	EOBS	ERA40 driven	CMCC-MED driven
NORTH	0.0445	0.0423	0.0395
CENTER	0.0486	0.0420	0.0258
SOUTH	0.0561	0.0396	0.0208

Seasonal cycles



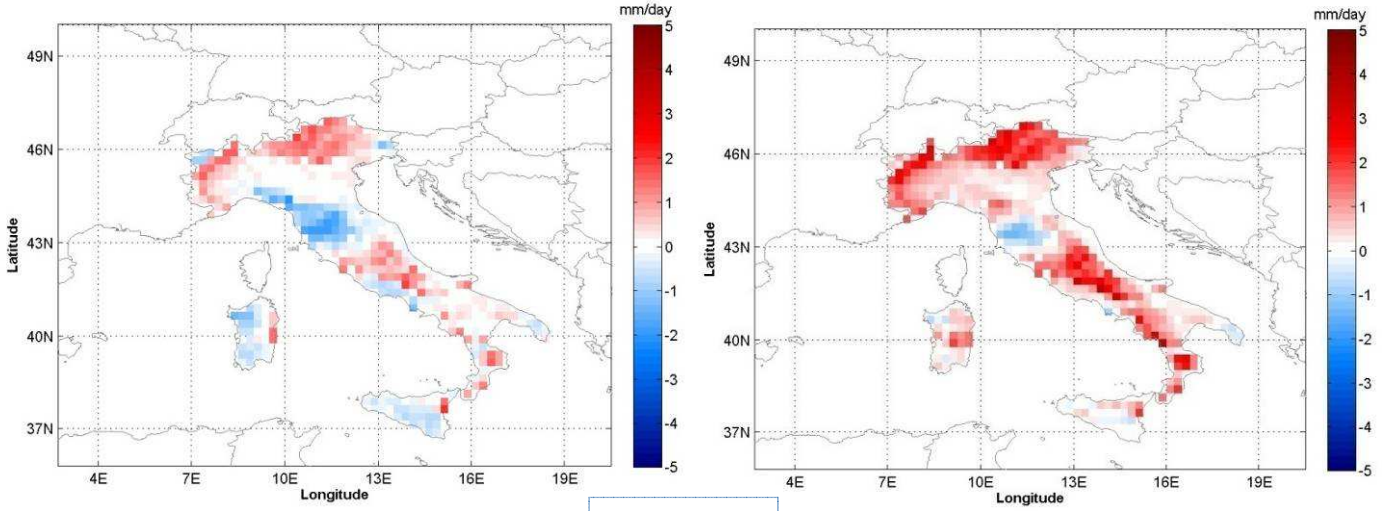
In the time series and seasonal cycles, both the simulations show a temperature underestimation, more evident in the case of the CMCC-MED forcing.
The observation trends are always higher, especially in the SOUTH subregion, where the strongest difference in the trend representation occurs.

Bias of precipitation (COSMO-EOBS) (mm/day): 1972-2000

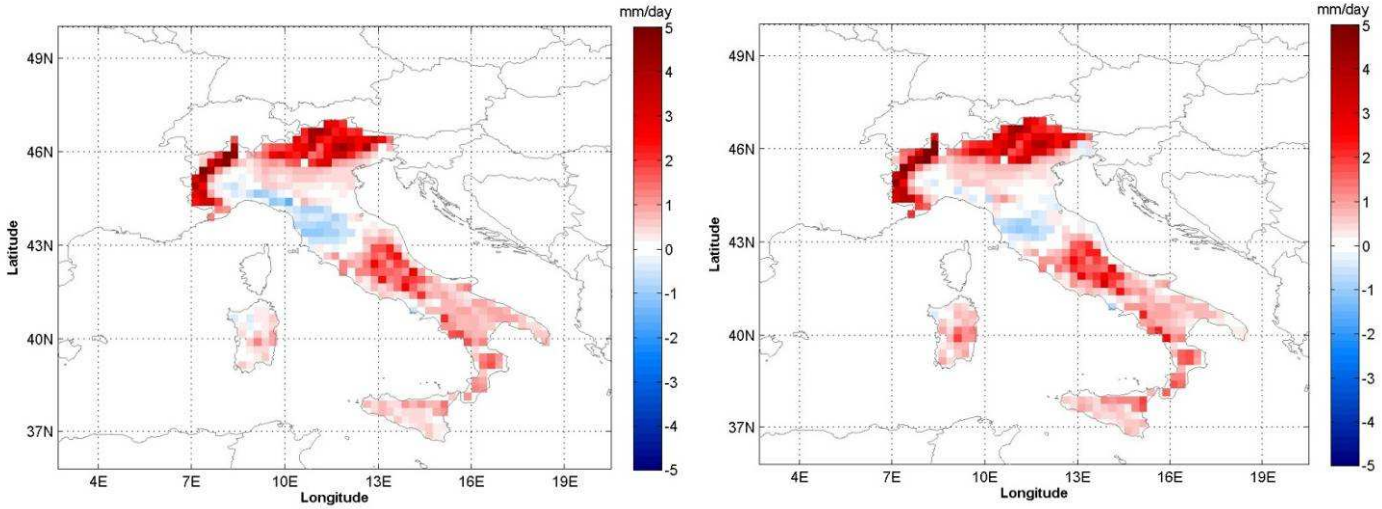
ERA40 driven

CMCC-MED driven

DJF



MAM



The difference between the results of the two simulations is less evident with respect to what observed for the temperature.

In DJF, the simulation driven by CMCC-MED shows a higher over-estimation than the one driven by ERA40, where the bias does not exceed 1.5 mm/day.

