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On the importance of accurate initial conditions for ice sheet modeling

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The credibility of numerical models used to estimate the contribution of ice sheets to sea level rise over the next few centuries crucially depends on our knowledge of the initial state. Possible sources of error include (1) limited understanding of physical processes involved, (2) the choice of approximations made by the numerical model, (3) values of tunable parameters, and (4) uncertainties in initial and boundary conditions. The response of an ice sheet model to given forcing contains the above mentioned error sources, with unknown weights.

In this work I focus on initial conditions. In a thermo-mechanically coupled ice sheet model, initial values for the ice sheet geometry, basal slipperiness, and the ice viscosity/temperature are needed. While the geometry is known with some confidence, basal slipperiness and viscosity/temperature remain poorly constrained. The full set of initial conditions required for a model run can be obtained either by inverse modeling or by a procedure often called "spin-up". A "spun-up" state of an ice sheet, i.e. a consistent state with the full set of initial conditions, can be obtained using different techniques: (1) Spin-up runs spanning many glacial-interglacial cycles driven by a paleo-climate forcing, (2) spin-up based on assimilation methods for parameter choices which force the model to match observed fields such as surface velocities, and (3) combinations of (1) and (2).

Four different spin-up methods are evaluated by comparing the spun-up state with observations including (a) diagnostic quantities such as ice volume, ice area extend, surface velocities, bore hole temperatures, and (b) transient quantities such as the rate of ice volume change. Then future climate experiments are performed and the sensitivity of the spun-up state on the model predictions is investigated.

While it is possible to tune the model such that it produces good agreement with some observations, our current knowledge of the present-day state of an ice sheet, especially of internal transient fields, is still insufficient to conclusively assess the credibility of the spinups. Results show that future climate experiments are extremely sensitive to initial conditions and that current techniques produce spun-up states that, when future climate experiments are performed, react to unphysical transients rather to future climate. There is a clear need to improve our understanding of the present state to increase our confidence in model predictions.