



From Heinrich Events to cyclic ice streaming: the grow-and-surge instability in the Parallel Ice Sheet Model

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Here we report on a cyclic, physical ice-discharge instability in the Parallel Ice Sheet Model, simulating the flow of a three-dimensional, inherently buttressed ice-sheet-shelf system which periodically surges on a millennial timescale. The thermo-mechanically coupled model on 1 km horizontal resolution includes an enthalpy-based formulation of the thermodynamics, a non-linear stress-balanced based sliding law and a very simple sub-glacial hydrology. The simulated unforced surging is characterized by rapid ice streaming through a bed trough, resulting in abrupt discharge of ice across the grounding line which is eventually calved into the ocean. We identify and visualize the central feedbacks that dominate the sub-sequent phases of ice build-up, surge and stabilization which emerge from the interaction between ice dynamics, thermodynamics and the sub-glacial till layer. A reduction in the surface mass balance or basal roughness yields a damping of the feedback loop which suggests that thinner ice sheets may be less susceptible to surging. The presented mechanisms underlying our simulations of self-maintained, periodic ice growth and destabilization may play a role in large-scale ice-sheet surging, such as the surging of the Laurentide Ice Sheet, which is associated with Heinrich Events, and ice-stream shut-down and reactivation, such as observed in the Siple Coast region of West Antarctica.