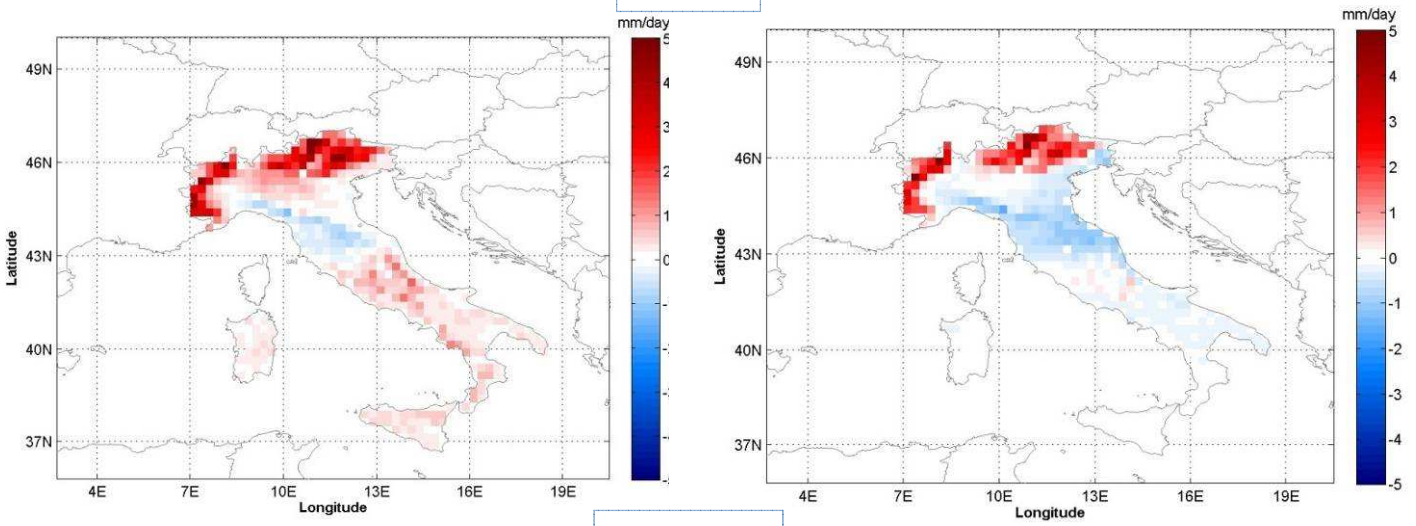
In MAM, the strongest overestimation occurs, especially over the Alps (5 mm/day).

