Project: **1201**

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

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Report period: **2023-11-01 to 2024-10-31**

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. 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 we developed an adjusted paleoclimate version (orbital, solar and volcanic forcings, greenhouse gas concentrations and land use changes) of the RCM COSMO-CLM (CCLM). After several test simulations to identify the appropriate settings and performance of the model in the first phase of the project, the implemented forcings were tested in a sensitivity experiment. The driving MPI-ESM-LR simulation with 1.875° horizontal resolution for the provision of CORDEX-compliant output for the complete period and a second realisation for the common era are finished. During the last year, we could finally finish the complete transient RCM simulation until the year 1850 CE. Unfortunately, due to the PI's maternity leave at the time of completion, few evaluations are available so far.

2. Completion of the transient simulation 500 BCE to 1850 CE

In 2021, we started a transient CCLM simulation on Mistral with beginning in the year 500 BCE. For this purpose, we used the output of a CMIP6-compliant MPI-ESM-LR simulation as input and implemented the therein used external forcings (orbital, solar, volcanic, greenhouse gases and land-use change) also in the CCLM. In 2024, after the changeover to Levante, which involved a number of hurdles and many months of apparently infinite simulations, we finally reached the year 1850 with the CCLM simulation. This is the first RCM simulation of its kind, meaning transient for a 2350 years period, without breaks, changes in input, external data, model or any other factor. Unfortunately, there are not yet any evaluations or plots available for the entire period. This will be done in the coming months.

3. Impact of large volcanic eruptions on the climate

In different collaboration projects, we focused on periods with large volcanic eruptions and studied the climatic response shown by the RCM. Those are for example the BCE eruptions in 426 and 43 BCE in the Aegean Sea and the Black Sea regions. In Figure 1 are shown the annual mean 2m-temperature (left) and the annual precipitation as anomalies to the mean of the shown period respectively. All plots show results for the Aegean Sea and the Black Sea and surrounding coasts. While the temperature shows a clear drop after the volcanic eruption, the precipitation does not have a clear signal connected to the eruption.

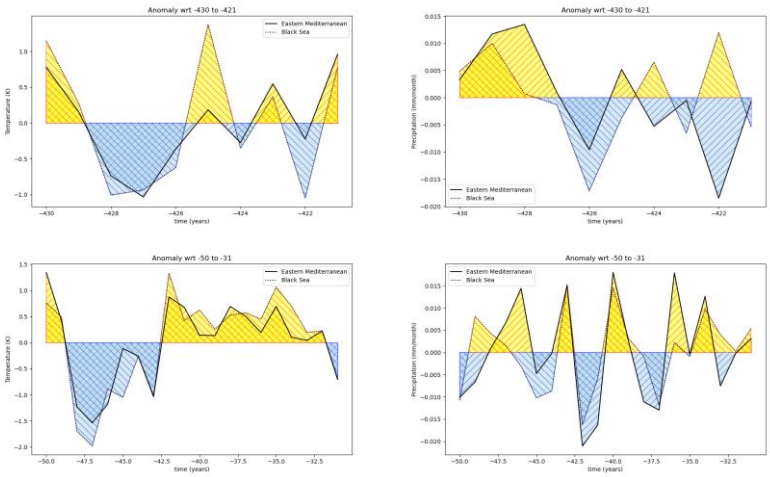

Figure 1. Annual mean temperature (left) and total precipitation (right) of the Aegean and the Black Sea for the volcanic eruptions in 426 BCE and 43 BCE as anomaly wrt 430-420/50-30 BCE respectively

Another example are the large volcanic eruptions around the years 540, 1257 and 1458 CE. The impacts of the eruption on the annual mean 2m-temperature in Macedonia are shown in Figure 2. After the two consecutive eruptions in the 6th century the temperature has strong negative anomalies. Also after the Samalas eruption in 1257 the temperature is cooler. After the 1458 eruption, the temperature is cooler but not as obvious as in the other cases.

Analysis like this are possible for the whole period 500 BCE to 1850 CE and on a very regional scale for the whole EMME-like domain of our simulation.

