Possible Added Value of an RCM for the Study of Past Climate Changes

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Introduction

In recent years the application of high-resolution regional climate models for paleoclimate studies has become more frequent. Nonetheless, apart from the work of Renssen et al. 2001 [1], the possible advantages of RCM simulations for the study of paleoclimate have never been addressed before. Within this context, in our discussion we try to highlight the importance of RCMs for the simulation of past climate change.

Here we report the preliminary results of a study for the mid-to-late Holocene European climate.

Methods

Climate Simulations

A complex experimental framework has been developed (Russo & Cubasch 2016 [2]). In a first step the results of a transient simulation with the coupled Atmosphere-Ocean Global Circulation Model (GCM) ECHO-G (Legutke et al. 1999 [3], Wagner et al. 2007 [4]), covering the last 7000 years, have been downscaled by means of an Atmosphere-only GCM, the ECHAM5 (Roeckner et al. 2003 [5]), for 7 selected time-slices. The outcomes of these simulations have been successively used to run a high resolution Regional Climate Model (RCM), the COSMO-CLM (CCLM (Bohm et al. 2003 [6])). Further information on the experimental framework are provided in Fig. 1, together with a map of the CCLM's orography.

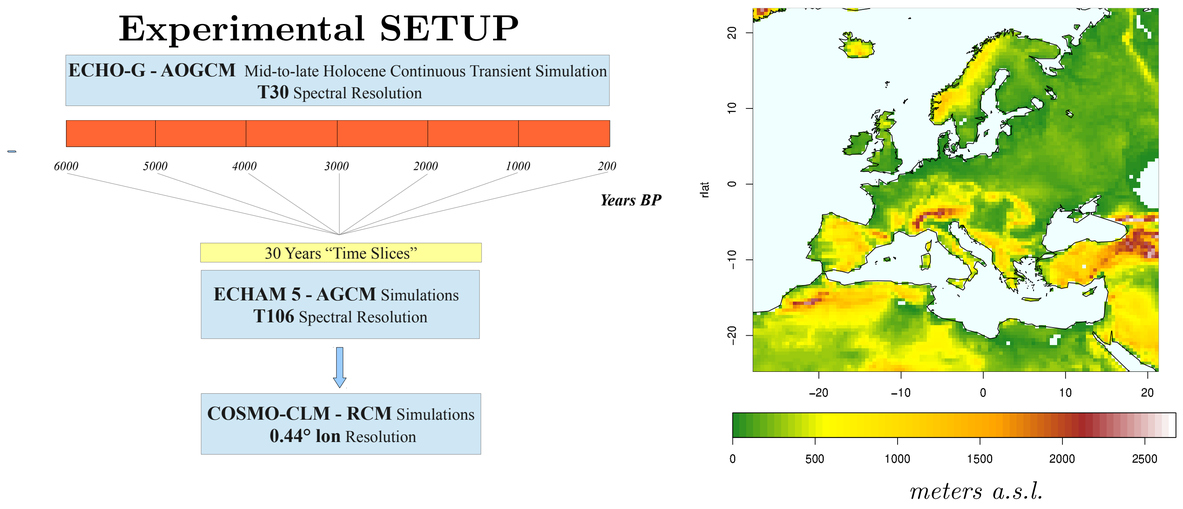

Figure 1: *(Left) Scheme of the experiment realization. (Right) Orography Map of the COSMO-CLM simulation domain in rotated coordinates.*

Proxy Data

For the comparison of models simulation results, the pollen-based reconstructions of Mauri et al. 2015 [7] have been used. While in a first step a gridded dataset has been used, successively, the original point-based data have been employed, whose spatial distribution is reported in Fig. .