Bias of precipitation (COSMO-EOBS) (mm/day): 1972-2000

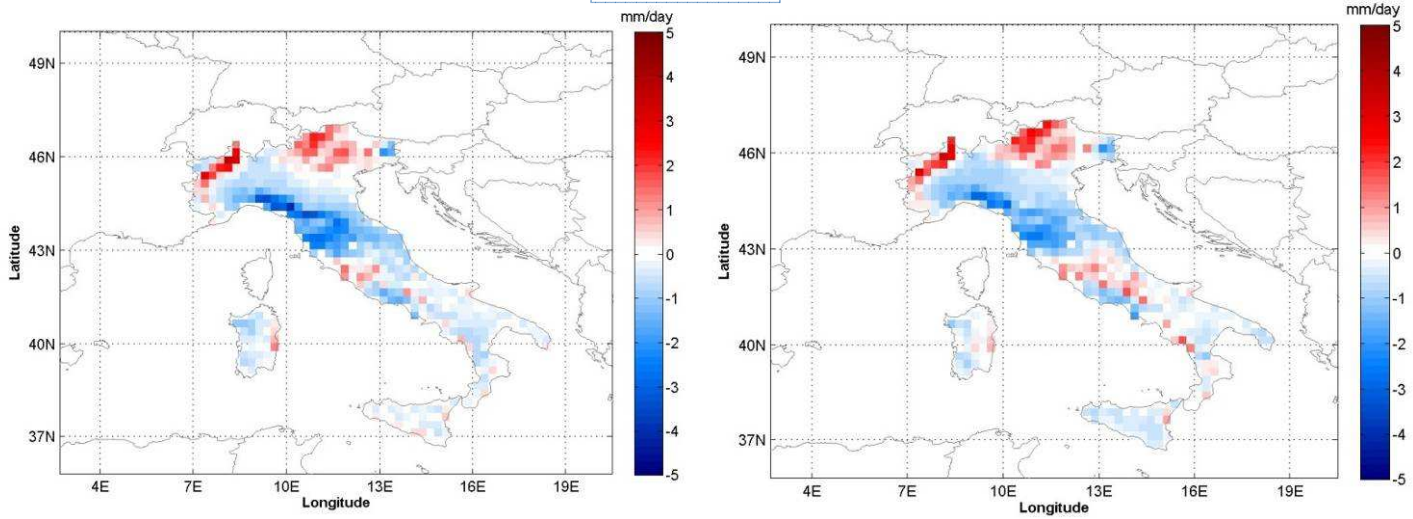
ERA40 driven

CMCC-MED driven

JJA



SON

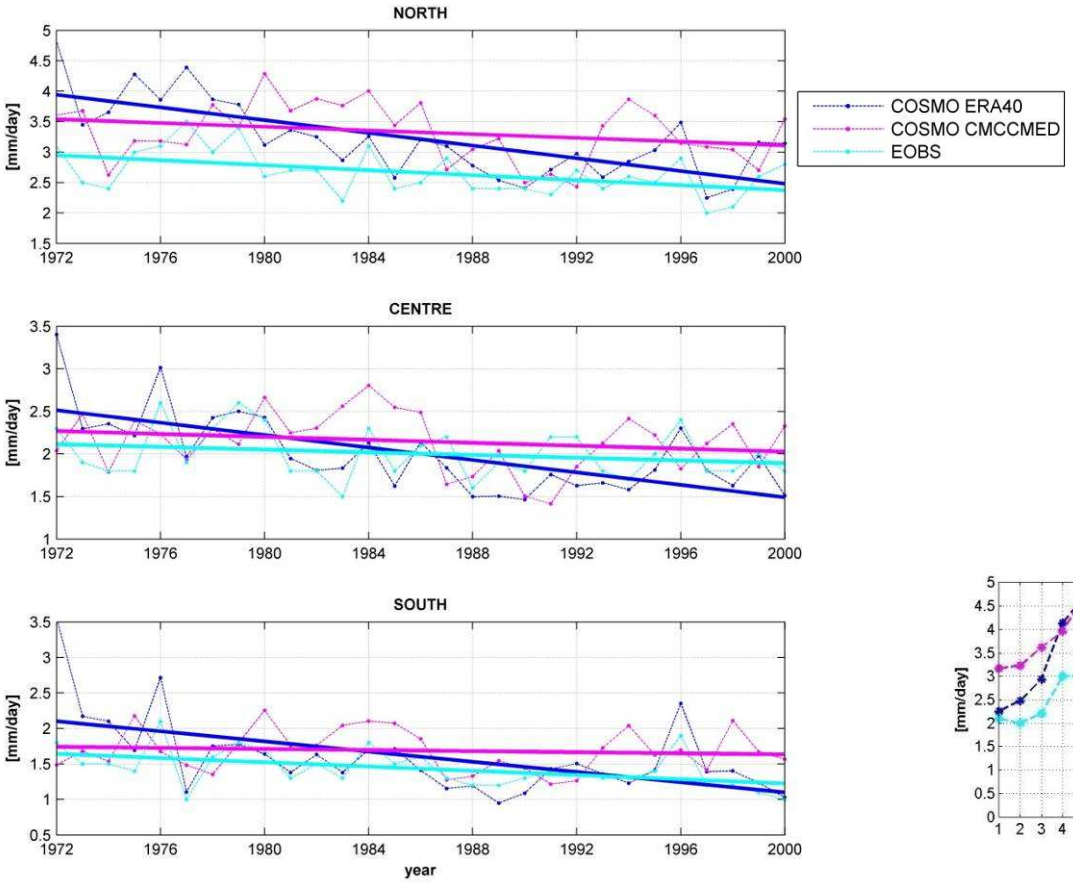


In JJA there is a very good agreement (±0.5 mm/day), except over the Alps. In the simulation driven by CMCC-MED, the bias is close to 0 mm/day in the central and south regions.

In SON the results of the two simulations are very similar, with a high underestimation on Tuscany (-3 mm/day)

Precipitation: time series, trends and seasonal cycles

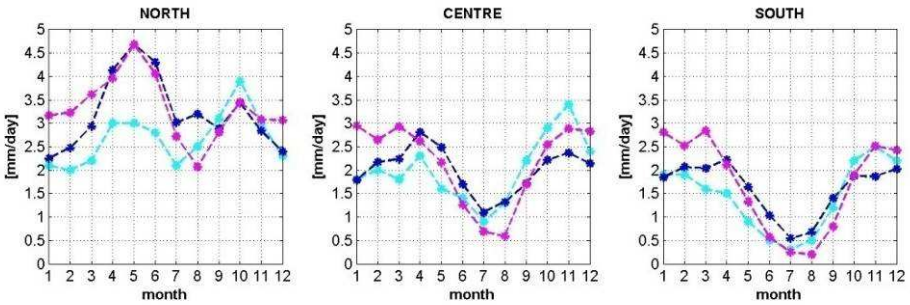
Time series



Trend (mm/day per year)

	EOBS	ERA40 driven	CMCC-MED driven
NORTH	-0.0153	-0.0522	-0.0153
CENTER	-0.0080	-0.0365	-0.0086
SOUTH	-0.0149	-0.0358	-0.0038

Seasonal cycles



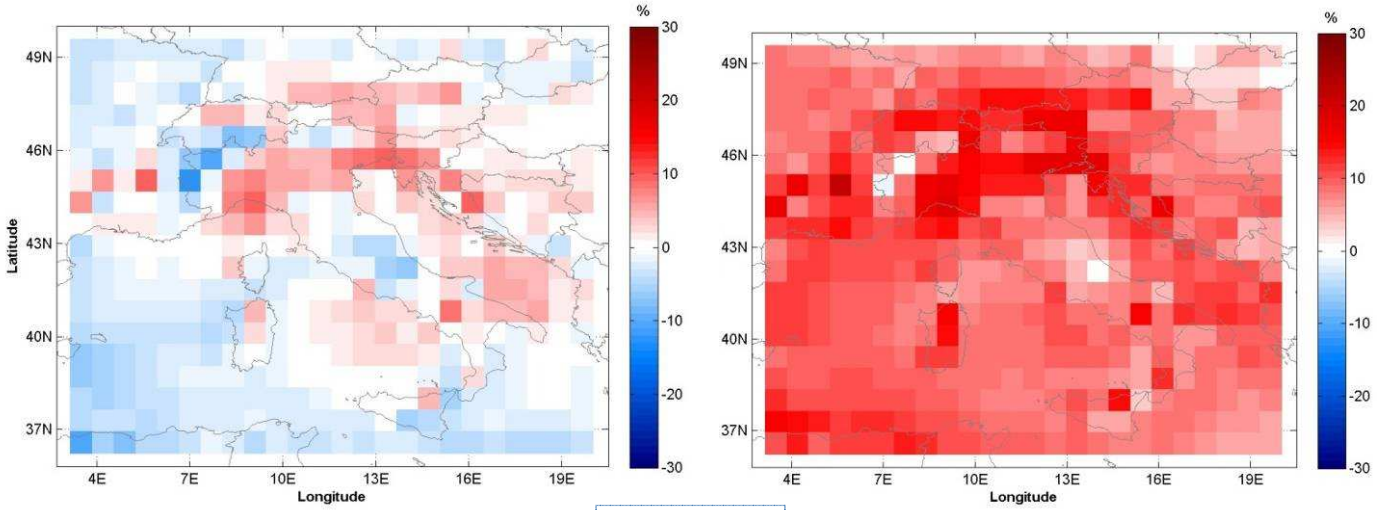
In the NORTH region from January to May, a strong overestimation is observed in the seasonal cycles, whereas in the other regions there is at most 1 mm/day of difference.
A significant decreasing trend is observed in the ERA40 driven simulation, especially in the NORTH subregion. The trends of EOBS and CMCC-MED driven simulations in the NORTH and CENTER subregions are very similar.

