THE ORIENTGATE NETWORK

Centro Euro-Mediterraneo sui Cambiamenti Climatici

Impacts on Soil and Coast Division

Cambiamenti climatici in Trentino: gli scenari futuri

Myriam Montesarchio
Alessandra Lucia Zollo
Nicola Ciro Zollo
Veronica Villani
Luigi Cattaneo
Paola Mercogliano

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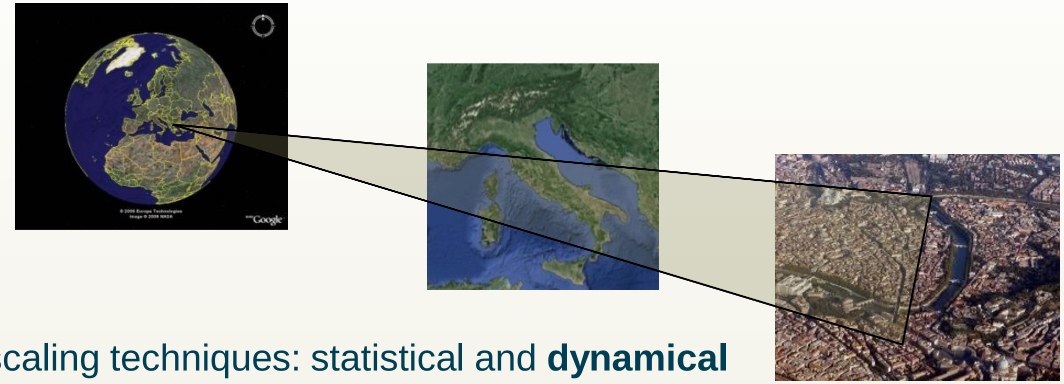
Outline

- Downscaling techniques
- Performed regional climate simulations in Orientgate project
- Performance evaluation and climate projections
- Focus on Trento pilot case: validation and bias correction
- Future scenarios over Trento

The downscaling

Downscaling indicates a reduction of scale, i.e. an increase of the spatial resolution: the aim is to increase information, maintaining the consistency of the atmospheric physical description.



Two main downscaling techniques: statistical and **dynamical**

Global Climate Models (GCMs) are used to simulate the response of global climate to the different IPCC emission scenarios. They allow the representation of several physical processes, but are characterized by low horizontal and vertical resolution.

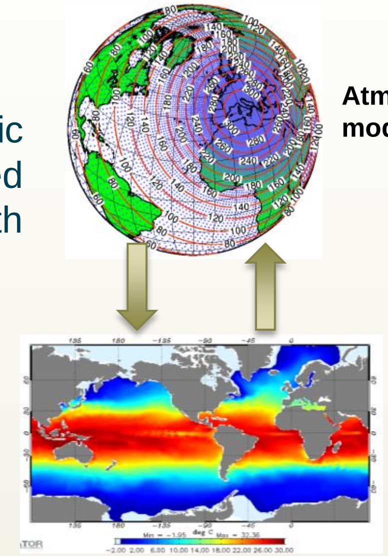
Regional Climate Models (RCMs) can be adopted to study the climate at local scale and the impacts due to climate changes. They allow a better representation of relevant atmospherical processes, also due to a better representation of the orography.

Global and regional climate models at CMCC

➢ GCM: CMCC-CM

CMCC-CM is a coupled atmosphere-ocean model. The atmospheric component is ECHAM5 (about 0.75° x 0.75° of resolution), coupled with the global ocean component OPA8.2 (resolution of 2° x 2° with a meridional refinement near the equator).

The coupling is carried out through the coupler OASIS3.



Atmosphere model

Ocean and sea-ice model

➢ RCM: COSMO-CLM

It is a non hydrostatic regional climate model, developed by the CLM-Community. It can be used for simulations on time scales up to centuries and spatial resolutions between 1 and 50 km (close to those requested by impact modellers). Moreover, the non-hydrostatic modelling allows providing a good description of the convective phenomena and an improved representation of subgrid scale physical processes (clouds, aerosols, orography, land and vegetation properties).

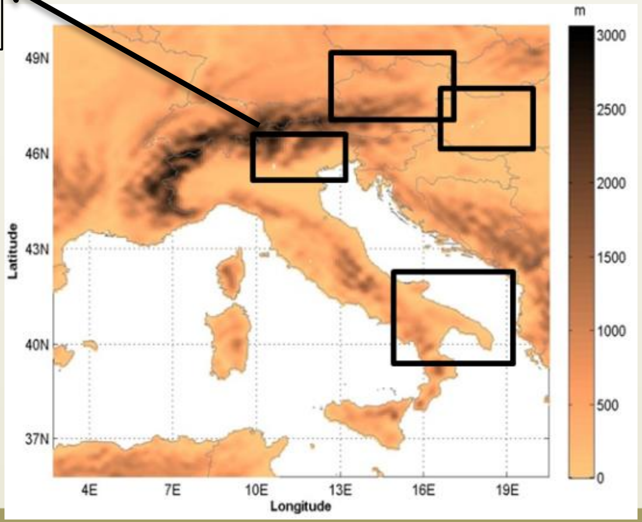
Numerical simulations (8 km)

In the framework of WP3, the performed numerical simulations, at 0.0715º (about 8km) of horizontal resolution, are driven by:

- **XX century**
  1. ERA40 reanalysis (horizontal resolution of 1.125° , about 128km), to assess the model performance in "perfect" boundary conditions, for the period 1971-2000.
  2. CMCC-CM, "sub-optimal" forcing following the IPCC 20C3M protocol (horizontal resolution of 0.75° , about 85km), for the period 1971-2005.
- **XXI century**
  1. CMCC-CM, considering the RCP4.5 scenario, for the period 2006-2070
  2. CMCC-CM, considering the RCP8.5 scenario, for the period 2006-2070

Simulated domain: (3-20º E; 36-50º N)

Trento pilot case



The E-OBS dataset has been used to evaluate the performances of the simulations over the whole domain.

In addition, for Trento region, simulations have been compared with the data provided by the Provincia Autonoma di Trento (PAT).

