Regional climate model downscaling with Multimodel SuperEnsemble in the Alpine area and wildfire potential evaluation in the scenario

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ACQWA

Assessing Climate Impacts on the Quantity and quality of WAter

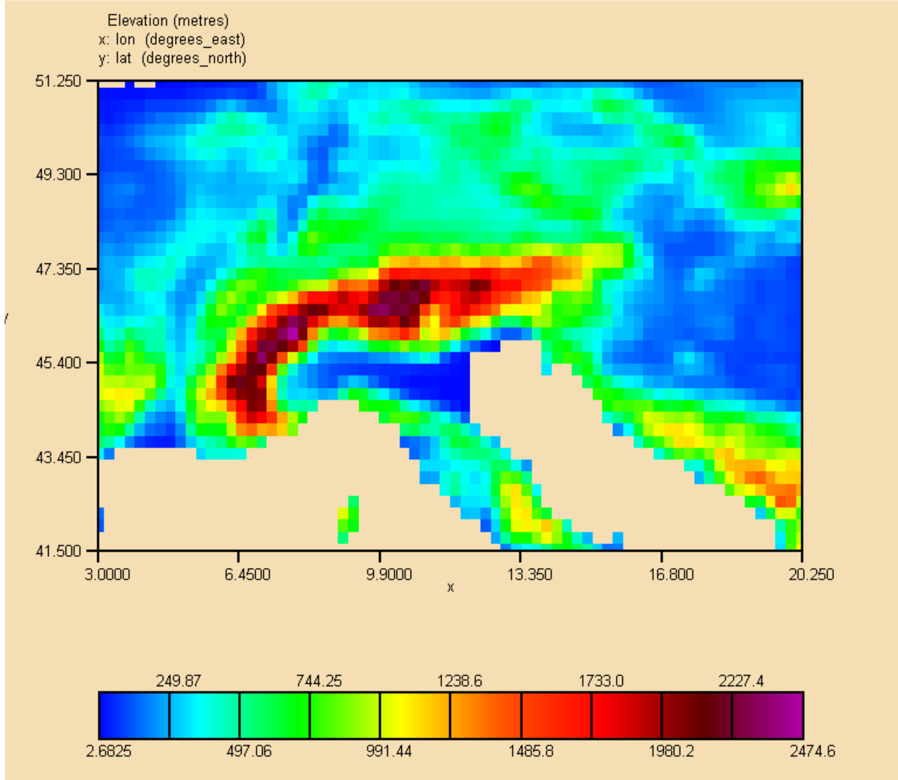
ALP FFIRS

Alpine Forest Fire Warning System

Outlook

- Observed data Optimal Interpolation
- Multimodel SuperEnsemble
  - Tests
  - Results
- Probabilistic Multimodel SuperEnsemble Dressing
  - Tests
  - Results
- Fire Weather Indices
  - Definition
  - Comparison with recorded forest fires
- Conclusions

Temperature and precipitation data



DOMAINS:

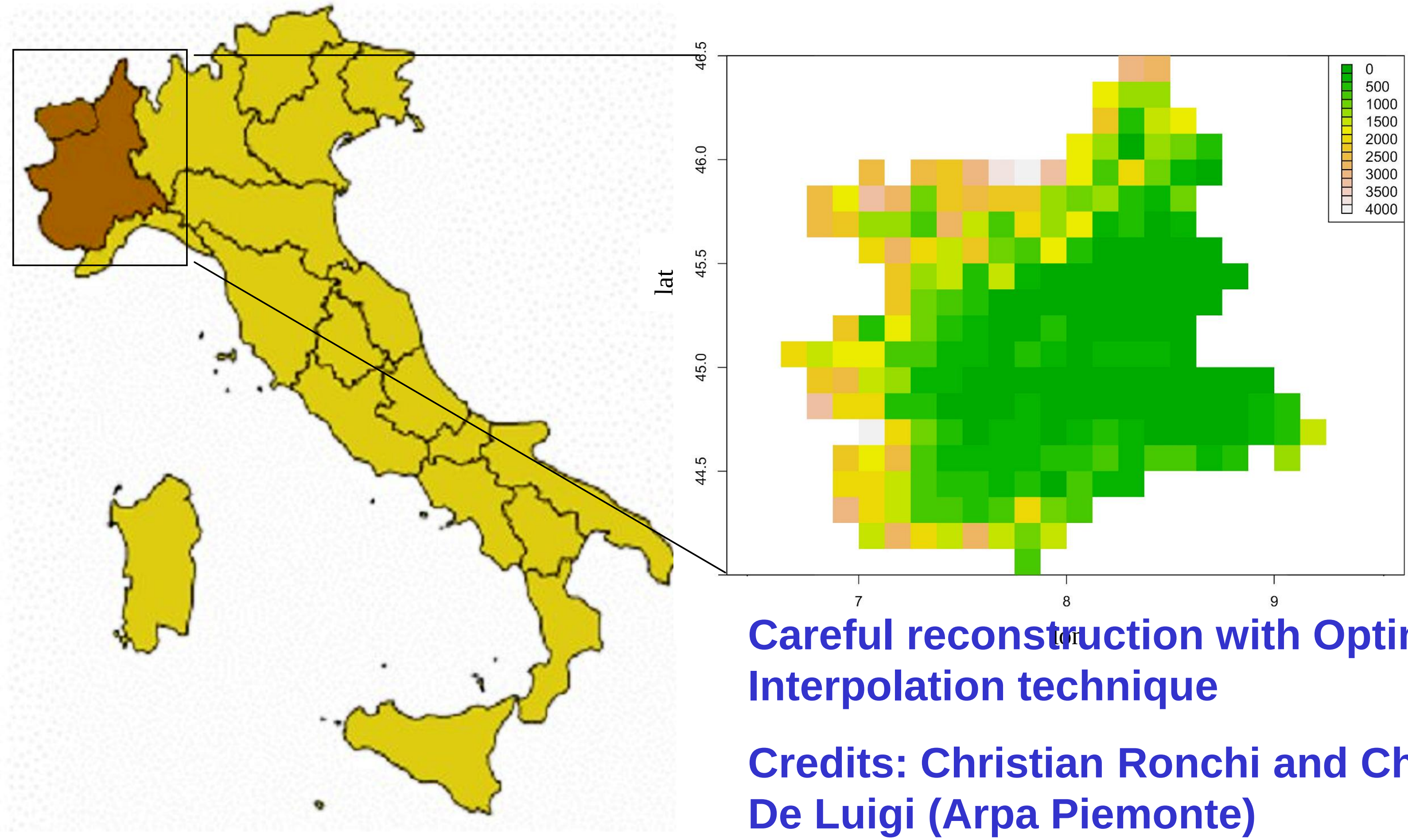
1) Greater Alpine Area

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

(NOT SHOWN IN THIS PRESENTATION)

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

Temperature and precipitation reconstruction



Careful reconstruction with Optimal Interpolation technique

Credits: Christian Ronchi and Chiara De Luigi (Arpa Piemonte)

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 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

