Project: **1006**

Project title: **Simulations of the Mid-Piacenzian Warm Period (~3.3-3.0 Ma BP) in the framework of the Pliocene Model Intercomparison Project Phase 2 (PlioMIP2)**

Project lead: **Gerrit Lohmann**

Report period: 01.07.2022 – 30.06.2023

During allocation period 2022/2023 we have continued to optimize our new modelling system AWI-CM3 (Streffing et al., 2022) towards the use on Levante. Furthermore, the model has been extended with the capability to adjust orbital forcing and greenhouse gases in a more convenient way for the purpose of application of the model for paleoclimate research. Extending the model with a component for dynamic vegetation, that will lead to the creation of the AWI Earth System Model, version 3 (AWI-ESM) is still ongoing in collaboration with EC-EARTH community colleagues at the University of Lund. Consequently, simulations proposed for the upcoming allocation period will be based on a modern fixed vegetation distribution. The plan to use dynamic vegetation in any simulations with AWI-ESM will be realized in future allocation periods.

We have taken the advise of the reviewer, that we received for the last proposal for computational resources in project ba1006, to heart. Instead of continuing the use of the AWI-CM3, that still has been in development during the majority of the ongoing allocation period, for extensive production of climate data on Levante, we have fully dedicated our efforts to 1.) finalizing the model, 2.) analysing the already available model data, and 3.) to continue our contribution to the collaborative model-data intercomparison effort in PlioMIP2. In parallel, Fernanda Matos, the AWI-INSPIRES PhD-student who started working on her research project „Warming Climates in AWI-ESM3“ (which will contribute to PlioMIP3), has started her modelling work with AWI-ESM3. She has made good progress and created first simulations at orbital time scales. Currently, her focus is the mid-Holocene and the Last Interglacial. Her work already has led to identification and removal of several model biases. A next step will be to set up the model with full paleogeography at tectonic time scales. A major effort of the coming year will be the work on applying the AWI-CM3 equipped with a mid-Piacenzian paleogeography towards climate research in the framework of PlioMIP3. To prepare this work we propose various sensitivity simulations that are based on a modern geography setup (see request document).

The already quite extensive publication record of PlioMIP2, to which our work has contributed over the last years (see report of allocation period 2021/2022 for details), has been further extended in 2022 and 2023. The intercomparison with other models in PlioMIP2 has led to a number of additional publications. Burton et al. (2023) quantifies the impact of carbon dioxide on the climate of the mid-Piacenzian. Pontes et al. (2022) explain the reduction in El Nino/Southern Oscillation in the mid-Piacenzian via a shift in the Pacific intertropical convergence zone. Weiffenbach et al. (2022) study mechanisms and implications of stronger mid-Pliocene Atlantic Meridional Overturning Circulation in PlioMIP2. Currently, there are publications in review that study the hydrological cycle and ocean circulation in the mid-Piacenzian Maritime Continent (Ren et al., 2022) and the extent of permafrost in the Northern Hemisphere of the mid-Piacenzian and the relation to future climate (Guo et al., in review). Another publication by Yong et al. (in prep.), that studies the East Asian Summer Monsoon dynamics during the mid-Piacenzian, is about to be submitted.

Furthermore, as a spinoff of our work in the framework of PlioMIP2, we have contributed to

the publications by Jian et al. (2023), where changes in the circulation in the Pacific Ocean are linked to differences in the carbon inventory of the global ocean. Furthermore, our contribution to the study by Yang et al. (accepted) has enabled linking modern observations of warming climate to the infant stage of global warming. This work has taken into account simulations of the mid-Piacenzian as one example of a past warmer-than-present climate state.

References

Burton, L. E., Haywood, A. M., Tindall, J. C., Dolan, A. M., Hill, D. J., Abe-Ouchi, A., Chan, W.-L., Chandan, D., Feng, R., Hunter, S. J., Li, X., Peltier, W. R., Tan, N., Stepanek, C., and Zhang, Z.: On the climatic influence of CO2 forcing in the Pliocene, Clim. Past, 19, 747–764, doi:10.5194/cp-19-747-2023, 2023.

