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An improved implementation of grounding-zone dynamics in a 3D coupled ice-sheet ice-shelf model

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To better assess the short-term response of the Antarctic ice sheet to global sea-level change grounding-zone dynamics can arguably be at least as important as surface mass-balance changes, the latter of which can be diagnosed directly from climate models. Here we present new schemes for grounding-line migration and higher-order basal sliding for implementation in our 3-D thermomechanical Antarctic ice-sheet model.

Firstly, a physical constraint on the ice flux at the grounding line was incorporated. The original concept from Schoof was generalized to two dimensions (horizontal plane) and the effect of buttressing from shearing along sidewalls and pinning points was taken into account. Our numerical implementation avoids strong discontinuities in the velocity field and behaves in a measured way in time-dependent situations. Secondly, a higher-order model was incorporated for basal sliding similar to the membrane stress concept investigated by others. The grounded velocity field now consists of a 'shallow shelf component' for basal sliding and a 'shallow ice component' for ice deformation on top of that. These new implementations allow us to model more accurately the feedbacks between grounded and floating ice and the potential propagation of fast changes inland at no extra computational cost compared to our previous grounding-zone treatment.

The new treatments have been thoroughly tested in a schematic three-dimensional setup resembling a marine ice sheet with an embayment. As should be expected, the model response is reversible for changes in accumulation rate, sea level stand, and ice-shelf melting. Buttressing was tested by changing the melting rate below the shelf. Under an increasing basal melt rate, the ice shelf thins, causing the grounding line to retreat in the embayment due to decreasing back stress, while the grounding line remains (almost) stationary elsewhere along the margin where buttressing is absent. Several other tests were performed to compare the effect of changing the grid size and basal sliding parameters. These refinements are implemented in our three-dimensional Antarctic ice-sheet model and the presentation will also discuss results from those runs.