Project: **1006**

Project title: **Simulations of the Mid-Piacenzian Warm Period (~3.3-3.0 Ma BP) using MPI-ESM 1.2.00 in the framework of the Pliocene Model Intercomparison Project Phase 2 (PlioMIP2)**

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Report period: 01.07.2016 – 30.06.2017

We report on our modelling efforts with MPI-ESM-LR on HLRE3/Mistral during the first 9 months of the allocation period 2016 – 2017. Proposed simulations $E^{400}$ and $E^{560}$ have been completed. The conduct of the Mid-Piacenzian simulations with various volume mixing ratios of carbon dioxide, $Eoi^{280}$, $Eoi^{350}$, $Eoi^{400}$, and $Eoi^{450}$, is still ongoing and will be continued utilizing the remaining computational resources of allocation period 01.07.2016 – 30.06.2017. Yet, it is foreseeable, that the remaining allocated computational resources are not sufficient to fully equilibrate these simulations. In order to bring the model into full equilibrium, we find that – independently of the prescribed concentration of carbon dioxide (400 parts per million or 560 parts per million) – a time span of about 2,000 model years is necessary (Fig. 1). Hence, we request in our follow-up proposal additional computational resources in order to provide a stable climate state also for simulations $Eoi^{280}$, $Eoi^{350}$, $Eoi^{400}$, and $Eoi^{450}$.

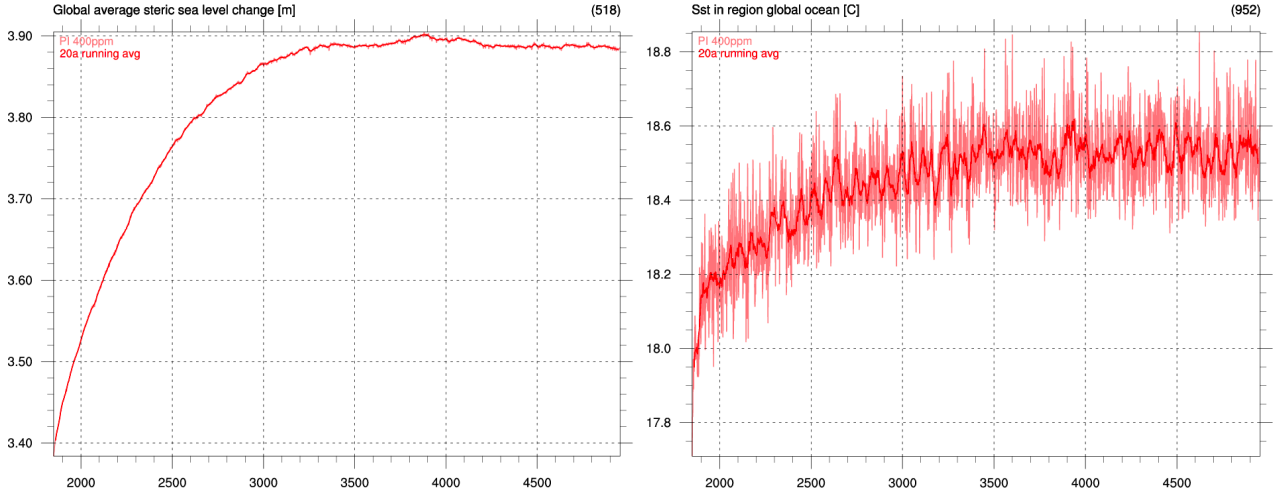


**Fig. 1: Simulated global average steric sea level change (left) and sea surface temperature (right) as a measure of equilibrium of the modelled climate system for simulation $E^{400}$, that differs from the pre-Industrial control simulation with respect to the prescribed volume mixing ratio of carbon dioxide (400 parts per million (ppm) vs. 280 ppm in the pre-Industrial). The model's ocean absorbs excess heat, introduced into the climate system by increased atmospheric back-radiation in the long-wave band, until about model year 3,500 – 3,750. This means that the ocean experiences a net gain of heat for 1,750 – 2,000 model years after starting the simulation at model year 1850. Energy absorption is indicated via the thermosteric part of sea level rise, which likely does not have a large influence on the analysis of the climate state. Yet, the results also show that a meaningful analysis of SST, and as a result of derived quantities like climate sensitivity and climate variability, is not possible before the model has been integrated for about 2,000 model years. Similar results hold for simulation $E^{560}$ (not shown) that is characterized by double the pre-Industrial atmospheric carbon dioxide concentration.**

The preparation of the Mid-Piacenzian simulations, based on a complete set of earth system boundary conditions that are indicative for the geologic time slice of the Mid-Piacenzian Warm Period, has been delayed with respect to the initially intended time schedule that has been conveyed in the proposal for allocation period 01.07.2016 – 30.06.2017. One reason for this delay was the need for longer equilibration of simulations $E^{400}$ and $E^{560}$, that were used as a test case to estimate the time scale that is necessary to prepare stable states of Mid-Piacenzian climate. Another reason for the delay were technical problems in the preparation of the boundary conditions for the submodels of MPI-ESM. Yet, these problems have been overcome and the preparation of the Mid-Piacenzian simulations is now on track. The simulations of Mid-Piacenzian climate for four different concentrations of carbon dioxide shall be continued in the following allocation period as described in the request for allocation of resources to DKRZ project 1006.

