Regional Climate Models Downscaling in the Alpine Area with Multimodel SuperEnsemble

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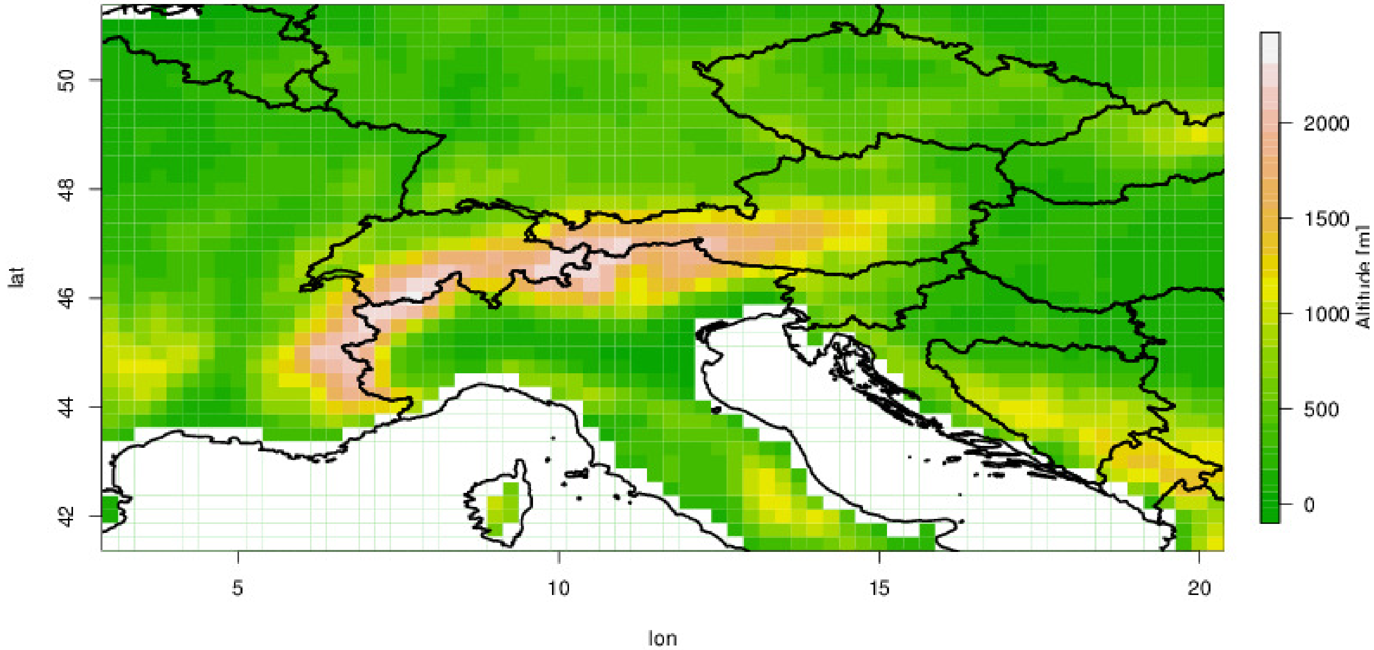
Outlook

- Introduction
- Observed data Optimal Interpolation
- Multimodel SuperEnsemble
  - Tests
  - Results
- Probabilistic Multimodel SuperEnsemble Dressing
  - Tests
  - Results
- Conclusions

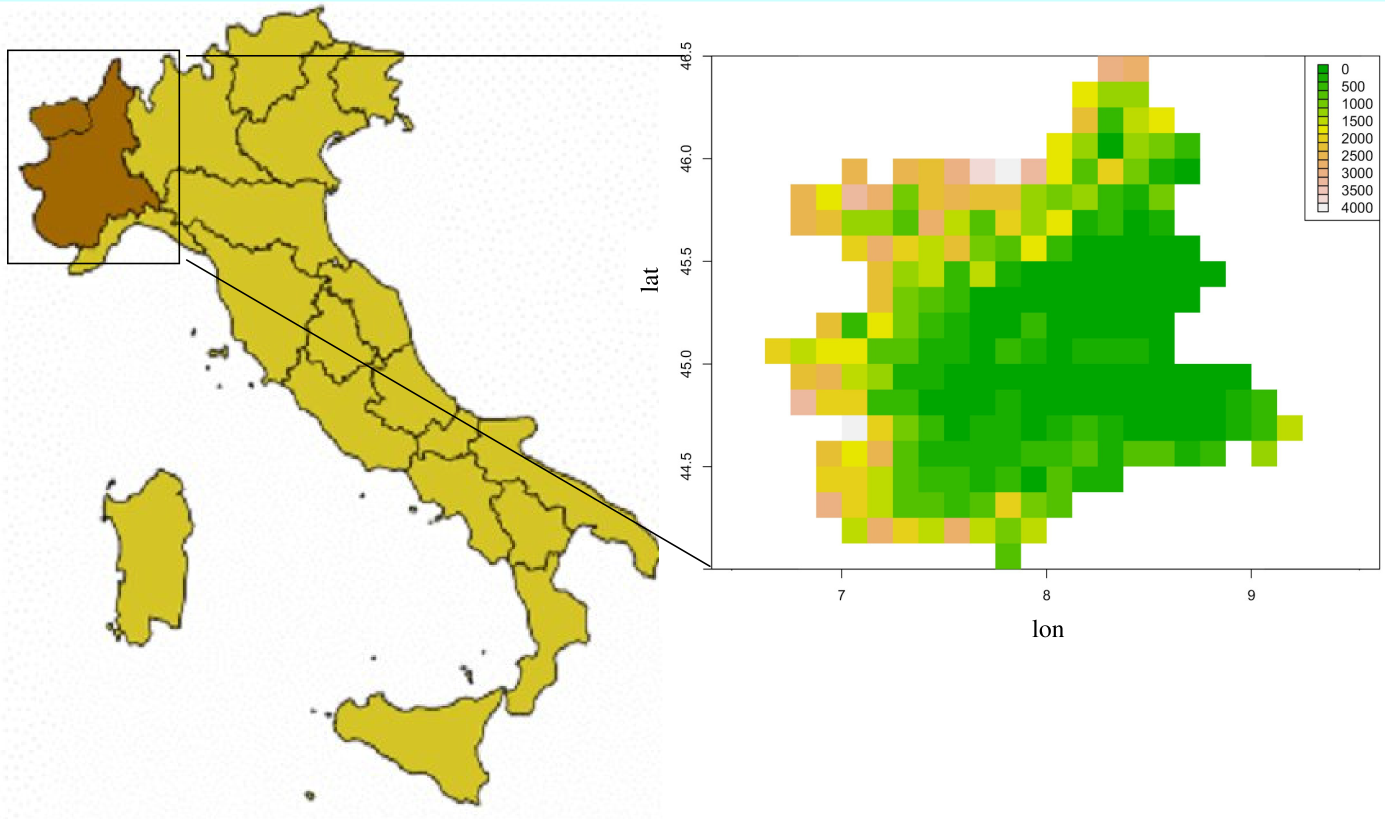
Domains



1) Greater Alpine Area

Observations: E-OBS dataset from the ENSEMBLES project (resolution: 25 km)

Domains



2) High resolution domain over Piemonte Region (resolution: 14 km)

Availability of a large dataset of independent measurements

Temperature and precipitation reconstruction

- An Optimal Interpolation (OI) technique is used to assimilate the **daily ground station data**, arbitrarily displaced in the region, on a selected regular three-dimensional grid map based on a background field (BF)
- The **background field** (only temperature) is obtained on a selected grid (0.125° resolution, with careful description of the complex orography of the region) by a linear tri-dimensional downscaling of **ERA-40 archive from 1957 to 2001** and of the **ECMWF objective analysis from 2002 to 2009**
- The use of ERA-40 on the regional area is suggested by checking that the **main climatological signals** (trends, etc.) **were congruent** with the signals resulted from a station subset working in the period 1950-2000 in Piemonte
- The method enables to weight the contribute to the temperature/precipitation value on each grid point from the nearest observation data, through suitable parameters. A **careful modulation of these parameters as a function of the data density** and the use of an external background field help to achieve the time homogeneity and the spatial coherence of the final dataset

Regional Climate Model data

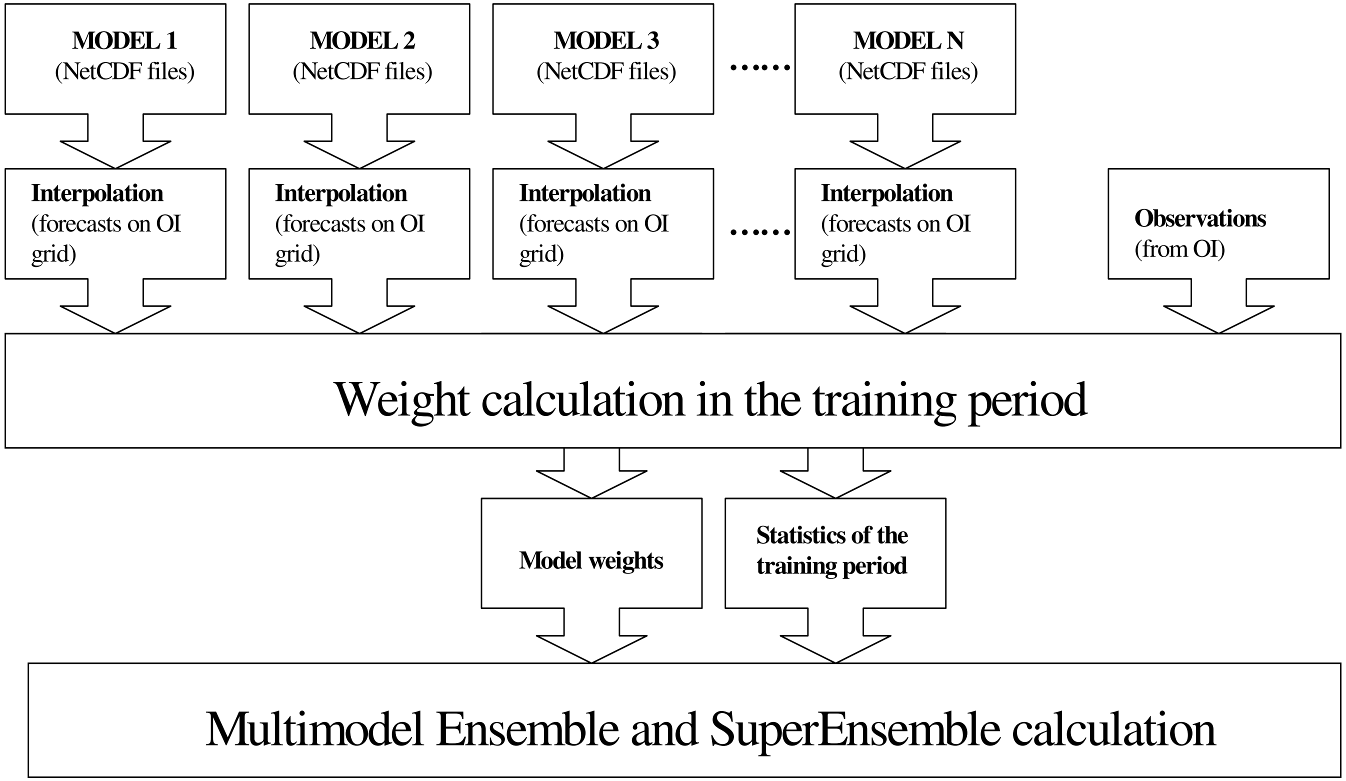
Reanalysis on ECMWF ERA-40 (1961-2000) and A1B scenario runs (1961-2100) of the following RCMs (daily data):

