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)**

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Report period: 01.07.2023 – 30.06.2024

During allocation period 2023/2024 we have continued to optimize our new modelling system AWI-ESM3 (that is based on AWI-CM3; Streffing et al., 2022) towards the use for paleoclimate research. This included the generation and optimization of boundary conditions for model components FESOM2 (ocean) and openIFS (atmosphere). Furthermore, we have been running first test simulations to study the impact of various components of Pliocene climate forcing and geography on climate. A significant amount of time has been spent by Fernanda Matos to complete the set of Pliocene boundary conditions for use with AWI-ESM3‘s atmosphere model openIFS. This has been done to ensure that our research will exploit the capabilities and skills of AWI-ESM3 to the maximum extent possible. We gratefully involved in this step colleagues from the University of Stockholm, who have long-standing experience with applying the atmosphere component of EC-Earth, that is the same as the atmosphere component of our model AWI-ESM3, for application in paleoclimate research at tectonic time scales. The time expended for this task is well-invested towards the scientific success of our project, but it also has resulted in less consumption of computational resources than planned.

Our long-term goal is to have an AWI-ESM3 model available that features dynamic vegetation as a model component. From our work with predecessor models we are aware of the importance of resolving vegetation dynamics for the sensitivity of paleoclimate to boundary conditions. Unfortunately, extending the model with a component for dynamic vegetation, that will lead to the finalization of the AWI-ESM3, is still ongoing in collaboration with the EC-EARTH community, in particular with colleagues at the University of Lund. Consequently, simulations proposed for the upcoming allocation period will be based on fixed vegetation distribution. The plan to use dynamic vegetation in any simulations with AWI-ESM3 will be realized in future allocation periods. We note that for the scientific work in PlioMIP3 this model deficiency is actually completely acceptable since the modelling protocol (see request document for details) expects modelling groups to use fixed reconstructed Pliocene vegetation in most simulations and to only sample the impact of vegetation dynamics in two sensitivity studies, if at all.

While the analysis of PlioMIP2 simulations has still been ongoing in the last year, with various peer-reviewed manuscript having been published, we have not yet submitted any results that are based on the model that we are currently working with. The plan is to prepare a model description paper as soon as the results for the PlioMIP3 Core simulations with AWI-ESM3 are becoming available.

Two of the tasks finished in the ongoing allocation period relate to analyzing model sensitivity to Pliocene geography (Figure 1) and to various parameter settings in the FESOM2 ocean model (Figure 2). We conclude that AWI-ESM3 is remarkably sensitive to geographic boundary conditions that are known to reduce model-data disagreement in PlioMIP. Furthermore, we decided to modify the FESOM2 namelist settings, that were conventionally used for coupled climate simulations in AWI-ESM2 and AWI-ESM3, for our work in PlioMIP3. Simulations with modified parameters suggest a reduced overall model-data disagreement (higher global temperature), and reflections on the function of parameter switches have led us to conclude that for paleoclimate an alternative setting is sensible.

