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A 3D Full-Stokes Calving Model Applied to a West Greenland Outlet Glacier

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Iceberg calving from outlet glaciers accounts for around half of all mass loss from both the Greenland and Antarctic ice sheets. The diverse nature of calving and its complex links to both internal dynamics and external climate make it challenging to incorporate into models of glaciers and ice sheets. Consequently, calving represents one of the most significant uncertainties in predictions of future sea level rise.

Here, we present results from a new 3D full-Stokes calving model developed in Elmer/Ice and applied to Store Glacier, the second largest outlet glacier in West Greenland. The calving model implements the crevasse depth criterion, which states that calving occurs when surface and basal crevasses penetrate the full thickness of the glacier. The model also implements a new 3D rediscretization approach and a time-evolution scheme which allow the calving front to evolve realistically through time. We use the model to test Store's sensitivity to two seasonal environmental processes believed to significantly influence calving: submarine melt undercutting and ice mélange buttressing.

Store Glacier discharges 13.9 km3 of ice annually, and this calving rate shows a strong seasonal trend. We aim to reproduce this seasonal trend by forcing the model with present day levels of submarine melting and ice mélange buttressing. Sensitivity to changes in these frontal processes was also investigated, by forcing the model with a) increased submarine melt rates acting over longer periods of time and b) decreased mélange buttressing force acting over a reduced period.

The model displays a range of observed calving behaviour and provides a good match to the observed seasonal evolution of the Store's terminus. The results indicate that ice mélange is the primary driver of the observed seasonal advance of the terminus and the associated seasonal variation in calving rate. The model also demonstrates a significant influence from submarine melting on calving rate. The results also highlight the importance of topographic setting; Store Glacier terminates on a large bedrock sill, and this was found to exert a first-order control on calving rate, explaining Store Glacier's comparative stability during a period when many Greenland outlet glaciers underwent concurrent retreat.