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Brittle and Elastic Ice Shelves: Coupling fracture and wave propagation

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Distant storms, tsunamis, and earthquakes generate waves in floating ice shelves. In several instances, seismic observations have clearly demonstrated a mechanistic link between periods of elevated wave activity and iceberg calving. The detailed mechanical interpretation of observed seismograms is complicated, however, by the existence of numerous types of waves that propagate in the coupled ice–ocean–earth system. Here, I describe wave propagation in an elastic, finite-thickness, buoyantly floating ice layer above a uniform and inviscid water layer. I place particular focus on waves with wavelength greater than the ice thickness, as have recently been observed on the Ross, Pine Island, and Amery Ice Shelves. I show that mode uncoupling occurs at long period such that waves occur as either symmetric or flexural modes. I calculate the stresses associated with the seismically observed wave field on the Ross Ice Shelf. In the second part of this work, I place these stresses the context of linear elastic fracture mechanics. I show that long rifts in buoyantly floating ice shelves experience stabilization due to the inability of a thin elastic layer to effectively transmit stresses over long distances. I derive a rift tip equation of motion that shows excellent agreement with observed rift tip propagation velocities. The theory presented here paves the way to an improved depiction of ice shelf calving in predictive ice sheet models.

Significance statement

Ice shelves provide a net resistive force to grounded ice sheets and therefore permit a greater terrestrial ice volume than would be possible in their absence. Ice shelves are limited in extent by 100 km long fractures called rifts. This work explores the formation and propagation of these rifts.

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