ISC - CAPUA

Very high resolution simulations with COSMO-CLM over Alpine space: benefits versus costs

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Introduction

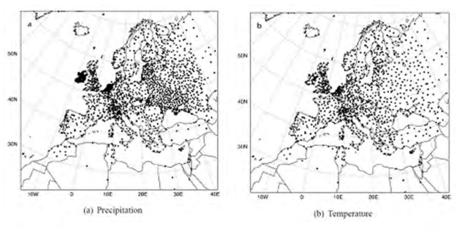
The Alps constitute an ambitious test ground for regional climate models: the complex topography (they are the most relevant topographic ridge of Europe) and land sea distribution are responsible for numerous mesoscale flow features and precipitation processes in response to synoptic-scale disturbances. This leads to the presence of different climates over the Alpine arc.
The aim of this work is the analysis of the improvement in reproducing the main features of the atmospheric variables over this complex area, obtainable increasing the spatial resolution. The regional climate model COSMO-CLM, with an optimized configuration over north Italy has been used, adopting three different horizontal resolutions: 0.125° (~14 km), 0.0715° (~8 km), and 0.02° (~2.2 km). The simulations have been performed with two different forcing datasets: ERA40 (Uppala et al., 2006) and ERA Interim Reanalysis (Dee et al, 2011), with the exception of simulation at 0.02° resolution, which has been nested into the 0.0715° resolution simulation (using a double nesting approach). The two-meter mean temperature and the daily precipitation have been considered for validation.

The COSMO-CLM model

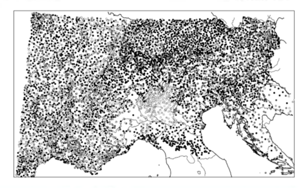
The COSMO-CLM is the COSMO model in Climate Mode (Rockel et al., 2008), developed by the CLM Community.
The COSMO-Model is a non hydrostatic limited-area atmospheric prediction model developed from the German Weather Service (DWD).
It is the only limited area numerical model system in Europe which has a range of applicability encompassing: operational numerical weather prediction (COSMO); regional climate modeling of past, present and future (CLM); the dispersion of trace gases and aerosol (ART); idealized studies (ITC).
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 modelers). Moreover, the non-hydrostatic modeling 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).

The observational datasets

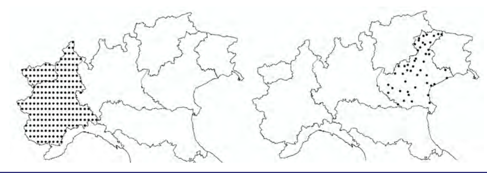
E-OBS: It is an European daily gridded dataset at a resolution of 0.25° (about 28km) for minimum, maximum and mean temperature, precipitation and sea level pressure for the period 1950-2012 (Haylock et al., 2008).



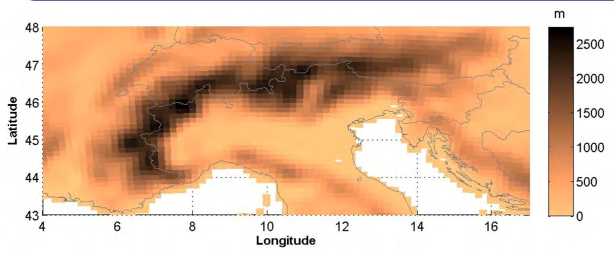
EURO4M-APGD: It is a precipitation daily gridded dataset at a resolution of 5km for the period 1971-2008, covering the Alpine space. It was constructed starting from high-resolution rain-gauge data from seven Alpine countries (Isotta et al., 2013).



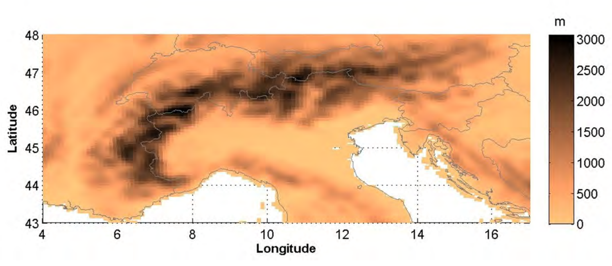
High resolution observed data provided by **ARPAs** (Regional Environmental Agencies) of Veneto and Piedmont region (the last one covers the Valle d'Aosta region too)



