Towards a Universal Calving Law: Modeling Ice Shelves Using Damage Mechanics

Morgan Whitcomb[1], Jeremy Bassis[1], Steve Price[2], William Lipscomb[3]*

[1]University of Michigan, Ann Arbor, MI
[2]Los Alamos National Laboratory, Los Alamos, NM
[3]National Center for Atmospheric Research, Boulder, CO

Modeling iceberg calving from ice shelves and ice tongues is a particularly difficult problem in glaciology because of the wide range of observed calving rates. Ice shelves naturally calve large tabular icebergs at infrequent intervals, but may instead calve smaller bergs regularly or disintegrate due to hydrofracturing in warmer conditions. Any complete theory of iceberg calving in ice shelves must be able to generate realistic calving rate values depending on the magnitudes of the external forcings. Here we show that a simple damage evolution law, which represents crevasse distributions as a continuum field, produces reasonable estimates of ice shelf calving rates when added to the Community Ice Sheet Model (CISM). Our damage formulation is based on a linear stability analysis and depends upon the bulk stress and strain rate in the ice shelf, as well as the surface and basal melt rates. The basal melt parameter in our model enhances crevasse growth near the ice shelf terminus, leading to an increased calving rate. This implies that increasing ocean temperatures underneath ice shelves will drive ice shelf retreat, as has been observed in the Amundsen and Bellingshausen Seas. We show that our model predicts broadly correct calving rates for ice tongues ranging in length from 10 km (Erebus) to over 100 km (Drygalski), by matching the computed steady state lengths to observations. In addition, we apply the model to idealized Antarctic ice shelves and show that we can also predict realistic ice shelf extents. Our damage mechanics model provides a promising, computationally efficient way to compute calving fluxes and links ice shelf stability to climate forcing.