Bias of cloud cover (COSMO-ERAInterim) (%): 1979-2000

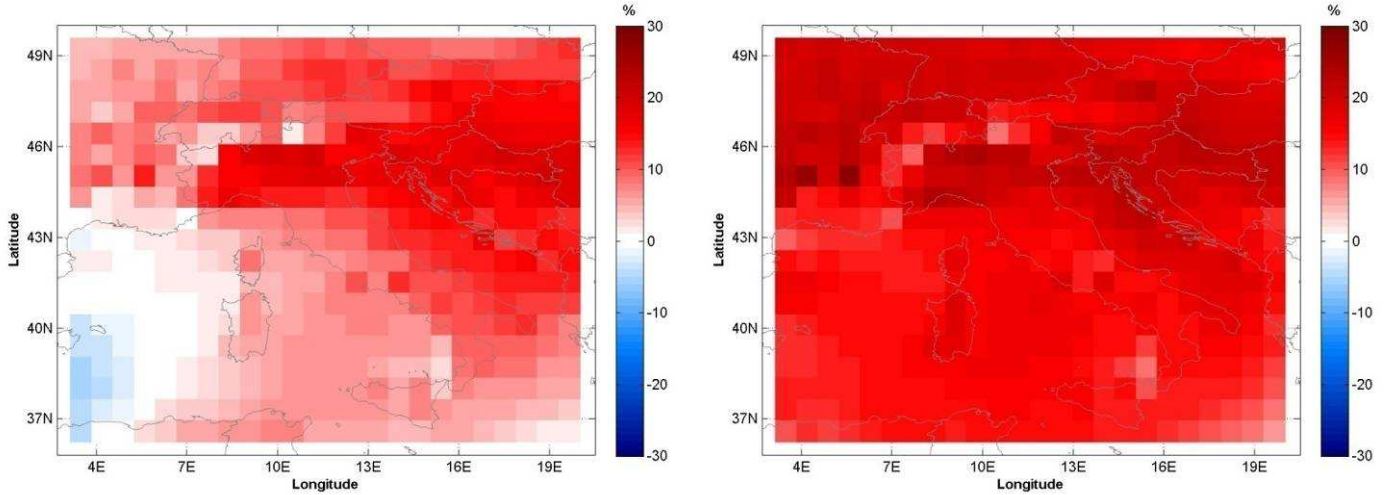
ERA40 driven

CMCC-MED driven

DJF



JJA



The simulation forced by CMCC-MED shows a general overestimation of the CLCT (up to 30%), stronger than the simulation forced by ERA40.

In the ERA40 driven simulation, the Po basin is the region with the worst performances.

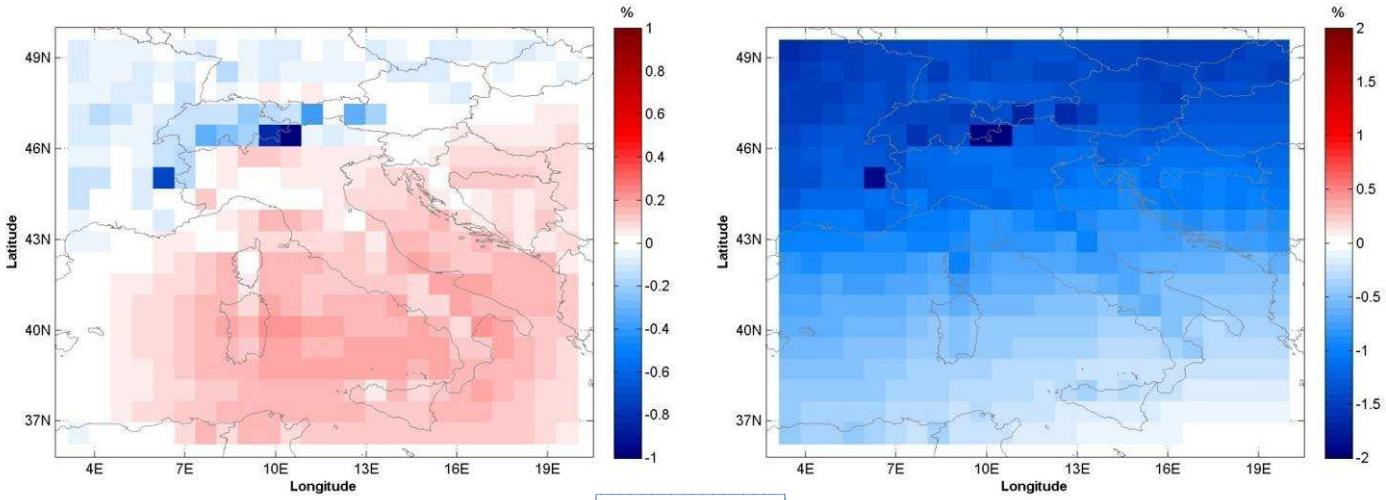
In DJF the bias is not well defined but never higher than ±10%.
JJA is characterized by an overestimation in almost all the domain.