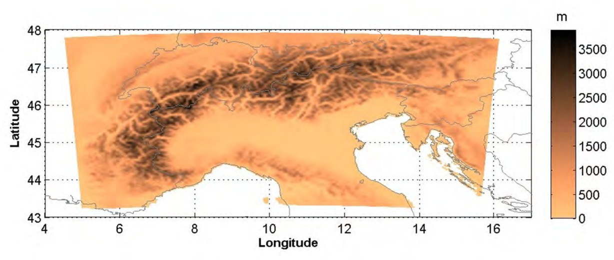
Model set-up and computational costs



Resolution = 0.125° (~14km)
Peak reached = 2733 m
Forcing = ERA40 and ERAInterim Reanalysis
Simulated periods= 1971-2000 and 1979-2011 (spin-up: 1 year)
Grid points= 62*37
dt=100 seconds



Resolution= 0.0715° (~8km)
Peak reached = 3065 m
Forcing = ERA40 and ERAInterim Reanalysis
Simulated periods= 1971-2000 and 1979-2011 (spin-up: 1 year)
Grid points= 109*64
dt=40 seconds



Resolution= 0.02°(~2.2km)
Peak reached = 3891 m
Forcing = double nesting approach (from simulation at 0.0715°)
Simulated period= 1979-1989 (spin-up: 1 year)
Grid points: 390*230
dt=10 seconds

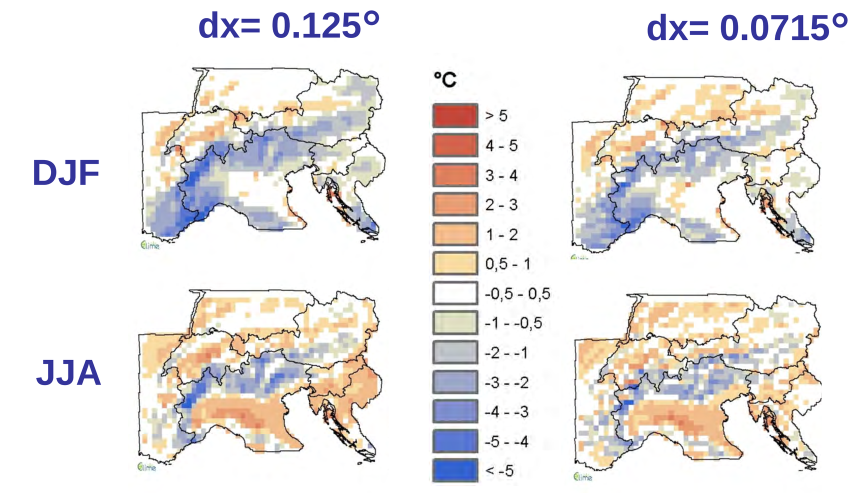
The effects of employing a very high spatial resolution were reported by Ban et al. (2012), who found a better capability in reproducing the spatial distribution of precipitation and in the representation of diurnal cycle for summer precipitation switching from parameterized convection to cloud resolving models.
In the present work, the main differences of the model configuration adopted for the 0.02° resolution (with respect to the lower resolutions) are:
- parameterization of the shallow convection (deep convection is resolved);
- max turbulent length scale = 150 m (instead of 500);
- critical value for normalized over saturation = 1.6 (instead of 4).

The simulations have been performed on IBM iDataPlex DX360M4 supercomputer of CMCC, installed at Lecce (Italy): it is a cluster of 482 nodes (7712 cores) interconnected with network FDR InfiniBand. This machine provides a computing power of about 160 TFlops and it is inserted in the Top500 list of the most powerful supercomputers in the world.
The following table reports an estimate for the elapsed time to simulate one climatological year at the different resolutions.

Resolution	0.125°	0.0715°	0.02°
Disk memory (GB) (1 year)	24.6	76	312.1
Time (min) with 1024 cores	-	2028	12200
Time (min) with 512 cores	420	2076	15240
Time (min) with 256 cores	612	3528	-