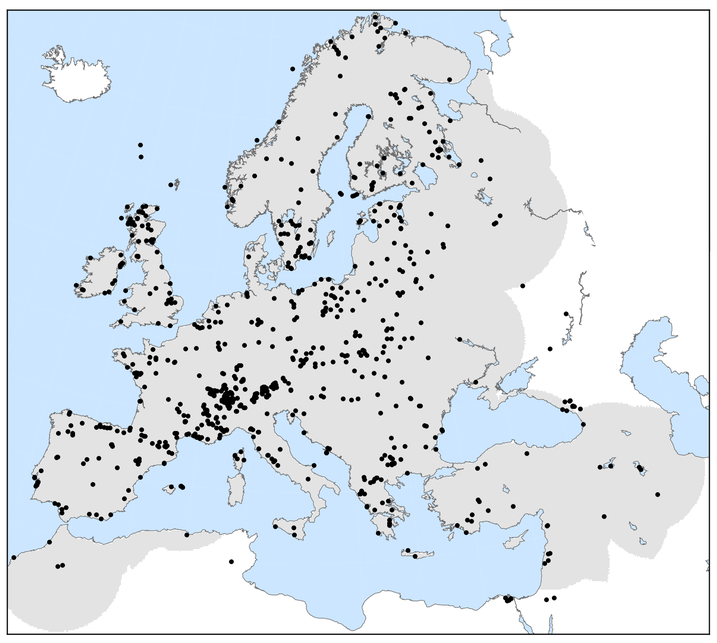

Figure 2: *Maps of the sites of the pollen-reconstructions employed by Mauri et al. 2015 [7].*

Added Value

Aiming at investigating the value added by highly resolved simulations for the comparison against proxy-reconstructions, analyses follow a two steps approach:

- In a first step a simple qualitative analysis is conducted.
- Then, a more quantitative comparison is conducted, by introducing a cost function defined by:

$$CF^k_{mod} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(T^k_{rec,i} - T^k_{mod,i})^2} \tag{1}$$

where CF^k_{mod} is the value of the cost function for each considered time slice *k* of the mid-to-late Holocene and each model *mod*. The parameter *n* represents the number of the reconstructions grid boxes. $T^k_{rec,i}$ is the temperature of the proxy-data at every location *i*, while $T^k_{mod,i}$ is the corresponding temperature of the model simulation.

The results are finally expressed as the percentage change given by:

$$\textbf{Percentage Change} = \frac{\mathbf{CF_{GCM}} - \mathbf{CF_{RCM}}}{\mathbf{CF_{GCM}}} \times \mathbf{100}$$

Results

Qualitative Analysis

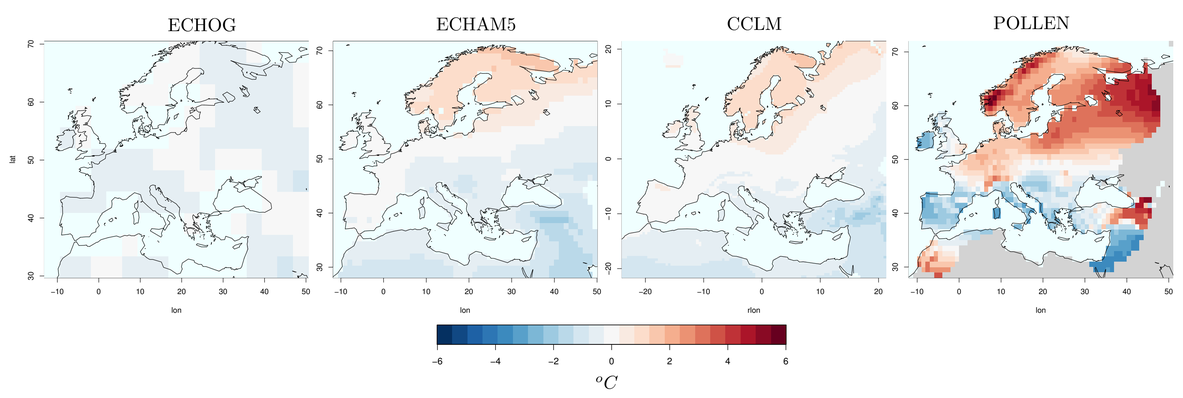

Figure 3: *Maps of Winter near surface temperature anomalies between 6000BP and the preindustrial period. From right to left the results of the pollen-based reconstructions of Mauri et al. 2015 [7] (4^th column) and the ones of the three different models are presented: CCLM (3^rd column), ECHAM5 (2^nd column), ECHO-G (1^st column).*

The higher resolved simulations capture a warmer bias over northern Europe in winter, also present in the proxy data, that the ECHO-G is not able to reproduce. Better defined patterns and more detailed information are also evident in the maps derived from the higher resolution models. Additionally, the land-sea area in the ECHO-G is considerably different than the ones of the other models.
Further analyses focus on the comparison between the ECHAM5 and the CCLM results.