Recently, a severe bug in the mixing scheme of the ocean model MPIOM of MPI-ESM has been identified (MPIOM-bug #7627, refer to https://code.zmaw.de/issues/7627 for details). This bug initially impacts on the ocean mixing. As a result, also other dynamical systems of the model climate are influenced, in particular the overturning circulation, and more generally the large scale ocean circulation. As a result, sea surface temperatures are influenced, and the overall distribution of salt and heat in the ocean is altered. We have prepared short model simulations to test the impact of the bug, that has been present in MPIOM for a long period of time, on the model climate of MPI-ESM-LR and its predecessor models. We find that the impact of the bug on the state of a pre-Industrial climate state, generated with MPI-ESM-LR, is not negligible (Fig. 2).

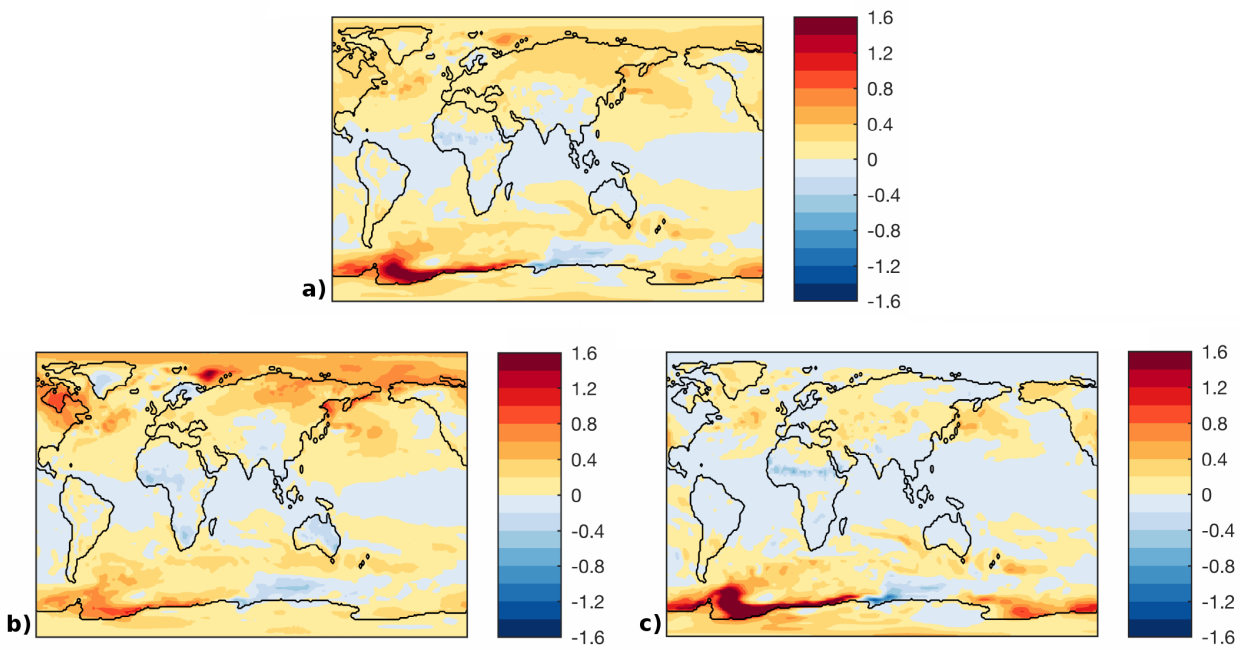


**Fig. 2: Simulated anomaly of surface air temperature (in °C) that results from fixing MPIOM-bug #7627 in a pre-Industrial control climate of MPI-ESM-LR; a) annual mean; b) Northern Hemisphere winter (DJF); c) Northern Hemisphere summer (JJA). The bug's impact is most pronounced in both hemispheres in the winter season, which indicates its impact on the simulated vertical mixing. Extreme anomalies are present in parts of Arctic Ocean and Southern Ocean. Yet, appreciable impact of the bug is also present in the region of the North Atlantic Ocean. This region is rather critical for an analysis of the mismatch between model simulation and sea surface temperatures as derived from the geologic record: There, a particularly large model-reconstruction-mismatch has been identified in the first phase of PlioMIP (Dowsett et al., 2013). The illustrations are courtesy of Dr. Xun Gong, Department of Paleoclimate Dynamics, Alfred Wegener Institute, Bremerhaven.**

Our current state of information is that the MPI-ESM-LR version, utilized by the Max Planck Institute for Meteorology and the DKRZ for the Climate Model Intercomparison Project, Phase 6 (CMIP6), will still contain MPIOM-bug #7627. As our simulations of project 1006 must be performed with the same model as other MPI-ESM simulations prepared for CMIP6 and the affiliated Paleoclimate Intercomparison Project, Phase 4, of which PlioMIP2 is a subproject, we are bound to submit the model data that is afflicted by the bug. Yet, we acknowledge the need to analyze the impact of that bug on results that will be presented in our model description manuscript in the PlioMIP2 special issue of Climate of the Past. To this end it is necessary to perform additional simulations as outlined in our proposal for the upcoming allocation period.

## References:


Dowsett, H. J., Foley, K. M., Stoll, D. K., Chandler, M. A., Sohl, L. E., Bentsen, M., Otto-Bliesner, B. L., Bragg, F. J., Chan, W.-L., Contoux, C., Dolan, A.M., Haywood, A.M., Jonas, J.A., Jost, A., Kamae, Y., Lohmann, G., Lunt, D. J., Nisancioglu, K. H., Abe-Ouchi, A., Ramstein, G., Riesselman, C. R., Robinson, M. M., Rosenbloom, N. A., Salzmann, U., Stepanek, C., Strother, S. L., Ueda, H., Yan, Q. and Zhang, Z.: Sea surface temperature of the mid-Piacenzian ocean: A data-model comparison, Sci. Rep., 3, doi:10.1038/srep02013, 2013.