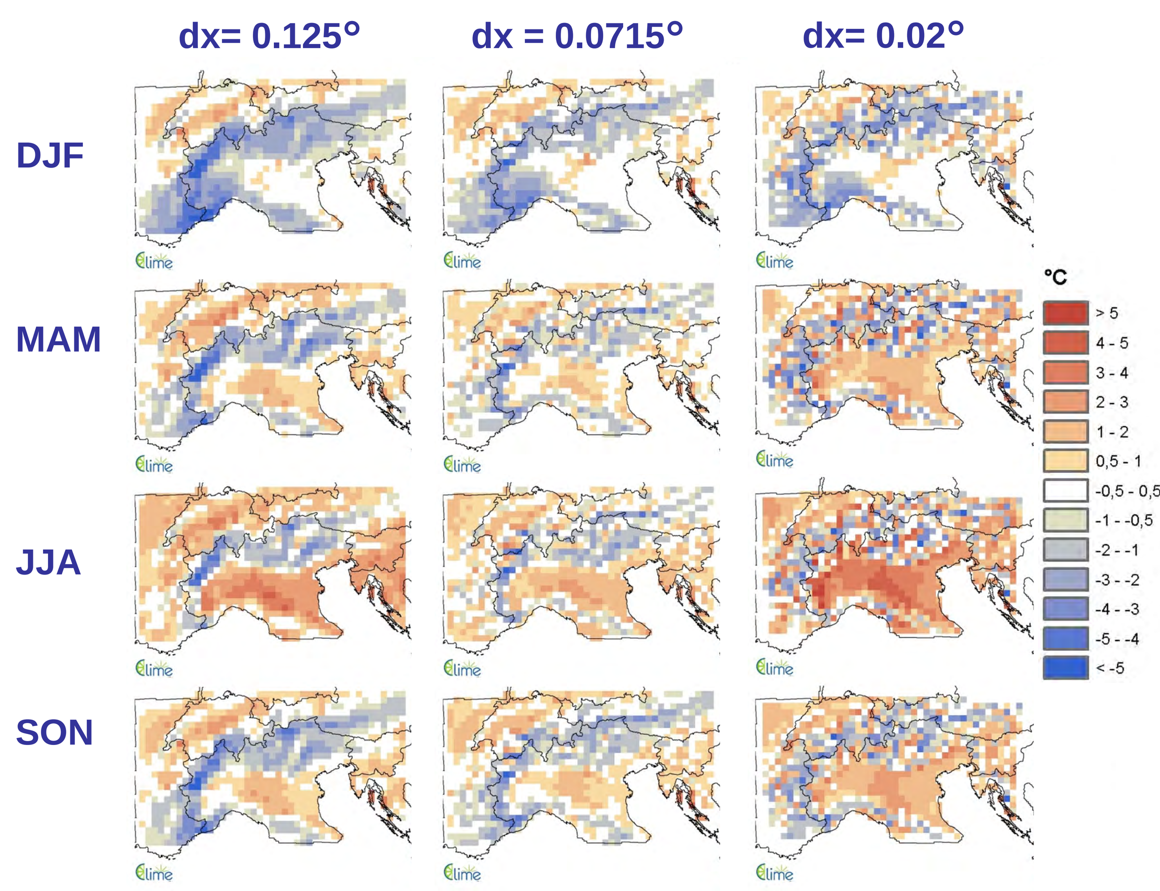
Analyses of the results

Temperature validation: 1972-2000 (ERA40 driven)



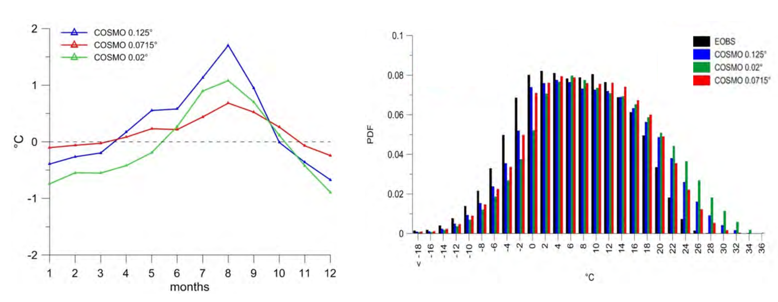
The 0.0715° simulation in DJF exhibits an average bias of -0.5°C (standard deviation 1.3); the highest error is reported in western Alps. In JJA the average bias is -0.1°C (standard deviation 1.2) with the highest error on the Po Valley for both configurations and on Western Alps for the lower resolution configuration.
The 0.125° simulation is colder over the Alpine arc in both seasons. The average bias in DJF is -0.9°C (standard deviation 1.4) and in JJA is -0.2°C (standard deviation 1.3). The increase of resolution significantly improve on the temperature field, especially over the Western Alps.

