Climate simulations of the last glacial cycle

Joint state-parameter estimation for the Last Glacial Maximum with CESM1.2

***T. Kovacs, A. Paul, M. Schulz**, MARUM - Center for Marine Environmental Sciences, University of Bremen*

In Short

- This project provides state-of-the-art climate reconstruction of global climate with uncertainty bounds during different periods of the last glacial cycle
- Homogenized multi-proxy observations within the scope of PALMOD are assimilated into the isotope-enabled comprehensive Community Earth System Model (CESM v1.2)
- Transient model simulations will be analyzed of the coupled atmosphere-ice-ocean system during the abrupt climate changes of the Marine Isotope Stage 3 (80-20 kyr BP) and the last deglaciation (19-11 kyr BP)
- Results are expected to enable the test of hypotheses about the direct effect of meltwater, detect different fingerprints of abrupt climate changes, and assess the reliability of paleothermometers.

This compute project is set within the framework of the 2nd phase of the BMBF-funded project PALMOD (from the Last Interglacial to the Anthropocene - Modeling a Complete Glacial Cycle). In this compute project we aim at a quantitative and proces-oriented comparison of model results and paleo data with a particular focus on stable water isotopes, indlucing planktonic foraminiferal abundances, for specific periods of the last glacial cycle.

We use model results and the most recent paleoclimate proxy databases created within the framework of PALMOD to obtain state-of-the-art climate reanalysis in circumstances that embrace a departure from the current climate. Thus, this project will contribute to the further understanding of global climate variability, and to constrain future climate projections under a globally warming Earth.

The foundation of this work is the direct forward modeling of stable water isotopes with the fully coupled CESM version 1.2. The planned experiments comprise transient simulations of different periods of the last glacial cycle, branching from a simulation that has reached equilibrium under climate forcings of a specific time-slice at the Last Glacial Maximum (LGM, 19-23 kyr BP).

Within the coming year, this computing project will focus on the effect of glacial meltwater forcing and its role in climate variability. For the first time, transient simulations of the Marine Isotope Stage 3 characterized by abrupt climate changes (Heinrich events), and the last deglaciation will be performed with a fully coupled model with a full carbon cycle, as well as carbon and oxygen isotopes.

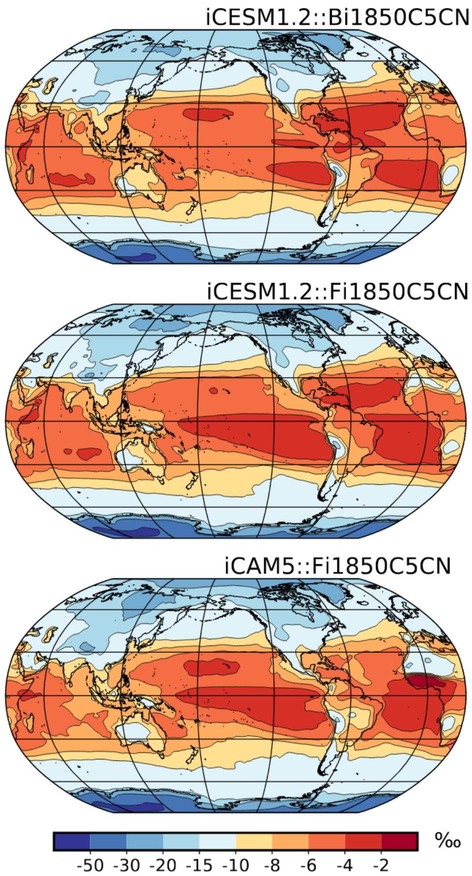

***Figure 1:** Comparison of $\delta^{18}O$ for for preindustrial conditions for the atmospheric model iCAM5, the atmosphere-only configuration of iCESM (Fi1850C5CN compsets), and the fully coupled run with CESM (Bi1850C5CN).*

First, we will equilibrate a steady-state preindustrial simulation that will serve as a comparison to modern-day climate. Then we will run out to equilibrium a model simulation under climate forcing representing the LGM. After the ocean in the LGM run has converged, this simulation will provide the basis for the transient runs that will branch from it. An ideal timeframe for a transient run for Heinrich events will most likely be 2000 to 3000 years, as sufficient time must be granted for the simulation to recover after the initial forcing perturbation. A transient run for the part of the last deglaciation that includes Heinrich event I will at least require a similar length.

