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The dynamics of viscous grounding lines

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Western Antarctica is composed principally of marine ice sheets, in which the mainland grounded ice sheet extends over the coastline as a floating ice shelf. Fed by snowfall upstream, marine ice sheets transport ice from the grounded component, over the grounding line, where the ice shelf lifts off, and into the ice shelf, which ultimately calves adding water to the ocean. An idealized two-dimensional ice shelf has no dynamical influence on the grounded ice sheet or the position of the grounding line. However, horizontal stresses within a three-dimensional ice shelf, caused for example by ice rises or the lateral walls of a bay can help fix the grounding line and prevent it from receding. To determine the role of such three-dimensional stresses, we develop a theoretical model for a three-dimensional marine ice sheet in which the grounding line evolution is controlled by a dynamic coupling between the grounded ice sheet and the floating ice shelf. We find solutions of the model equations in specific three-dimensional examples, which we use to show how transverse stresses in the ice shelf lead to buttressing of the ice sheet. To demonstrate the behaviour of the system and test the predictions of the model, we have conducted a series of laboratory experiments using simple fluids.