Project: **1346**

Project title: **Deep-time large scale circulation patterns**

Principal investigator: **Fanni Kelemen**

Report period: **2025-11-01 to 2026-10-31**

Overview

The project focuses on paleoclimate modelling the climate of the early Eocene Climatic Optimum (EECO, 53.5 Ma), a Hothouse climate with extreme high CO_2 concentrations. We are interested in heat transport processes and large scale atmospheric circulation patterns, focusing on mid-latitude and tropical cyclones, blocking systems and monsoon. The early Eocene is also investigated by the Deep-Time Model Intercomparison Project, which is now in its second phase (DeepMIP-p2). We are working on contributing to DeepMIP-p2 with ICON-XPP simulations.

In 2026 we published one (Kelemen et al., 2026) and submitted one study (Kelemen and Meijer, 2026), which are both based on CESM1.2 simulations. These simulations were extended from already equilibrated early Eocene simulations. Moreover, we adapted the boundary conditions of ICON-XPP to the early Eocene paleogeography of the first DeepMIP phase and tested the model through 180 model years. Now, as the CAP7 version of ICON-XPP is finalised and the new paleogeography of the second phase of DeepMIP (Lunt et al., 2026) is available, we are in the process of starting longer simulations of ICON-XPP with the updated DeepMIP-p2 paleo boundary conditions.

Publications

In 2026 we published a paper (Kelemen et al., 2026), based on CESM simulations done at DKRZ. The study focuses on how paleogeography influences large-scale atmospheric circulation patterns and their heat transport. We found that the early Eocene continental configuration lead to more balanced heat transport between the hemispheres, compared to the pre-industrial one. Furthermore, we submitted a paper investigating model-proxy discrepancy in early Eocene East Asian mid-latitudes (Figure 1). The CESM simulations show that the region is experiencing monsoonal precipitation, which is sensitive to sea surface temperatures changes and additionally it highlights the possibility of tropical cyclones contributing to the summertime mid-latitude precipitation in East Asia during the early Eocene hothouse climate.

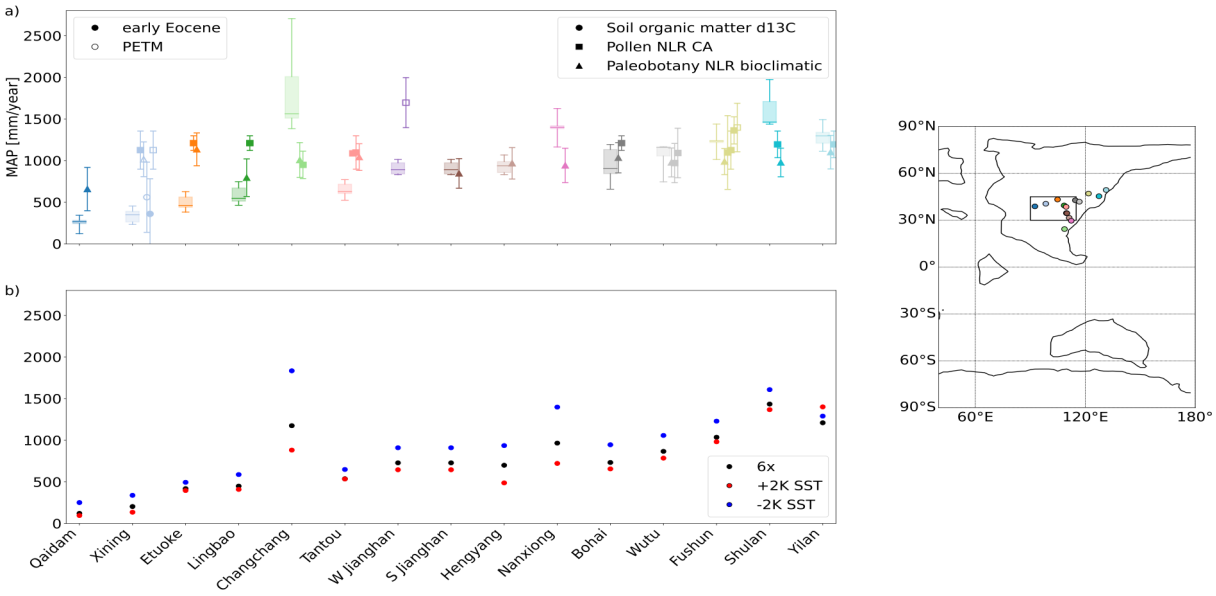


Figure 1. Comparison of mean annual precipitation (MAP) at the proxy sites (see location on the map) from the different paleoclimatological records and from the early Eocene ($6xCO_2$) CESM1.2

sensitivity experiment with -2 K SST (box-whisker plots) (a), and mean values from the control early Eocene ($6xCO_2$) simulation and the +2K SST and–2K SST sensitivity experiments (b) (from Kelemen and Meijer, 2026).

ICON-XPP

Parallelly to our above mentioned analyses we are working on the technical adaptation of ICON-XPP to deep-time boundary conditions. This includes changing to the land-sea mask, which means a new ocean grid is needed and surface parameters are need to be adjusted, furthermore the vegetation types and their distribution are changed based on DeepMIP protocols. The hydrological discharge model and river routs are adapted based on the steepest gradient of the topography. Subgrid scale orography parameters are calculated with a random forest model based on pre-industrial training. As the early Eocene was an extreme warm hothouse climate, no continental ice sheets are initiated.

In the first half of 2026 we were testing ICON with the DeepMIP-p1 boundary conditions and the test showed the model was stable through the 180 simulated years and started to move toward its new equilibrium (Figure 2). In the second half of 2026 we have been working on the DeepMIP-p2 boundary conditions, where both the paleogeography and vegetation distribution was updated from the first phase. For the remaining part of 2026 we are planning to start a longer test simulation with early Eocene conditions at $1xCO_2$ and $5xCO_2$ concentration to spin up the model to the altered conditions.

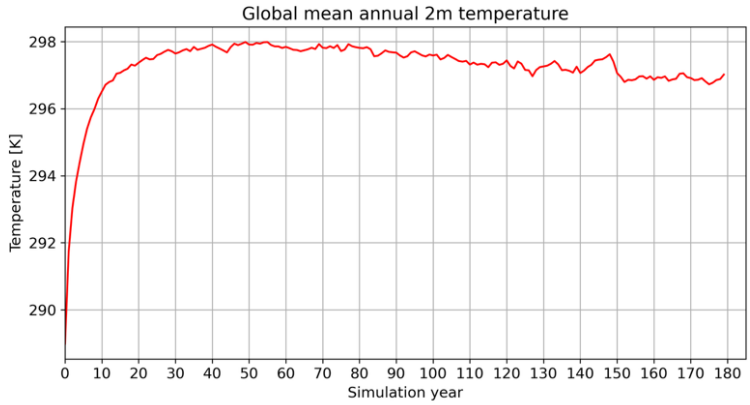


Figure 2. Global mean annual 2 m temperature from our test simulation with ICON-XPP with early Eocene paleo boundary conditions (paleogeography, no ice sheets, vegetation, rivers) at pre-industrial CO2 concentration level.

References

Kelemen, F. D., Lohmann, R., Zhu, J., Ahrens, B., 2026: Role of paleogeography on large-scale circulation during the early Eocene, Clim. Past, 22, 505–516, https://doi.org/10.5194/cp-22-505-2026

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