Fully coupled ice sheet–earth system simulations: The Greenlandic ice sheet response and its interaction with the climate system under raising CO_2 concentrations

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Enhanced melting of the Greenland ice sheet is driven by the observed distinct warming in the Arctic and the northward flow of tropical water masses, which both adds more fresh water into the ambient ocean. Ongoing accelerating ice loss would stabilize the water column and threatens deep water formation. With fully coupled ice sheet-earth system models we approach questions about Greenland changes under ongoing raising CO2 forcing and how it influences the climate system and the thermohaline driven meridional overturning circulation (MOC). We have performed idealized future projections with two independent two-way coupled ice sheet-earth system models based on two system models (ESM) MPI-ESM and EC-Earth.

For the study we have used two state-of-the-art CMIP5 earth system models which are both coupled to the Parallel Ice Sheet Model (PISM) covering Greenland. One setup uses the MPI-ESM that comprises the atmosphere model ECHAM6 (T63L47), the vegetation model JSBACH and the ocean biogeochemical model MPIOM / HAMOCC (GR15L40, nominal horizontal resolution of 1.5° with one pole over Greenland), where PISM has a horizontal resolution of 10 km. The other setup uses EC-Earth with the atmosphere model IFS (T159L62) and the ocean model-sea ice model NEMO / LIM (TP10L42, nominal horizontal resolution of 1° with three pols); here PISM has a horizontal resolution of 20 km.

We'll present the building blocks of our fully coupled systems, which includes a physical based calculation of the ice sheet’s surface mass balance and ice sheet-ocean interaction in some cases; The ESM receives fresh water fluxes and see changes in ice extent and geometry, for instance. Since the behavior of an ice sheet in the near future is controlled by both the external forcing and by its initial conditions, we have performed Latin Hyper Cube (LHC) simulations with the ice sheet model over more than one glacial-interglacial cycle utilizing standard techniques to obtain a reasonable initial state for the MPI-ESM system. In contrast to commonly used strategies, our coupled ice sheets inherits the memory of a glacial cycle simulations obtain from ESM fields. Furthermore we do neither apply flux corrections nor utilize anomaly coupling.

Under different CO_2 forcing scenarios — for example, raising CO_2 by 1%/year until four times the pre-industrial concentration (4xCO_2) has reached, abrupt raise to 4xCO_2 — the response of the coupled system is analyzed. For instance, an abrupt CO_2 forcing leads to an immediate response of the Greenlandic ice sheet. The surface mass balance turns strongly negative within a couple of years, causing skyrocketing melting rates and sea level rise. The contribution of the ocean-ice sheet interaction decreases instead, because the ice sheets retreats from the coast and is therefore less susceptible to an eroding ocean. The additionally released fresh water and the heat both have the potential to stifle the MOC. However sensitivity experiments indicate that the additional fresh water has a negligible influence on the MOC with a time scale of a century or longer in our model system.