Temperature validation

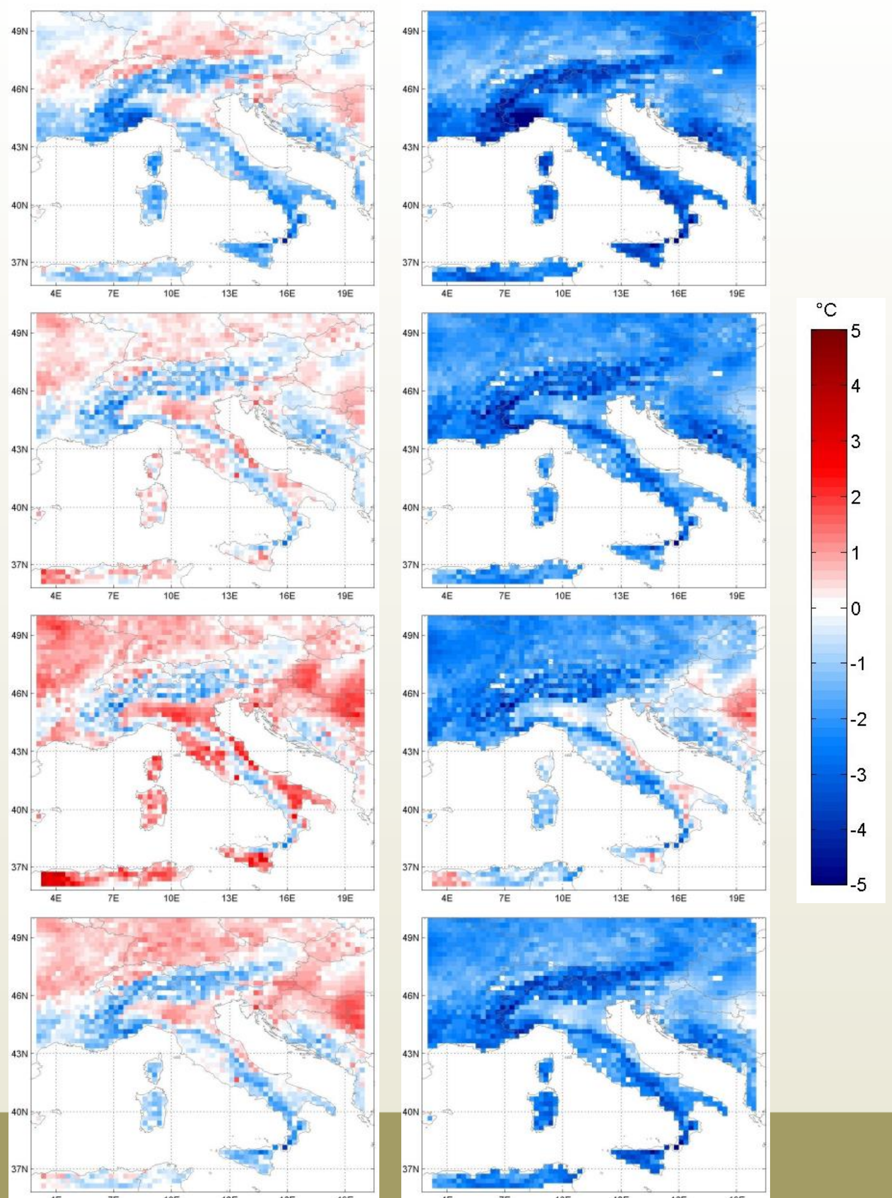
ERA40 driven CMCC-CM driven

DJF

MAM

JJA

SON



The GCM driven simulation shows a general high underestimation of temperature, more accentuate in winter. In summer, a lower bias with a slight overestimation is observed.

The bias of the simulation forced by ERA40 Reanalysis never exceeds 3° C in absolute value: the highest difference with EOBS is reached in DJF (underestimation up to 3° C in the Ligurian Alps) and in JJA (general hot bias).