- **HIRHAM5 – DMI (GCM: Arpege)**
- **REGCM3 – ICTP (GCM: ECHAM5)**
- **HadRM3Q0 - Hadley Center (GCM: HadCM3Q0)**
- **RM4.5 – CNRM (GCM: Arpege)**
- **CLM - ETH Zurich (GCM: HadCM3Q0)**
- **RACMO2 – KNMI (GCM: ECHAM5)**
- **REMO - Max Plank Institute (GCM: ECHAM5)**

Source: ENSEMBLES project

- **Model data are interpolated to the OI grid via bi-linear interpolation**

Standard Multimodel SuperEnsemble



Weights calculated with a Gauss-Jordan minimisation

$$S = \overline{O} + \sum_{i=1}^{N} a_i \left(F_i - \overline{F_i} \right)$$

Krishnamurti T.N. et al., "Improved weather and seasonal climate forecasts from Multimodel SuperEnsemble", Science 285, 1548-1550, 1999

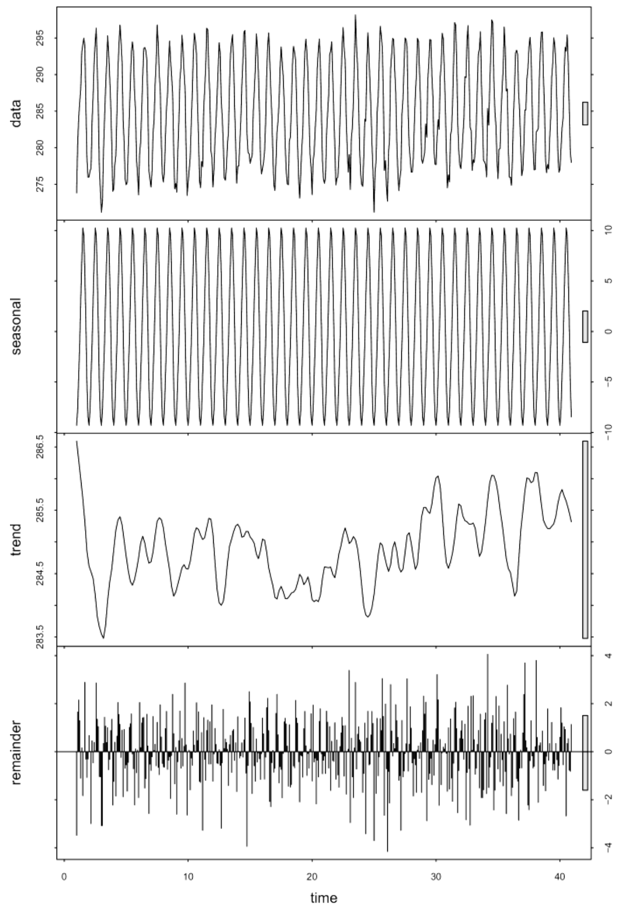
Cane D., Milelli M., "Weather forecasts obtained with a Multimodel SuperEnsemble Technique in a complex orography region", Meteorologische Zeitschrift, Vol. 15, No. 2, 207-214, 2006

Seasonal Decomposition

An example of the signal decomposition according to the Seasonal Decomposition of Time Series by LOESS (Cleveland et al., 1990).

Data are calculated daily, but statistics are performed on a monthly basis.

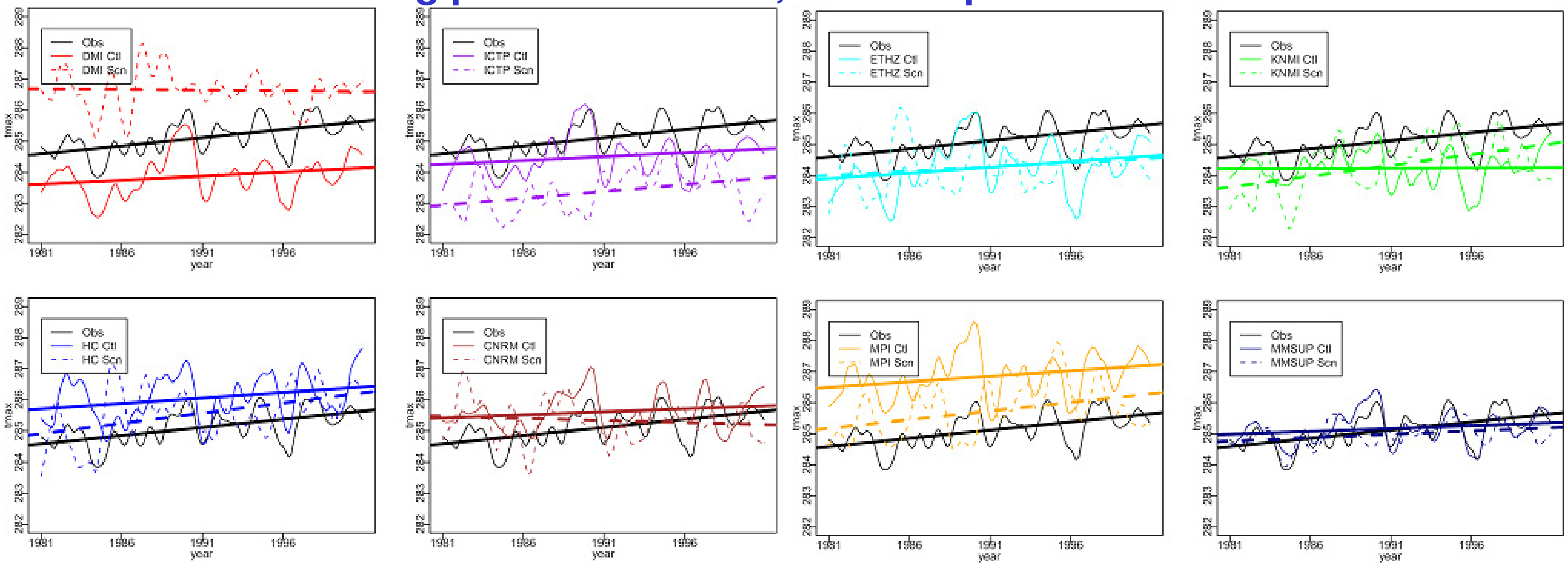
Maximum temperature



Training period 1961-1980, forecast period 1981-2000

Test in the control period

Training period 1961-1980, forecast period 1981-2000.



Maximum temperature: trends calculated with the Seasonal Decomposition of Time Series by Loess from observations (black lines), reanalysis runs (solid lines) and scenario runs (dashed lines)

