EGU General Assembly 2025

EGU25-8507, updated on 06 Mar 2026
https://doi.org/10.5194/egusphere-egu25-8507
EGU General Assembly 2025

Deglaciation and abrupt events in a coupled comprehensive atmosphere--ocean--ice sheet--solid earth model

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During the last 20,000 years, the climate of the Earth evolved from a state much colder than today with large ice sheets covering North America and Northwest Eurasia to its present state. The fully-interactive simulation of this transition represented a hitherto unsolved challenge for state-of-the-art climate models. We use a novel coupled comprehensive atmosphere-ocean-vegetation-ice sheet-solid earth model to simulate this transient climate evolution, referred to as the last deglaciation. The model considers dynamical changes of ice sheets (shape and extent) as well as changes in the land-sea mask and river routing. The model also contains a dynamical iceberg component. An ensemble of eight transient model simulations realistically captures the key features of the last deglaciation, as depicted by proxy estimates.

In addition, our model simulates a series of abrupt climate changes, which can be attributed to different drivers. Sudden weakenings of the Atlantic meridional overturning circulation during the glacial state and the first half of the deglaciation are caused by Heinrich-event like ice-sheet surges, which are part of the model's internal variability. We show that the timing of these surges depends on the initial state and the model parameters, illustrating the stochastic nature of the events. Abrupt events during the second half of the deglaciation are caused by a long-term shift in the sign of the Arctic freshwater budget, by changes in the opening of ocean passages and/or by abrupt changes in the river routing. In contrast to the Heinrich-event like ice-sheet surges, the abrupt events of the second half of the deglaciation are deterministic, as they occur as inherent features of the deglaciation.