

When Buttressing Matters: a sensitivity study

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In a warming world the buttressing influence of ice shelves on the ice streams which flow into them may be substantially reduced. The potential impact that this loss of buttressing would have on an ice-stream/ice-shelf system includes thinning and grounding-line retreat, contributing to ongoing sea-level rise. Therefore it is critical to assess the sensitivity of such systems to a change in buttressing. We examine this sensitivity using a model of the couple mass and momentum balance of an ice-stream/ice-shelf system. The diagnostic momentum balance component model is appropriate for thin, channelized flow, and includes longitudinal deviatoric stress, driving stress and lateral and basal drags, with downstream buttressing prescribed as a dynamic boundary condition. The prognostic mass balance component model is derived from depth-integrated continuity, and for simplicity we have neglected accumulation, yielding a simple balance between thinning rate and flux convergence. The equations are nondimensionalized to isolate important parameters. The resulting model equations are cast in numerical form using finite elements in space and implicit finite differences in time, with a form of Petrov-Galerkin upwinding applied to the mass balance to aid in efficiency. Several numerical experiments were conducted to explore the response to a loss in buttressing. The set of experiments include a reference experiment, with parameter values roughly appropriate for Pine Island Glacier (PIG), as well as several experiments to assess the sensitivity of the results to the choice of parameter values. In all of the experiments buttressing was removed from an initially steady-state system and allowed to evolve to a new steady-state. The results show a marked grounding-line retreat, equivalent to an 8-18 km retreat in dimensional terms. The bulk of this adjustment occurs within a few decades. Also of interest is the reduction in the volume of ice that was initially above flotation, which indicates the impact of the loss in buttressing on sea level. Here the results show a 20\ to 43\ loss in this volume, roughly corresponding to a modest net addition of 1 mm to sea level. These results may well underestimate the magnitude of the response for several reasons. For example, our neglect of accumulation means that we do not include the inland migration of sub-ice-shelf melting as the grounding line retreats. The experiments which assessed the sensitivity of the results to the choice in parameter values suggest that systems which are wider, have a stickier bed, or have a larger driving stress will be more sensitive to a loss in buttressing. The Siple Coast ice streams do generally have lower driving stress than PIG, but some are also wider near the grounding line. Thus we cannot rule out significant sensitivity of some of the Siple Coast ice streams to a loss in buttressing. We suggest that further experiments are warranted to explore the sensitivity of the Siple Coast ice streams, as well as to investigate the importance of sub-ice-shelf melting.