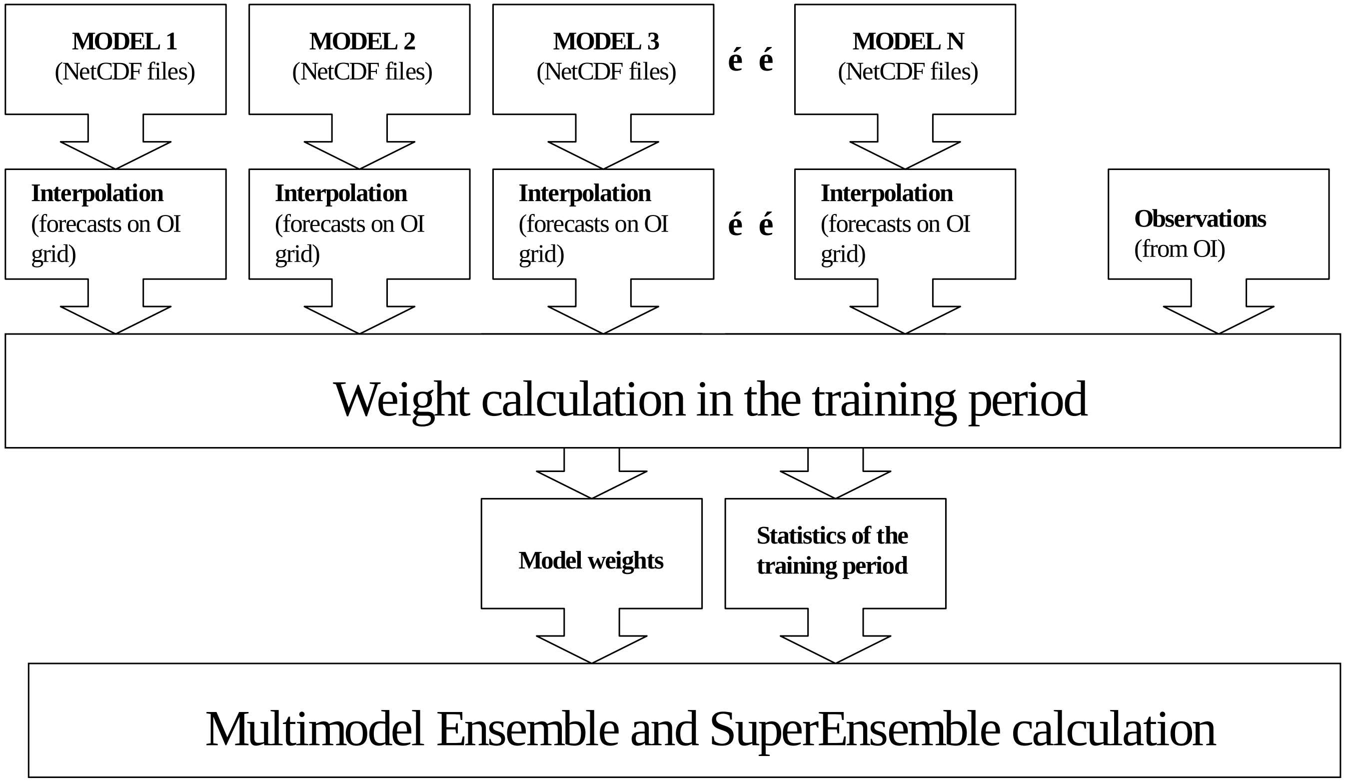
Reanalysis on ECMWF ERA-40 (1961-2000) and A1B scenario runs (1961-2100) of the following RCMs (daily data):

- **HIRHAM5 ï DMI (GCM: Arpege)**
- **REGCM3 ï ICTP (GCM: ECHAM5)**
- **HadRM3Q0 - Hadley Center (GCM: HadCM3Q0)**
- **RM4.5 ï CNRM (GCM: Arpege)**
- **CLM - ETH Zurich (GCM: HadCM3Q0)**
- **RACMO2 ï 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

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

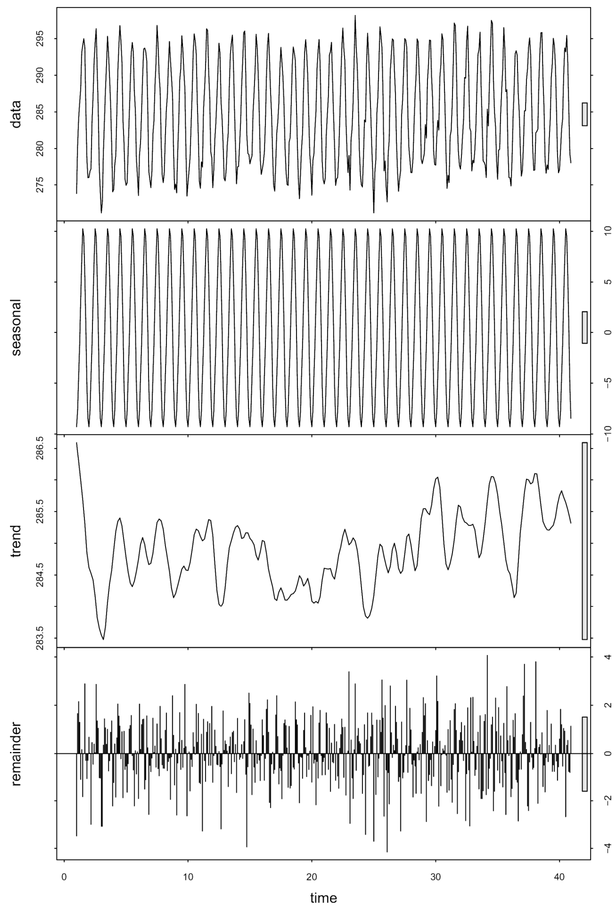
Krishnamurti T.N. et al., “Improved weather and seasonal climate forecasts from Multimodel SuperEnsemble”, Science 285, 1548-1550, 1999
Cane D., Milelli M., “Weather forecasts obtained with a Multimodel SuperEnsemble Technique in a complex orography region”, Meteorologische Zeitschrift, Vol. 15, No. 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.

