Project: **1407**

Project title: **Digital Twin for Paleoclimate**

Principal investigator: **Gerrit Lohmann**

Report period: **2025-11-01 to 2026-10-31**

Maximum of 2 pages including figures. 9 pt minimum font size.

In the previous allocation period (2025), work was done on applying the model setup, including the mid-Holocene (MH) forcing, which was previously validated for the LR configuration, to the high-resolution XR configuration of the AWI-CM3 model. First results were presented based on the limited number of simulated years (30) available in the XR configuration at the time of writing the last report. During the remainder of the previous allocation period (2025) and during the current allocation period (2026), the simulation length was successfully increased. However, the large cut in the granted resources due to great demand on HLRE-4 resulted in a limited extension of the simulation, short of the 120 years envisaged when writing the last allocation request. Thus, the results presented here are based on the available data so far (90 years), and we are still planning to extend the simulation to 120 years as soon as possible (see this year's Resource Allocation Request) in order to gain further increase in statistical power and further reduce model drift as described in earlier allocation requests.

With the data so far, a comparison of the large-scale climate change signal (compared to present-day, PD climate) can be made. Fig. 1 shows the change (MH-PD) in climatological 2m air temperature as a function of latitude and time of year. Both the LR (left) and XR (right) configurations show qualitatively similar climate change patterns. Mid-Holocene orbital forcing causes northern hemisphere boreal summer warming and winter cooling. At the same time, reduced greenhouse gases cause overall cooling in the annual mean at all latitudes (left side panels). The resemblance between XR and LR does, however, not hold in terms of magnitude. For example, Northern Hemisphere winter sea ice growth is larger in the XR configuration than in the LR configuration (not shown), which results in the stronger high-latitude cooling in the XR case in Fig. 1. Compared to the limited data (30 years) in the last report, the agreement in the anomaly (MH-PD) pattern between both resolutions has decreased, resulting in a larger resolution-dependency of the climate change signal than anticipated in the previous report.

A region where the difference in LR and XR is especially large is the Atlantic Ocean. The XR configuration is eddy-resolving here with oceanic resolution being about 5 km here whilst the LR configuration is typically at least 10 times coarser requiring eddy parametrization in the model. It is known that increasing oceanic resolution and explicitly resolving eddies improves the path of the Gulf Stream and the North Atlantic Current (NAC). This is also seen in our simulations (Fig. 2). It shows climatological Sea Surface Temperature (SST) for mid-Holocene (top) and present-day (bottom) simulations. In both cases, increasing the model resolution from low resolution (right) to high resolution (left) causes significant change in the SST pattern due to the Gulf Stream separating earlier and the NAC being less zonal in the XR configuration, a known asset of high-resolution simulations (Athanasiadis et al., 2022; Moreno-Chamarro et al., 2022; Sein et al., 2018).

