Project: **1201**

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

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Report period: **2020-11-01 to 2021-08-31**

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 of local and regional historical events with climate, owing to the broad-spectrum instrumental time series, documentary information and natural archives. Recent studies revealed that paleoclimate modelling with coarse horizontal resolution cannot fully help to understand the complex interactions between the atmospheric circulation, climate variables and connect potential 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 forcing 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 find the correct settings and test the performance of the model are carried out so far. Finished experiments details can be found in Table 1. Furthermore, a fully forced MPI-ESM-LR simulation with 1.875° horizontal resolution is currently running for the provision of CORDEX-compliant output over the last 2500 years. Other than that, a fully forced COSMO-CLM regional climate simulation over the selected domain forced by the new MPI-ESM-LR output will start to run in the near-future.

Table 1. Overview of the performed simulations (* Volcanic, Orbital, Solar, GHG or LUC)

Experiments	Description	Resolution	Simulation years
Eval_44	Present climate – ERAInterim	0.44	1979-2019 (40)
Eval_11_nest	Present climate – ERAInterim	0.11	1979-2019 (40)
Present_44	Present climate – MPI-ESM	0.44	1970-2000 (30)
Present_11_nest	Present climate – MPI-ESM	0.11	1970-2000 (30)
Samalas_*	* forcing– MPI-ESM	0.44	1255-1265 (5*10)
Samalas_full	Full forcing– MPI-ESM	0.44	1255-1265 (10)

2. Present Climate

In Figure 1, the 2-meter air temperature and the precipitation annual cycle of the four completed present-day simulations and observational/reanalysis data are shown for the Nile and the EMME region separately. We can see that the 2-meter air temperature over the Nile basin and the EMME are well simulated with COSMO-CLM both in 0.44 and 0.11° horizontal resolution, compared to the forcing data ERA-Interim and the observational data CRU (Climatic Research Unit). However, the 2-meter temperature in the Nile basin shows better accordance in the 0.11° simulation, compared to the 0.44° simulation whereas in the EMME the differences are neglectable. Contrariwise, the precipitation shows better performance in the 0.44° simulation compared to the 0.11° simulation.

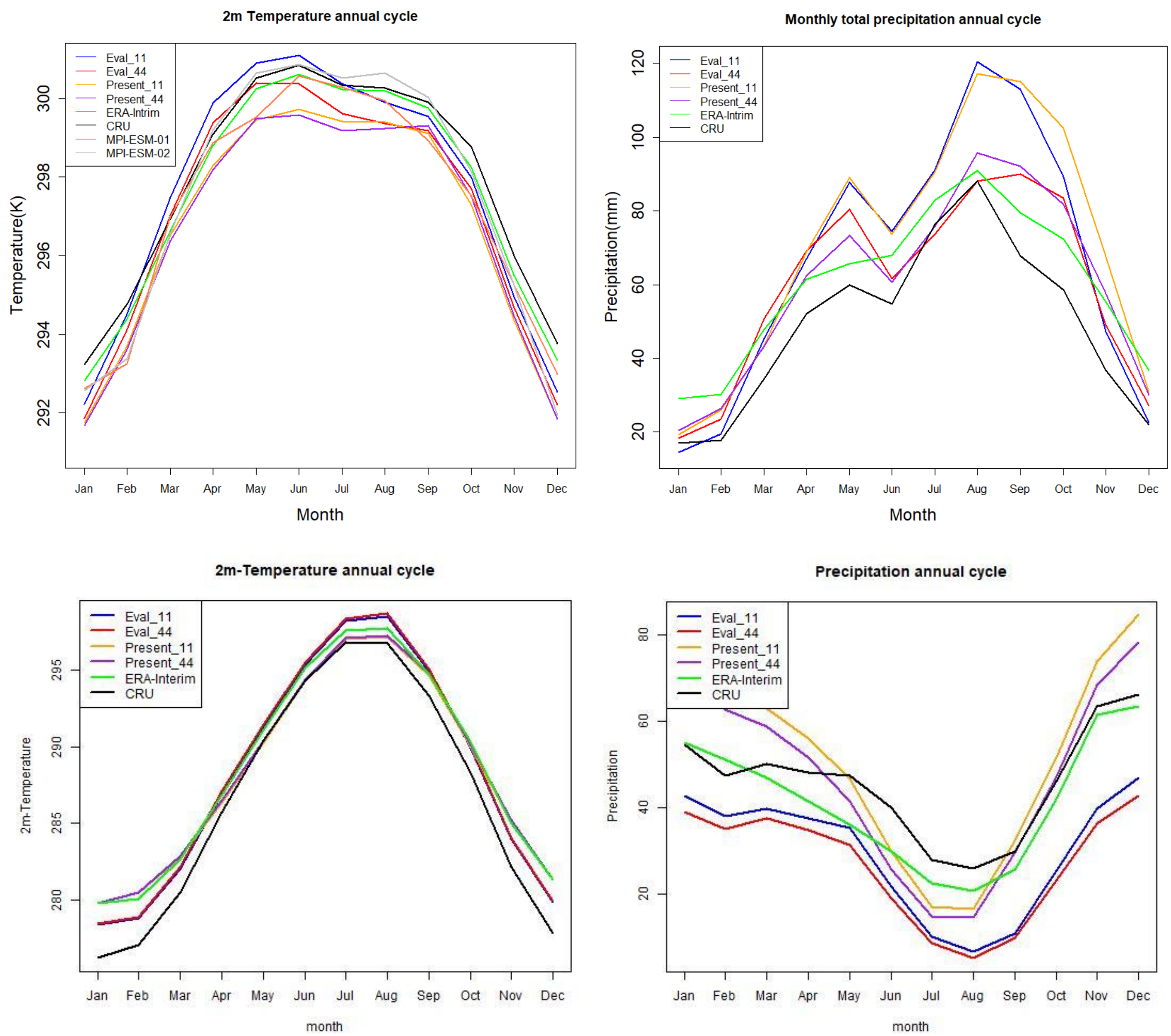

Figure 1. Annual cycle of 2m air temperature (left) and precipitation (right) for the Nile (top) and the EMME (bottom) regions.