Temperature validation: 1980-1989 (ERA Interim driven)

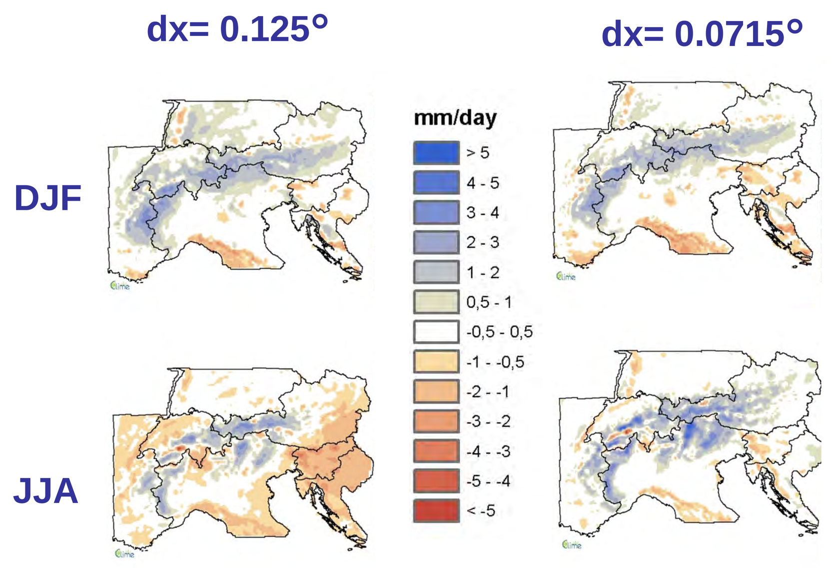


For this period, the simulation (validation performed with E-OBS) at 0.0715° generally shows the best results. The 0.02° simulation, in fact, has a lower bias in DJF, especially over Piedmont, but a larger bias in JJA. Moreover, the results of 0.02° simulation appear to be "noisier". This in mainly due to the lower EOBS resolution (about 0.25°).

