Project: **1201**

Project title: **Regional Paleoclimate in the EM, the ME and Nile based on COSMO-CLM**

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Report period: **2021-11-01 to 2022-10-31**

1. Overview

The Eastern Mediterranean and the Middle East (EMME) and the Nile River basin (Nile) are of profound interest for the study of the relationship between historical events and climate variability and change, owing to the broad-spectrum instrumental time series, documentary information and natural archives available in the area. Recent studies revealed that paleoclimate modelling with coarse horizontal resolution cannot fully help to understand the complex interactions between the atmospheric circulation, climate variables at the local scale, and connect climate impacts that may trigger or contribute to major social-historical events. Thus, the RCM COSMO-CLM (CCLM), in an adjusted paleoclimate version (orbital, solar and volcanic forcings are adjusted), and accordingly greenhouse gas concentrations and land use changes, is used in this project. Several test simulations for the implementation of the forcings and present-day simulations to identify the appropriate settings and testing the performance of the model were carried out in the first phase of the project. During last year, the implemented forcings were tested in a sensitivity experiment and we started the transient simulation from the year 500 BCE. The driving MPI-ESM-LR simulation with 1.875° horizontal resolution for the provision of CORDEX-compliant output concluded in 1850 CE and the RCM simulation has reached the year 600 CE. Completed experiments details can be seen in Table 1.

Table 1. Overview of the performed simulations (* volcanic, orbital, solar, GHG, LUC)

Experiments	***Model***	***Description***	***Resolution***	***Simulation years***
Samalas_*	*CCLM*	*Individual forcings**	*0.44*	*1255-1265 (5*10)*
Samalas_full	*CCLM*	*Full forcings*	*0.44*	*1255-1265 (10)*
Samalas_orig	*CCLM*	*Original configuration*	*0.44*	*1255-1265 (10)*
mythos500bc	*MPI-ESM*	*transient (CMIP6)*	*1.875*	*500 BCE – 1850 CE (2350)*
mythos500bc_cclm	*CCLM*	*transient*	*0.44*	*500 BCE – 600 CE (1100)*

2. Samalas sensitivity experiment

In Figure 1 the annual 2-meter air temperature of the EMME region (domain after Zittis et al., 2022) is shown for the 10-years sensitivity experiment for the Samalas volcanic eruption. On the left, the correctly simulated temperature decrease after the eruption in September 1257 can be seen. The driving MPI simulation and the differently forced CCLM simulations all show a similar order decrease. After some colder years, the temperature returns to values comparable to those prior the eruption. On the right, the temperature anomalies compared to the original CCLM simulation (without explicitly implemented forcings). Here the differences between the individually forced simulations are clearly visible. In general, the land-use forcing seems to have the largest effect on air temperature, while around the volcanic eruption the volcanic forcing has, as expected, the largest impact.

