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Simulation of ice speedup events in Greenland from seasonal surface melt signals via explicit modelling of basal water pressure

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We model the glacial dynamic response of Greenland to seasonal patterns of surface melt. Our aim is to produce a model that can explain a number of aspects of observed speed-up behaviour in Greenland. These include: a seasonal acceleration of ice, differing speed-up of outlet and land terminating ice, and inter-annual variability of sliding velocity.

The model is based on an ice-sheet scale model of basal water pressure HYDRO, originally developed to consider basal melt inputs to the subglacial environment. This is coupled to the community ice sheet model GLIMMER, via two principle mechanisms. First, the basal water pressure is incorporated into a function to describe a basal drag coefficient. This in turn is used in a sliding law which has a linear dependence on shear stress. Second, the model also defines a friction coefficient which explicitly defines basal heating rates as a function of basal ice velocity and water pressure. Water pressure distribution is predicted by resolving large-scale water production and flow over the ice sheet domain driven by hydraulic pressure gradients. This is based on a simple Darcian expression, but the model has the capacity to represent areas of efficient and inefficient flow by modifying the overall basal hydraulic conductivity as a function of water flux. Thus with high water throughput, the model can switch to an efficient mode, serving as a simple large-scale proxy to the development of basal water conduits without explicit specification of the system. The bed becomes impermeable where it is frozen.

The surface system is coupled to the basal model by, a) developing a simple expression to pond any surface melt locally on the ice sheet surface (surface flow is omitted for simplicity) b) developing a simple proxy mechanism to hydrofracturing by allowing ponded water to reach the bed instantaneously once its depth is greater than a specific threshold, but controlled probabilistically c) such water is then included as if it were instantaneous basal melt. d) any further melt in the same season goes directly to the bed.

An approximation to present Greenland is first modelled assuming quasi-equilibrium with present climate. This provides an ice temperature field and initial basal pressure regime. The model is then run for a further period using monthly time steps and surface water inputs. In doing so we can demonstrate a variety of speed-up behaviour at the margin linked to seasonal melt patterns. Given there is no explicit description of longitudinal stresses in the model we show a) a small response inland from where water reaches the bed, b) seasonal speed-up in some margins, but less so in those which already experience low effective pressures (e.g. Ilulissat), c) multi-seasonal pressure build-up and speed-up in some areas, d) a relative insensitivity to the overall magnitude of surface melt input fluxes but complex behaviour resulting from the triggered inclusion of surface water into the basal system.