Precipitation validation

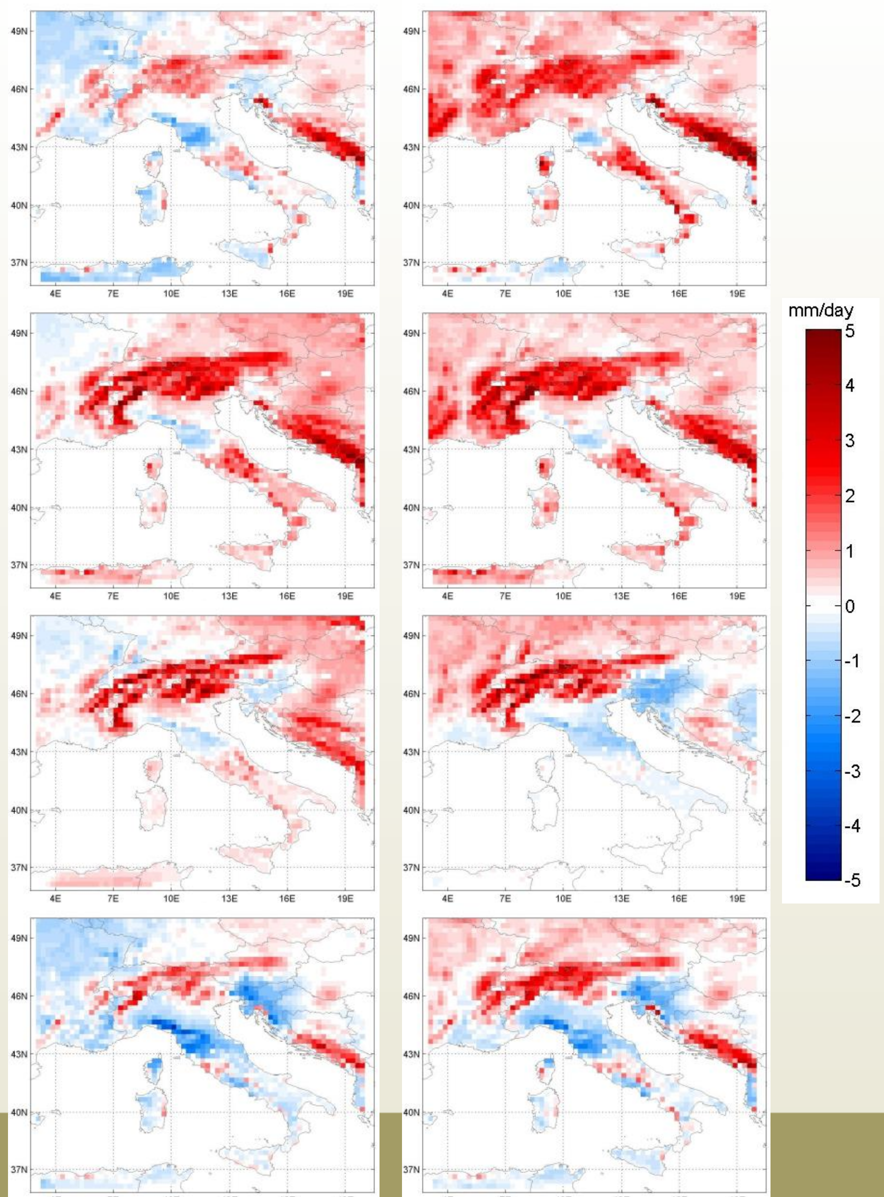
ERA40 driven | CMCC-CM driven

DJF

MAM

JJA

SON



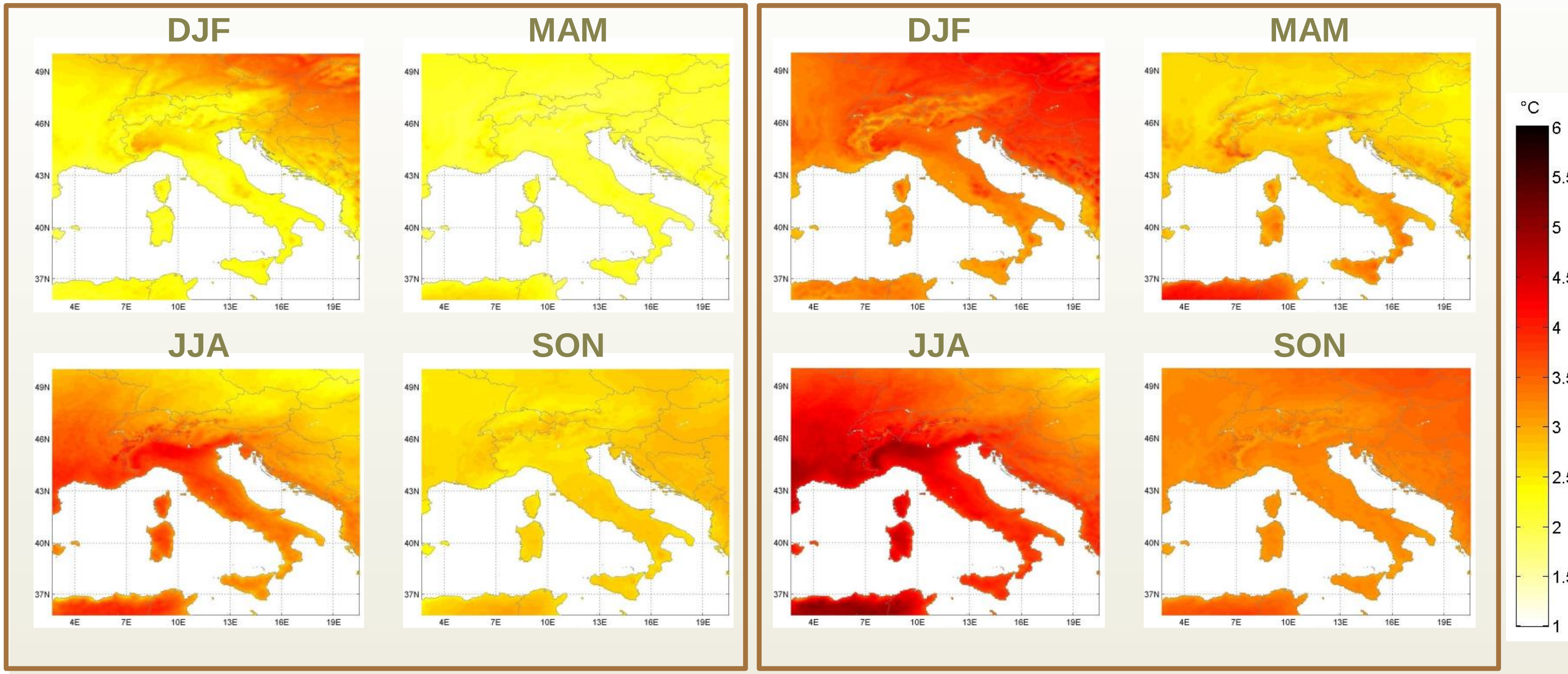
Both the simulations highlight an overestimation over the Alps in all the seasons, but more pronounced in spring and winter.

The GCM driven simulation shows a high precipitation overestimation in DJF months (stronger over Alps and Adriatic coast) but an error close to 0 mm/day in JJA in southern Italy.

MAM is the season affected by the highest error (similar behaviour for the two simulations analysed).

Temperature future projections: 2041-2070 vs 1971-2000

RCP4.5 SCENARIO / RCP8.5 SCENARIO

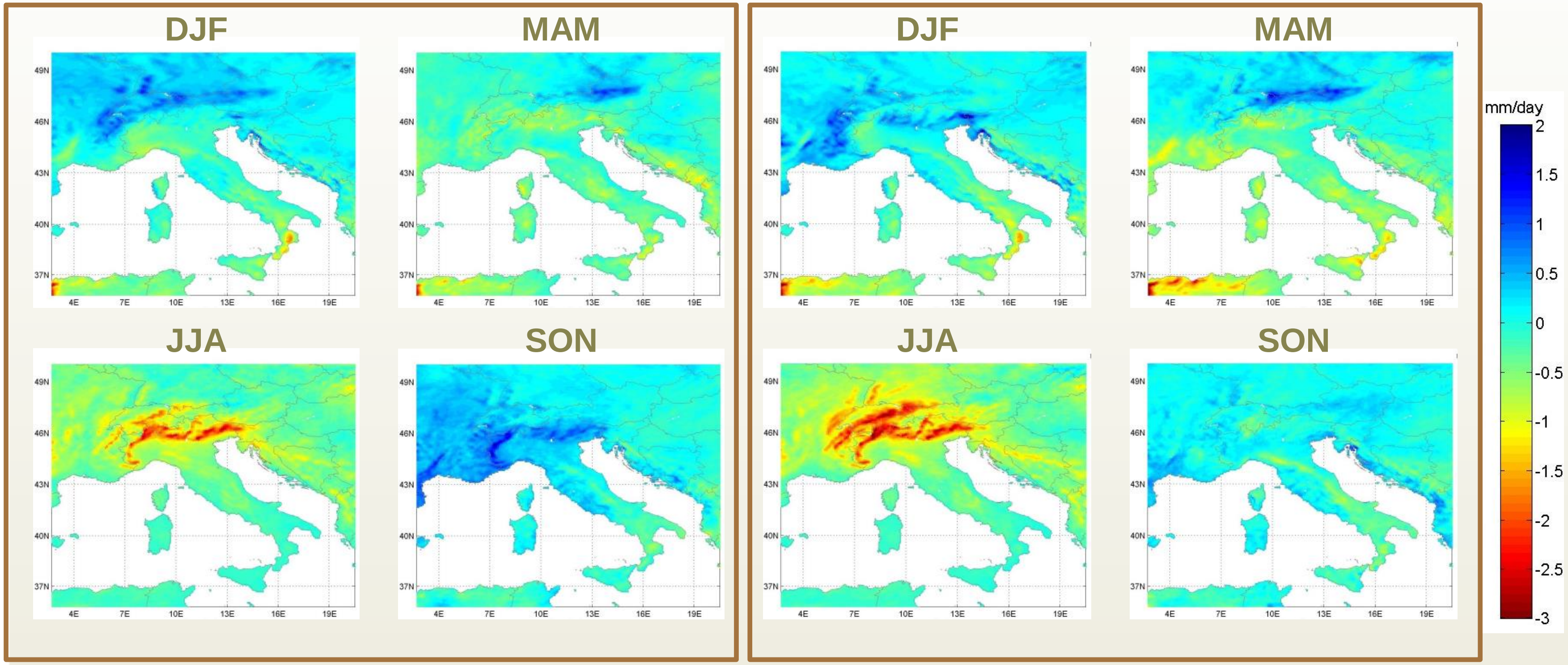


A general temperature increase is projected, more pronounced in DJF and JJA. MAM (for RCP4.5) and SON (for RCP8.5) are characterized by a very homogeneous growth of temperature.

The temperature increase under RCP8.5 scenario is, on average, 1.5° C higher than under the RCP4.5 one.