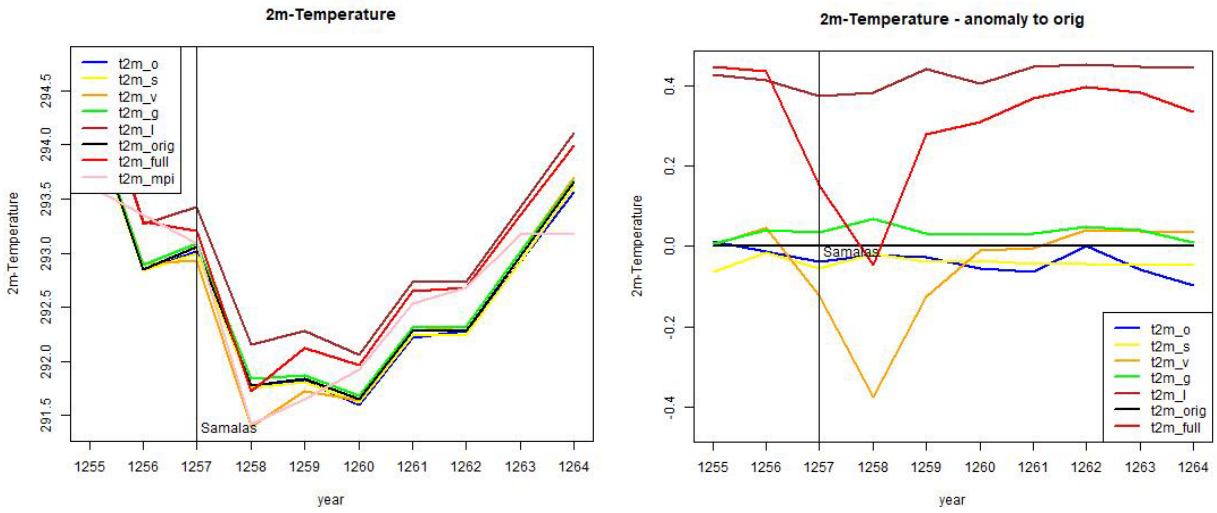

Figure 1. Annual EMME 2m air temperature (left) and anomalies to the simulation with the original configuration (right) ('_orig'=no forcing, '_o'=orbital, '_s'=solar, '_v'=volcanic, '_g'=greenhouse gas, '_l'=land-use, '_full'=fully forced, '_mpi'=MPI-ESM simulation).

3. Differences between current and 2000 years before present climate

Differences between the past (400-362 AD) and present (1980-2018 CE) climate conditions are evaluated in terms of mean and variance for both precipitation and temperature of the CCLM reconstruction data. The Student's t-test at each grid point and the 99% significance level is used to assess differences between the two periods. In Figure 2, we are showing the mean and standard deviation differences of the 2m air temperature between the past and present period. Mean air temperature statistically significant differences for winter (DJF) and summer (JJA) characterize larger areas in the south and the north of the simulated region, respectively. Summer temperature variability appears slightly decreased for the current climate, whereas CCLM simulates overall higher variability for winter.

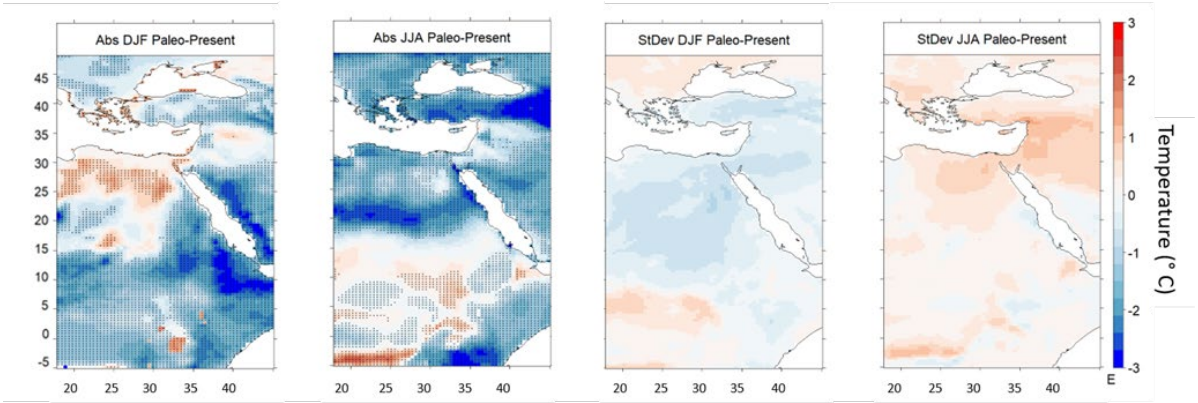

Figure 2. Mean temperature and standard deviation differences between current and 2000 years before present climate

4. Summary and Outlook

In this study, we performed a) simulations with CCLM to define optimum settings for the paleo-climate simulations and b) sensitivity tests to the different forcings. A transient simulation with the optimum configuration started in 500 BCE. The simulation is forced with the MPI-ESM-LR, CMIP6 compliant, and identical external forcings as those implemented in the CCLM. This enables us to study and compare the climate 2000 years before present with current conditions. The continuation of the transient simulation in the next months is imperative for the study of interesting periods with respect to climate, society and history in the EMME and the Nile River basin. The completed run will be the first continuous and transient RCM simulation of the last 2500 years that allows for a broad spectrum of studies of the climate of the past.

5. Literature

Zittis, G., Almazroui, M., Alpert, P., Ciais, P., Cramer, W., Dahdal, Y., et al. (2022). Climate change and weather extremes in the Eastern Mediterranean and Middle East. *Reviews of Geophysics*, 60, e2021RG000762. https://doi.org/10.1029/2021RG000762

Hartmann, E., Zhang, M., Adakudlu, M., Wagner, S., Xoplaki, E., Implementing External Climate Forcings into the COSMO-CLM - A Samalas Sensitivity Study. In prep.

Zhang, M., Hartmann, E., Adakudlu, M., Wagner, S., Xoplaki, E., The climate of the Eastern Mediterranean and the Nile basin 2500 years before present: a fully forced COSMO-CLM experiment. In prep.