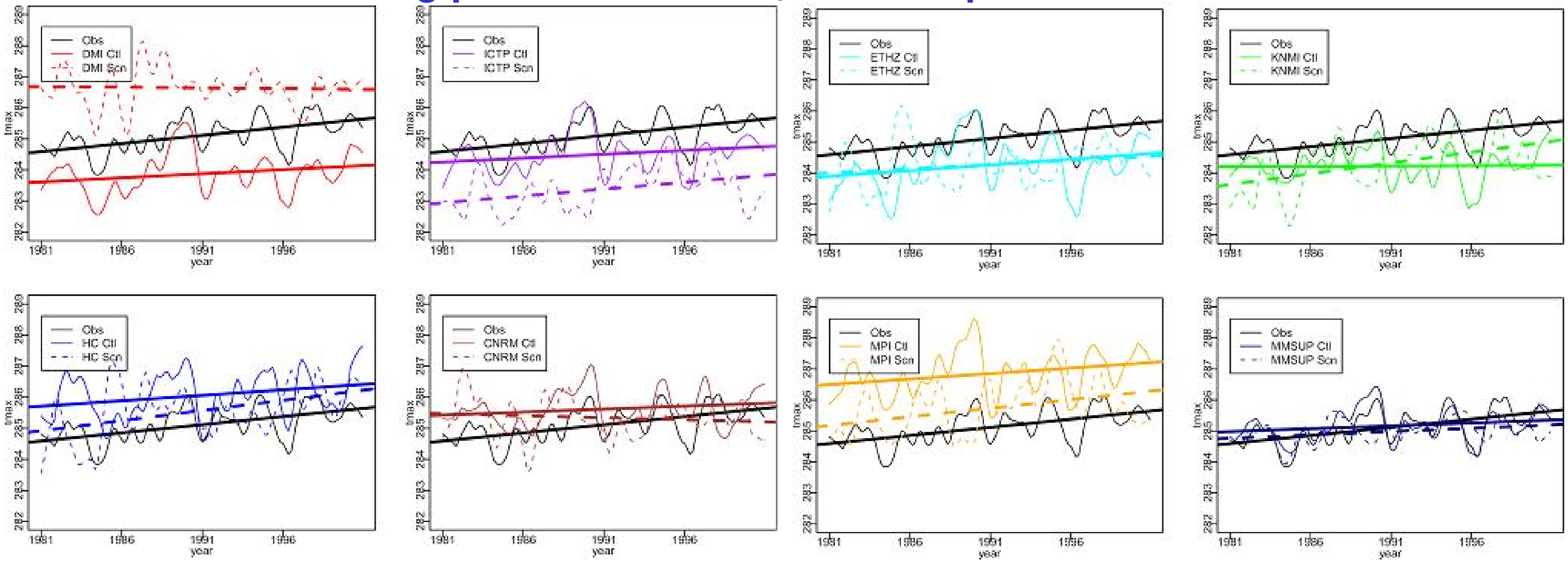
Maximum temperature



Training period 1961-1980, forecast period 1981-2000

Test in the training period

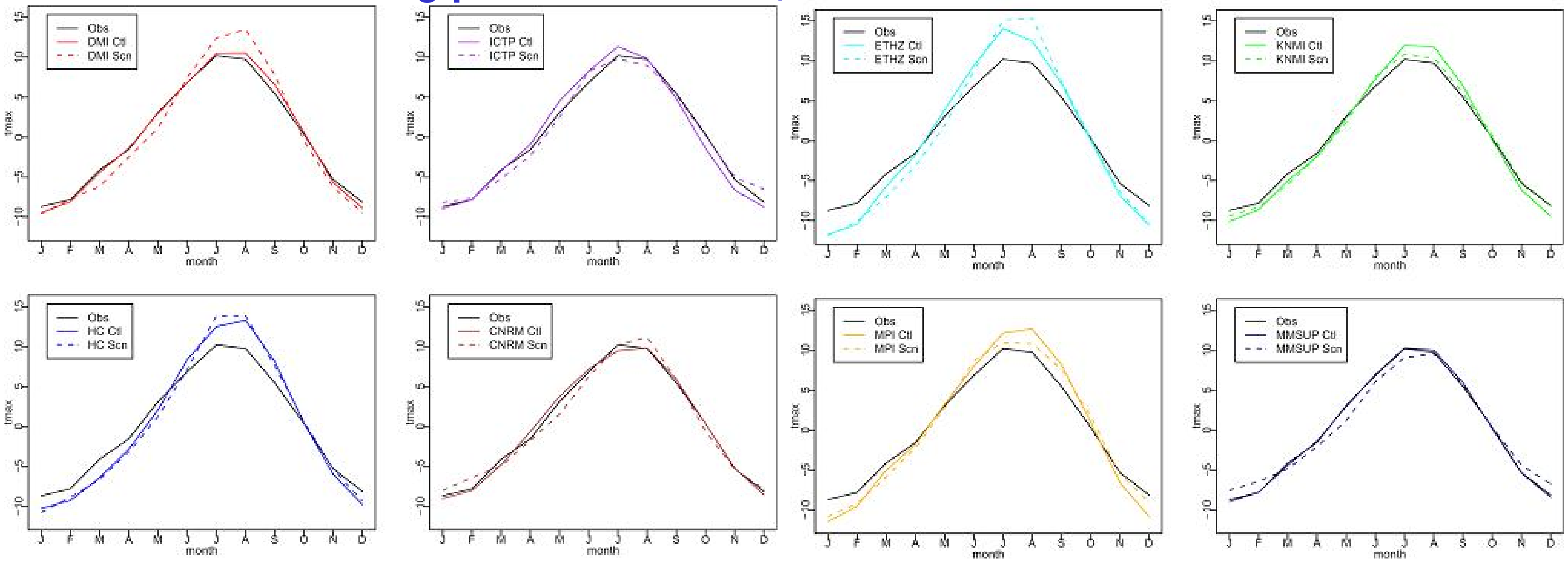
Training period 1961-1980, forecast period 1981-2000.



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)

Test in the training period

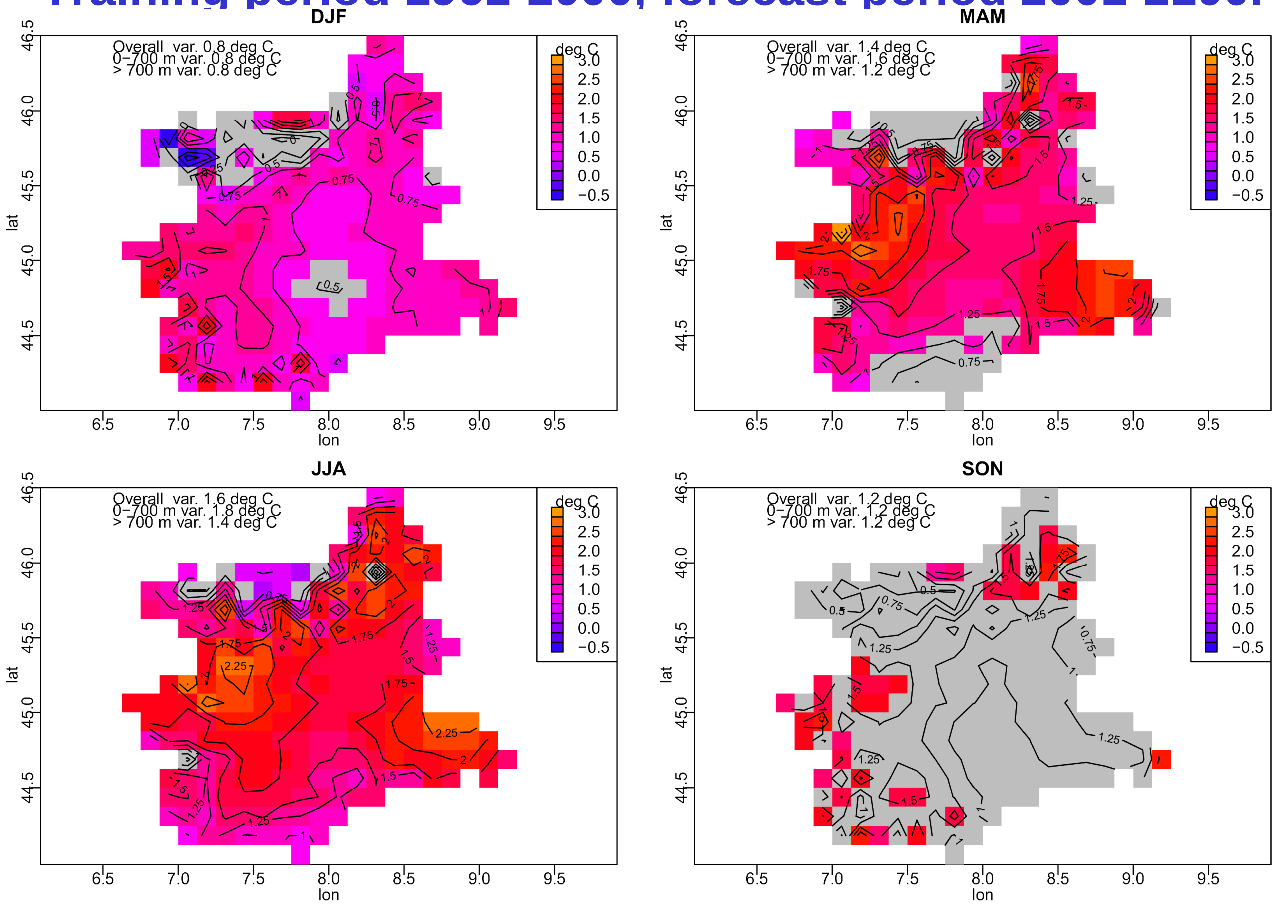
Training period 1961-1980, forecast period 1981-2000.



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)

Multimodel SuperEnsemble results

Training period 1961-2000, forecast period 2001-2100.