Precipitation future projections: 2041-2070 vs 1971-2000

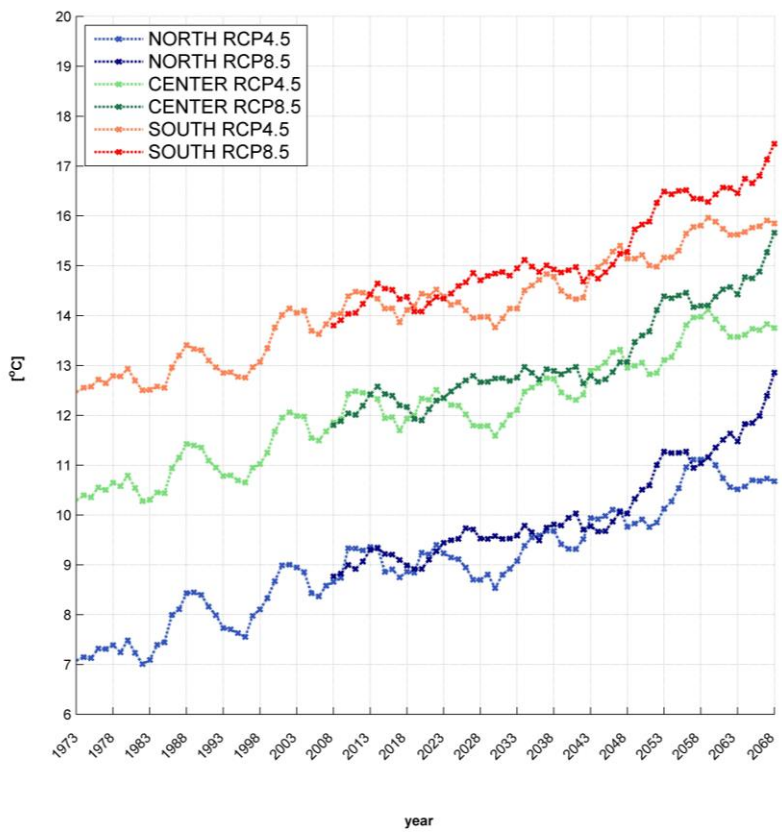
RCP4.5 SCENARIO | RCP8.5 SCENARIO

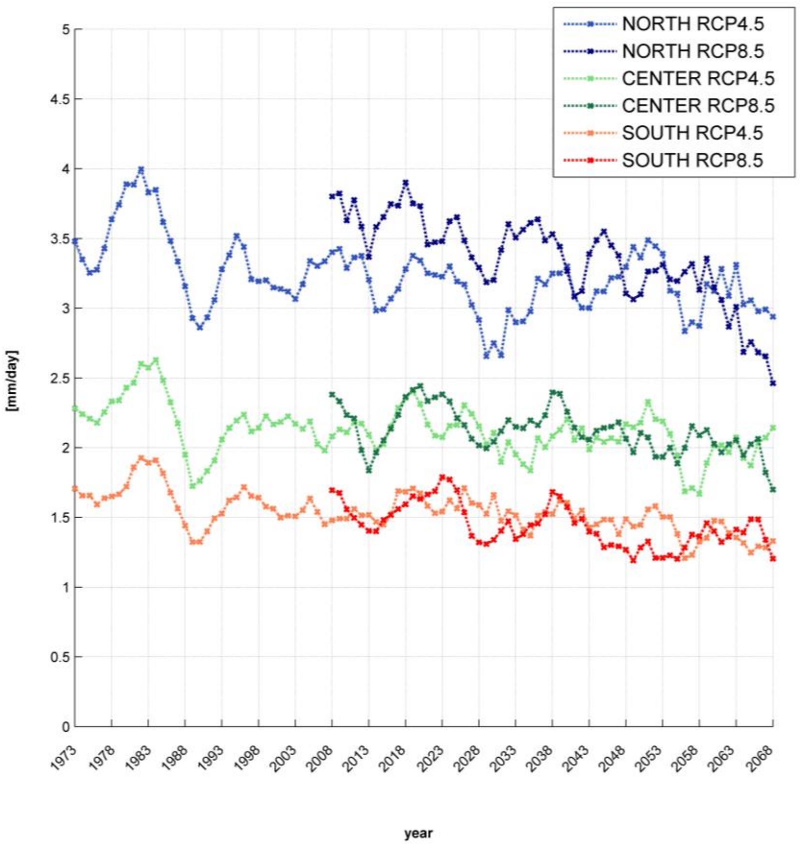


A precipitation increase is simulated in DJF over the north-west part of the domain and in MAM over the eastern Alps (up to 1.5 mm/day under RCP8.5 scenario).

In JJA a decrease is simulated over Alpine region (up to -3 mm/day under RCP8.5); in SON a different trend is observed for the two scenarios.

Future projections for three subregions of Italian peninsula



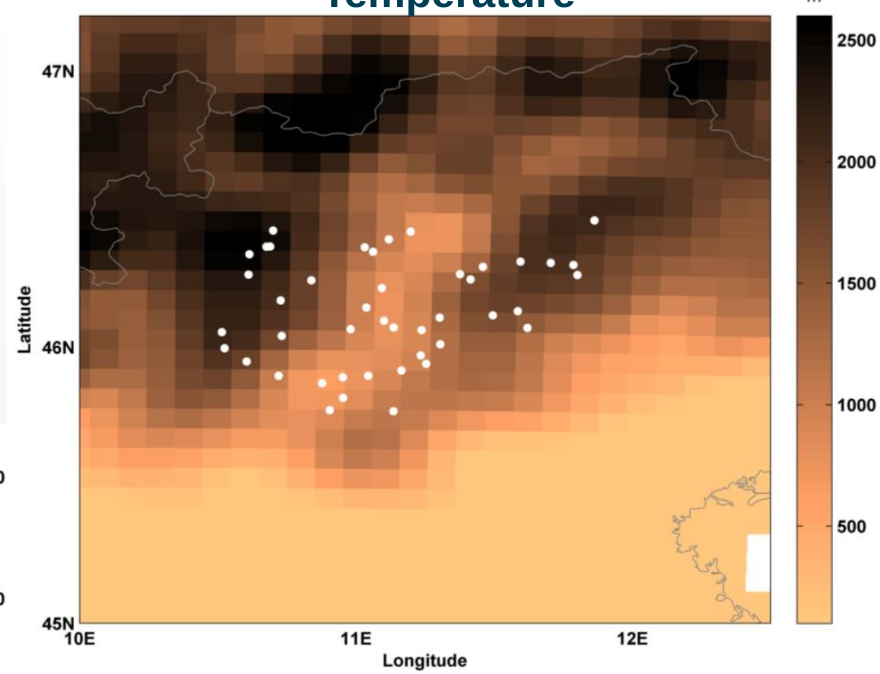


T2m: a general warming is projected, higher under RCP8.5 scenario.
Precipitation: a slight decrease for RCP4.5 and a more evident reduction for RCP8.5 is simulated.