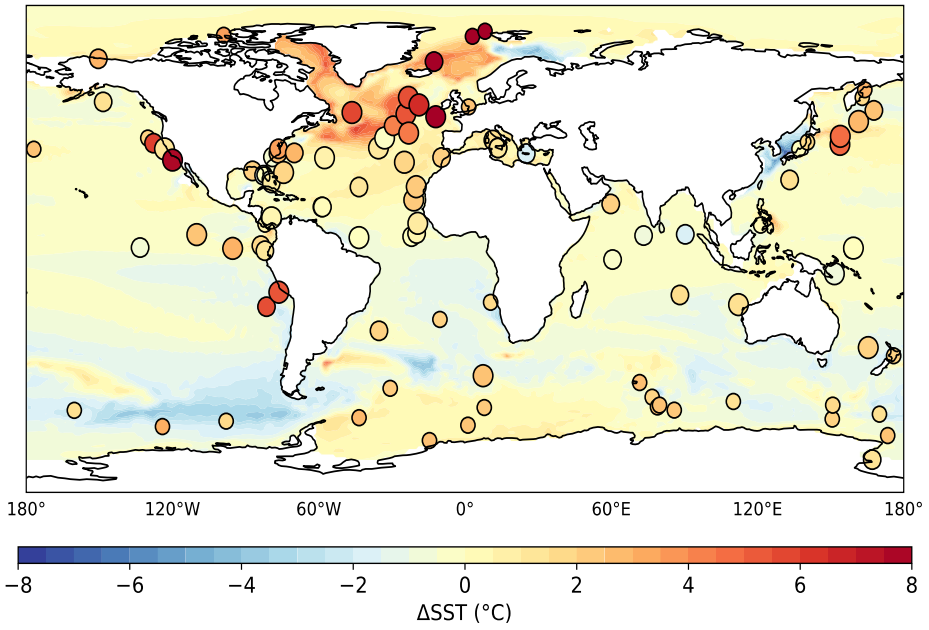

Figure 1: Difference in sea surface temperature (SST) between a simulation with modified geography (partially completed setup of simulation LP[280]) and the PI control simulation where geography is as modern. While the full Pliocene forcing for geography has not yet been implemented, we already see a strong sensitivity of the coupled AWI-ESM3 model system to changes in boundary conditions that are, based on our experience, crucial for a reduced model-data discord that was evident in PlioMIP1 and PlioMIP2. Figure courtesy of Fernanda Matos. See request document for details on simulation setups.

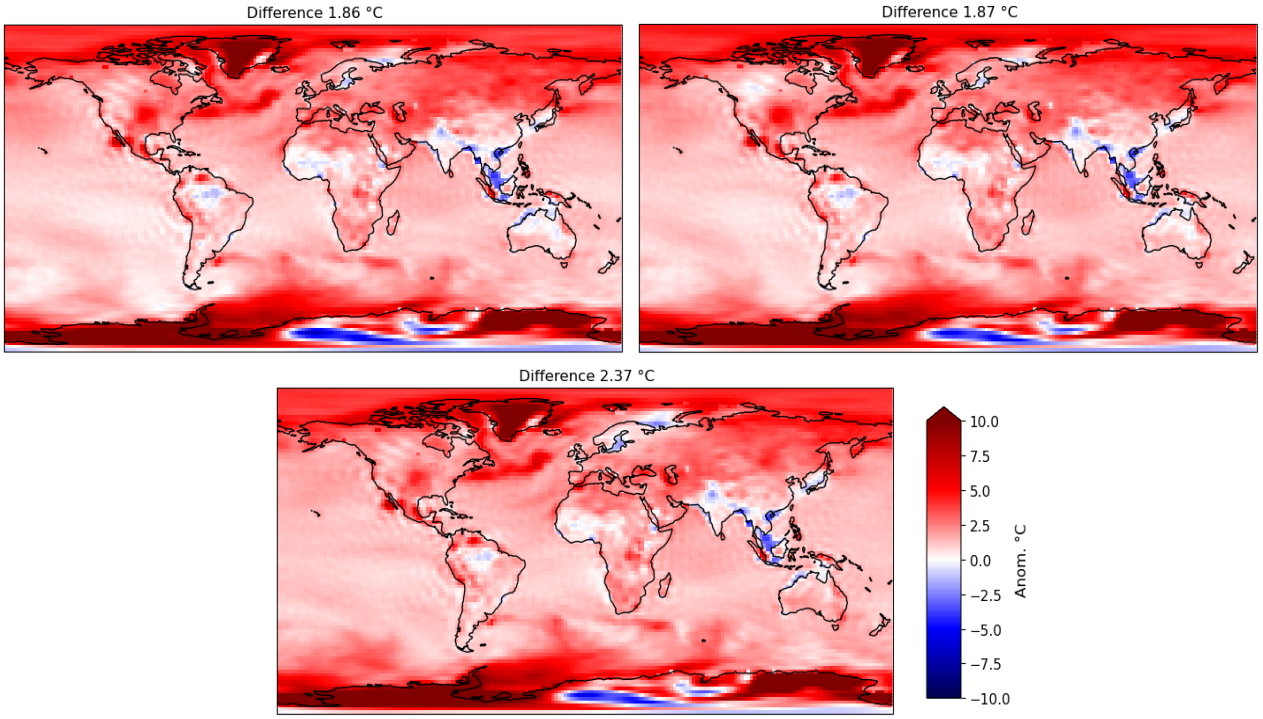

Figure 2: Sensitivity of simulated surface air temperature (global averages shown as headers) to different settings of salt plume parameterization and vertical mixing in FESOM2. Shown are anomalies with respect to the Preindustrial control state. All simulations are based on FESOM2 in a coupled atmosphere-ocean setup. Simulation with the largest anomaly is with momix-switch off and salt plume parameterization on. Figures courtesy of Paul Gravis, University of Melbourne, who collaborates with us in the context of PlioMIP3 with a focus on understanding of Pliocene climate based on proxy reconstructions.