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Modelling large-scale ice-sheet–climate interactions at the last glacial inception

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In order to investigate the interactions between coevolving climate and ice-sheets on multimillenial timescales, a low-resolution atmosphere-ocean general circulation model (AOGCM) has been coupled to a three-dimensional thermomechanical ice-sheet model. We use the FAMOUS AOGCM, which is almost identical in formulation to the widely used HadCM3 AOGCM, but on account of its lower resolution (7.5° longitude × 5° latitude in the atmosphere, 3.75° × 2.5° in the ocean) it runs about ten times faster. We use the community ice-sheet model Glimmer at 20 km resolution, with the shallow ice approximation and an annual degree-day scheme for surface mass balance. With the FAMOUS-Glimmer coupled model, we have simulated the growth of the Laurentide and Fennoscandian ice sheets at the last glacial inception, under constant orbital forcing and atmospheric composition for 116 ka BP. Ice grows in both regions, totalling 5.8 m of sea-level equivalent in 10 ka, slower than proxy records suggest. Positive climate feedbacks reinforce this growth at local scales (order hundreds of kilometres), where changes are an order of magnitude larger than on the global average. The albedo feedback (higher local albedo means a cooler climate) is important in the initial expansion of the ice-sheet area. The topography feedback (higher surface means a cooler climate) affects ice-sheet thickness and is not noticeable for the first 1 ka. These two feedbacks reinforce each other. Without them, the ice volume is ∼90% less after 10 ka. In Laurentia, ice expands initially on the Canadian Arctic islands. The glaciation of the islands eventually cools the nearby mainland climate sufficiently to produce a positive mass balance there. Adjacent to the ice-sheets, cloud feedbacks tend to reduce the surface mass balance and restrain ice growth; this is an example of a local feedback whose simulation requires a model that includes detailed atmospheric physics.