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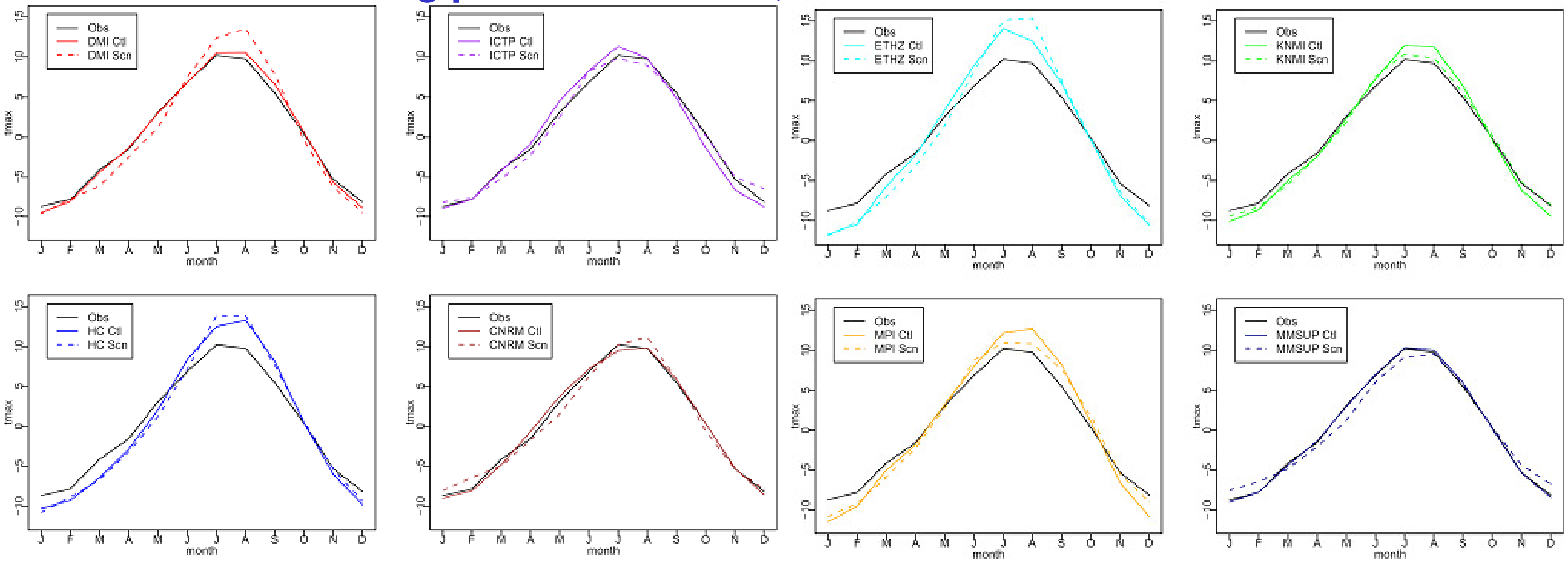
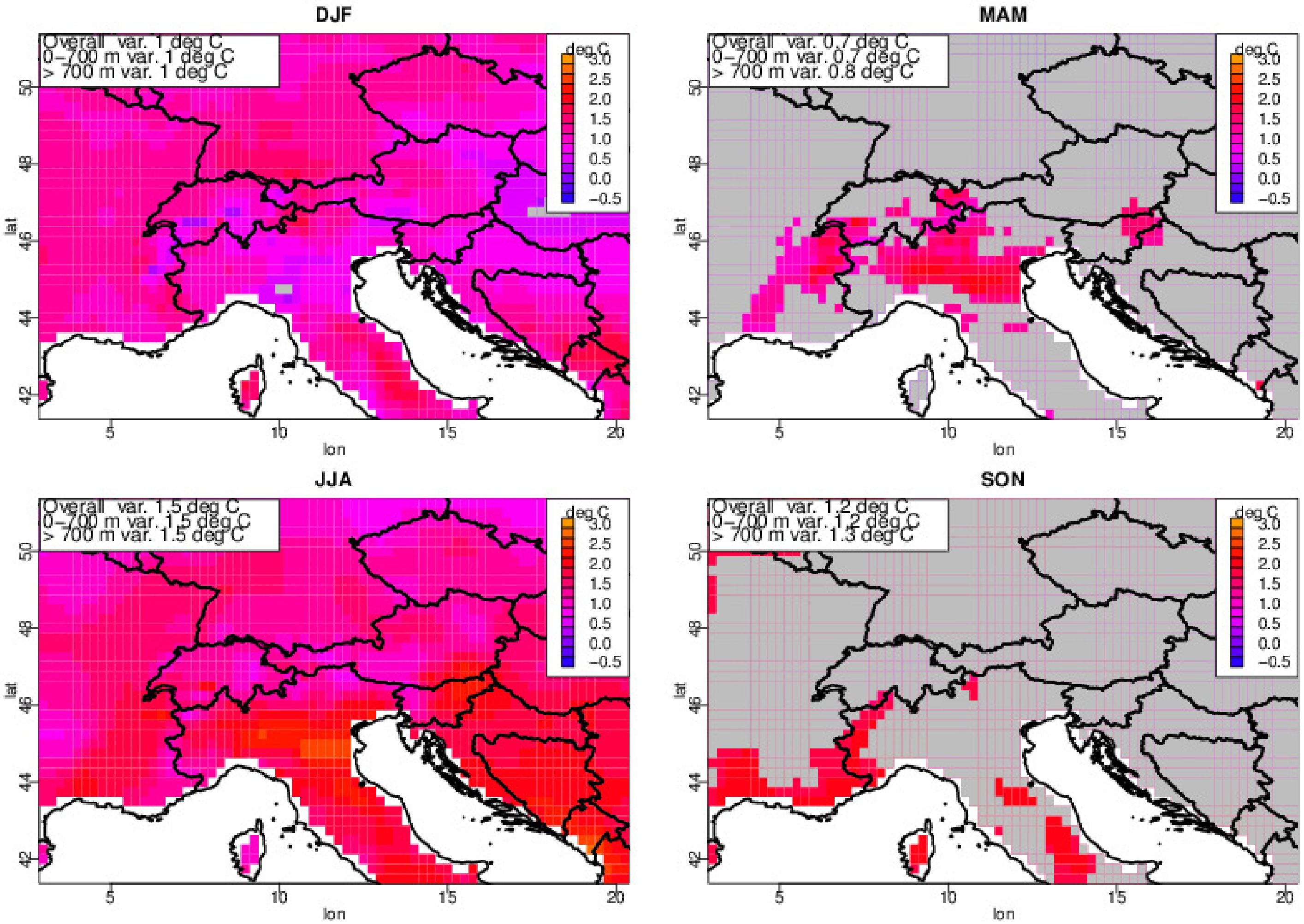


Maximum temperature: seasonal component calculated with the Seasonal Decomposition of Time Series by Loess from observations (black lines), reanalysis runs (solid lines) and scenario runs (dashed lines)

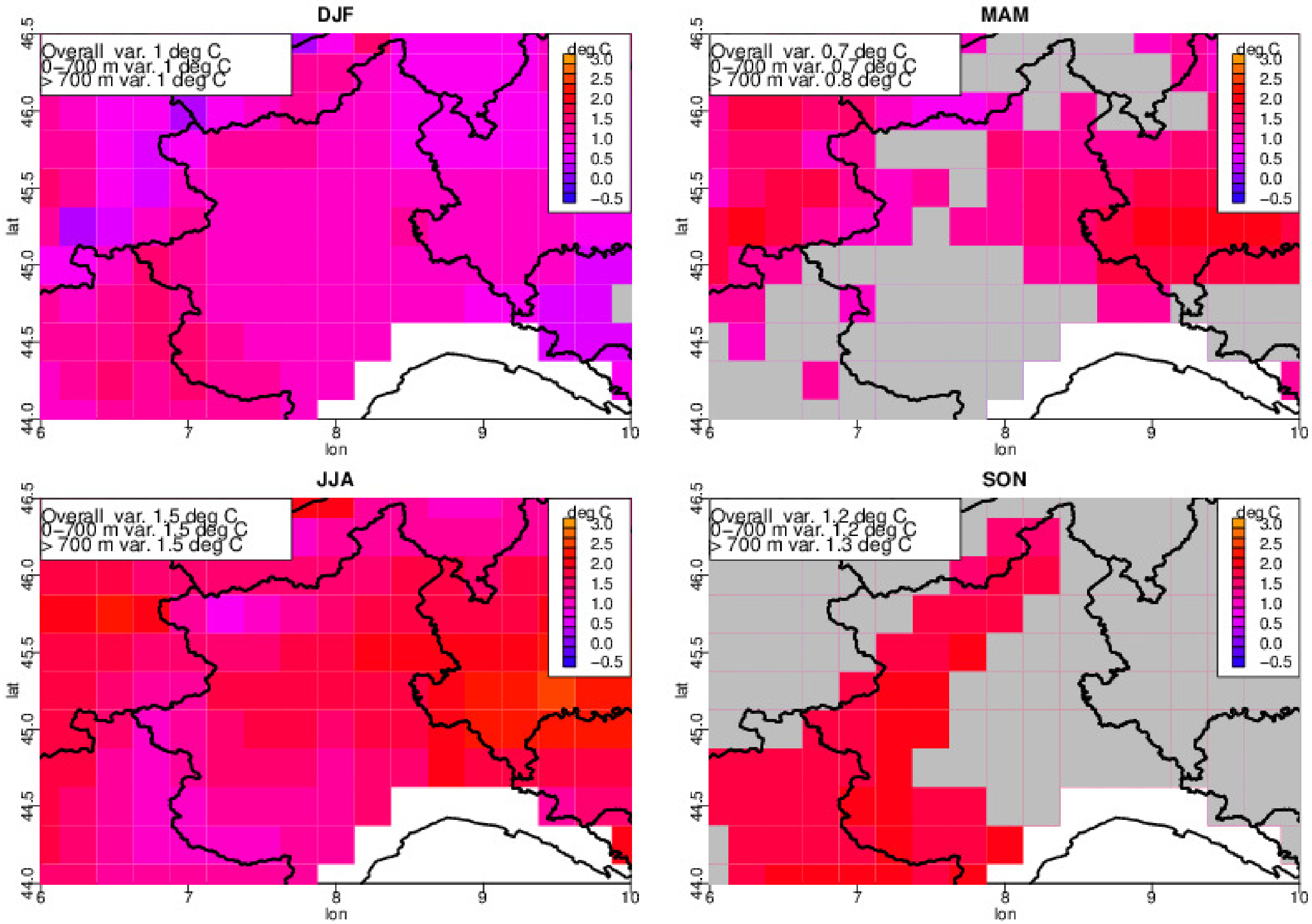
Projection to the future



Difference between the Multimodel SuperEnsemble scenario maximum temperatures averaged over the period 2031-2050 with respect to the period 1981-2000, as a function of the season (T-test conf. level 95%).

