Project: **1346**
Project title: **Deep-time large scale circulation patterns**
Principal investigator: **Fanni Kelemen**
Report period: **2022-11-01 to 2023-10-31**

During the allocation period we planned to simulate paleoclimate with the model CESM2, targeting the warm climate of the Eocene. Our aim is to investigate meridional heat transport processes (e.g. Hadley cell, monsoon systems, midlatitude cyclones) with higher temporal and spatial resolution, than in our previous study (Kelemen et al., 2023, Meijer et al., 2023), based on simulations from the Deep-Time Model Intercomparison Project (DeepMIP) (Lunt et al., 2017, 2021).
For our own simulations, we planned to use the coupled climate model CESM2, which is the newer and further developed version of CESM1.2, the version used in DeepMIP. A previous study has shown (Zhu et al., 2021), that CESM2 has a high equilibrium climate sensitivity (ECS), which is not in line with the proxy data from the Last Glacial Maximum's (LGM) cold climate. Thus, Zhu et al. (2022) suggested changes in the cloud microphysics parametrization, which led to successful simulations of the cold climate of the LGM and the observed twentieth century climate. This set up is referred to as CESM2.1.1 PaleoCalibr. In our proposal we planned to use the paleo-calibrated CESM2.1.1. set up. Nevertheless, it has been shown recently in the CESM community, that the paleo-calibrated set up did not improve the model's high ECS in the warm, high CO_2 climate of the Eocene. Currently, both CESM2 and CESM2 PaleoCalibr model set ups run away at high CO_2 concentration. These findings are not yet published and we also found them out recently. Nevertheless, this led us to re-evaluate our original plan in using CESM2. We decided to restart our work with the older, but stable model version, CESM1.2. This decision has several advantages, namely that it is the same version as used in DeepMIP, thus our further results are well connected to our previous study, moreover it is a thoroughly tested version, which has been shown to simulate well the Eocene climate (Lunt et al. 2021). The disadvantages of this decision are however, that it is an older version, without the developments of the last years, and that we had to restart our porting and testing process at Levante. Still, we see it as the better route, since staying with the unstable version could have led to many failed experiments. In summary, after our detour with CESM2, we would like to continue our work with CESM1.2 to answer our research questions regarding large scale circulation patterns in the warm climate of the Eocene. For this, we are applying for our project's prolongation to the next year.

Work done during report period:

- Porting of CESM2.1.1 PaleoCalibr to Levante.
- Testing the processor layout and control simulation, with CESM2.1.1 PaleoCalibr.
- Porting and testing of CESM1.2 (in progress).

Planed work for the rest of the year:

- Starting the preindustrial control simulation with CESM1.2.
- Preparing the Eocene simulations boundary and initial files.

References

Kelemen, F. D., Steinig, S., Boer, A. de, Hutchinson, D. K., Niezgodzki, I., Knorr, G., Chan, W.-L., Abe-Ouchi, A., Zhu, J., & Ahrens, B. 2023: Meridional heat transport in the DeepMIP Eocene ensemble: Non-CO2 and CO2 effects. Paleoceanography and Paleoclimatology, 38, e2022PA004607. https://doi.org/10.1029/2022PA004607

Lunt, D. J., Bragg, F., Chan, W. Le, Hutchinson, D. K., Ladant, J. B., Morozova, P., Niezgodzki, I., Steinig, S., Zhang, Z., Zhu, J., Abe-Ouchi, A., Anagnostou, E., De Boer, A. M., Coxall, H. K., Donnadieu, Y., Foster, G., Inglis, G. N., Knorr, G., Langebroek, P. M., ... Otto-Bliesner, B. L. (2021). DeepMIP: Model intercomparison of early Eocene climatic optimum (EECO) large-scale climate features and comparison with proxy data. *Climate of the Past*, *17*(1), 203–227. https://doi.org/10.5194/cp-17-203-2021

Lunt, D. J., Huber, M., Anagnostou, E., Baatsen, M. L. J., Caballero, R., DeConto, R., Dijkstra, H. A., Donnadieu, Y., Evans, D., Feng, R., Foster, G. L., Gasson, E., Von Der Heydt, A. S., Hollis, C. J., Inglis, G. N., Jones, S. M., Kiehl, J., Turner, S. K., Korty, R. L., ... Zeebe, R. E. (2017). The DeepMIP contribution to PMIP4: Experimental design for model simulations of the EECO, PETM, and pre-PETM (version 1.0). *Geoscientific Model Development*, *10*(2), 889–901. https://doi.org/10.5194/gmd-10-889-2017

Meijer, N., Licht, A., Woutersen,A., Hoorn,C., Robin-Champigneul, F., Rohrmann, A., Tagliavento, M., Brugger, J., Kelemen, F.D., Schauer, A., Hren, M., Sun, A., Fiebig, J., Mulch, A., Dupont-Nivet, G. (2023). Extreme Eocene warmth drove proto-monsoons and desert greening far into the Asian interior. *Nature Geoscience* (in review)

Zhu, J., Otto-Bliesner, B. L., Brady, E. C., Gettelman, A., Bacmeister, J. T., Neale, R. B., Poulsen, C. J., Shaw, J. K., McGraw, Z. S., & Kay, J. E. (2022). LGM Paleoclimate Constraints Inform Cloud Parameterizations and Equilibrium Climate Sensitivity in CESM2. *Journal of Advances in Modeling Earth Systems*, *14*(4), 1–49. https://doi.org/10.1029/2021MS002776

Zhu, J., Otto-Bliesner, B. L., Brady, E. C., Poulsen, C. J., Tierney, J. E., Lofverstrom, M., & DiNezio, P. (2021). Assessment of Equilibrium Climate Sensitivity of the Community Earth System Model Version 2 Through Simulation of the Last Glacial Maximum. *Geophysical Research Letters*, *48*(3). https://doi.org/10.1029/2020GL091220