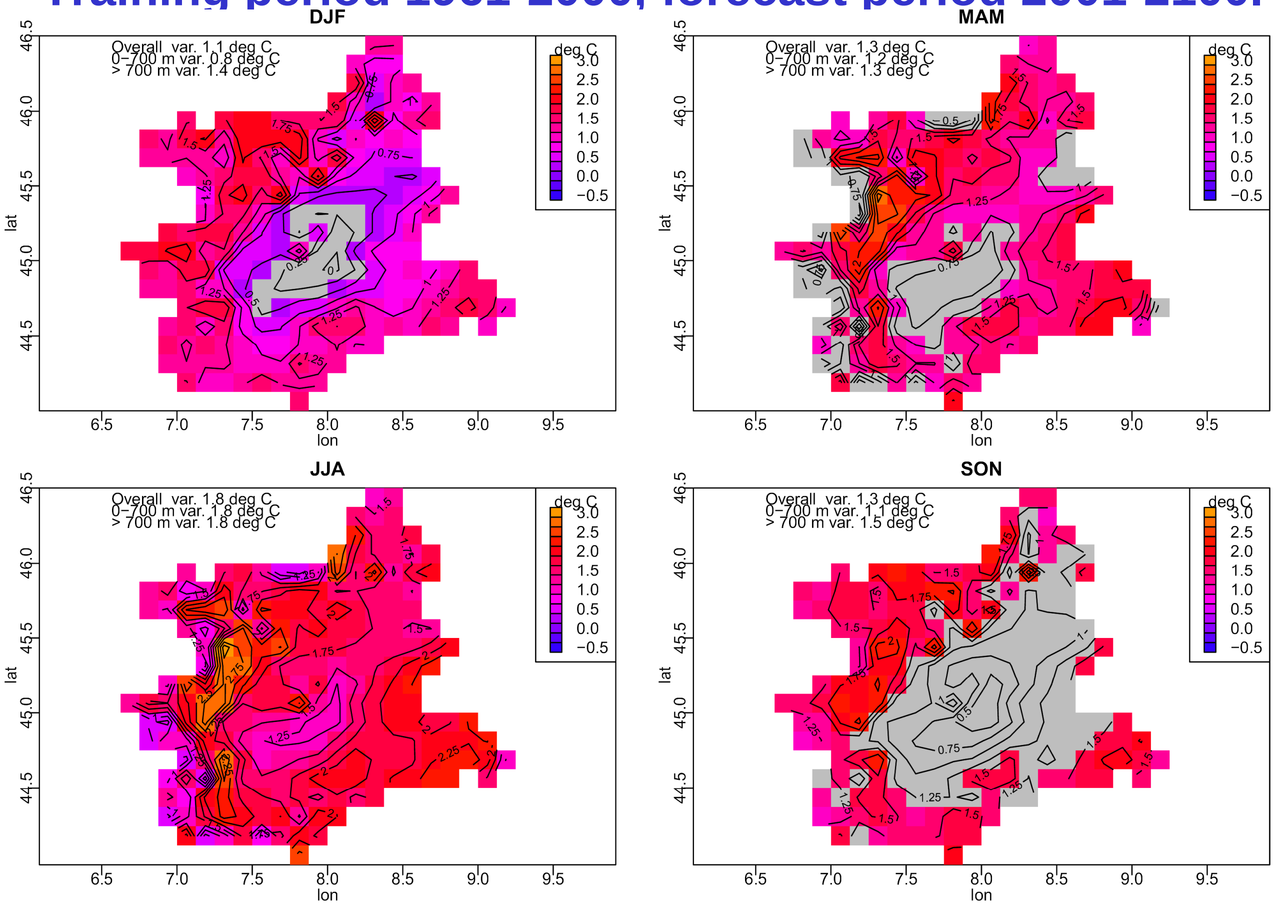


Difference between the Multimodel SuperEnsemble scenario maximum temperatures averaged over the period 2031-2050 with respect to the period 1981-2000, as a function of the season (T-test conf. level 95%).

Maximum temperatures increase more on the plains than in the mountains in spring and summer

Multimodel SuperEnsemble results

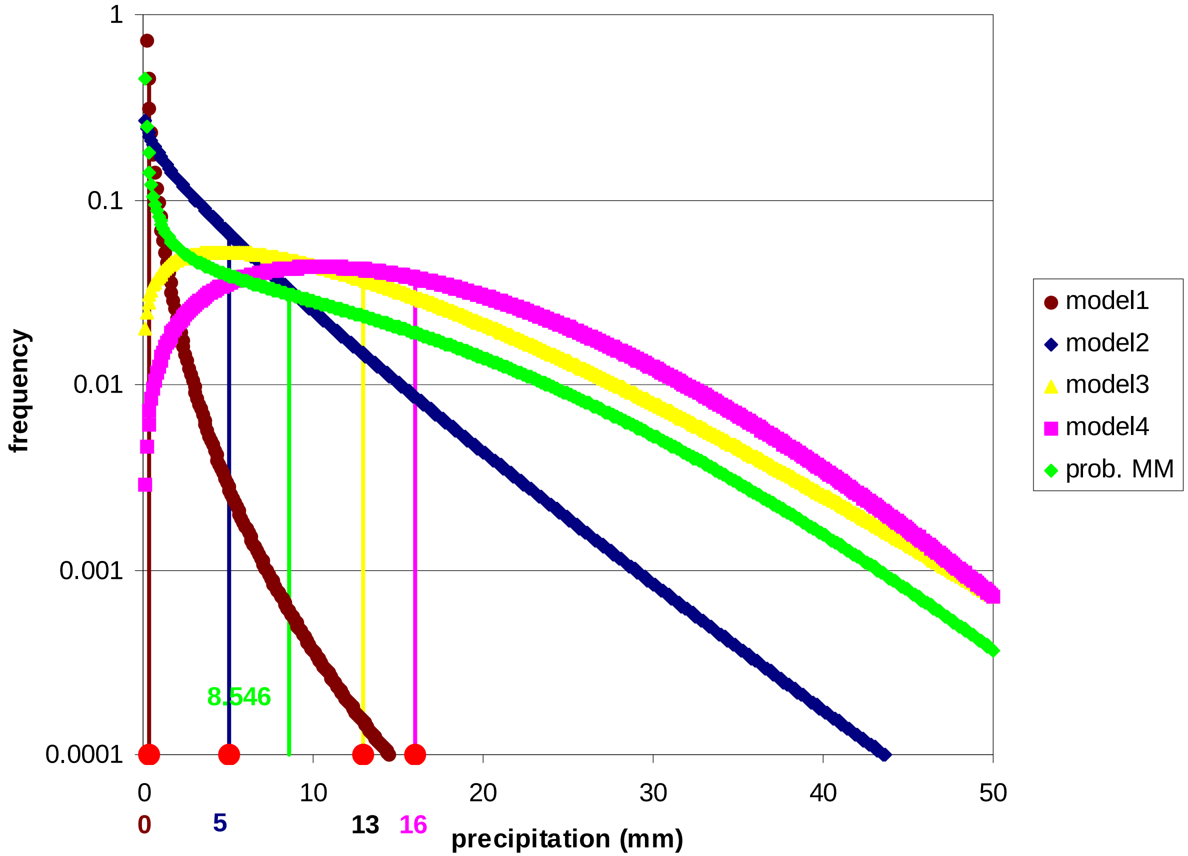
Training period 1961-2000, forecast period 2001-2100.



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%).

Minimum temperatures increase more in the mountains than on the plains in autumn and winter

Multimodel SuperEnsemble dressing



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

Weights are evaluated with the Multimodel SuperEnsemble technique.