D. Cane, S. Barbarino, L. Renier, C. Ronchi

Projection to the future



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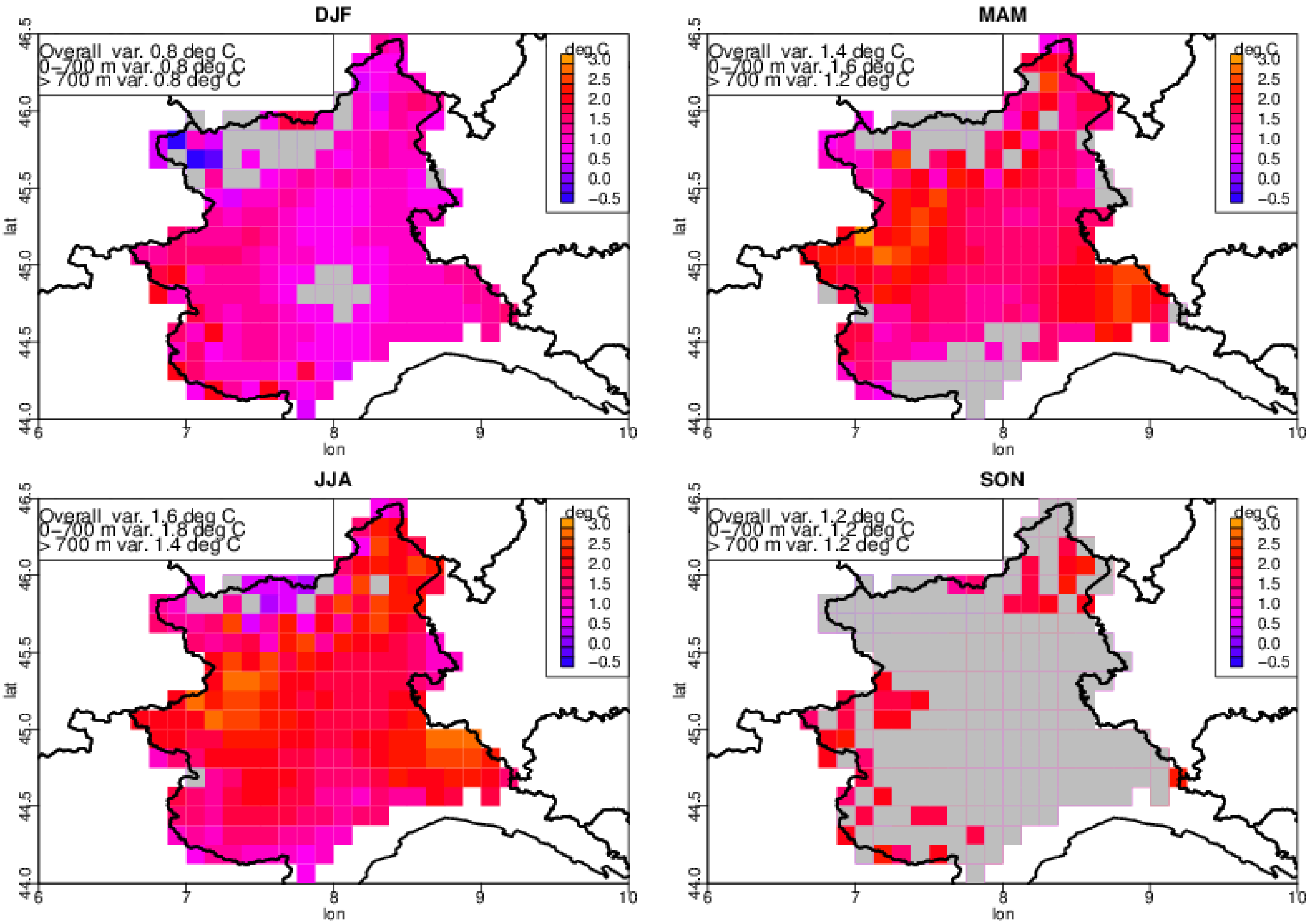

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Projection to the future

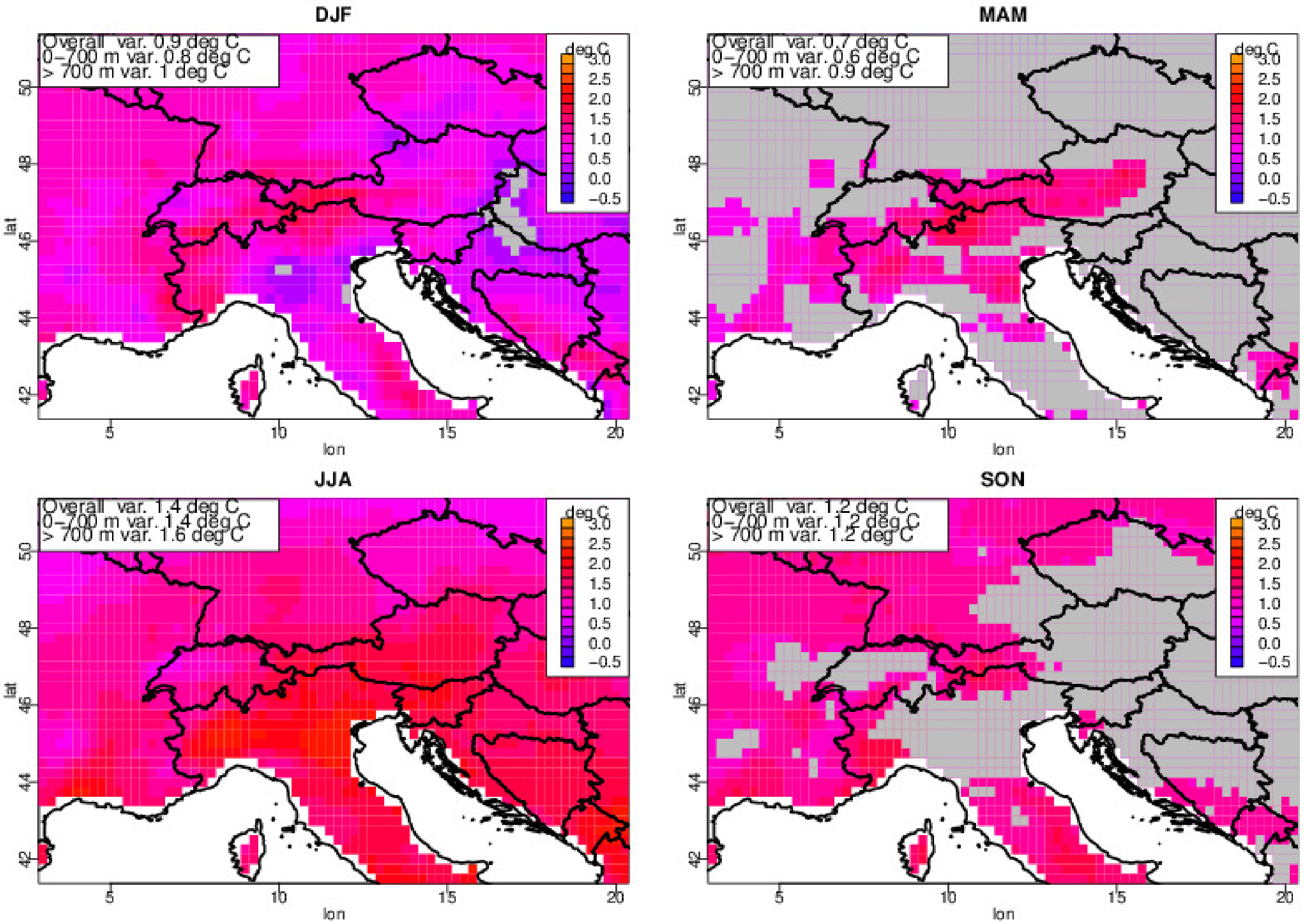
GAR area

- **maximum temperatures increase is significant everywhere in winter (+1 °C) and summer (+1.5°C), in limited areas in spring and autumn.**
- **there are few differences among the plain (<700 m) and the mountains (>700 m).**

Piedmont

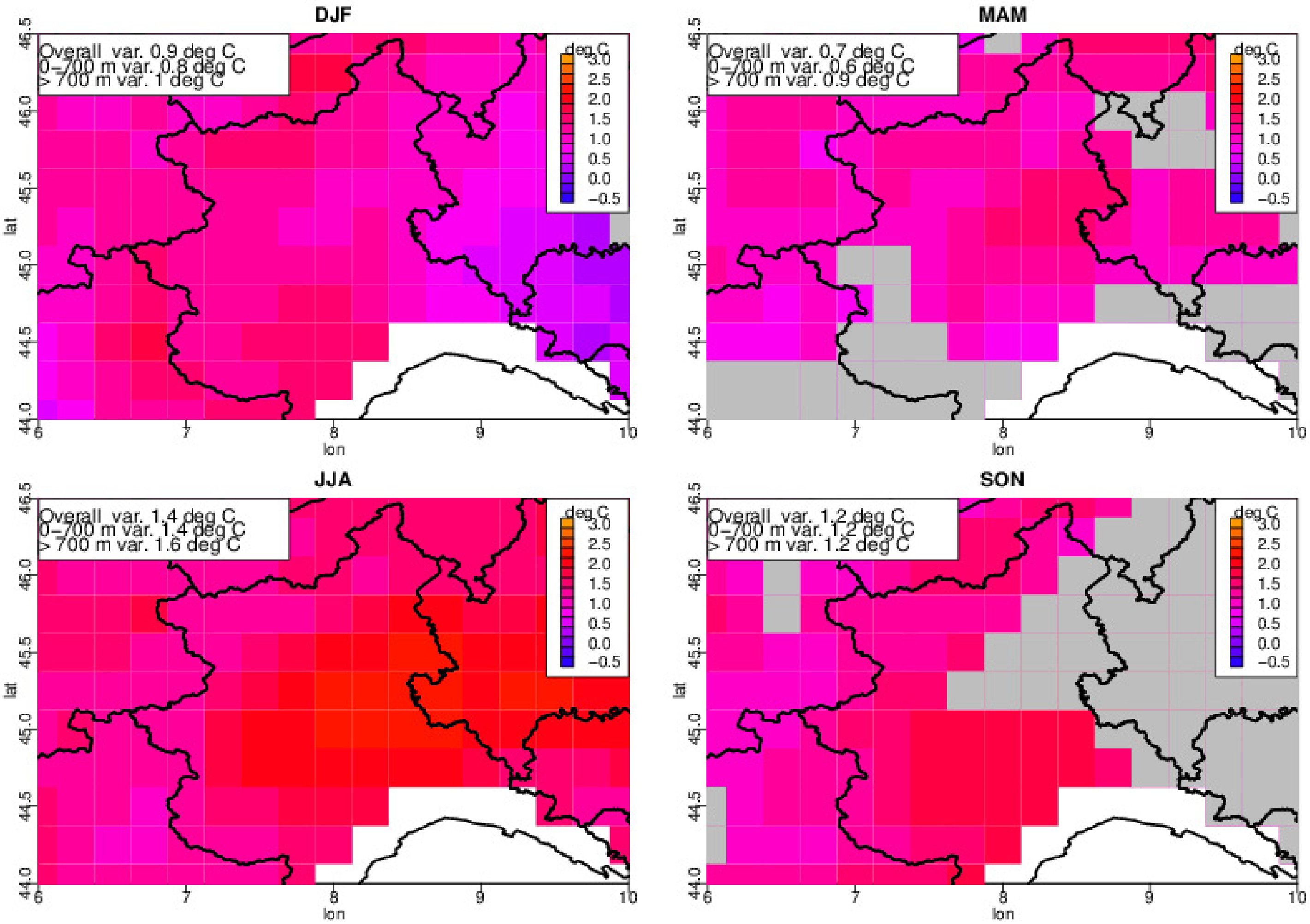
- **the coarse resolution dataset shows the same results of the whole Alpine area, the western Alps are a place were a significnat increase is expected also during autumn (+1.2 °C)**
- **the high resolution dataset shows significant increase in winter (+0.8 °C), spring (+1.4 °C), summer (+1.6 °C) and autumn, limited to the mountains (+1.2 °C). Maximum temperatures during spring and summer increase more on the plains than in the mountains.**