Guo, D., Wang, H., Romanovsky, V., Haywood, A. M., Pepin, N. C., Salzmann, U., Sun, J., Yan, Q., Zhang, Z., Li, X., Otto-Bliesner, B. L., Feng, R., Lohmann, G., Stepanek, C., Abe-Ouchi, A., Chan, W.L., Peltier, W.R., Chandan, D., von der Heydt, A. S., Contoux, C., Chandler, M. A., Tan, N., Zhang, Q., Hunter, S. J., and Kamae, Y.: Highly restricted near-surface permafrost extent during the mid-Pliocene warm period, in review for potential publication in PNAS.

Jian, Z., Dang, H., Yu, J., Wu, Q., Gong, X., Stepanek, C., Colin, C., Hu, L., Lohmann, G., Zhou, X., and Wan, S.: Changes in deep Pacific circulation and carbon storage during the Pliocene-Pleistocene transition, Earth and Planetary Science Letters, 605, 118020, doi:10.1016/j.epsl.2023.118020, 2023.

Pontes, G.M., Taschetto, A.S., Sen Gupta, A., Santoso, A., Wainer, I., Haywood, A.M., Chan, W.-L., Abe-Ouchi, A., Stepanek, C., Lohmann, G., et al.: Mid-Pliocene El Niño/Southern Oscillation suppressed by Pacific intertropical convergence zone shift, Nature Geoscience, 15, 726–734, https://doi.org/10.1038/s41561-022-00999-y, 2022.

Ren, X., Lunt, D. J., Hendy, E., von der Heydt, A., Abe-Ouchi, A., Otto-Bliesner, B. L., Williams, C. J. R., Stepanek, C., Guo, C., Chandan, D., Lohmann, G., Tindall, J. C., Sohl, L. E., Chandler, M. A., Kageyama, M., Baatsen, M. L. J., Tan, N., Zhang, Q., Feng, R., Chan, W.-L., Peltier, W. R., Li, X., Kamae, Y., Zhang, Z., and Haywood, A. M.: The hydrological cycle and ocean circulation of the Maritime Continent in the mid-Pliocene: results from PlioMIP2, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2022-1281, 2022.

Streffing, J., Sidorenko, D., Semmler, T., Zampieri, L., Scholz, P., Andrés-Martínez, M., Koldunov, N., Rackow, T., Kjellsson, J., Goessling, H., Athanase, M., Wang, Q., Hegewald, J., Sein, D. V., Mu, L., Fladrich, U., Barbi, D., Gierz, P., Danilov, S., Juricke, S., Lohmann, G., and Jung, T.: AWI-CM3 coupled climate model: description and evaluation experiments for a prototype post-CMIP6 model, Geosci. Model Dev., 15, 6399–6427, https://doi.org/10.5194/gmd-15-6399-2022, 2022.

Sun, Y., Wu, H., Ding, L., Chen, L., Stepanek, C., Zhao,Y., Tan, N., Su, B., Yuan, X., Zhang, W., Liu, B., Dolan, A., Haywood, A. M., Abe-Ouchi, A., Otto-Bliesner, B., Contoux, C., Lunt, D., Hill, D., Chandan, D., Lohmann, G., Dowsett, H., Tindall, J., Baatsen, M., Peltier, W., Li, Q., Feng, R., Salzmann, U., Chan, W.-L., Zhang, Z., and Ramstein, G.: Decomposition of physical processes controlling EASM precipitation changes during the mid-Piacenzian: new insights into data–model integration, in prep.

Weiffenbach, J. E., Baatsen, M. L. J., Dijkstra, H. A., von der Heydt, A. S., et al.: Unraveling the mechanisms and implications of a stronger mid-Pliocene Atlantic Meridional Overturning Circulation (AMOC) in PlioMIP2, Clim. Past, 19, 61–85, https://doi.org/10.5194/cp-19-61-2023, 2023.

Yang, H., Lohmann, G., Stepanek, C., Wang, Q., Huang, R. X., Shi, X., Liu, J., Chen, D., Wang, X., Zhong, Y., et al.: The emergent pattern of infant stage ocean warming in satellite measurements, accepted for publication in Nature Communications.