Example:

model1 -> 0 mm

model2 -> 5 mm

model3 -> 13 mm

model4 -> 16 mm

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

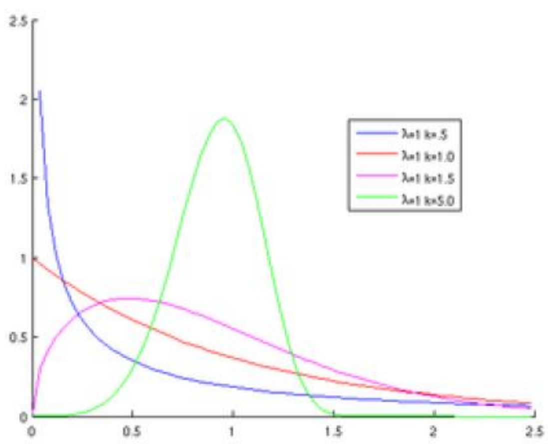
Precipitation PDF

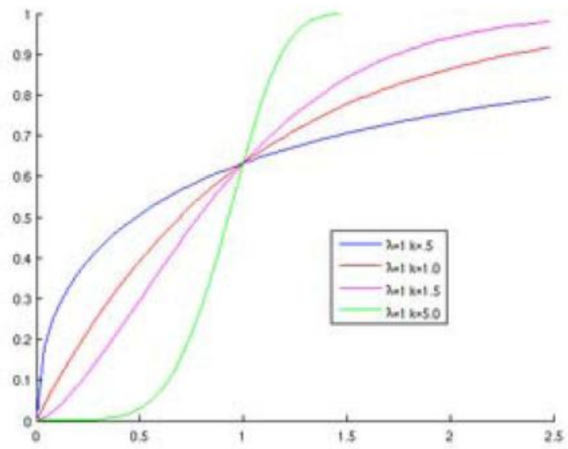
Which kind of function can we use for the PDF fitting?

Weibull Distribution

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

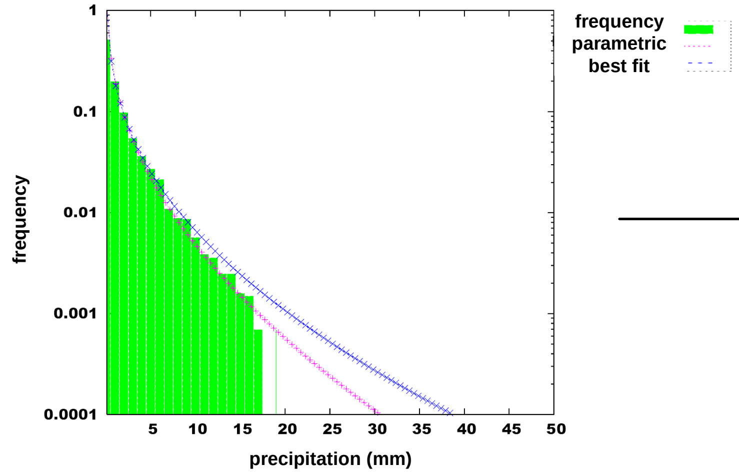
Parameters	$\lambda > 0$ scale (real) $k > 0$ shape (real)



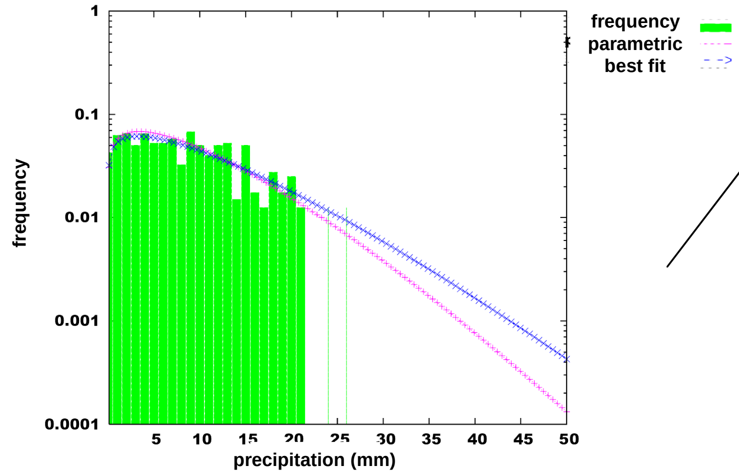


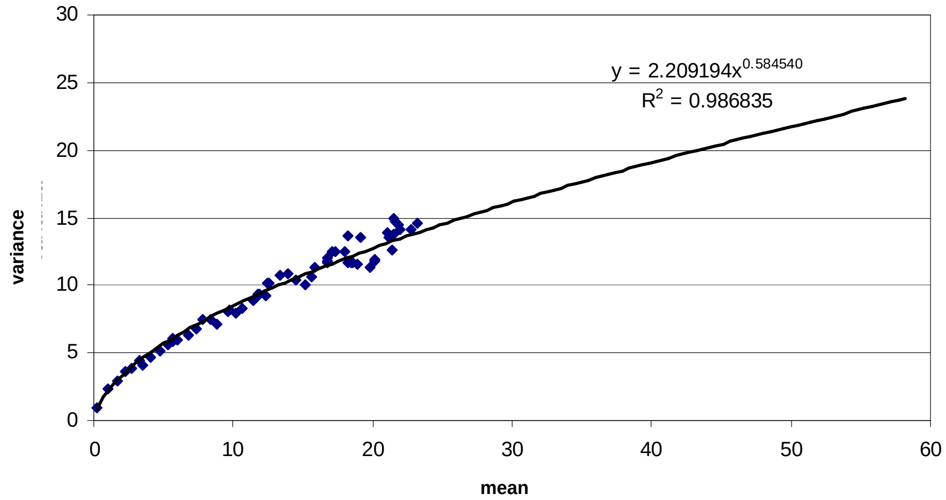
PDF calculation

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

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

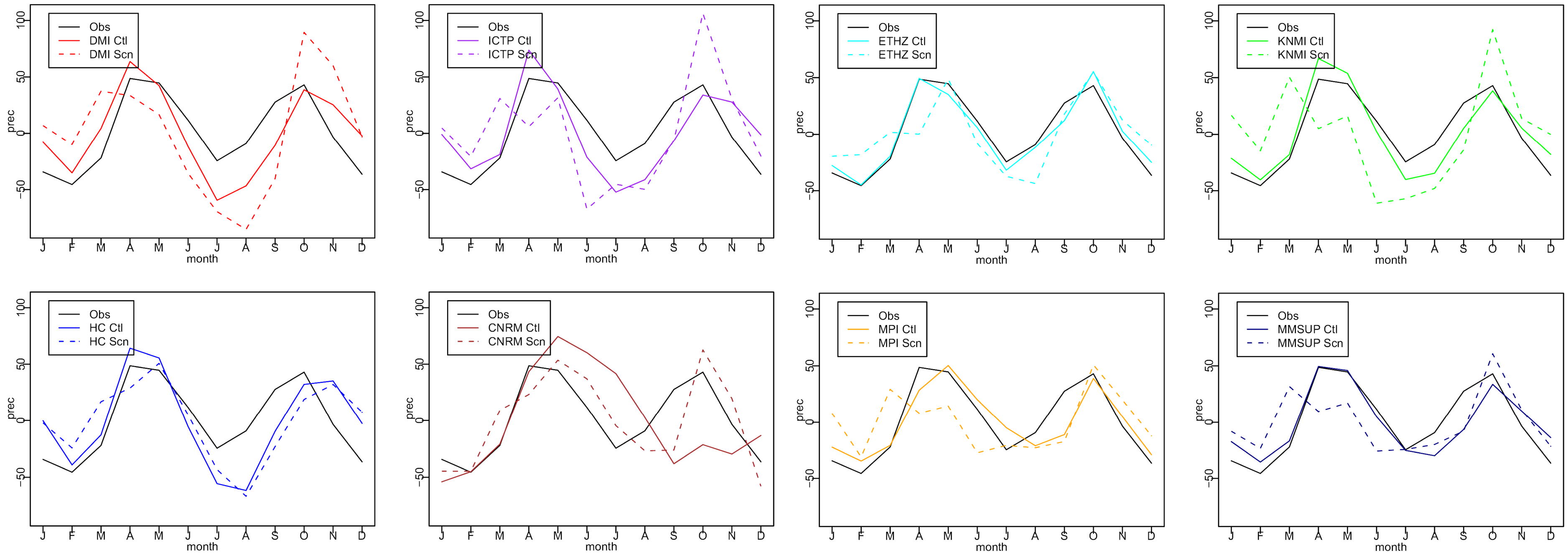
NOTE: the CRPSs are calculated on the Reanalysis and not on the model (for calculation a correspondence between forecast and observation is needed day by day)