Projection to the future



Difference between the Multimodel SuperEnsemble scenario minimum temperatures averaged over the period 2031-2050 with respect to the period 1981-2000, as a function of the season (T-test conf. level 95%).

Projection to the future



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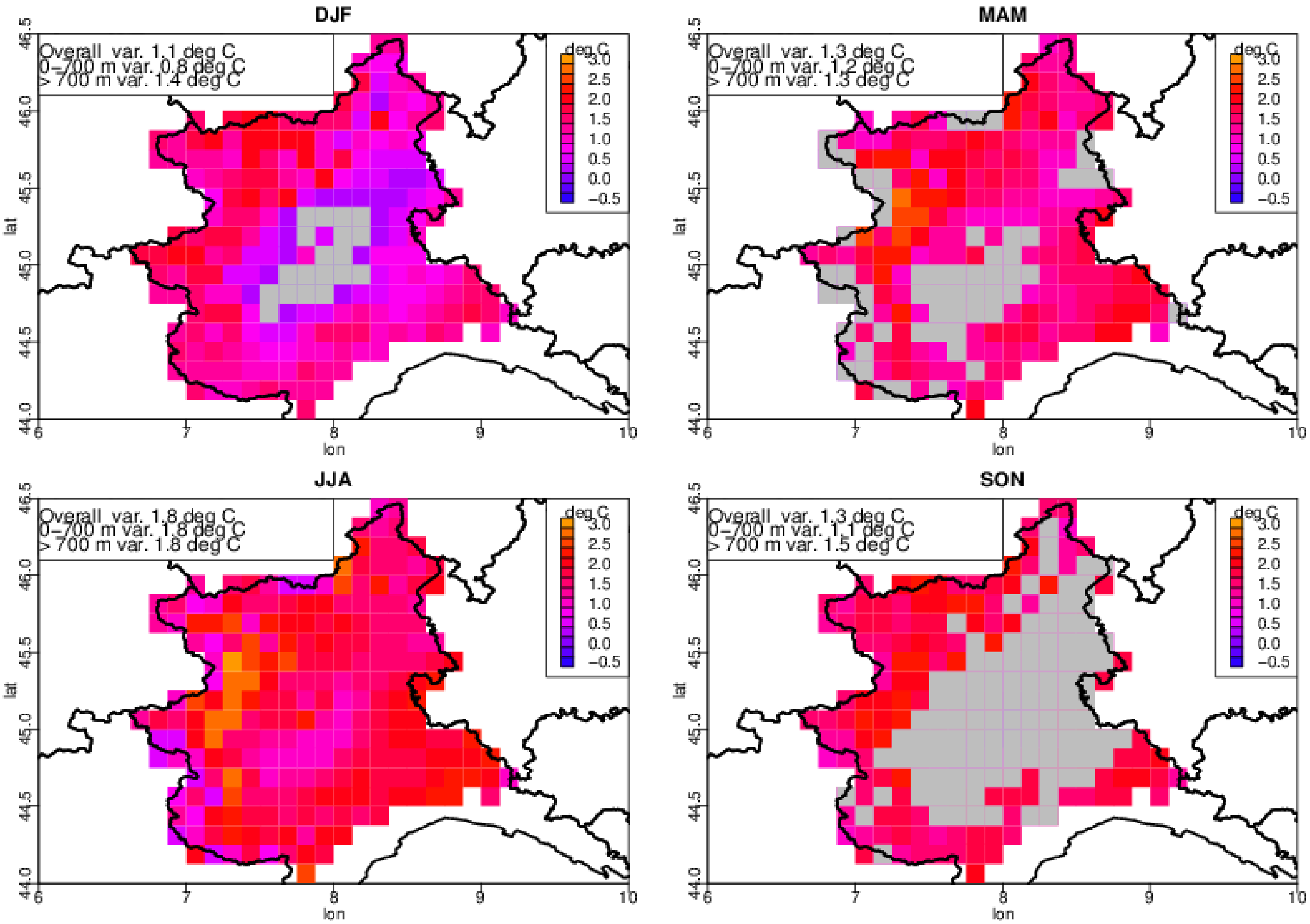

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Arpa Piemonte – Agenzia Regionale per la Protezione Ambientale

Projection to the future

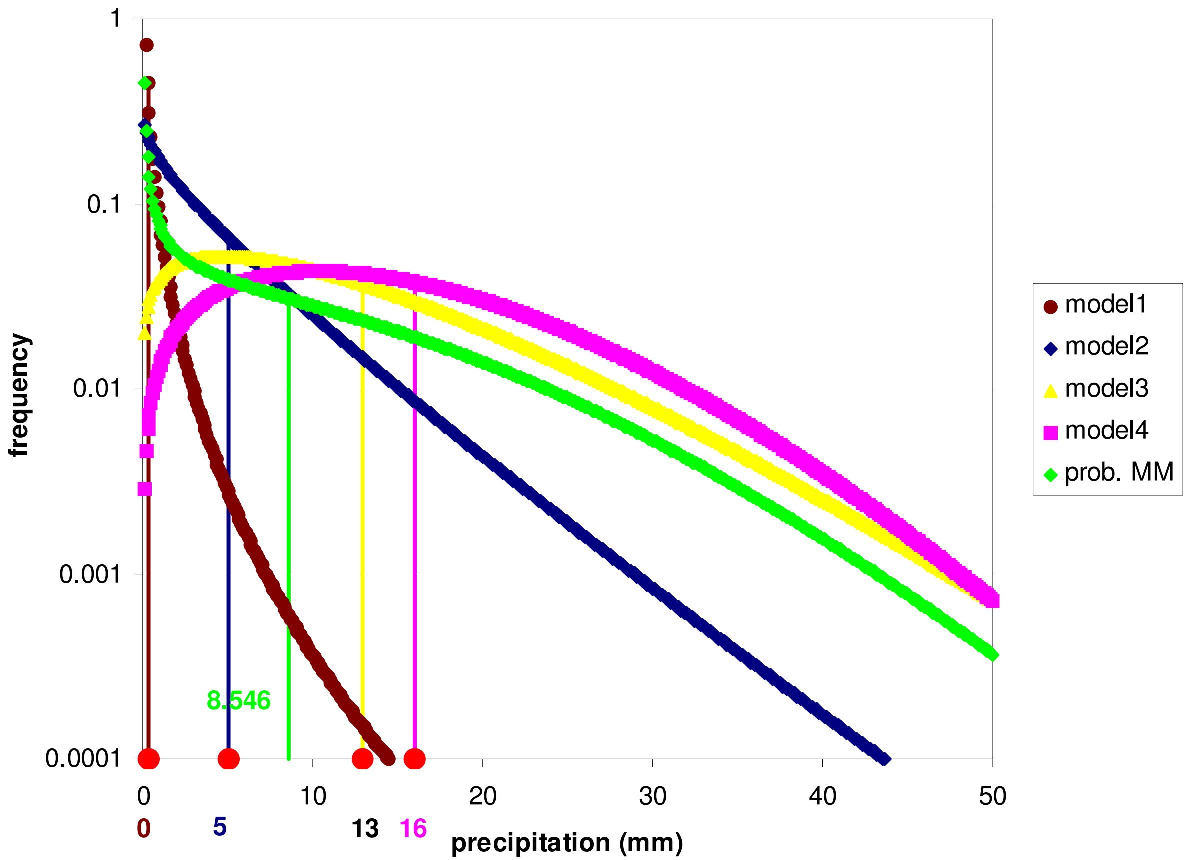
GAR area

- minimum temperatures increase is significant everywhere in winter (+0.9 °C) and summer (+1.4°C), in large areas in spring (+0.7 °C) and autumn (+1.2 °C).
- there are few differences among the plain (<700 m) and the mountains (>700 m).

Piedmont

- the coarse resolution dataset shows the same results of the whole Alpine area.
- the high resolution dataset shows significant increase in winter (+1.1 °C), spring (+1.3 °C), summer (+1.8 °C) and autumn, limited to the mountains (+1.3 °C). Minimum temperatures during autumn and winter increase more on the plains than in the mountains.

Multimodel SuperEnsemble dressing



We associate to each model's QPF the empirical Probability Density Function (PDF) and we calculate the (weighted) mean PDF.

The PDFs come from observations conditioned to forecast values in the training period.

