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Heinrich events modeled with a coupled complex ice sheet–climate model

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We investigate glacial climate variability with a coupled ice sheet model (ISM) – atmosphere-ocean-vegetation general circulation model (AOVGCM) system, focusing on one of the most prominent features of glacial climate variability, the Heinrich events. Modeling past climates and periods of past climate change is an important test of the capability of climate models to correctly represent future climate changes. Only if we can correctly represent past climates and climate changes, we can be confident about our predictions of future climate changes.

We show results from two experiments: (1) a steady-state LGM experiment where the ice sheet model is accelerated by a factor of 10 compared to the climate model covering 30 kyrs in the ISM (3 kyrs in the AOVGCM) and (2) a synchronously coupled experiment focusing in on one ice sheet collapse covering 3.2 kyrs in both models. For the experiments, we coupled a modified version of the Parallel Ice Sheet Model (mPISM) bidirectionally with the AOVGCM ECHAM5/MPIOM/LPJ. ECHAM5 and LPJ were run in T31 resolution ($\sim 3.75°$), MPIOM on a grid with a nominal resolution of $3°$ and poles over Greenland and Antarctica, mPISM on a 20 km grid covering most of the northern hemisphere. In the models, as well as in the coupling, no flux correction or anomaly maps are applied. The ice sheet surface mass balance is computed using a positive degree day scheme with lapse rate correction and height desertification effect.

In the experiments, the surges of the Hudson Strait Ice Stream reach discharge rates of 60 000 m^3/s and show a typical recurrence interval of 7 kyrs, matching the basic characteristics for Heinrich events inferred from proxy data. The surges are consequences of an internal instability mechanism suggested by MacAyeal (1993) and various parts of the ice sheets show repeated surging.

The large ice discharge during a surge of the Hudson Strait Ice Stream causes an expansion of the sea ice cover in the Labrador Sea and the adjacent North Atlantic. The freshwater, that is released when the ice melts, stabilizes the density stratification in the northern Atlantic. Consequently, the north Atlantic deepwater (NADW) cell weakens by about 10% and the Antarctic Bottom Water cell strengthens slightly. The weaker NADW cell transports less heat to the north and thus the ocean heat release decreases. With the increase in sea ice cover and the decrease in ocean heat release, the air over the northern Atlantic cools. This cooling spreads downwind into Eurasia. The lower temperature and the increased sea ice cover reduce the evaporation over the northern Atlantic and the Nordic Seas. Consequently, Eurasia receives less precipitation. All in all, the changes in the climate system caused by the ice stream surges are consistent with the proxy reconstructions for Heinrich events.

References:

D R MacAyeal, 1993. Binge/Purge Oscillations of the Laurentide Ice Sheet as a Cause of the North Atlantic's Heinrich Events. *Paleoceanography*, 8, 1993. `http://dx.doi.org/10.1029/93PA02200`.