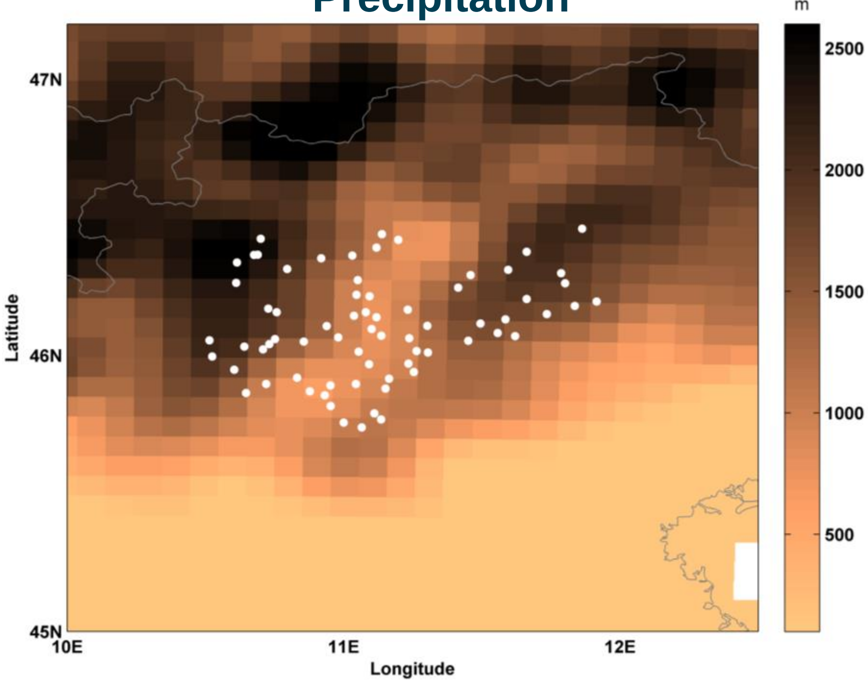
Trento pilot case

The general purpose of the pilot study in the Trento province is to assess the impact of climate change on future water resource availability at the basin scale

Temperature



Precipitation



Observed data provided by Provincia Autonoma di Trento (PAT)

Daily time series of <u>minimum and maximum temperature</u> and <u>precipitation</u> from point stations. Period of available data: 1960-2010

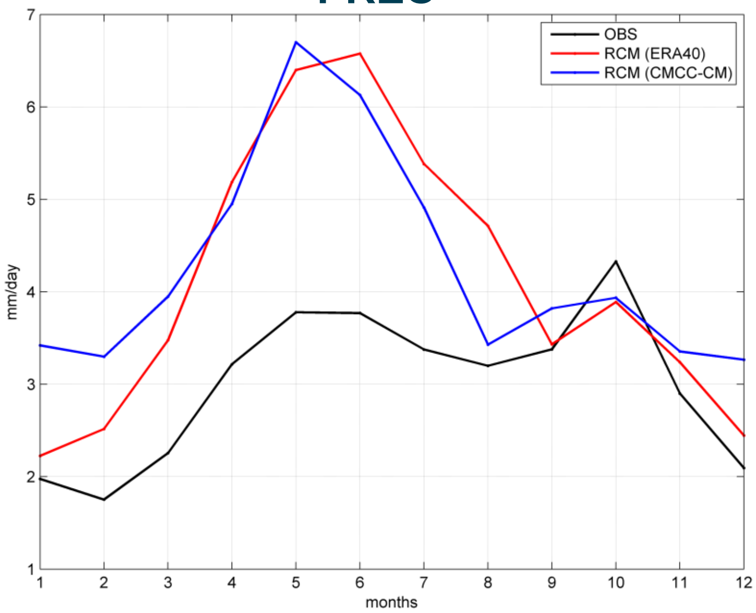
Trento pilot case - seasonal cycles

PREC: significant overestimation, especially in spring

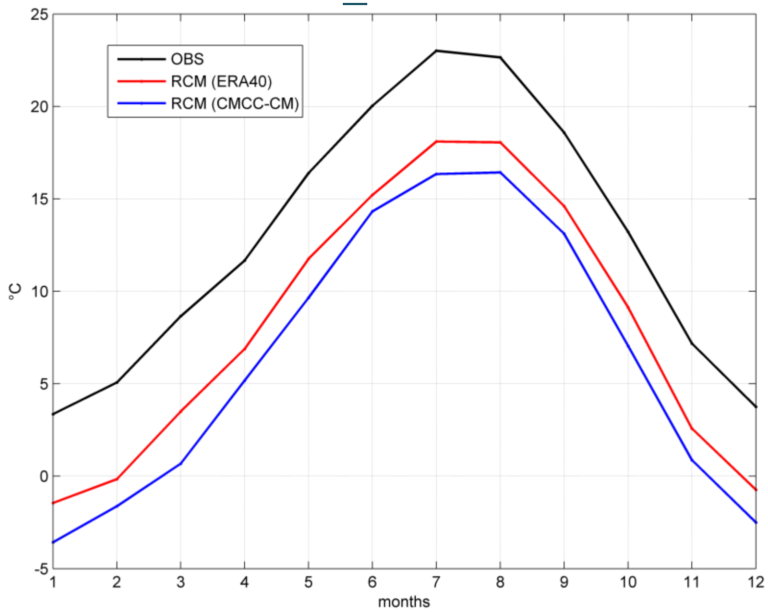
T_MAX, T_MIN: underestimation in all months, more accentuated for T_MAX

In general worse performance for CMCC-CM driven simulation.

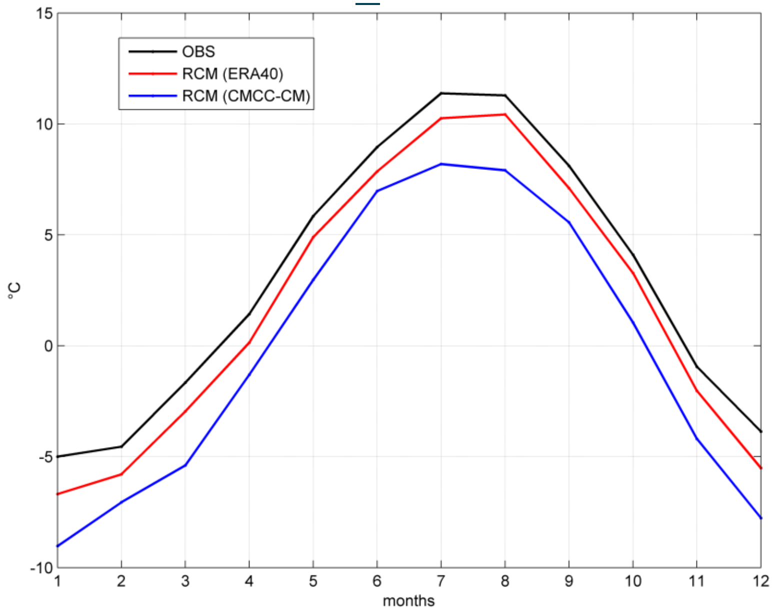
PREC



T_MAX



T_MIN



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Need of bias correction

- Regional climate models (RCMs) provide detailed information at local scale
- In climate change impact assessment the output of RCMs can be used as input for impact models
- The direct use of RCM simulations in hydrological impact studies is challenging due to model bias originated from different sources of error:
  - boundary problems transferred from GCMs to RCMs
  - model approximations
  - insufficiently resolved surface properties (e.g.orography)
  - errors due to numerics and parameterizations
- Different bias correction approaches are available to reduce these errors:

Linear Scaling LS

monthly correction values obtained as:
- ratio μ(OBS)/μ(RCM), for precipitation
- difference μ(OBS)-μ(RCM), for temperature