Bias of seasonal cycle and PDF with respect to EOBS

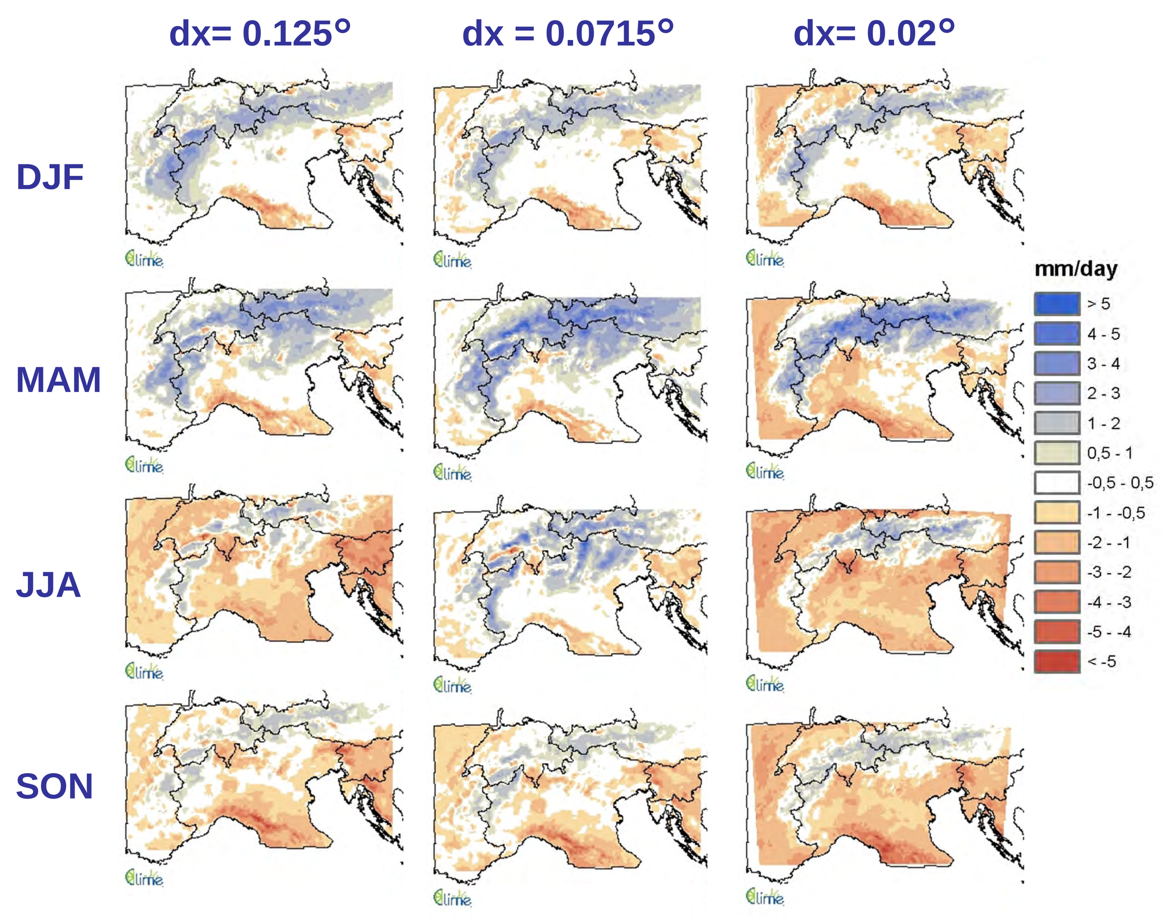


Precipitation validation: 1972-2000 (ERA40 driven)



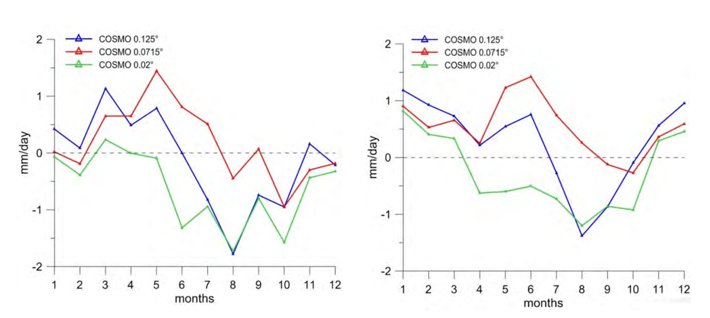
The 0.0715° simulation exhibits an average bias of 0.3 mm/day (standard deviation 0.9) in DJF and of 0.2 mm/day (standard deviation 0.84) in JJA. An overestimation on the Alps for both seasons is registered.
At 0.125° resolution, the average bias in DJF is 0.4 mm/day (standard deviation 0.84), while in JJA is 0.3 mm/day (standard deviation 0.92).
The finer resolution simulation shows slight better results.

Precipitation validation: 1980-1989 (ERA Interim driven)

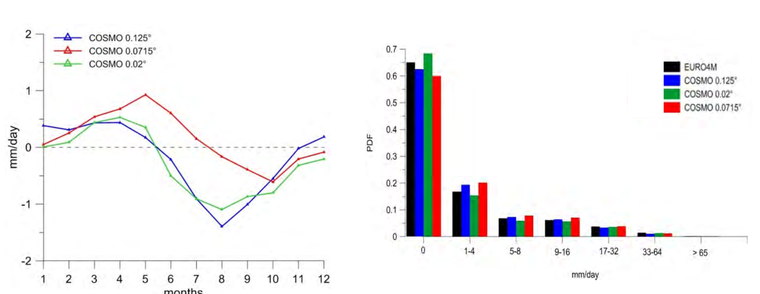


The most evident result is the larger bias (validation performed with EURO4M-APGD) for the 0.02° simulation over the Po valley, especially in JJA. Nevertheless, an improvement of the performances occurs over the Alpine arc especially over Western Alps.
Comparison with high resolution observational datasets over Veneto and Piedmont confirms the good performances in DJF of the 0.02° simulation.

Bias of seasonal cycle
with respect to Veneto obs — with respect to Piedmont obs



Bias of seasonal cycle and PDF with respect to EURO4M



Conclusions

The simulations performed have highlighted that increase of resolution from 0.125° to 0.0715° significantly improve (against a sustainable increase of computational costs) the results quality, especially in JJA. The current configuration of the 0.02° is able to get further enhancements over the Alpine arc in winter, but it shows worst performances in summer. This behaviour could be explained by a non optimized parameterization of the shallow convection over Po Valley, characterized by very specific climate behaviour. In the future work, the shallow convection parameterization over this area will be deeply investigated. Nevertheless, the use of a higher resolution over Alps exhibits positive results, showing the importance of correctly representing the complex orography of the area.

References

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