Geophysical Research Abstracts
Vol. 20, EGU2018-14581, 2018
EGU General Assembly 2018

Response of ocean carbon cycle to different glacial ocean circulation states

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There is still little consensus about the interplay of mechanisms causing the glacial-interglacial variations in atmospheric CO_2 concentrations of roughly 80-100 ppm. However, it is certain that some of those mechanisms are driven by alterations of ocean biogeochemistry. Hence, it is crucial to understand ocean biogeochemistry dynamics during glacial-interglacial transitions. Marine biogeochemical dynamics is strongly influenced by the ocean physical conditions. Yet, the state of the Atlantic Meridional Overturning Circulation (AMOC) during the last glacial maximum (LGM) remains unconstrained, resulting in uncertainties in marine biogeochemistry dynamics. For this, we adjust the Hamburg Ocean Carbon Cycle model (HAMOCC), which is a component of the Max Planck Institute Earth System Model (MPI-ESM), to represent glacial ocean biogeochemical conditions. A specific focus here is on an advanced representation of stable carbon isotope ^{13}C, which is essential for constraining, for instance, the overturning strength and the depth of the North Atlantic Deep Water cell. Now we explicitly simulate ^{13}C in all carbon pools of the model. To evaluate model performance, we apply the extended model to the pre-industrial state and compare modelled $\delta^{13}C$ with observations.

To investigate the response of ocean biogeochemical dynamics to various ocean circulation states during LGM, we carry out a number of simulations. First, we conduct one reference LGM run with glacial orbit, land-sea mask, topography, ice sheets and with a glacial atmospheric CO_2 concentration of 190 ppm. Next, we carry out sensitivity experiments, which are driven by different atmospheric CO_2 concentration of 170, 150, 130 and 110 ppm, respectively. The motivation for such sensitivity study is that previous simulations suggest that in MPI-ESM (as well as in some other GCM-based models), a relatively low atmospheric CO_2 concentration ($<$190 ppm) is required to produce an AMOC overturning state that agrees with the glacial state inferred from proxy data. Finally, we conduct an additional simulation, in which the ocean circulation model (MPIOM) runs under a relatively low atmospheric CO_2 concentration ($<$190 ppm) but HAMOCC “sees” an atmospheric CO_2 concentration of 190 ppm. Model results from the simulations described above will be presented and evaluated against proxy data.