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 ñwhite noiseò random number

Test in the training period

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



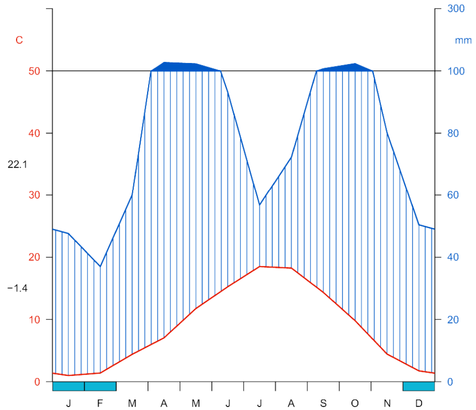
Precipitation: seasonal component calculated with the Seasonal Decomposition of Time Series by Loess from observations (black lines), reanalysis runs (solid lines) and scenario runs (dashed lines)

Test in the training period

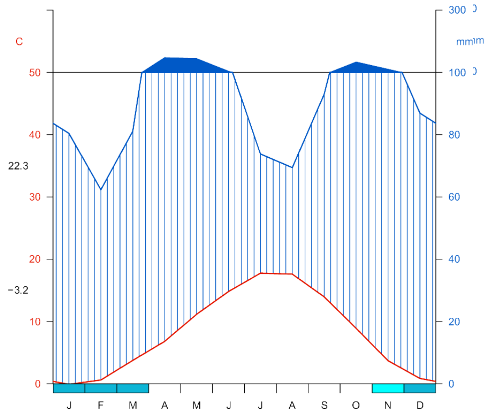
Training period 1961-1980, forecast period 1981-2000.

