Project: **1201**
Project title: **Regional Paleoclimate in the EM, the ME and Nile based on COSMO-CLM**
Principal investigator: **Eva Hartmann**
Report period: **2025-11-01 to 2026-10-31**

1. Overview

The Eastern Mediterranean and the Middle East (EMME) and the Nile River basin (Nile) are of profound interest for studying the relationship between historical events and climate variability and change. Recent studies revealed that paleoclimate modeling with coarse horizontal resolution cannot fully help to understand the complex interactions between atmospheric circulation, climate variables at the local scale, and climate impacts that may trigger or contribute to major socio-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). We completed the driving MPI-ESM-LR simulation at 1.875° horizontal resolution to provide CORDEX-compliant output for the full period, along with a second realization for the common era. The complete transient RCM simulation between the years 500 BCE and 1850 CE is ready and was analyzed with a strong focus on large volcanic eruptions. We used the last year to analyze data for several publications with different foci. Additionally, we started with tests using the RCM ICON-CLM.

2. Analysis of the complete transient simulation from 500 BCE to 1850 CE

In 2021, we started a transient CCLM simulation on Mistral with a 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, we finished until 1850 CE. This is the first RCM simulation of its kind, meaning transient for a 2350-year period, without breaks, changes in input, external data, model or any other factor. Results for the temperature and precipitation of the complete domain are shown in Figure 1 as anomalies to the Common Era mean. The largest negative temperature anomalies (blue stars) can be linked with large volcanic eruptions (pink triangles).

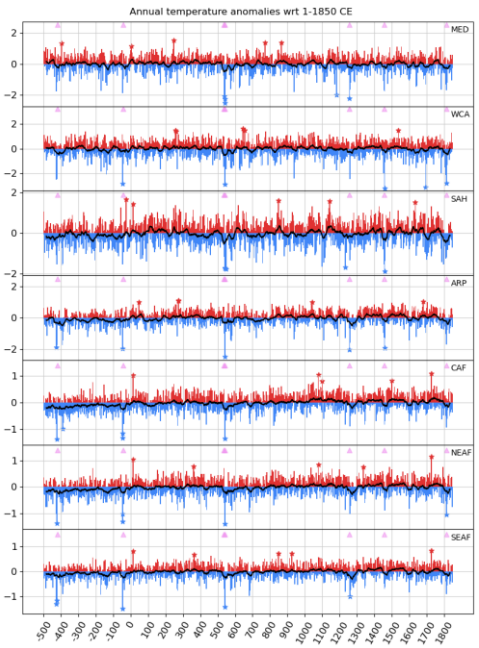


Figure 1. Annual mean temperature anomaly wrt the CE 1-1850 for the seven IPCC subregions for regional analysis

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 2 are shown the annual 2m-temperature as anomalies to the mean of the centuries before the Common Era (500-1BCE) for the Aegean. The temperature shows a clear drop after the volcanic eruption. Other examples are the large volcanic eruptions around the years 540, 1257 and 1458 CE, where in all cases the temperature clearly decreases after the volcanic eruption. Analyses 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.

4. Proxy-based climate reconstructions

Over the last month, proxy-based climate reconstruction work was carried out to support comparisons with CCLM simulations. As part of this effort, CPU resources were mainly used for proxy data processing and proxy network optimization. Newly collected proxy records, particularly raw tree-ring measurements from the International Tree-Ring Data Bank (ITRDB), were processed through quality control, detrending, standardization, and site-level chronology construction to improve data consistency and expand the existing proxy database. Subsequently, proxy network optimization was conducted using the Coral Reef Optimization (CRO) algorithm to identify the most informative proxy networks for reconstructing temperature, precipitation, and their covariability over the Euro-Mediterranean region. CPU nodes were used to perform iterative optimization experiments, evaluate candidate proxy networks based on reconstruction errors, and explore the influence of proxy selection, spatial distribution, and seasonal sensitivity on reconstruction performance.

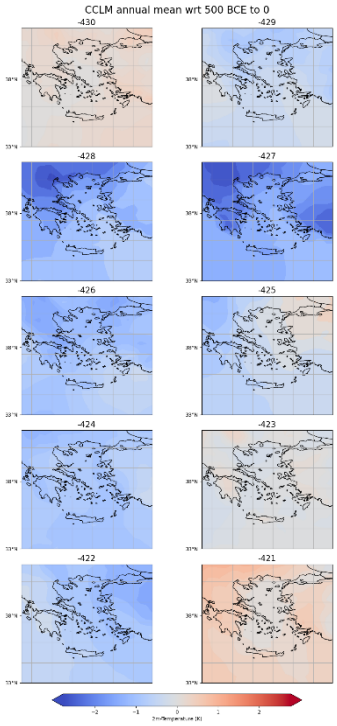


Figure 2. Annual mean temperature anomaly of the Aegean in the 5th century BCE wrt BCE 500-1

5. Preparation of ICON-CLM simulations

We started planning the experiment, quantifying the required resources, and developing a set of tests built around the domain definition and optimizing model parameters starting from the COPAT3 reference ICON-CLM configuration. The model system is ICON-CLM-2024.07, run on Levante within the SPICE v2.4 modelling framework.

6. Summary and Outlook

In this project, we have performed since the beginning 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 e) an additional second realization of the driving and the RCM model for limited periods f) regional climate simulations over China g) proxy-based climate reconstructions work to compare the simulations to and h) the preparation of newer regional climate simulations with ICON-CLM. 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.

A manuscript with focus on the 6th century CE is currently under review in Climate of the Past. Other manuscripts, including one focusing on volcanically forced hydroclimatic changes over eastern China during 1591–1850 CE and another on the 426 BCE eruption, using results from our regional climate simulations, are expected to be accepted soon. Additional interdisciplinary studies together with the proxy-based reconstructions, proxy data and historical information are in preparation.