Cane D., Milelli M., "Can a Multimodel SuperEnsemble technique be used for precipitation forecasts?", Advances in Geoscience, 25, 17-22, 2010

Precipitation PDF

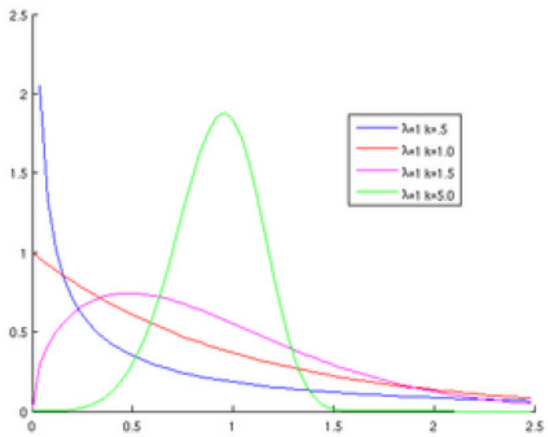
Which kind of function can we use for the PDF fitting?

Weibull Distribution

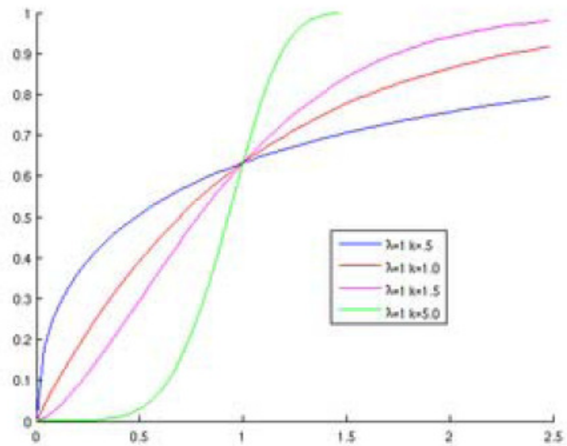
Probability density function (pdf)	$f(x) = \begin{cases} \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-(x/\lambda)^k} & x \geq 0 \\ 0 & x < 0 \end{cases}$

Parameters	$\lambda > 0$ scale (real) $k > 0$ shape (real)

Probability density function



Cumulative distribution function



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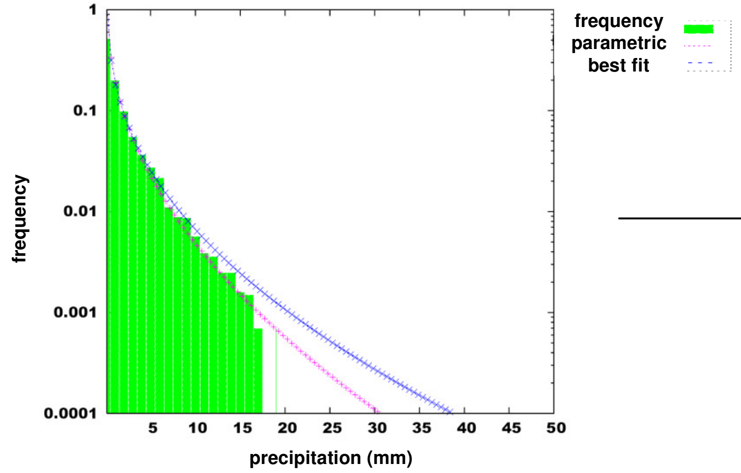
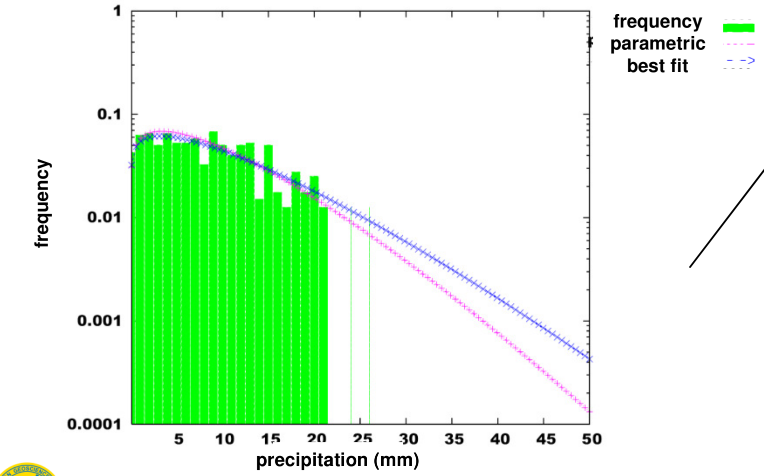
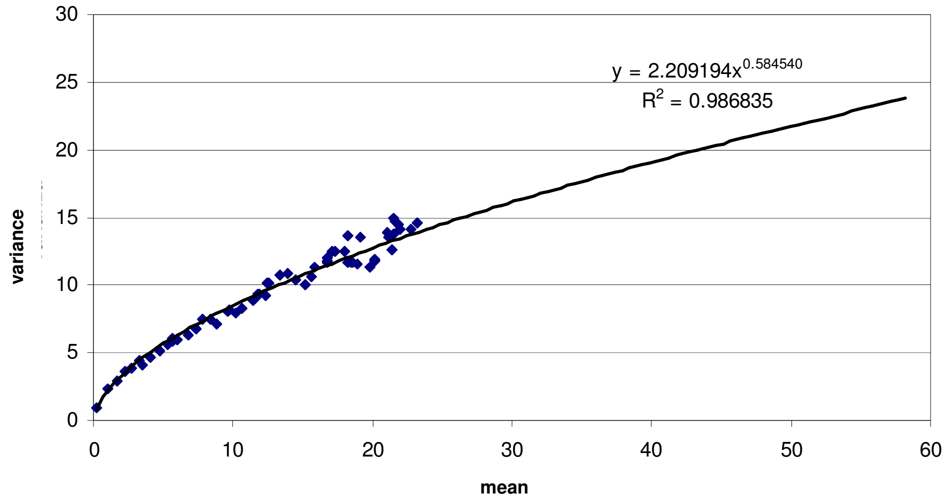
PDF calculation

Observed precipitation frequency for 2 mm forecast



Observed precipitation frequency for 10 mm forecast





The Weibull distribution parameters are calculated numerically from the fitted distribution moments (extrapolation)

Multimodel calculation

Weights: inverse of the continuous ranked probability score (CRPS), normalized to the sum of inverses of the CRPSs of the models

$$CRPS = \int_{-\infty}^{\infty} \left(P_f(x) - P_o(x)\right)^2 dx$$

NOTE: the CRPSs are calculated on the Reanalysis and not on the scenario (for calculation a correspondence between forecast and observation is needed day by day)

For any day of the scenario a given precipitation value is extracted randomly from the PDF.

TO DO: use of a correlated (auto-regressive) random number distribution instead of a “white noise” random number

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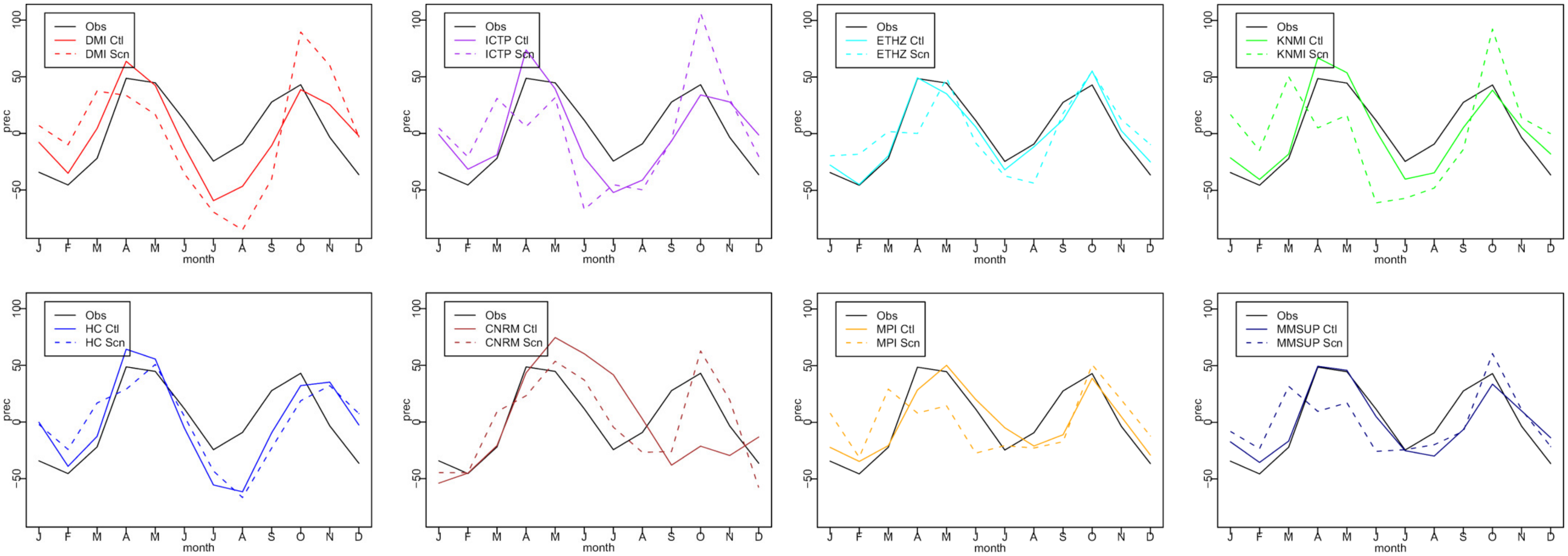

Precipitation: seasonal component calculated with the Seasonal Decomposition of Time Series by Loess from observations (black lines), reanalysis runs (solid lines) and scenario runs (dashed lines)