Precipitation: Walter and Lieth diagrams

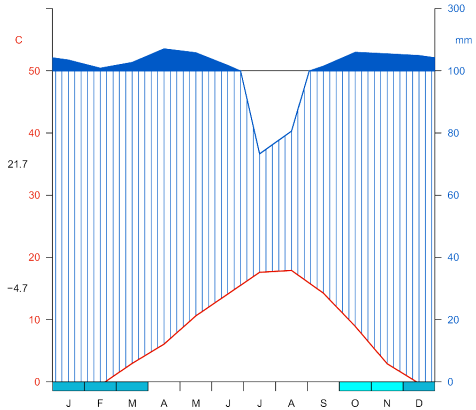
Obs



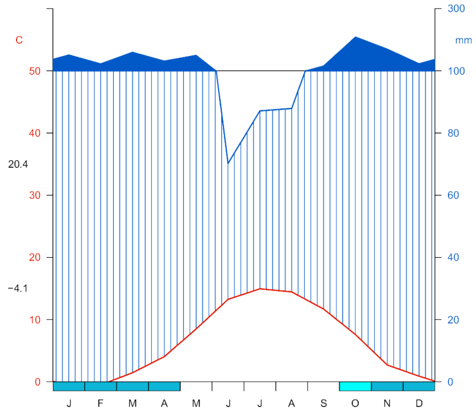
MMSUP



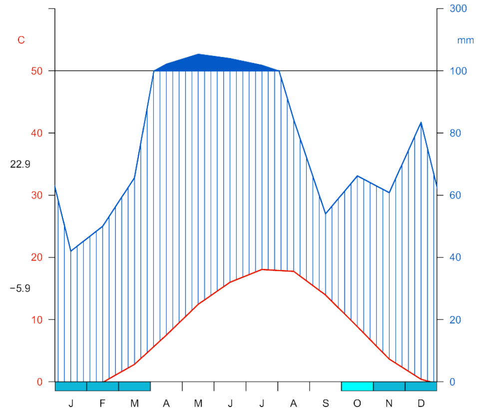
DMI



ICTP

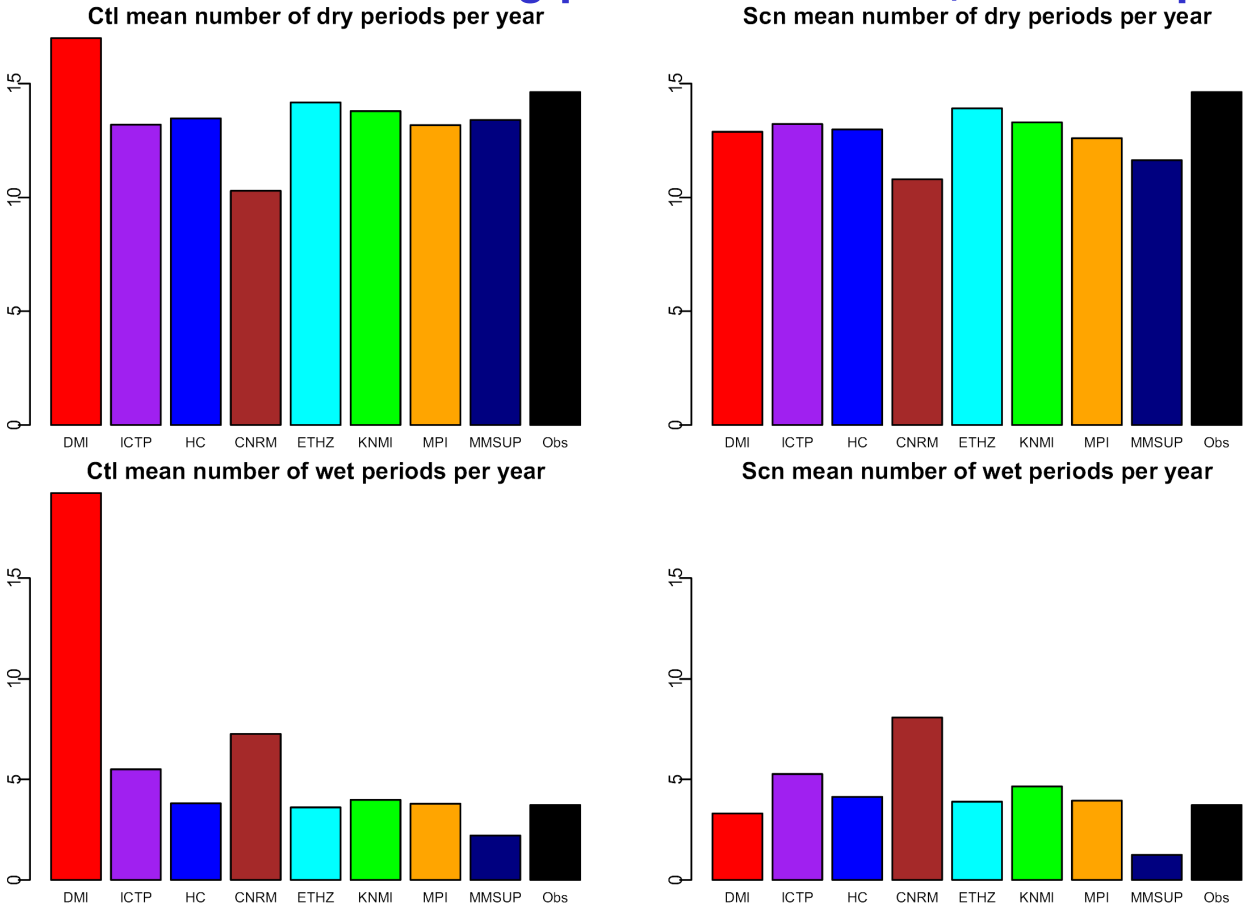


CNRM



Test in the training period

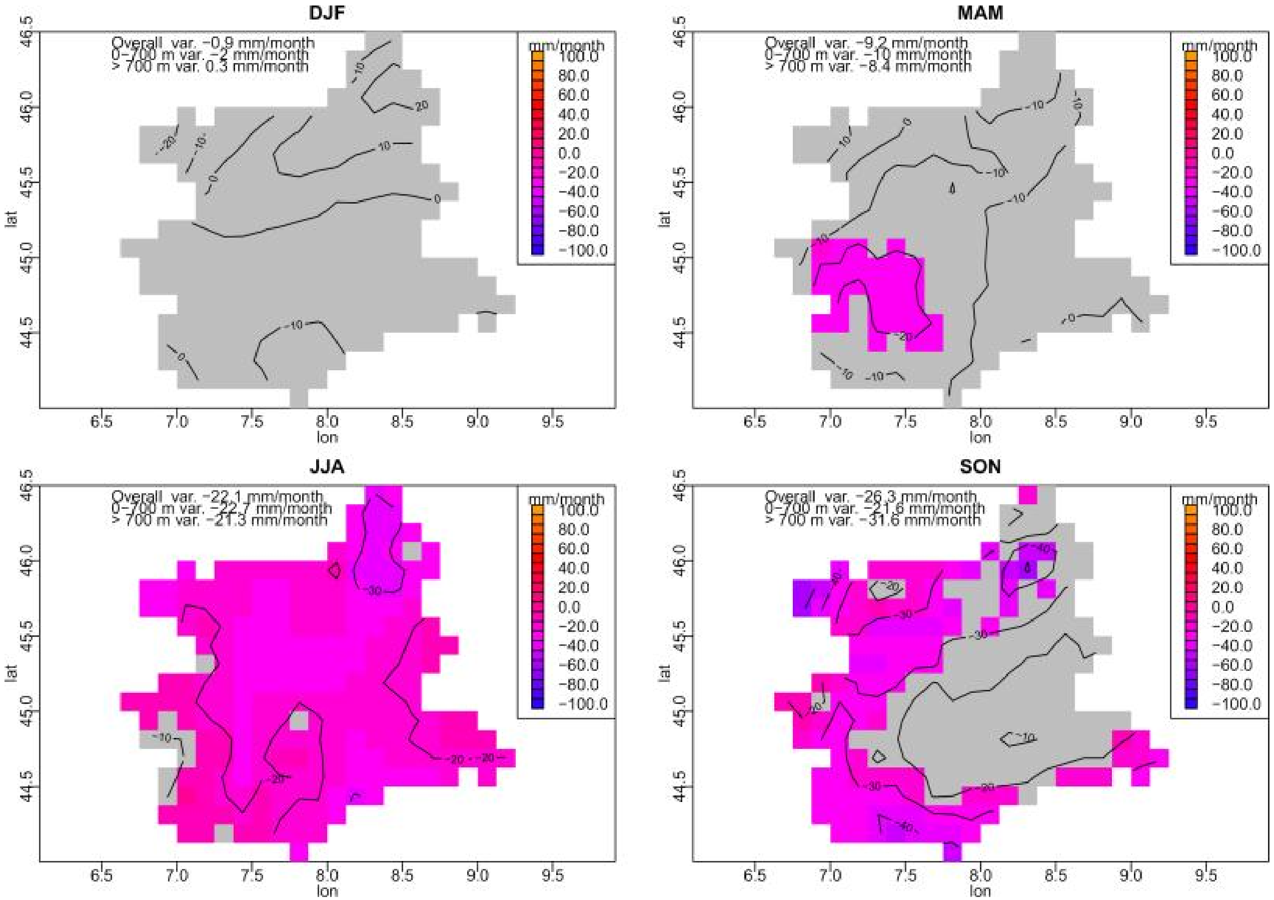
Training period 1961-1980, forecast period 1981-2000.



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

Multimodel results

Training period 1961-2000, forecast period 2001-2100.



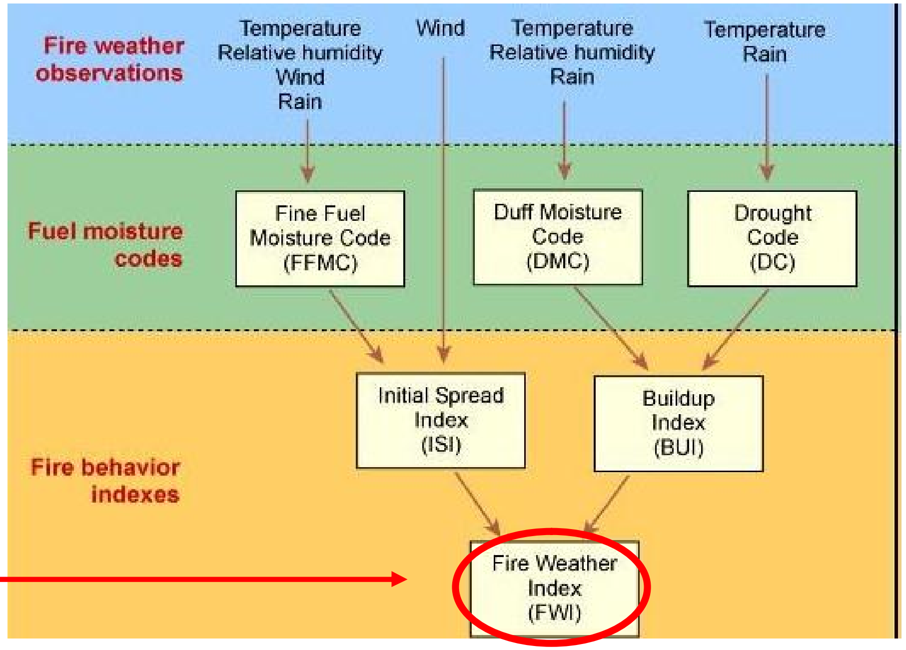
Difference between the Multimodel SuperEnsemble scenario precipitation averaged over the period 2031-2050 with respect to the period 1981-2000, as a function of the season (T-test conf. level 95%).

Significant precipitation decrease only in summer and autumn, more enhanced in the mountains.

Fire weather index FWI

Piedmont Region fire prevention and suppression system calculates the Canadian fire weather index (FWI) for its daily operational use.
The FWI is based on the moisture content of three classes of forest fuel plus the effect of wind on fire behaviour.

three indices related to fuel moisture, physically based



three indices related to fire behaviour

FWI

Climate scenario FWI calculation

OBS:

- **Temperature: Optimal Interpolation**
- **Precipitation: Optimal Interpolation**
- **Rel. humidity: Poor Man Ensemble RCMs reanalyses**
- **Wind speed: Poor Man Ensemble RCMs reanalyses**

+ # recorded forest fires in Piedmont 1957-2009

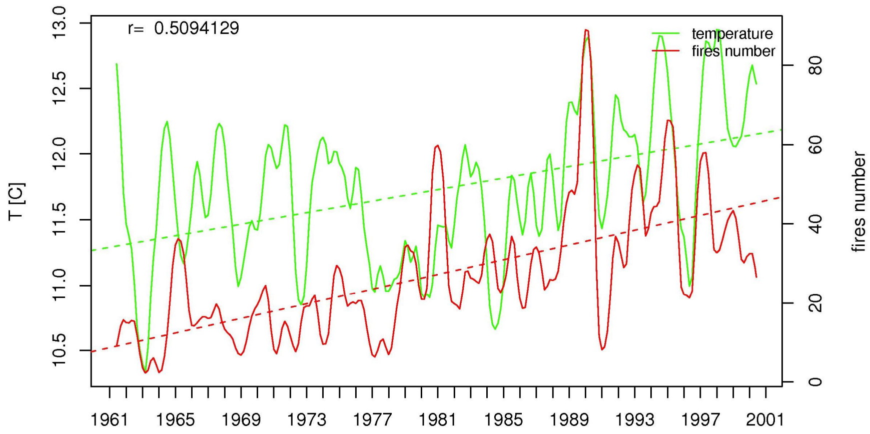
Scenario/reanalysis:

