Grounding line migration and ice shelf buttressing in a two-dimensional marine ice stream model

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The role played by warming oceans in the dynamics of marine ice sheets depends on the degree of coupling between ice streams and their floating ice shelves. Ocean thinning of an ice shelf changes the stress balance within the shelf, but these changes must be transmitted across the grounding line in order to effect changes in the flow and extent of grounded ice. This mechanism is thought to be of some importance in several West Antarctic ice streams, including Pine Island Glacier.

We seek to recreate and investigate this driving of ice sheet changes through ocean melting and accretion in an ice stream-ice shelf flow model. The model consists of a depth-integrated stress balance with Glen's Law rheology (MacAyeal, 1989) with a basal stress parameterization applied to the ice stream. We make the model fully two-dimensional and allow the shear (arising, for example, from rigid sidewalls) to be determined by the solution rather than parameterized. Stresses are continuous across the grounding line and are not a priori set to zero anywhere in the interior. The thickness of the stream/shelf evolves through a depth-integrated continuity equation. The grounding line is allowed to migrate (and change topology, such as the formation of an ice rise) by way of a flotation criterion that is evaluated after each timestep.

Grounding line migration is problematic to the modeling of marine ice streams. The sharp transition in basal tangential stress and in thickness makes it difficult for a low-resolution model to capture the steep velocity gradients accurately, and strong qualitative dependence of behavior on numerical discretization and resolution is sometimes observed. We deal with this difficulty without sacrificing computational time and overhead by using an adaptive mesh, which provides higher resolution to the parts of the domain where it is needed. We show that solutions are convergent with respect to resolution, and not very sensitive to discretization details as long as the scheme is consistent.

A preliminary result of the model is that under certain conditions, generated using a domain periodic in one direction, is that grounding lines may be stable to small transverse variations. This implies that receding (or advancing) grounding lines may not exhibit morphological instabilities in the presence of small-scale transverse bed or stream thickness variation. Another is that the presence of rigid sidewalls can lead to much lower along-flow velocities as compared to unconfined shelves, not only within the ice shelf but in a narrow region upstream of the grounding line as well. We plan to investigate more fully this buttressing effect, both with idealized and more realistic geometry and basal stress parameterization.