Bias of geopotential at 850hPa (COSMO-ERAInterim) (%): 1979-2000

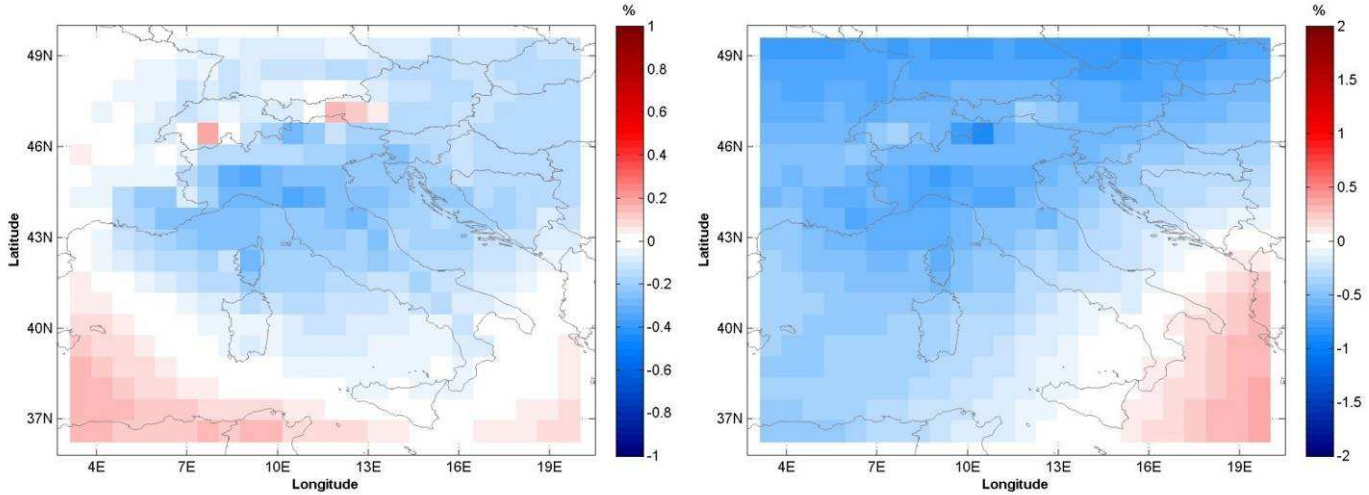
ERA40 driven

CMCC-MED driven

DJF



JJA



The percentage variation of the geopotential never exceeds 1% in the simulation driven by ERA40 and 2% in the CMCC-MED driven one.

The simulation forced by the ERA40 shows a general positive bias in DJF (except over the Alps).

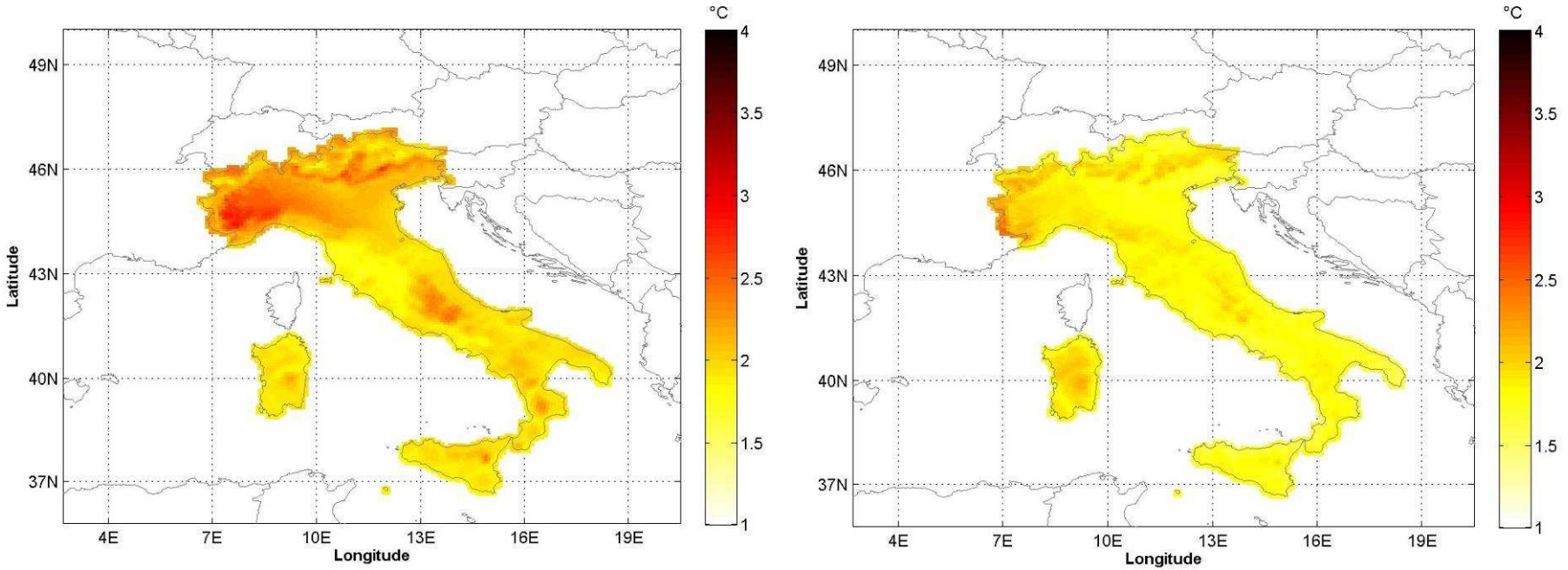
In JJA the CMCC-MED driven simulation has a lower bias than the other seasons, with a percentage variation of about 0.5%.

