Project: **1066**

Project title: **Simulations of the Last Interglacial and of the Mid-Holocene with MPI-ESM and AWI-CM in the framework of the Paleoclimate Model Intercomparison Project, phase 4 (PMIP4)**

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Report period: **2020-01-01 to 2020-12-31**

We report on our modelling efforts with MPI-ESM-LR and AWI-ESM (i.e. AWI-CM (Sidorenko et al., 2019) with vegetation dynamics and related climate-vegetation feedbacks) during the first 10 months of allocation period 2020 in the framework of simulations for the Paleoclimate Model Intercomparison Project, Phase 4 (PMIP4), that is related to the Climate Model Intercomparison Project, Phase 6 (CMIP6). First of all, we would like to thank the WLA for the positive evaluation of our last proposal. During the year of 2020 we have continued our simulations as proposed in our request document with a focus on the CMIP6 DECK simulations, that were scheduled for the first quarter of 2020. This included the *1pctCO2_ramp* and the *abrupt-4xCO2* simulations conducted with AWI-ESM. Until we had to restructure our work procedures due to the ongoing CoVid19 pandemic we made good progress with our modelling efforts. Unfortunately, the situation since the first lock-down in spring has reduced our productivity modelling-wise. Student supervision, teaching remotely, and collaborative further development of our models, that are employed for the various computing projects at DKRZ, takes much more time than it did before. This has considerably reduced our consumption of granted node hours. Since the situation is not looking like it will get any better before spring, we will request only a modest amount of computational resources for 2021 for further CMIP6/PMIP4 related simulations with an updated version (AWI-ESM2-2) of the AWI-ESM1-2 with coupled ice sheets. The latter has been developed in the framework of PalMod and the work is currently in review (Gierz et al., 2020), but the model is already being superseded by a version that is much more computationally efficient based on the finite volume approach of FESOM2 (Danilov et al., 2017). In addition to the modest request made now, we would like to ask the WLA to allow us, once the CoVid-19 related situation has hopefully cleared up in spring and we are back to normal work procedures, to request additional computational resources during the April 2021 round of resource allocations. In that request we will plan further work in project ba1066 for the allocation period of 2021. We will formulate our computational demand in the light of consumption of computational resources during the first quarter of 2021.

We are glad that we can also report on more positive aspects of our scientific work in 2020. We are very happy that the work in generating CMIP6/PMIP4 conforming simulations at DKRZ has been bearing fruit in the context of authoring and co-authoring a number of scientific publications. Simulations, that we have been producing during the first two years and in the ongoing allocation period of DKRZ project ba1066, have been analyzed. As a result of this the AWI-ESM1, AWI-ESM2, and MPI-ESM1.2 have been evaluated in the framework of various model-model and model-data intercomparison studies for various time periods since the Last Interglacial.

After publication of the MPI-ESM1.2 Last Interglacial simulation *lig127k* by Scussolini et al. (2019), also the publication by Otto-Bliesner et al. (2020), that has been resubmitted after revisions, will include results from the MPI-ESM Last Interglacial simulation *lig127k* in the revised version. This will enable an evaluation of the MPI-Met's model in PMIP4 also in the context of the Last Interglacial – a past warm period that is among those that have been considered as potentially bearing resemblance to future warm climates. Hence, the Last Interglacial carries, beyond pure academic interest, also importance for the modern and future societies. Furthermore, during 2020, so far six publications have become available where the scientific discourse has directly profited from simulations that have been created by means of DKRZ resources in the framework of project ba1066. The AWI-ESM1 simulations *piControl*, *midHolocene*, and *lig127k* have been, together with the Last Glacial Maximum simulation *lgm* (the latter of which has been created in the framework of project ba0989) employed by Brown et al. (2020) in an evaluation of the El Nino Southern Oscillation across interglacial and glacial climates. Arctic sea ice, as simulated by AWI-ESM2 in simulation *lig127k*, has been compared to that simulated by other models in a publication by Kageyama et al. (2020). We are glad that our *lig127k* simulation ensemble, that now consists of three comparable simulations performed with AWI-ESM1, AWI-ESM2, and MPI-ESM-1.2, contributes to the analysis of large-scale patterns of Last Interglacial climate performed by Otto-Bliesner et al. (2020). In the recently published manuscript by Brierley et al. (2020) the AWI-ESM-1 simulation *midHolocene* features in an analysis of large-scale features and in an evaluation of PMIP4-CMIP6 *midHolocene* simulations. The AWI-ESM1 *piControl* and *historical* simulations have been utilized towards a comparison

of AMOC recovery in a set of experiments that have been conducted with and without interactive Northern Hemisphere ice sheets (Ackermann et al., 2020). The authors found that interactive ice sheets are important towards resolving decadal variability of surface runoff into the North Atlantic Ocean. The standard simulations employed by Ackermann et al. (2020) without interactive ice sheets originate from efforts in project ba1066. Their simulations with interactive ice sheets (based on AWI-ESM-1-2, that has been recently published by Gierz et al. (2020) and is an output of project ba0989, but has as well profited from efforts in project ba1066) have been conducted in the framework of other projects. As many parts of our future modelling work will be based on AWI-ESM2 with interactive ice sheets, as a logical next step we will propose CMIP6 simulations with the new AWI-ESM-2-2, that is, similarly to AWI-ESM1, an extension of the AWI-ESM2 and equipped with interactive ice sheets. We note that this proposed work (see application document) will be fruitful also for the success of other DKRZ projects – this is particularly the case for project ba0989, where AWI-ESM2-2 will be the main working horse in the years to come.