- **Temperature: tmax (MM standard)**
- **Precipitation: MM probabilistic**
- **Rel. humidity: Poor Man Ensemble RCMs reanalyses/scenarios**
- **Wind speed: Poor Man Ensemble RCMs reanalyses /scenarios**

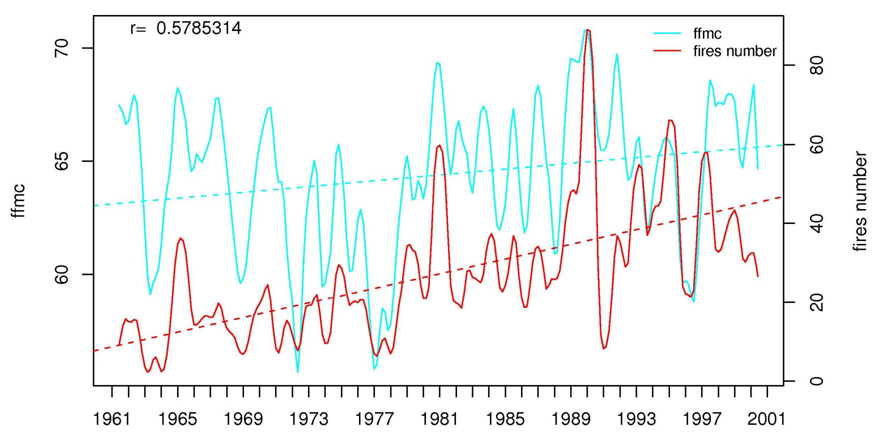
Results

Obs 1961-2000: trends

temperature



ffmc



90% of Piedmont Region forest fires have an anthropogenic cause, but the fire potential is strongly linked to the climate.

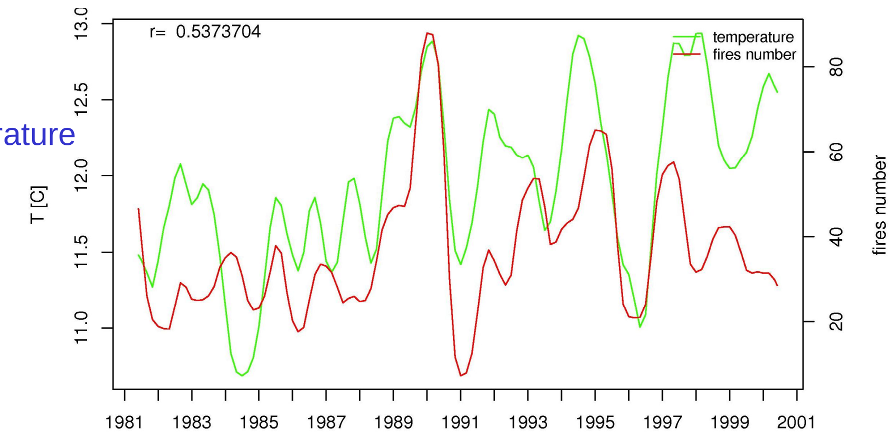
Observation

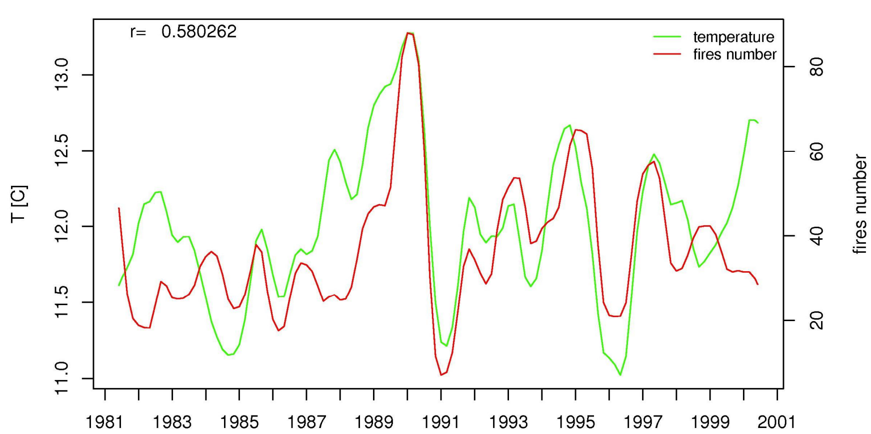
Reanalysis 1981-2000

Multimodel SuperEnsemble

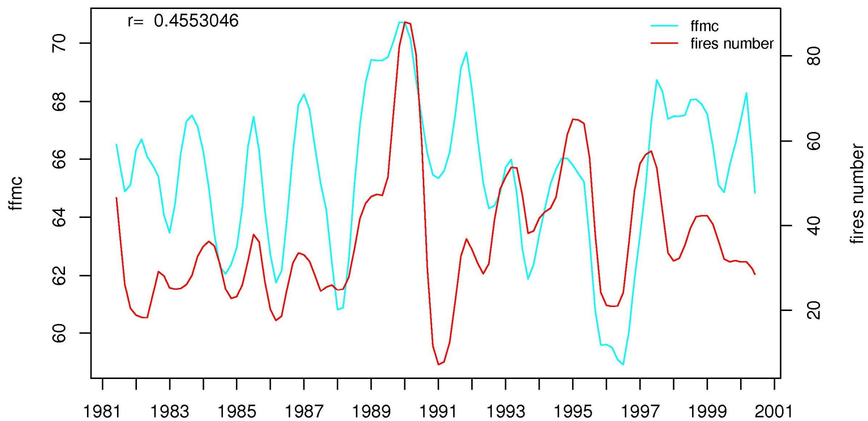
Reanalysis 1981-2000

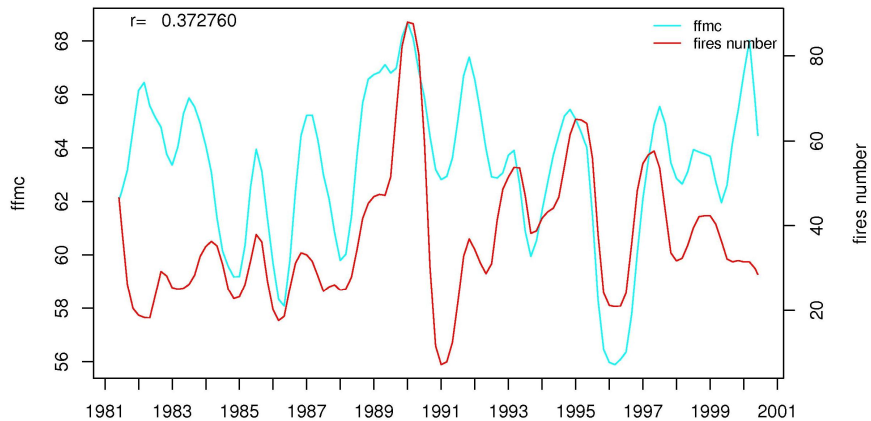
Temperature





ffmc





Conclusions

- Multimodel SuperEnsemble technique (standard and probabilistic) can be applied to the RCMs outputs to downscale the scenarios over complex terrain regions like Piemonte.
- The scenario projection obtained with Multimodel SuperEnsemble, thanks to the use of the high resolution analysis, allows a better characterization of the temperature and precipitation variations in the alpine area, with differences between mountainous and plain regions.
- The Fire Weather Index evaluated on the climate reanalyses show a surprising good agreement with the recorded forest fires.

To doé

ACQWA project results:

- Evaluation of the water budget in Piedmont and in the whole Alpine area in the scenario

ALP FFIRS project results:

- Calculation of the Fire weather Index in the scenario
- Comparison between general FWI distribution and distribution in cases of recorded forest fires (FWI skill score) and change in FWI distribution in the future scenario.
- Calculation of FWI on the whole Alpine Area

ALP FFIRS
Alpine Forest Fire Warning System