Temperature climate projections: 2031-2060 vs 1971-2000

DJF

RCP4.5 SCENARIO

MAM



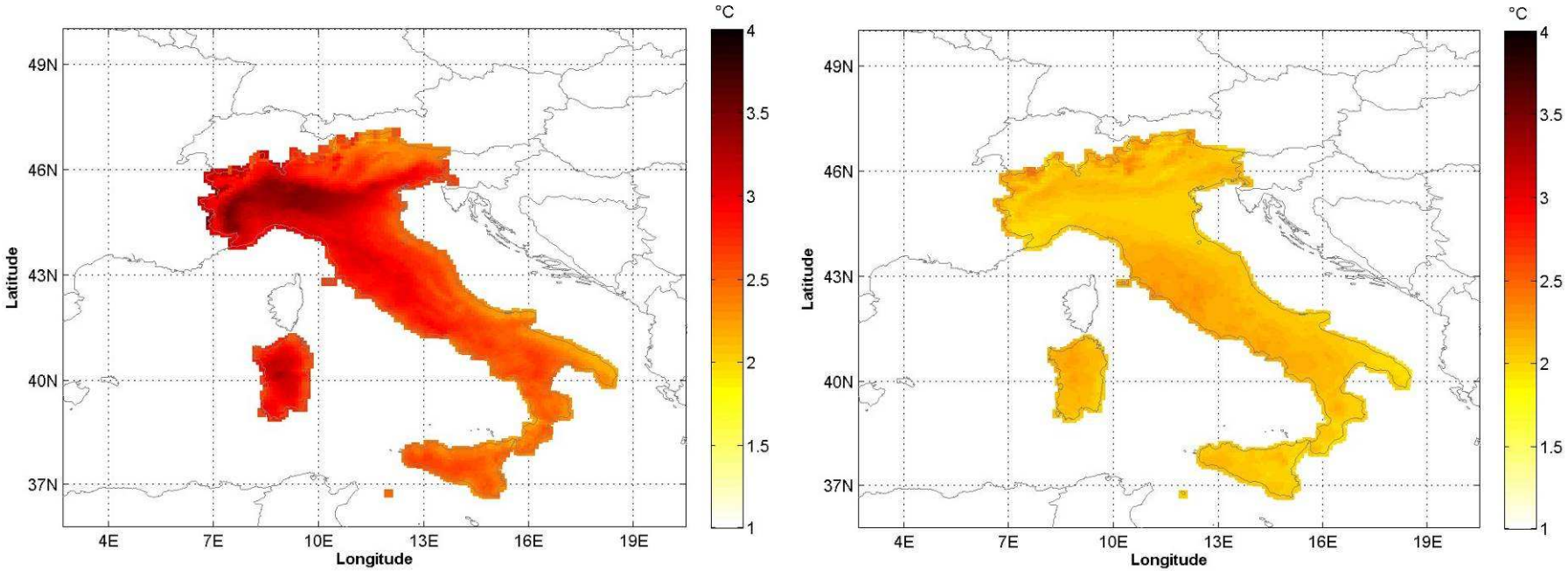
A general warming in projected in the future, more pronounced in winter (up to 3°C), especially in the Piedmont region (north-west Italian area) and in the central Italy. In spring, the temperature increase is of about 2°C.

Temperature climate projections: 2031-2060 vs 1971-2000

JJA

RCP4.5 SCENARIO

SON



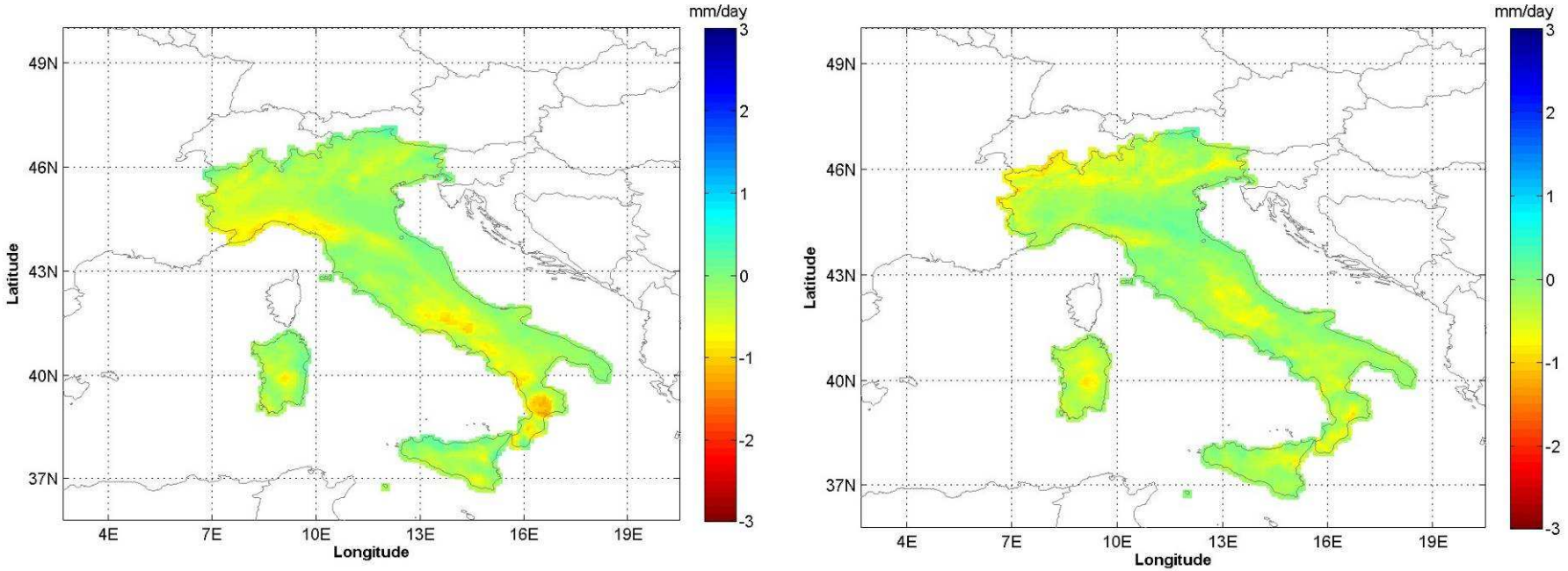
The summer warming is always larger than 2.5°C and it reaches 4°C in the northern Italy.
In autumn, the temperature increase is homogeneous, being about 2.5°C in the whole domain of interest.

