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Dynamic subglacial processes in a high-order ice sheet model

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Current predictions of ice sheet mass balance and discharge variability including sea-level rise, are severely limited because subglacial processes are not reliably implemented in large scale ice sheet models. One of the most limiting factors is the challenging nature of simulating the fast and transient flow of ice streams that drain the interior and discharge large volumes of ice into the polar ocean. This difficulty is partly due to uncertainties in the nature of subglacial processes, but also due to the complexity in including local basal processes at the scale computationally required to run a whole ice sheet model.

We aim to improve the predictive capability of a community ice sheet model (Glimmer-CISM) by (i) implementing higher order ice flow physics and (ii) introducing dynamic subglacial processes that include hydrologically controlled shear strength evolution in a till layer with Coulomb plastic rheology.

Here, we focus on the development and use of the latter within the large scale model. The basal processes model has been originally developed for simulations of the Siple Coast ice streams, explaining their observed variabilities with internal processes taking place at the ice-till interface. The coupling between the subglacial processes model and the ice sheet model is done via the determination of the bed strength, which is assessed from water availability within the till layer. Basal melting (freezing) weakens (strengthens) the till layer and reduces (increases) the basal resistance to flow.

So far, experiments have been carried on a simple idealized ice stream domain. This allows us to do sensitivity tests on a range of model parameters (e.g., sediment type, thickness and distribution) and to tune the model before applying the calculation to the entire Antarctic Ice Sheet.

We compare our model results to a case that uses the more common linear-viscous till rheology, where the sliding parameter is defined as a function of the subglacial water depth. Preliminary results show that flow regimes are distinctly different in these two cases.

Additional modelling developments will include the generalization of the subglacial processes model by coupling pore water pressure in the till layer to a regional hydrology model. We anticipate that our model will be able to reproduce the inland thinning observed along the Amundsen Coast as well as the stagnation of ice streams in the Ross sector. We therefore expect our model to produce reliable sea-level rise prediction for the 21st century.