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To float or not to float: conditions for a steady grounding line

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To gain insight into the instability hypothesis of marine ice sheets, we investigate the conditions required for a steady grounding line position. In the numerical approach, the full Stokes equations are solved with a finite element model. The position of the grounding line is fixed, but the air-ice free surface and ice-sea free surface are unknown and part of the solution that we are seeking. Steady state solutions are sought for a range of mass fluxes, basal conditions, and back pressures. We demonstrate that for physically acceptable solutions, the simulations must satisfy two contact inequalities: the compressive normal stress at the base of the grounded ice should exceed water pressure, and the shelf surface should not get into contact with the bedrock. Violation of either condition would result in grounding line migration. We show that when ice slides over the bedrock and for a given sea level, only one combination of mass flux, grounding line thickness and back pressure, satisfies the contact conditions. When ice is frozen to the bedrock, however, a range of mass fluxes, grounding line thicknesses and back pressures satisfies the contact conditions for a particular sea level. The implication of these results for the instability hypothesis of marine ice sheets is addressed.