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The effect of buttressing on grounding line dynamics

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Changes in ice shelf properties can affect the flow of grounded ice by altering the stress balance at the grounding line. However, attributing observed changes in the flow of grounded ice to specific forcing mechanisms (e.g. variability in oceanic forcing), and quantifying the effects of varying forcings, remains a major challenge for ice sheet modeling. The conclusions drawn from these models often depend on the type of model used. For example, recent simulations with two-dimensional, plan view, ice-flow models suggest that ice shelves can change the stability of grounding lines through buttressing. In contrast, many flow line models exclude ice shelves from their momentum balance. To investigate the role of buttressing for grounding line dynamics, we extend a recently developed boundary layer approach to laterally integrated ice flow models with parameterized buttressing. This approach allows us to determine the backstress at the grounding line as a function of ice shelf properties such as shelf width and length, and to establish the functional dependence of the ice flux at the grounding line on these properties. We find that the steady-state position and stability of marine ice sheets depend on the calving front boundary conditions, and that different calving laws have different effects on grounding line dynamics. Our results show that the prescription of a constant calving front position can lead to multivalued flux-ice thickness relationships and stabilize grounding lines on retrograde slopes. In contrast, a prescribed ice thickness at the calving front can lead to both stable and unstable grounding line positions on beds sloping downwards towards the ocean.