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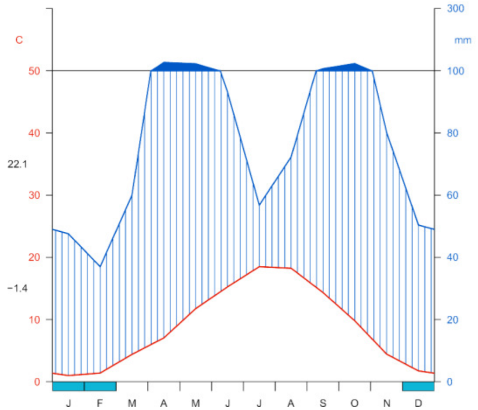
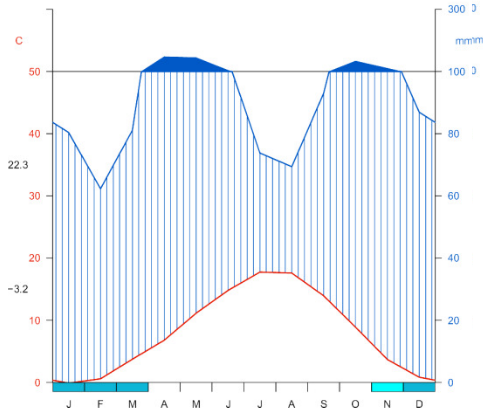
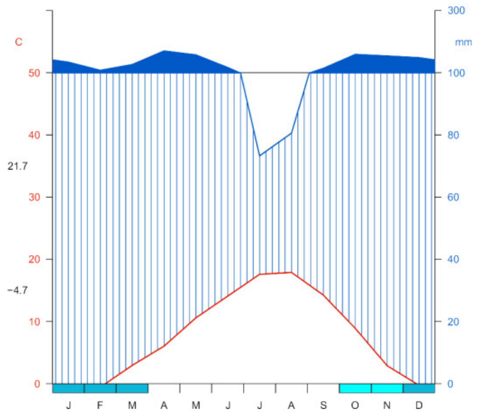


MMSUP

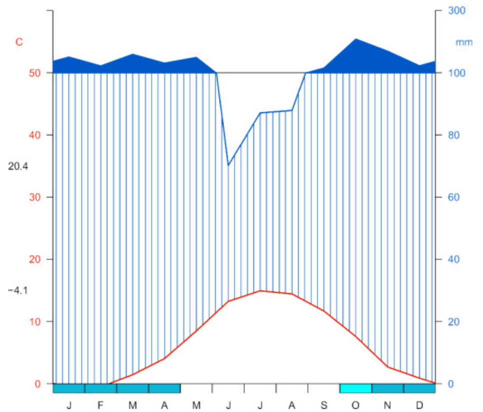


Precipitation: Walter and Lieth diagrams

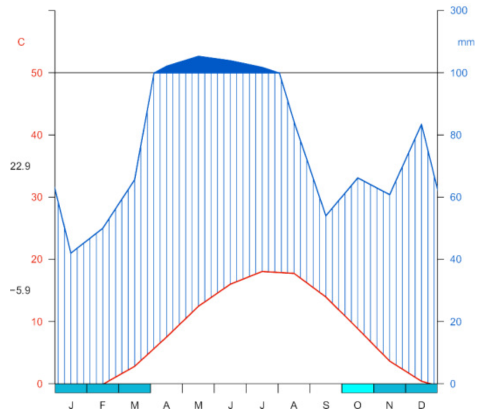
DMI



ICTP



CNRM



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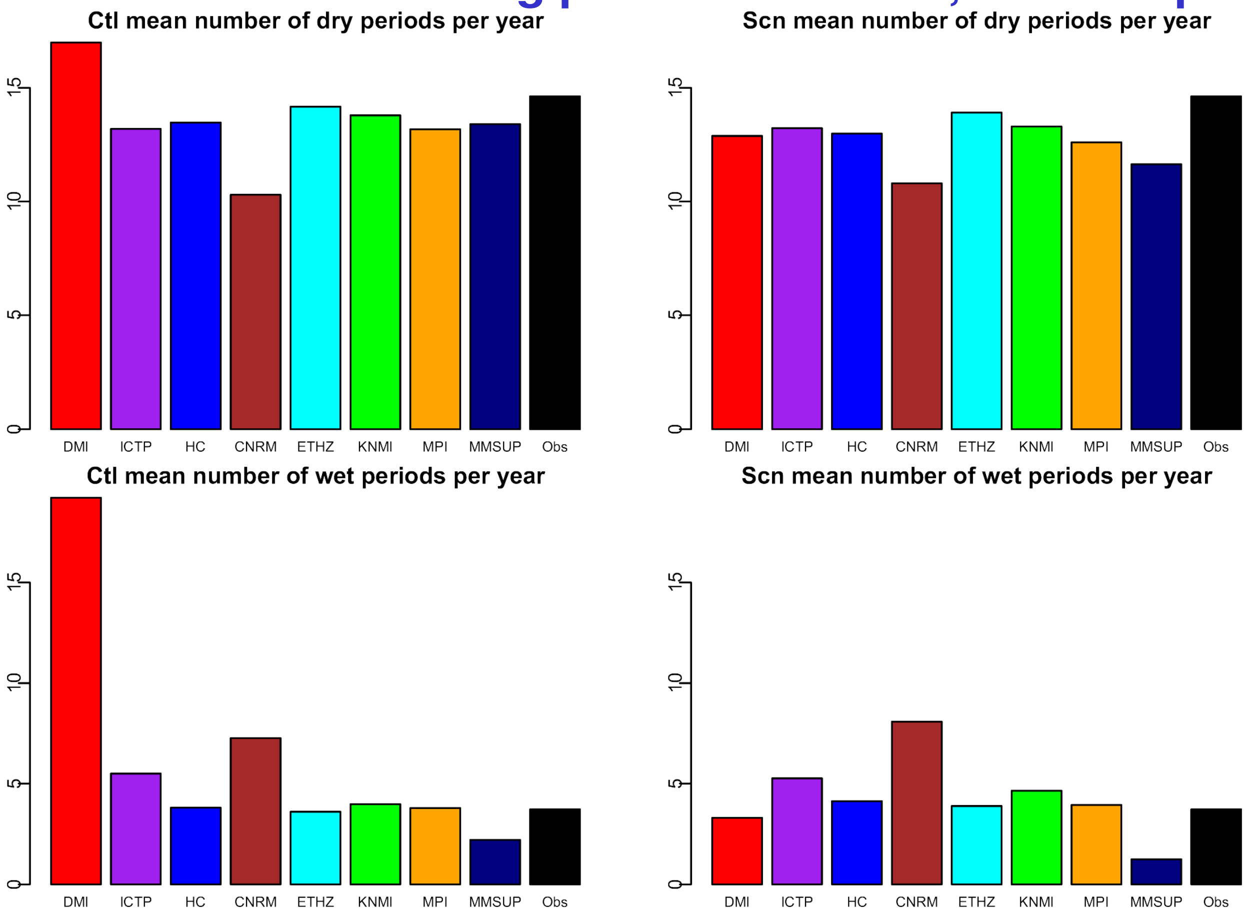

Precipitation: mean number of dry periods (5 cons. days of prec < 1 mm/day) and wet periods (5 cons. days of prec >= 1 mm/day) for Control runs and Scenario runs

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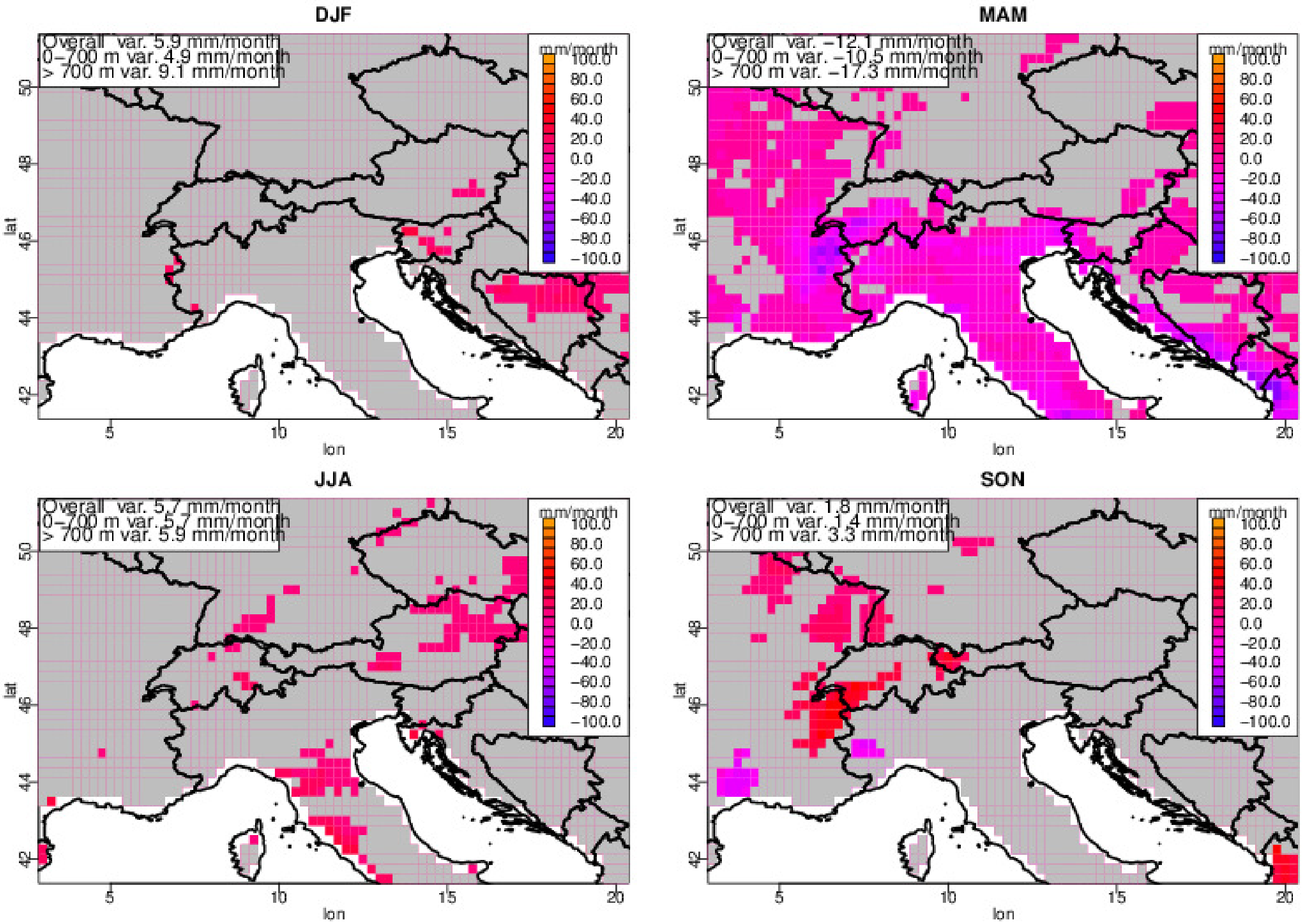
Projection to the future



Difference between the Multimodel SuperEnsemble scenario precipitation averaged over the period 2031-2050 with respect to the period 1981-2000, as a function of the season (T-test conf. level 95%).

