Geophysical Research Abstracts
Vol. 20, EGU2018-7533, 2018
EGU General Assembly 2018

Evaluating the performance of a numerical ocean model by a comparison with a paleoceanographic state estimate for the LGM

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As part of the PalMod project (https://www.palmod.de/), we plan to do climate simulations at the glacial-interglacial time scale with the Community Earth System Model (CESM). Those will include simulations of the marine carbon cycle, which is considered to be a fundamental factor in the climate evolution at such a long time scale. In this preparatory study, our focus is on the evaluation of the ocean component (Parallel Ocean Program version 2, hereafter POP2) including the marine carbon cycle.

To evaluate the performance of numerical ocean models for paleo simulations, the direct comparison between model variables and corresponding data is widely used. With only a direct comparison between model and data, however, model evaluation is inevitably restricted. For example, paleoceanographic data are usually sparsely distributed, and information at other than the data locations is not available. Moreover, most physical diagnostics of the ocean state such as the heat-, freshwater-, or volume-transport of the ocean circulation are not directly measurable.

In this study, besides such a direct comparison with data, we also compare the model results of POP2 with a state estimate obtained with the MIT general circulation model (MITgcm) and the adjoint method (Kurahashi-Nakamura et al. 2017). The state estimate represents an optimized model state such that the disagreement between the model and data (sea-surface temperature and the isotopic composition of oxygen and carbon) is minimized. Consequently, the information provided by the proxy data is complemented by the ocean physics in the model.

This study illustrates that state estimates provide the possibility to perform an extended comparison between a model and data through an analysis of the original data. It promises to be an efficient method to check comprehensive Earth system models against paleoclimate reconstructions for selected time slices or periods of the past, saving expensive computer time on long transient simulations.