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A new coupled ice sheet/climate model: description and sensitivity to model physics under Eemian, Last Glacial Maximum, late Holocene and modern climate conditions

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Abstract. The need to better understand long-term climate/ice sheet feedback loops is motivating efforts to couple ice sheet models into Earth System models which are capable of long-timescale simulations. In this paper we describe a coupled model that consists of the University of Victoria Earth System Climate Model (UVic ESCM) and the Pennsylvania State University Ice model (PSUI). The climate model generates a surface mass balance (SMB) field via a sub-gridded surface energy/moisture balance model that resolves narrow ice sheet ablation zones. The ice model returns revised elevation, surface albedo and ice area fields, plus coastal fluxes of heat and moisture. An arbitrary number of ice sheets can be simulated, each on their own high-resolution grid and each capable of synchronous or asynchronous coupling with the overlying climate model. The model is designed to conserve global heat and moisture. In the process of improving model performance we developed a procedure to account for modelled surface air temperature (SAT) biases within the energy/moisture balance surface model and improved the UVic ESCM snow surface scheme through addition of variable albedos and refreezing over the ice sheet.

A number of simulations for late Holocene, Last Glacial Maximum (LGM), and Eemian climate boundary conditions were carried out to explore the sensitivity of the coupled model and identify model configurations that best represented these climate states. The modelled SAT bias was found to play a significant role in long-term ice sheet evolution, as was the effect of refreezing meltwater and surface albedo. The bias-corrected model was able to reasonably capture important aspects of the Antarctic and Greenland ice sheets, including modern SMB and ice distribution. The simulated northern Greenland ice sheet was found to be prone to ice margin retreat at radiative forcings corresponding closely to those of the Eemian or the present-day.

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