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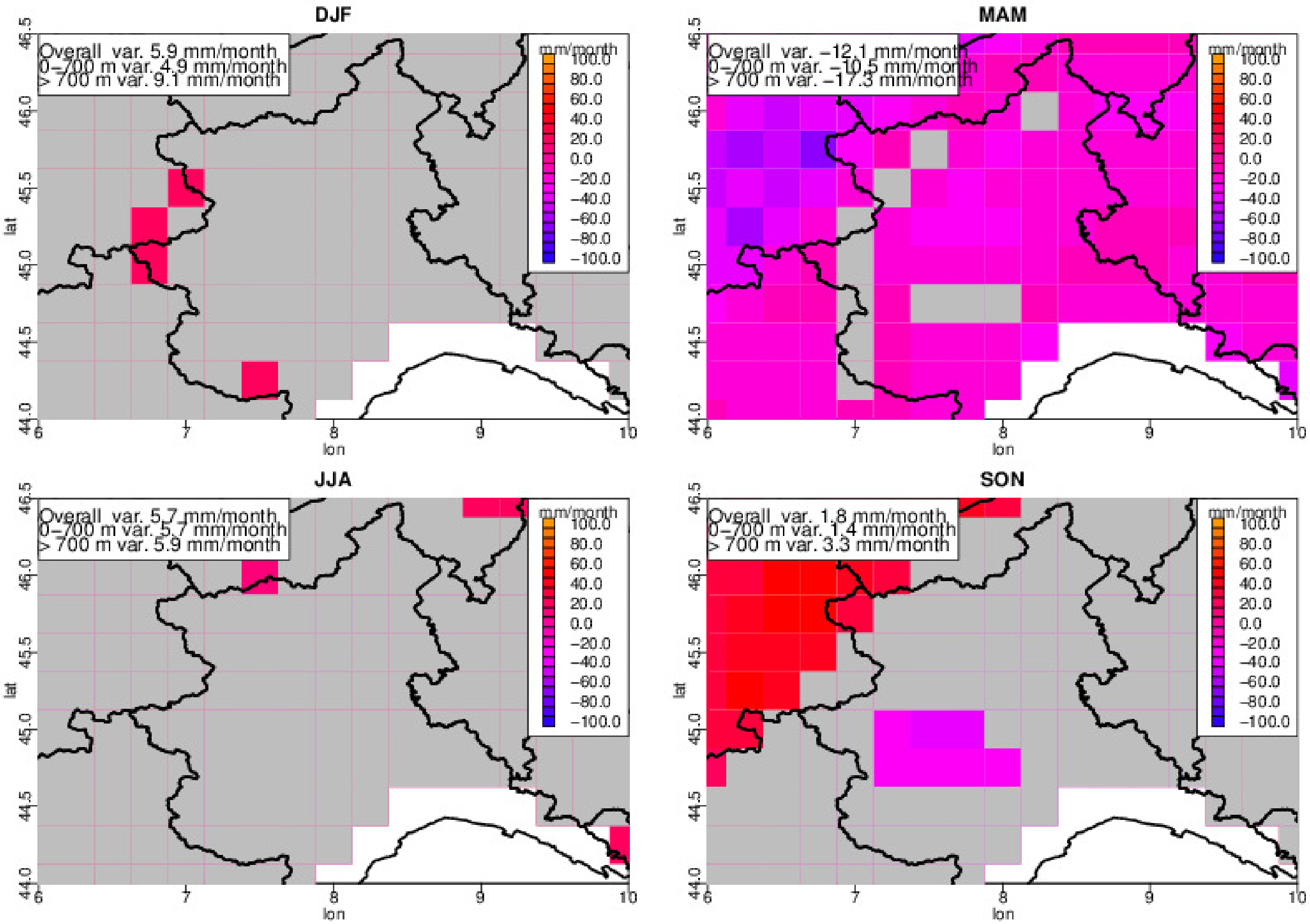

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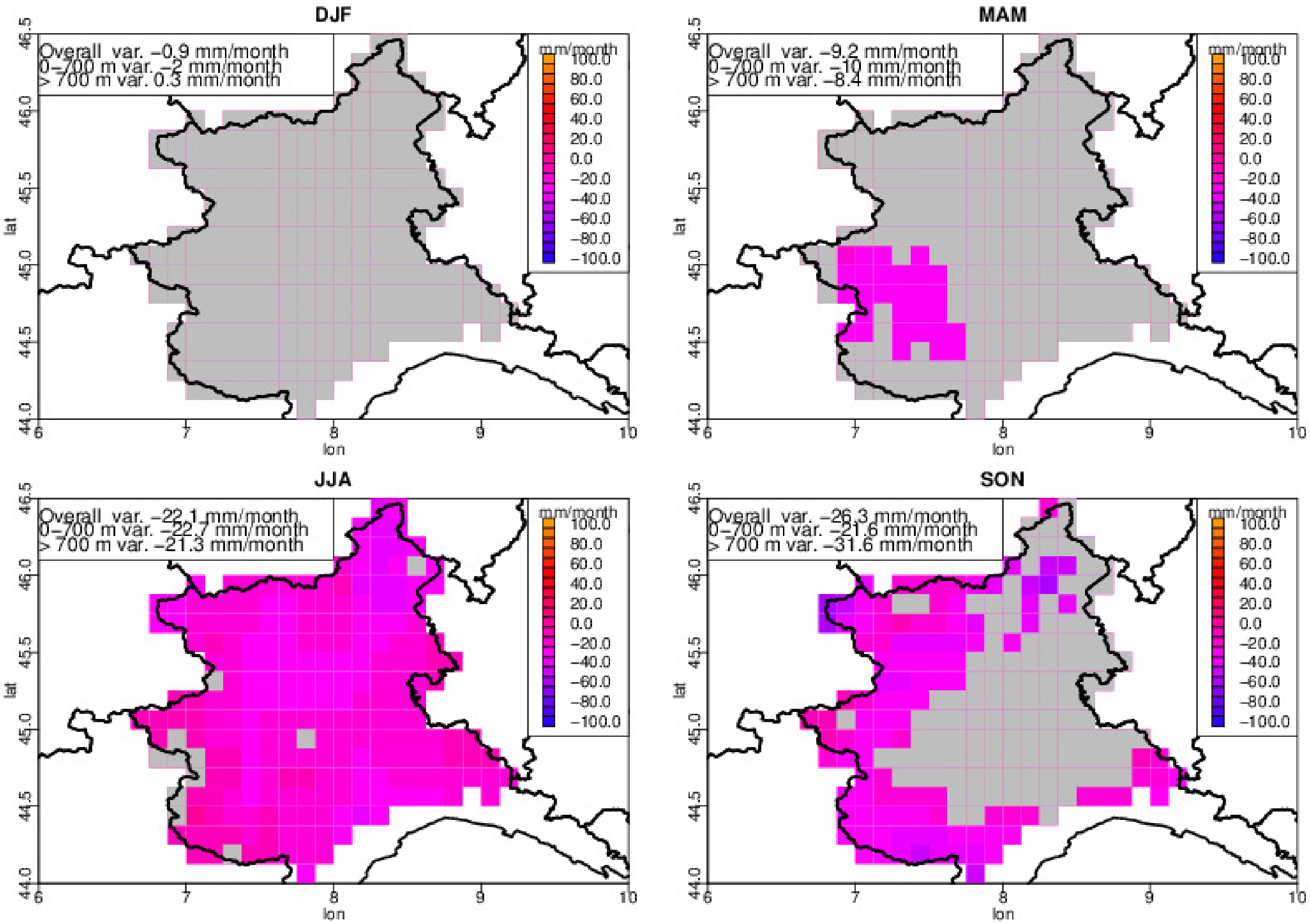

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Projection to the future

GAR area

- annual precipitation does not change in a significant way, due to significant decrease (-12 mm/month) in spring and ligth increas in the rest of the year.
- the decrease in spring is higher in the mountains (>700 m) than on the plain (<700 m).

Piedmont

- the coarse resolution dataset shows the same results of the whole Alpine area.
- the high resolution dataset shows significant decrease in spring (-9 mm/month only in the western Alps), summer(-22 mm/month), with few differences among mountains and plains and autumn, limited to the mountains (-26 mm/month).

Conclusions

- Multimodel SuperEnsemble technique (standard and probabilistic) can be applied to the RCMs outputs to downscale the scenarios over complex terrain regions like Piemonte with the use of two independent observation datasets, with coarser and finer resolution,
- The temperature projections obtained with the two scenarios are coherent. The fine resolution scenario shows slightly different behaviour for mountain and plain areas and a warmer autumn.
- The precipitation projection obtained with the two scenarios differ significantly, with a “dryer” projection from the fine resolution scenario, in particular during summer.

Impact studies

- **Permafrost evolution**
- **Biodiversity in the Alps**
- **Effects on hydrology**
- **Wildfires**
- **Effects on alpine lakes**
- **Other (heat waves, droughts…)**

permanet
Permafrost Monitoring Network

Biodiversità: una ri-sorsa da conservare

ACQWA
Assessing Climate Impacts on the Quantity and quality of WAter

ALP FFIRS

silmas alpine lakes network