Precipitation climate projections: 2031-2060 vs 1971-2000

DJF

RCP4.5 SCENARIO

MAM



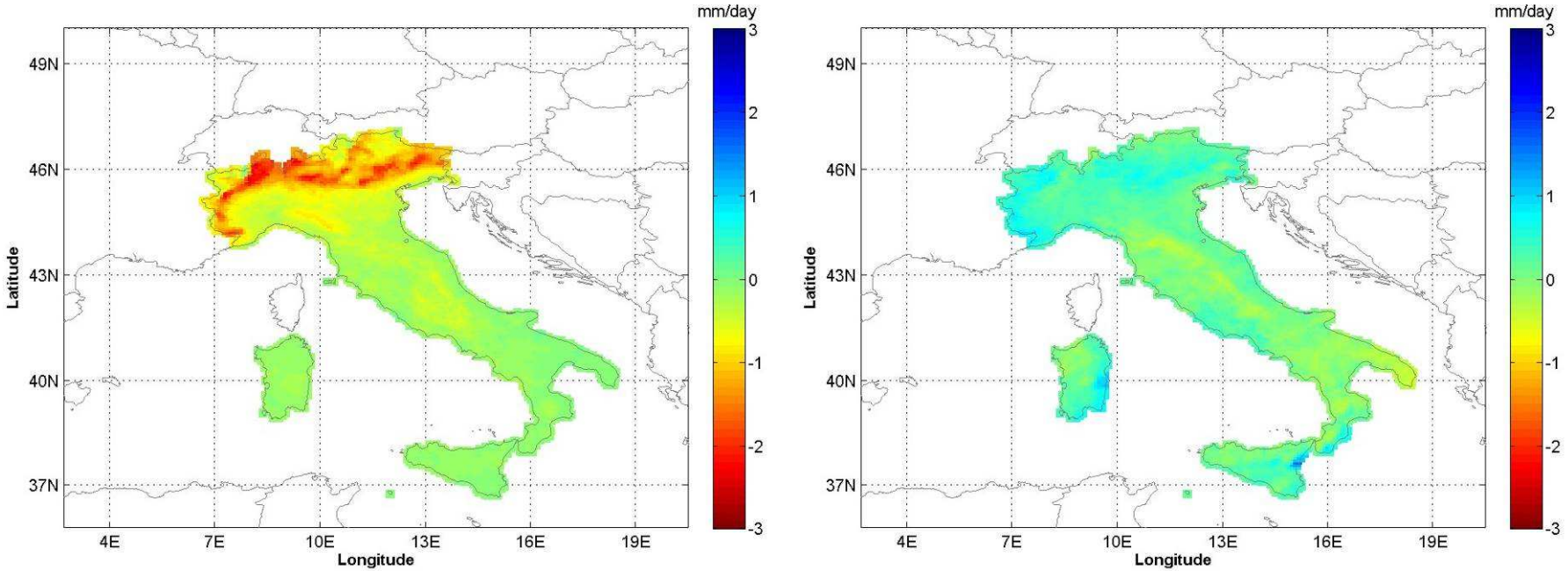
A decrease of precipitations in both the seasons is projected; in DJF, it is more pronounced in the Ligurian region (north coastal area) and in southern Italy (up to -2 mm/day); in MAM, it is higher on the Alps, in the central part of the domain and in Sardinia.

Precipitation climate projections: 2031-2060 vs 1971-2000

JJA

RCP4.5 SCENARIO

SON



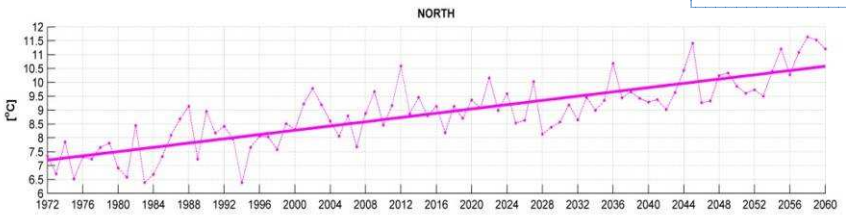
In JJA, a strong decrease of the precipitation occurs on the whole Alpine arc (-3 mm/day), with no significant changes in the other zones. In SON, instead, an increase on the Alps and in some other parts of Italian domain is projected (up to 1 mm/day)