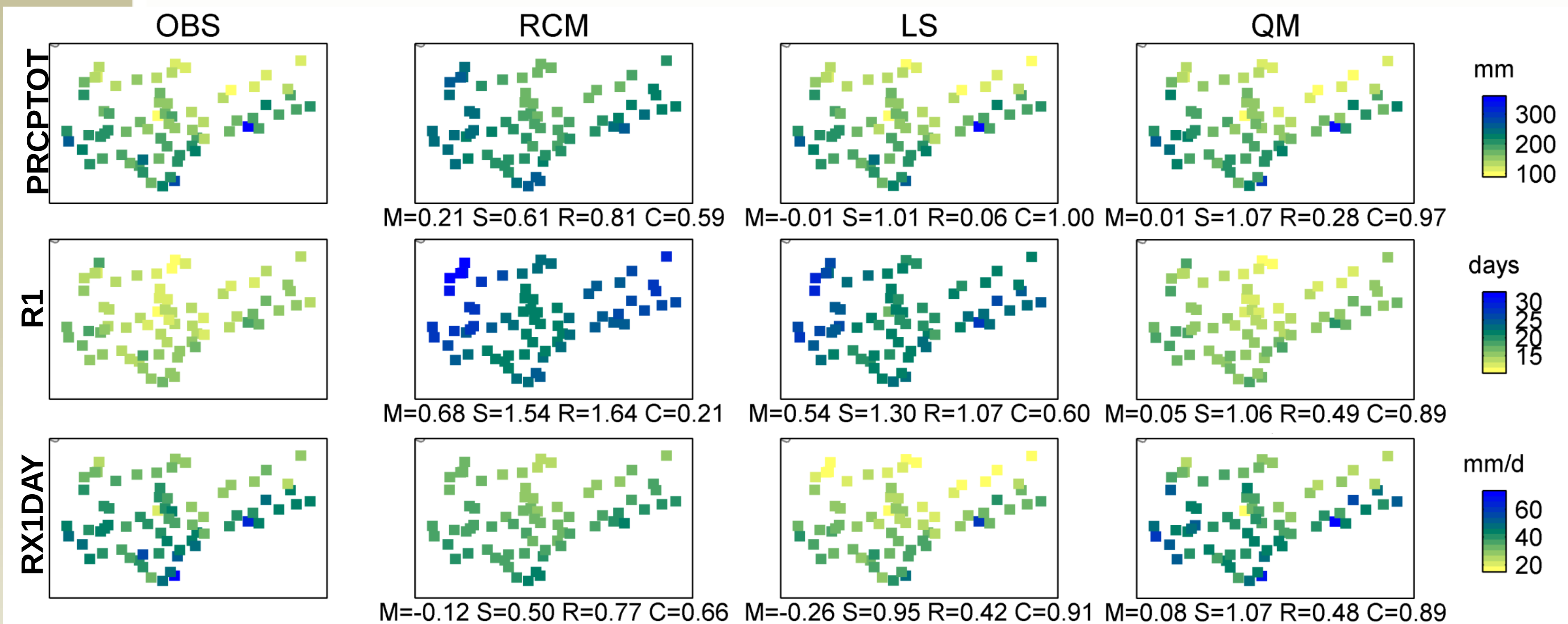
Quantile Mapping QM

the idea is to correct monthly the PDF of the RCM to agree with the observed PDF
- fitting a Gamma distribution, for precipitation
- fitting a Gaussian distribution, for temperature

Teutschbein, C. and Seibert, J. "*Bias correction of regional climate model simulations for hydrological climate-change impact studies: Review and evaluation of different methods*". J. Hydrol., *pages* 456–457, 2012

PREC winter spatial pattern

ERA40-driven simulation, values averaged over the 1971-2000 period.



Label	Description	Units
PRCPTOT	total precipitation	mm
R1	number of days with precipitation over 1 mm/day	days
RX1DAY	maximum precipitation in 1 day	mm

Below each subplot is indicated mean bias (**M**), relative standard deviation (**S**), centered root-mean-square (**R**) and correlation (**C**) of RCM, LS and QM methods w.r.t. observations.

QM has better performances as it improves not only the representation of mean regimes, but also of frequency of wet and dry day and of extremes of precipitation. In terms of PRCPTOT, LS and QM are practically equivalent.

Future scenarios over Trento and extreme events

- Over Trento, anomalies in terms of extreme values of temperature and precipitation have been investigated, starting from the original output of COSMO-CLM.

- The warming of the climate system in recent decades is now evident from observations (IPCC, 2012) and a changing climate is expected to lead to changes in seasonal means and in frequencies of regional extreme temperatures (high and low) and humidity (high and low), extreme or prolonged precipitation (rain, snow, ice, etc.) or prolonged lack of precipitation (drought), extreme wind, thunderstorms, etc.

- The increased frequency and intensity of extreme weather can cause events such as flooding, landslides, hydrological drought, wild fires etc. which present a range of complex challenges to the resilience of infrastructures.



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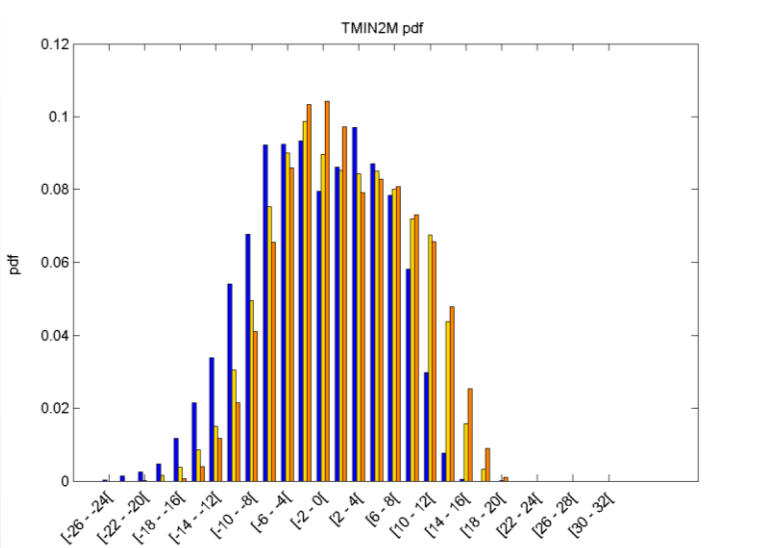
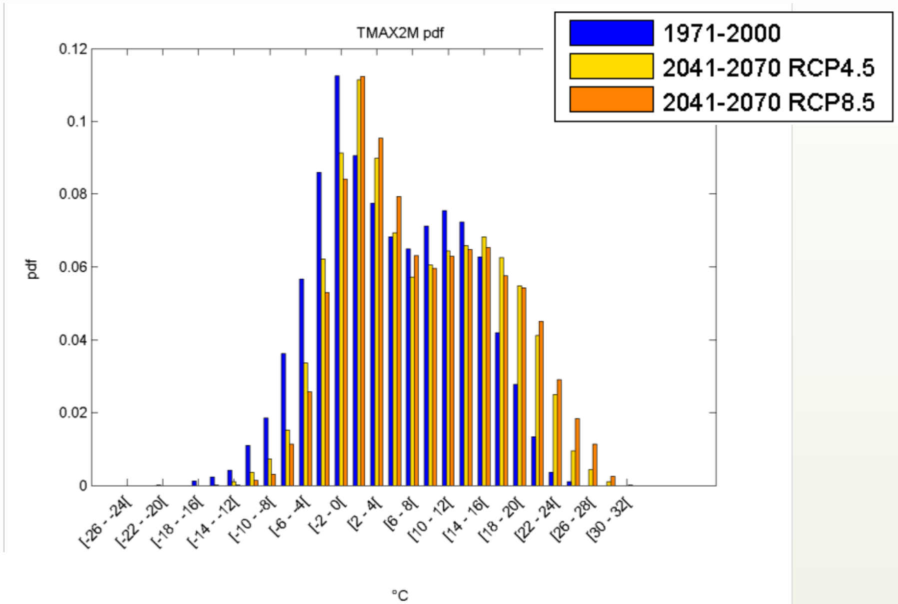
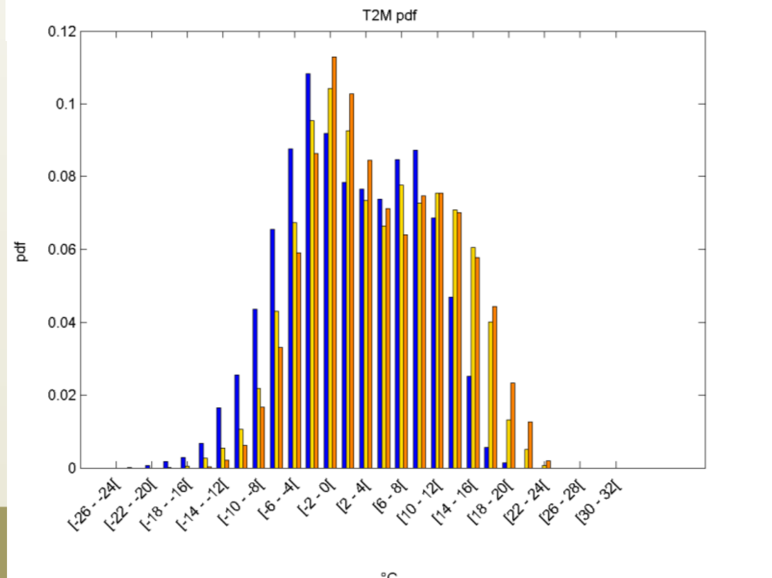
Temperature PDFs over Trentino region







