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The stability of ice shelf rifts

Bradley Lipovsky
Department of Earth and Planetary Sciences, Harvard University, United States (brad_lipovsky@fas.harvard.edu)

Fractures, often in the form of through-cutting rifts, limit the ability of floating ice shelves to stabilize marine ice sheets. Here, I investigate rift propagation with an eye towards several processes that tend arrest rift propagation and therefore stabilize marine ice sheets.

First, I note that horizontal ice shelf rift propagation is expected to occur when deviatoric stresses exceed the pressure of ice above the water line. I then go on to explore the role of ductile flow at high confining pressure. I find that ice shelves are most susceptible to brittle fracture when their thickness is less than the brittle–ductile transition thickness, defined as the depth at which the overburden pressure equals the local yield strength in tension.

Second, I ask the question, how fast can rifts propagate? I propose that rift propagation speeds may be limited by the rate at which water can flow into the rift. I solve a coupled free surface water flow and inertial fracture initial value problem. I find that as the rift tip accelerates it generates a low water pressure anomaly that acts to suck water into the newly formed rift. This flow, in turn, may in some cases limit the rate at which propagation may occur.

Finally, I quantify the role of thermoelastic stresses in rifting. During rift propagation thermal expansion occurs as cold ice contacts much warmer ocean water. The resulting swelling may oppose additional rift propagation by closing the rift. Perhaps surprisingly, I find that the magnitude of thermal bending may greatly exceed the well-known bending moment associated with the imbalance of the hydrostatic and overburden stresses at the ice front.

Taken together, these results constitute the beginning of a framework for evaluating the stability of ice shelves and the marine ice sheets that they support.