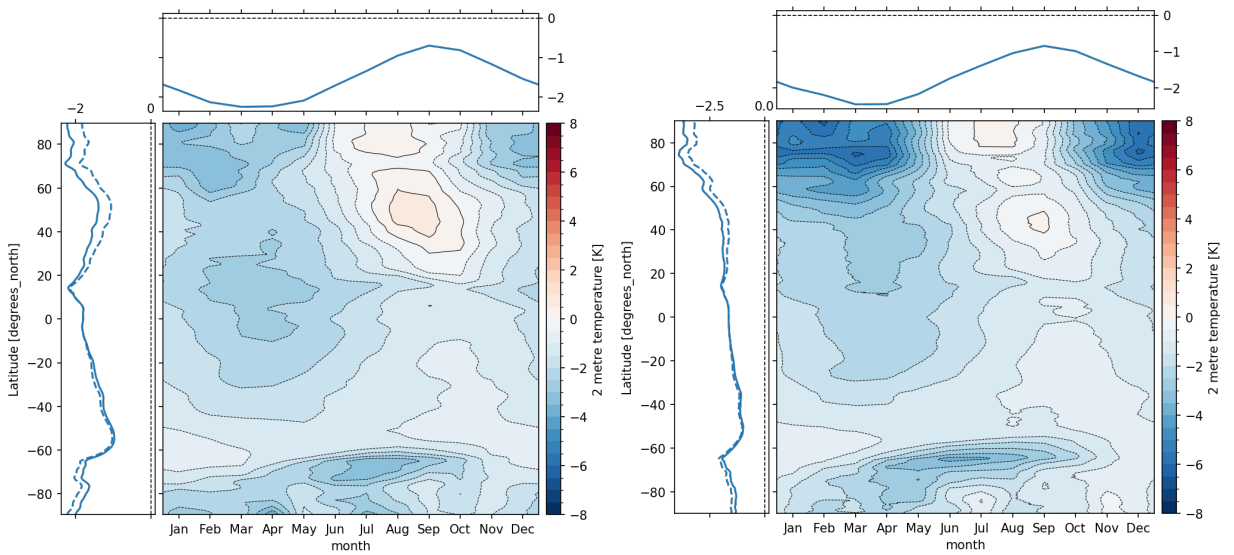


Fig. 1: Hovmöller diagram of climatological zonal mean 2m temperature anomaly (MH-PD) as a function of latitude and time of year, comparing LR (left) and XR (right) configurations of the model

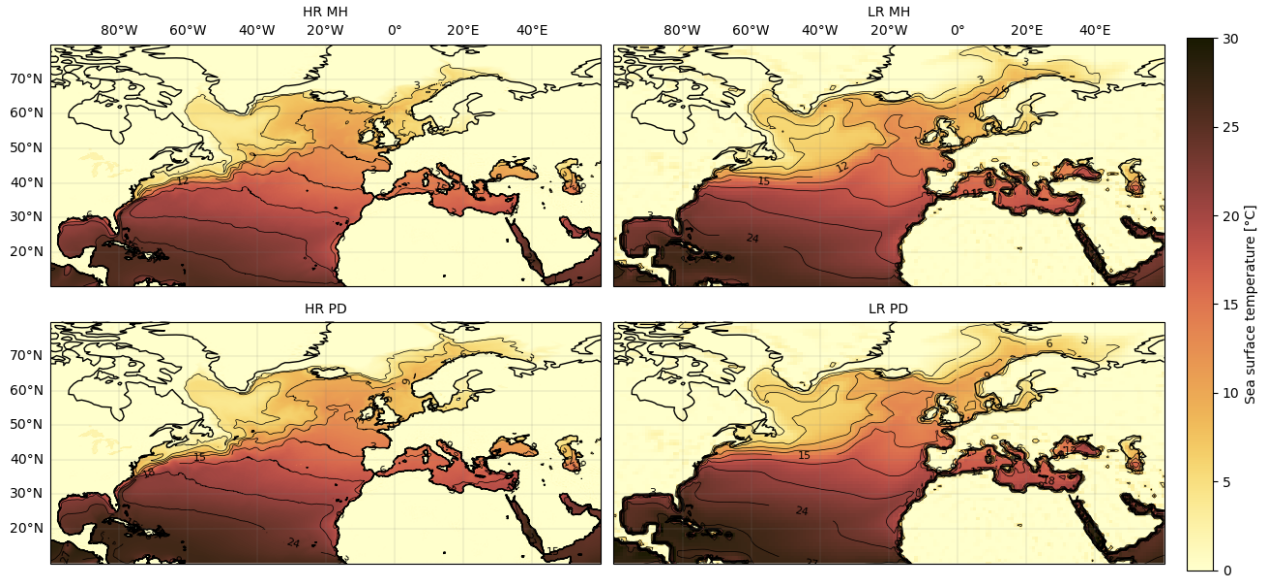


Fig. 2: Comparison of the climatological SST Patterns in the Euro-Atlantic region between high-resolution (left) and low-resolution (right) simulations of mid-Holocene (top) and present-day (bottom) climate.

References

Athanasiadis, P.J. *et al.* (2022) “Mitigating Climate Biases in the Midlatitude North Atlantic by Increasing Model Resolution: SST Gradients and Their Relation to Blocking and the Jet,” *Journal of Climate*, 35(21), pp. 6985–7006. Available at: https://doi.org/10.1175/JCLI-D-21-0515.1.

Moreno-Chamarro, E. *et al.* (2022) “Impact of increased resolution on long-standing biases in HighResMIP-PRIMAVERA climate models,” *Geoscientific Model Development*, 15(1), pp. 269–289. Available at: https://doi.org/10.5194/gmd-15-269-2022.

Sein, D.V. *et al.* (2018) “The Relative Influence of Atmospheric and Oceanic Model Resolution on the Circulation of the North Atlantic Ocean in a Coupled Climate Model,” *Journal of Advances in Modeling Earth Systems*, 10(8), pp. 2026–2041. Available at: https://doi.org/10.1029/2018MS001327.