There is an evident shift in the distribution for both the scenarios, but stronger for the RCP8.5: a decrease of cold events and an increase of the warm ones is simulated.

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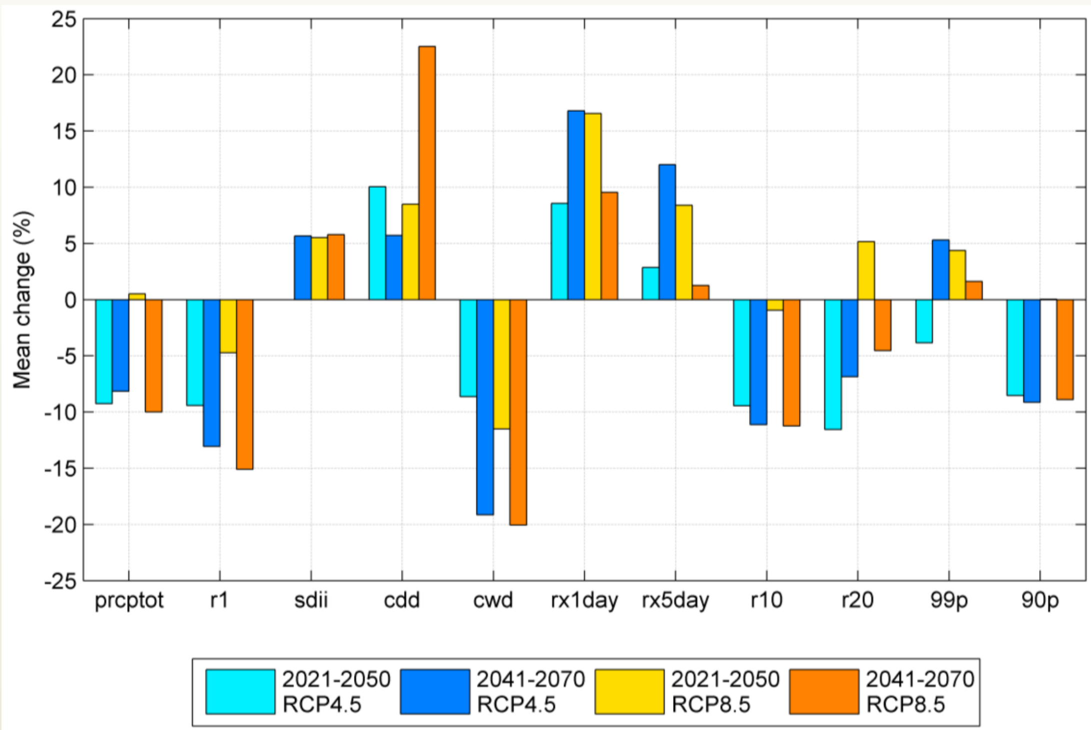
Precipitation scenarios

The climate change signal projected for precipitation indices indicates a general decrease of total precipitation, number of rainy days, consecutive wet days and number of days with precipitation over 10 and 20 mm/day, while there is a general increase of mean precipitation amount on wet days (sdii), consecutive dry days and maximum of precipitation (rx1day and rx5day). Moreover, scenarios describe an increase in the 99th percentile ('more extreme' index) and a decrease of 90th percentile ('less extreme' index). The comparison between the RCP4.5 and RCP8.5 scenarios indicates that, except for some cases, the sign of the climate change signal remains the same.

Label	Description	Units
PRCPTOT	Total precipitation	mm/day
R1	Number of days with precipitation over 1 mm/day (i.e. rainy days)	days/year
SDII	Mean precipitation amount on wet days	mm/day
CDD	Consecutive dry days (< 1 mm)	days/year
CWD	Consecutive wet days (> 1 mm)	days/year
RX1DAY	Maximum precipitation in 1 day	mm/day
RX5DAY	Maximum precipitation in 5 days	mm/5days
R10mm	Number of days with precipitation over 10mm/day	days/year
R20mm	Number of days with precipitation over 20mm/day	days/year
PREC99P	99th Percentile of the total daily precipitation	mm/day
PREC90P	90th Percentile of the total daily precipitation	mm/day



Climate change signals for RCP4.5 and RCP8.5 considering 2021-2050 and 2041-2070 vs 1971-2000.