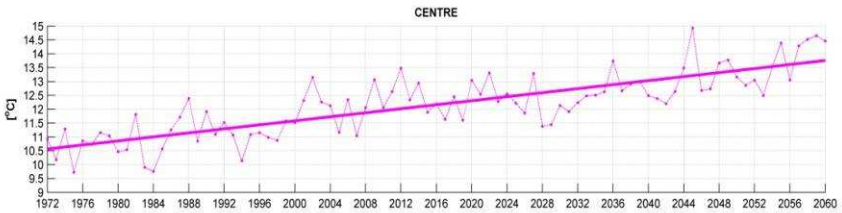
Time series of temperature and precipitation

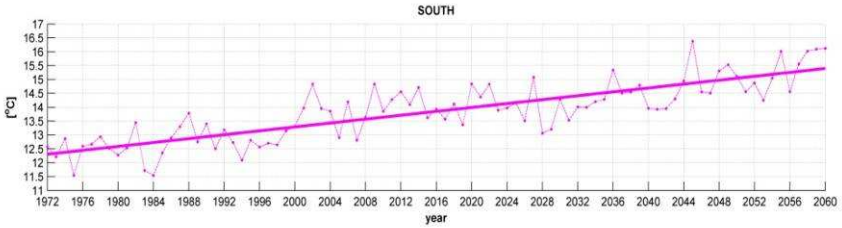
Temperature

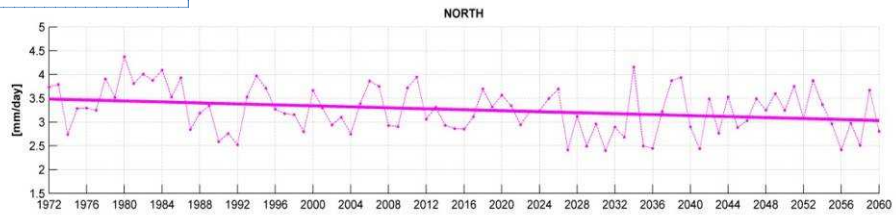
RCP4.5 SCENARIO

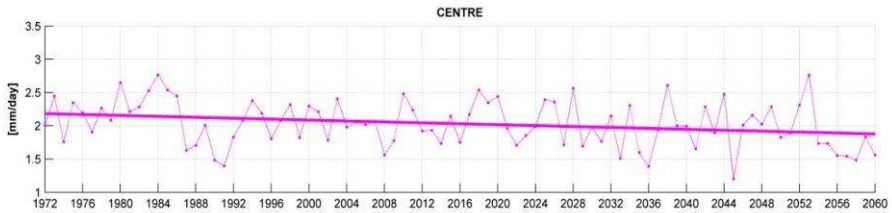
Precipitation

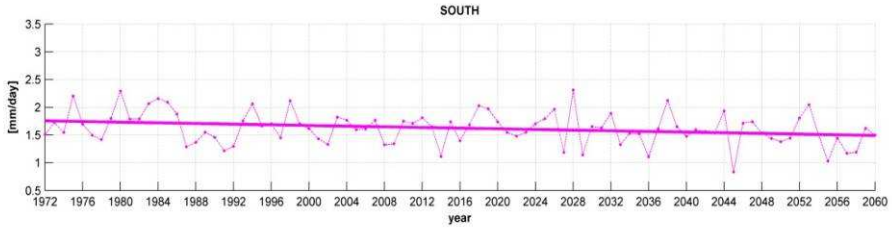












Trend (°C and mm/day per year)

	Temp.	Prec.
NORTH	0.0385	-0.0051
CENTER	0.0363	-0.0035
SOUTH	0.0351	-0.0030

The precipitation decrease is very slight (especially in CENTER and SOUTH subregions), whereas the temperature increase is a more evident, similar in all the subregions.

Conclusions and future work (1)

- Two simulations covering the period 1971-2000 have been evaluated: one driven by ERA40 Reanalysis and one by CMCC-MED global climate model, in order to assess the performances of COSMO-CLM over Italy by using a configuration chosen after a sensitivity study.

- A comparison between the period 2031-2060 and 1971-2000 has been carried out to analyze the mean changes in the future in terms of 2-metre temperature and precipitation.

- COSMO-CLM generally underestimates the temperature in winter and overestimates it in summer; the seasonal cycles are very well captured. CMCC-MED driven simulation shows a strong cold bias in all the seasons, up to -5°C. The bias of the ERA40 driven simulation does not exceed 3°C.

- For the precipitation, a less evident difference between the two simulations output occurs; the bias is always between -4 and 5 mm/day, with a wet bias on the Alps, especially in spring.

- The total cloud cover is generally overestimated (the bias is higher in the case of the simulation forced by CMCC-MED), especially in spring and summer.

- Concerning the geopotential, the simulation forced by ERA40 has a bias close to 0 for both the pressure levels considered (500 hPa and 850 hPa), whereas the CMCC-MED driven simulation shows a slight underestimation, at most 2%.

Conclusions and Future works (2)

- It is worth noting that the bias found on the Alps (cold and wet) can be attributed not only to the model, but also to the observation values, because in some cases the measurement stations are not at high altitudes, with a consequent low-elevation station bias (Adam and Lettenmainer 2003).

- The mean temperature increase is in agreement with several literature works (Perini et al. 2007, Brunetti et al. 2002). Unfortunately, it is difficult to make a detailed comparison with other papers because in the literature the studies are conducted over different observation periods and in different regions.

- The precipitation reduction is in agreement with Buffoni et al. 1999, Piervitali et al. 1998, Coppola and Giorgi 2010. Also for precipitation, the trend values obtained in this work are not directly comparable with the literature papers due to the different time period considered.

- Currently, two simulations are running:

  - forced by the global climate model CMCC-MED with the IPCC RCP4.5 scenario up to 2100 (now at 2067);
  - forced by the global climate model CMCC-MED with the IPCC RCP8.5 scenario up to 2100 (now at 2018).

Thanks

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