3. Implementation of Forcings

The forcings were implemented step by step and tested in the period 1255 to 1265 CE. The period has been selected due to the occurrence of the major Samalas volcanic eruption in Indonesia in 1257. The volcanic forcing should thus have a large impact in this period and makes the 10-year period an appropriate test period for the forcings implementation. In addition, with more than 750 years in the past, the other forcings impact, orbital, solar, greenhouse gases and land-use changes, is significantly different compared to the present. The different forcings (but the land use that starts in 850 CE) are available for the period 500 BCE to 1850 CE. The AOD (volcanic forcing) increases abruptly due to volcanic eruptions and returns to lower levels between the eruptions. The TSI (solar forcing) represents the solar activity with time. The eccentricity, obliquity and the longitude of perihelion together build the orbital forcing. The concentrations of CO2, CH4 and N2O are combined to the CO2-equivalent and represent the forcing of the greenhouse gases concentrations. In Figure 2 are shown the results of the simulations with different forcings implemented separately and all together in the 'full' simulation. The 'orig'-run is the original CCLM without any transient forcing. To illustrate the differences between the forcings, the 'orig' value is subtracted for each value. The annual 2m air temperature as well as the annual precipitation decrease in 1258, the year after the volcanic eruption in 1257. Looking at the simulations with the different forcings, it is obvious that this decrease is due to the volcanic forcing, which was expected from previous research [Guillet et al., 2017].

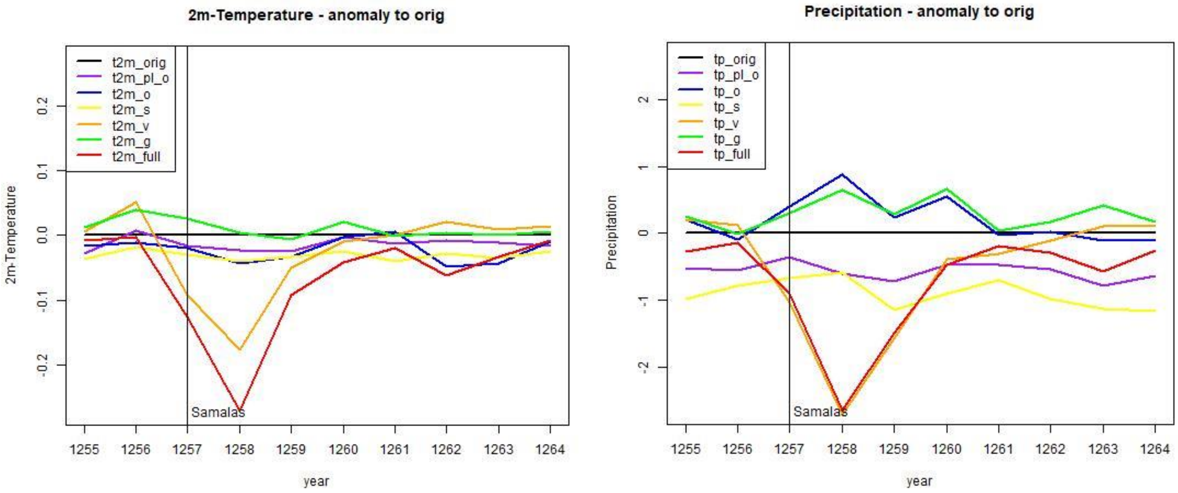

Figure 2. Annual EMME 2m air temperature (left) and precipitation (right) deviations to the original CCLM version with the different forcings implemented ('_orig'=no forcing, '_pl_o'=orbital forcing by Patrick Ludwig, '_o'=orbital, '_s'=solar, '_v'=volcanic, '_g'=greenhouse gas, '_full'=fully forced).

4. Summary and Outlook

In this study, we performed several simulations with COSMO-CLM to identify the optimum settings for the Paleoclimate simulations. The present-day simulations show that the temperature and precipitation are reasonably simulated compared to reanalysis and observational data in general. There is some variability in specific regions that can be explained with complex atmospheric circulation patterns and complex terrain and could therefore be expected. With studying the different resolutions of 0.11° and 0.44°, we found out that the added value of the increased resolution is limited especially for the precipitation. This is the reason why we would like to concentrate for the transient simulations on the 0.44° resolution in the second half of this project period. The transient paleo-version is ready to run and will start in the second part of the project.

5. Literature

Guillet, S., Corona, C., Stoffel, M. *et al.* Climate response to the Samalas volcanic eruption in 1257 revealed by proxy records. *Nature Geosci* **10,** 123–128 (2017). https://doi.org/10.1038/ngeo2875