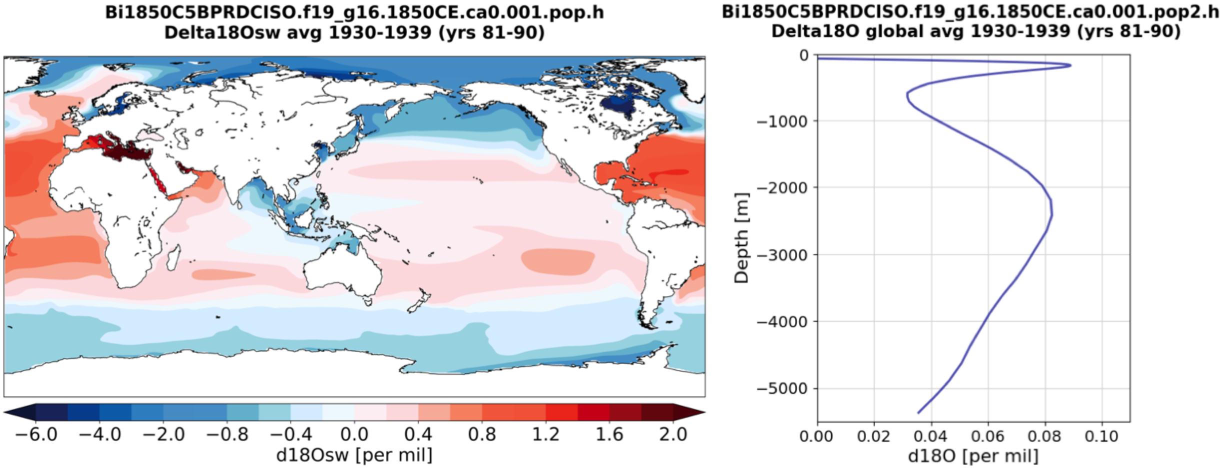

Figure 2: *Mean surface values (top) and vertical profile (bottom) of $\delta^{18}O$ in the global ocean in our preindustrial run.*

We have recently moved our simulations to HLRN-IV phase 2 in Berlin, and after further testing, we have been able to increase the speed of model integration while also reducing computing costs. This is important because the setup, resolution, and length of the planned experiments make this project computationally very challenging.

Our previous runs at HLRN-IV comprised an initial run at LGM without water isotopes, and a run with the new atmospheric component (CAM5) including water isotopes. A fully coupled model including water and carbon isotopes was also started running towards its equilibrium for preindustrial conditions. Figure 1 shows an example of these model runs.

However, our fully coupled preindustrial run lacked the convergence of oceanic water isotopes. Since then, we have identified the reason for this as an erroneous adjustment of their surface fluxes in the oceanic model component. Restarting our preindustrial simulation with a Bi1850C5BPRDCISO compset (with the above mentioned ecosystem and carbon isotopes modules as well) now there is a convergence in oceanic water isotopic composition. This simulation is currently running. Figure 2 shows the surface values and a mean vertical profile of $\delta^{18}O$ in the global ocean for this experiment. The values are reasonably close to observations and the run is currently on its way to converge to equilibrium.

The simulations with water isotopes are going to be branched off and carried out for selected time periods of the last glacial cycle from transient runs without isotopes, provided by another working group in PALMOD. An initial state for the water isotopes that is consistent with the ocean circulation is to be generated using a tracer-transport acceleration technique including water isotopes. The model results will be compared to the deglacial proxy-data synthesis prepared by the previous project phase. Furthermore, the integration of a proxy-system model and model-data comparison metrics in data assimilation algorithms for CESM will be evaluated, building on [1] and [2].

Our planned transient simulations will provide a significant contribution to the PALMOD project, as one of its expected major outcomes is to obtain a comprehensive data synthesis of paleoclimatic conditions during the last glacial cycle, associated with explicit estimates of uncertainty. This involves combining in the best possible ways the outcome of long-term climate model simulations with the last generation of multi paleo proxy data.

WWW

https://www.palmod.de/

More Information

[1] T. Kurahashi-Nakamura, A. Paul, M. Losch, *Paleoceanography* (2017). doi: http://10.1002/2016PA003001

[2] J. Garcia-Pintado, A. Paul, *GMD* (2018). doi: 10.5194/gmd-11-5051-2018

Project Partners

AWI, CAU, DKRZ, GEOMAR, HZG, IfBM, University of Mainz, FUB, KIT, TROPOS, MARUM, MPI-C, MPI-M, MUN, University of Bonn / HErZ, PIK, University of Hamburg

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