While this review of recent literature shows that our modelling efforts in project ba1066 have started to reflected in published literature, we note that more analyses of our various CMIP6/PMIP4 simulations are underway. As one example we highlight the value that a large set of CMIP6 simulations, conducted by means of computational resources in project ba1066, has for estimating climate model metrics in AWI-ESM1 towards proper evaluation of paleoclimate simulations conducted with the model. This includes the ability to not only derive equilibrium climate sensitivity of the climate model, but to also quantify the degree of equilibrium in CMIP6 reference states of the model (Fig. 1).

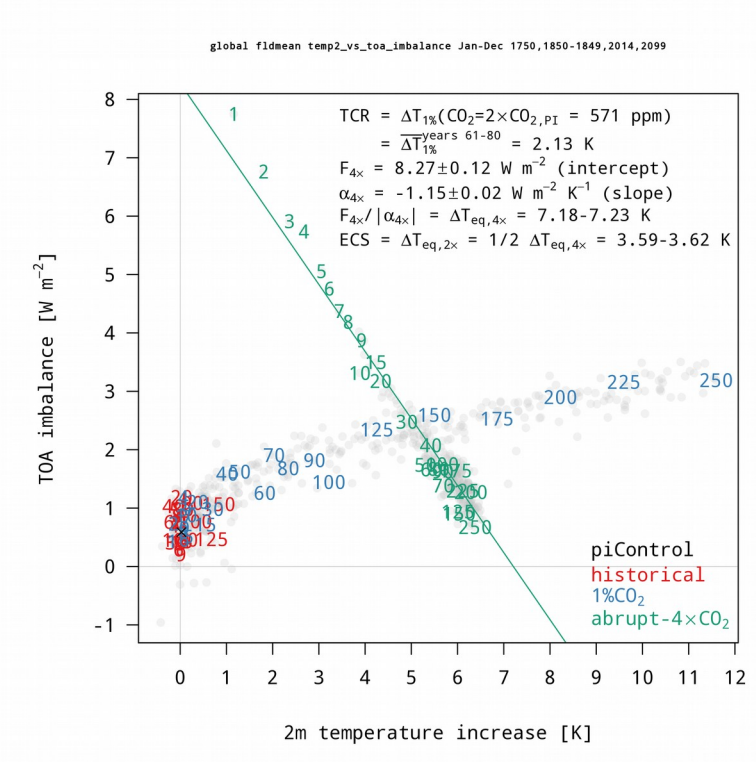


**Fig. 1:** Gregory plot (per definition of the analysis by Gregory et al., 2004) showing the increase of near surface air temperature at two metres above the ground (in K) in AWI-ESM-1-1-LR against the increase of radiative imbalance (that is the sum of incoming shortwave and incoming and outgoing longwave radiation at top of atmosphere (TOA); in W m-2), both globally and annually averaged and with respect to the piControl simulation. A non-zero TOA radiative imbalance represents a delayed warming of the ocean due to forcing (i.e. the piControl run is not fully in equilibrium). Numbers indicate the model year with respect to the arbitrary start year of the experiment for some of the model years, each of which is indicated by a gray dot. For piControl, the mean of the last 100 model years is shown (black cross). We compute equilibrium climate sensitivity (ECS) from slope and intercept of a least square regression of the *abrupt-4xCO2* experiment (green line).

We also would like to highlight the value that project ba1066 has for other scientific projects, and in particular for PalMod2 and for PalMod2's working group 1 (DKRZ project ba0989). We have outlined details of the benefits of our work in ba1066 in the report for allocation period 2019. There, we highlighted

the relevance that characterization of climate patterns and performance of our models has in the framework of paleoclimatological research in CMIP6/PMIP4 towards enabling comparison in the context of performance as well as model- and climate-characteristics of other models (including the presence or absence of dynamic vegetation). We believe that recent publications by Gierz et. al (2020) and Ackermann et al. (2020) demonstrate a fruitful collaboration between DKRZ projects ba0989 and ba1066. Furthermore, the fact that PMIP4 publications have considered our climate simulations, that have been conducted with various models and for various time periods since the Last Interglacial by means of computational resources of DKRZ project ba1066, demonstrates that our modelling efforts are contributing to the overall progress of science in the framework of CMIP and PMIP.

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