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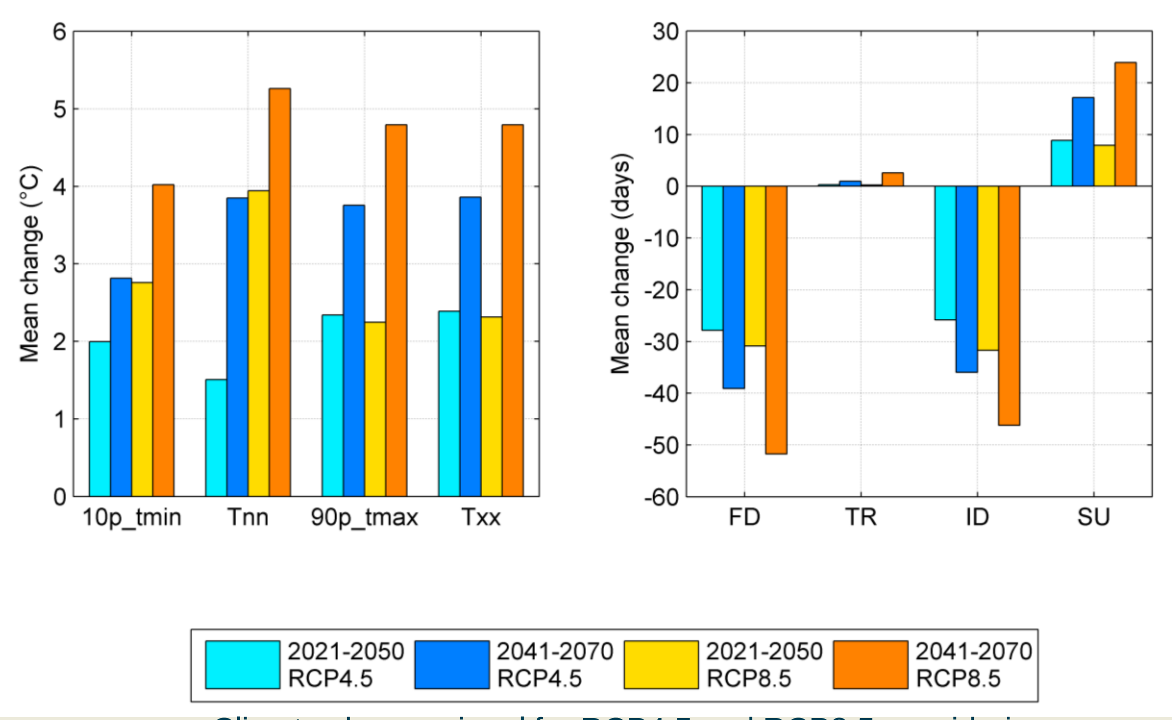
Temperature scenarios

The climate change signal projected for temperature indicates a significant increase of both minimum and maximum temperature for all considered indices. Moreover, there is an accentuated decrease of frost days (FD - days with Tmin<0° C) and icing days (ID - days with Tmax<0° C), an increase of summer days (SU – days with Tmax>25° C) and a substantial steady signal for tropical nights (TR – days with Tmin>20° C). The comparison between the RCP4.5 and RCP8.5 scenarios indicates that in all the cases the sign of the climate change signal remains the same for both scenarios, but the magnitude of the change is much greater for the RCP8.5.

Label	Description	Units
10p_tmin	10th percentile of daily Tmin	°C
Tnn	Annual minimum value of daily minimum temperature	°C
90p_tmax	90th percentile of daily Tmax	°C
Txx	Annual maximum value of daily maximum temperature	°C
FD	Annual count of days when the daily Tmin is below 0°	days/year
TR	Annual count of days when the daily Tmin is above 20°	days/year
ID	Annual count of days when the daily Tmax is below 0°	days/year
SU	Annual count of days when the daily Tmax is above 25°	days/year



Climate change signal for RCP4.5 and RCP8.5 considering 2021-2050 and 2041-2070 vs 1971-2000.

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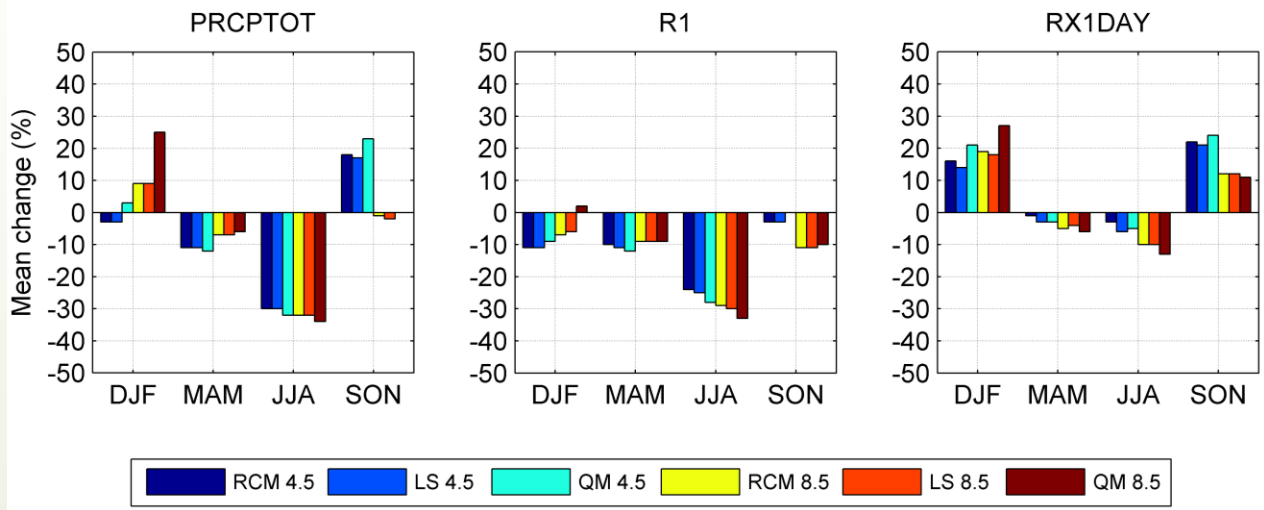
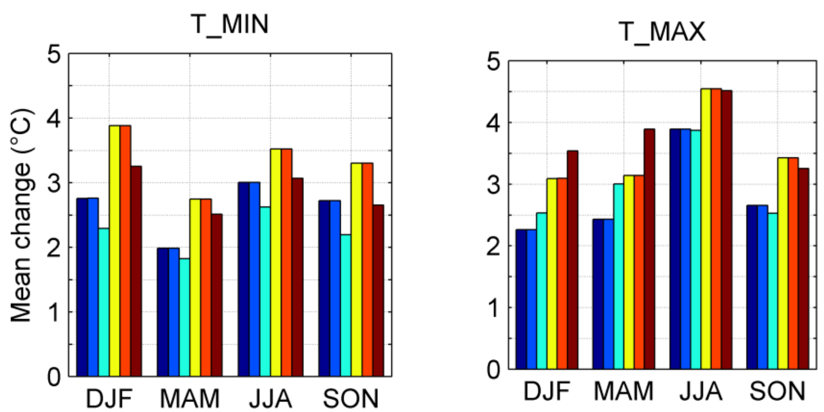
Bias corrected scenarios

The change signal obtained using LS and QM methods is generally comparable to that obtained by the COSMO-CLM model for both the scenarios, indicating the capability of these post-processing techniques to preserve the climate change signal of the RCM.

More pronounced changes are:

- decrease in the number of rainy days and total precipitation in summer;
- increase of maximum daily precipitation in winter and autumn;
- increase of temperature in all the seasons.





The mean change is calculated between control (1971-2000) and future (2041-2070) periods.

Conclusions

- Regional climate simulations performed with the RCM COSMO-CLM have been analyzed over the Italian peninsula, focusing on Trento region.
- The model is generally characterized by a general temperature underestimation and precipitation overestimation.
- To reduce the bias, two bias correction techniques, linear scaling and quantile mapping, have been tested (the second one shows better performances), over the Trento pilot case. The application of bias correction methods clearly outperform the performance of the simulations.
- Future climate projections show a general temperature increase and a precipitation decrease, always stronger when the RCP8.5 scenario is considered.
- Climate change signal is preserved after the application of bias correction techniques.
- The original and corrected RCM data over Trento region (8 km of resolution) have been provided to the Provincia Autonoma di Trento.

Thank you