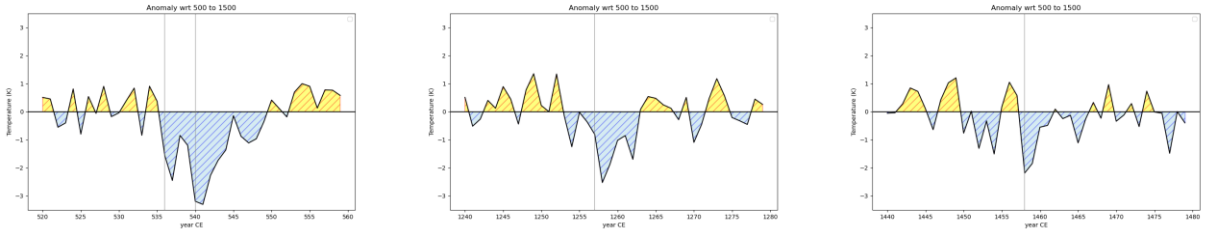

Figure 2. Annual mean 2m-temperature for the 2 decades before and after the volcanic eruptions in 536/540, 1257 and 1458 as anomalies wrt 500-1500 mean.

4. Climate of the 6th (and 7th) century

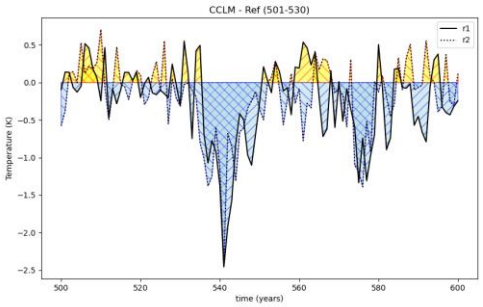

Figure 3. Annual mean temperature of the EMME in the 6th century for two RCM realisations as anomaly wrt 501-530

The climate of the 6th and 7th century was influenced by major volcanic eruptions in the years 536, 540, 574, 626, 682. In the left part of figure 2 we already saw that the cooling effect of the volcanic eruption is highest after the two consecutive eruptions in the years 536 and 540. The impact of those cluster volcanoes amplifies however, the strength of the signal varies in different areas and seasons. Because this cooling is often discussed in literature, we also take a closer look into the climate of the 6th century and its following years/decades. In Figure 3 this is done for the annual mean temperature of the EMME domain with two different realisations of both, the driving ESM and the RCM. The temperature decreases after each of those eruptions. Since the two eruptions in 536 and 540 occurred very shortly after each other, the effect is amplified and is visible for a longer time of up to 15 years until about 550. The length of the cooler period is also strongly debated in literature. The two realisations help to justify that the shown results are not only an artefact of one simulation but are very reasonable. When looking into climatic variables with smaller scale effects as for example precipitation, the advantage of the RCM comes even more into play. While the spatial mean does not show signals after the volcanic eruption, some specific regions do.

5. Summary and Outlook

In this project, we performed so far a) simulations with CCLM to define optimum settings for the paleo-climate simulations b) sensitivity tests for the different forcings c) a transient CCLM simulation from 500 BCE to 1850 CE and d) the driving global MPI-ESM-LR, CMIP6 compliant, simulation as well as an additional second realization of the driving and the RCM model for limited periods. This enables us to study the climate of the last 2500 years on a regional scale. The completed transient run is 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. This is imperative for the study of interesting periods with respect to climate, society and history in the EMME and the Nile River basin. In the coming months, we will focus on the analysis of the long transient simulation together with second realisations and nesting of special periods and areas. A second focus opens up with the extension of the domain to china.

6. Literature

Hartmann, E., Zhang, M., Adakudlu, M., Wagner, S., Xoplaki, E., Implementing External Climate Forcings into the COSMO-CLM~5.0 - A Sensitivity Study around the Decade of the Samalas Volcanic Eruption in the Eastern Mediterranean and Middle East. In prep.

Zhang, M., Hartmann, E., Wagner S., Adakudlu, M., Luther, N., Zerefos C., Xoplaki, E., The climate of the Eastern Mediterranean and the Nile River basin 2000 years ago using the fully forced COSMO-CLM simulation. In prep.