EGU2020-15790
https://doi.org/10.5194/egusphere-egu2020-15790
EGU General Assembly 2020

Deriving a Physically-Based Calving Rate Law for Marine Ice-Cliff Instability

Anna Crawford[1], Joe Todd[1], Doug Benn[1], Jan Åström[2], and Thomas Zwinger[2]
[1]University of St Andrews, St Andrews Glaciology Group, Geography and Sustainable Development, St Andrews, United Kingdom of Great Britain and Northern Ireland (ajc44@st-andrews.ac.uk)
[2]CSC – IT Center for Science, Espoo, Finland

Rapid grounding line retreat at marine-terminating glaciers could expose ice cliffs with heights greater than those on observational record. However, the finite strength of ice places a limit on the height of subareal cliffs. It is proposed that marine ice-cliff instability (MICI) will begin once a stable height threshold is exceeded. If a glacier is situated over a retrograde slope, as is the case for Thwaites Glacier and much of the West Antarctic Ice Sheet, MICI can be expected to accelerate as retreat progresses and increasingly tall and unstable ice cliffs are formed. This is consequential for global sea level rise, yet large uncertainties remain in the prediction of MICI retreat rates.

We investigate MICI by pairing the full Stokes continuum model Elmer/Ice and the Helsinki Discrete Element Model (HiDEM). Viscous flow, simulated in Elmer/Ice, is found to be a necessary pre-condition for MICI collapse. Forward advance and bulging lead to ice-front instability and pervasive crevassing in HiDEM. This culminates in full-thickness calving events. We do not observe calving at ice faces prior to viscous deformation. HiDEM simulations that implement viscous flow (HiDEM-ve) also show forward advance and waterline bulging, similar to the Elmer/Ice simulations. However, the importance of granular shear is highlighted by pronounced shear bands and patterns of surface lowering in HiDEM-ve output. These results emphasize the importance and complexity of viscous and brittle process interaction during MICI.

A simulation matrix of grounded termini shows that calving frequency and magnitude increase with the thickness of the calving front. The time required for viscous flow to recreate unstable conditions is influenced by thickness as well as ice temperature and basal friction. Simulations of buoyant termini are seen to calve through basal-crevassing and block-rotation, as opposed to incising surface-crevasses. Lastly, we observe that buttressing mélange can suppress retreat rate if a sufficient resistive force is delivered to the calving front. A physically-based law for MICI retreat rate is derived from our simulation matrix; this calving rate law can be incorporated into large-scale ice sheet models to constrain projections of Antarctic retreat and associated global sea level rise. Our results will also be used to investigate the future retreat of Thwaites Glacier, which is vulnerable to MICI due to a retreating grounding line, fragile floating ice shelf, and precarious positioning above an overdeepening basin.