Quantitative Analysis

Time Slice	T 2M		PREC	
	JJA	DJF	JJA	DJF
6000BP	**+0.04%**	**+2.28%**	**+44.10%**	**-0.97%**
5000BP	**-2.42%**	**+1.33%**	**+47.04%**	**-2.58%**
4000BP	**-0.37%**	**+3.69%**	**+49.19%**	**-0.88%**
3000BP	**+1.56%**	**+2.48%**	**+46.66%**	**-1.86%**
2000BP	**+0.49%**	**+1.91%**	**+43.80%**	**-3.22%**
1000BP	**+0.12%**	**+0.58%**	**+50.13%**	**-2.55%**

Table 1: Percentage Change of near surface temperature and precipitation summer and winter seasonal values, calculated taking as reference the CF of the ECHAM5 simulation.

Results show that significant improvement is evident only for summer precipitation.

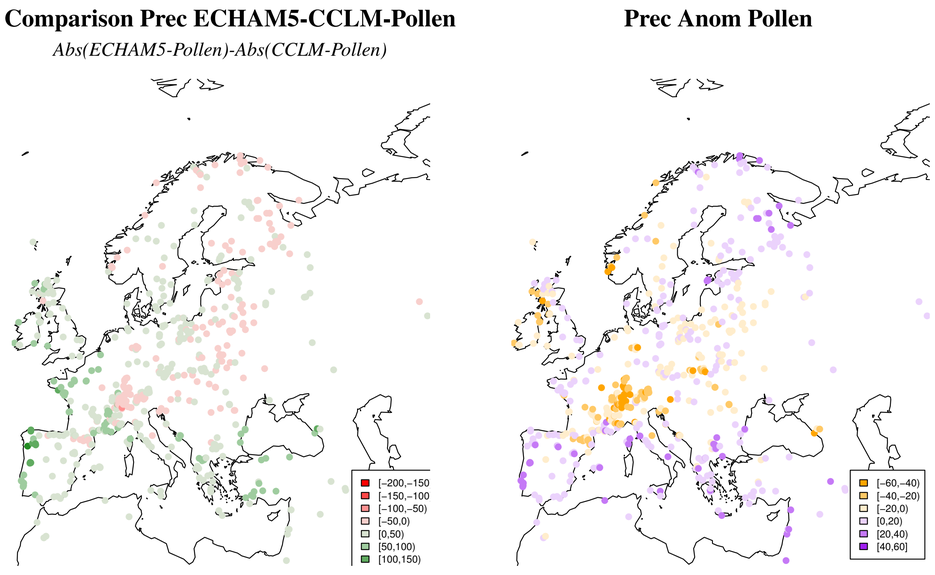

Figure 4: *(Left) Map of the distance of the CCLM and ECHAM5 results from the proxy values of summer precipitation for the 6000BP time-slice. Red values indicate points where ECHAM5 values are closer to the ones of the proxies, while the green points represent the points for which the values of the CCLM are closer to the reconstructed ones. (Right) Map of reconstructed anomalies of summer precipitation for the 6000 BP time-slice.*

Conclusions and Future Outlook

According to the evinced results it is possible to conclude that:

- There seems to be the potential for RCMs, relatively to this case study and for specific variables, to add value to simulation of past climate changes.

This work constitues a preliminary study, setting the basis for further analyses in which:

- Uncertainties related to the climate models and to the proxies data need to be properly considered
- The results of other RCM-GCM couples have to be investigated

References

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