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Finite Element Analysis of Small Scale Continuous Calving

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Ice shelves are floating ice masses, which are sensitive to climate changes. The main mechanisms for the mass loss of ice shelves around Antarctica are basal melting and calving. For an understanding of the mechanisms of calving the influence of environmental parameters needs to be investigated. We use a fracture mechanical approach to examine the nature and frequency of calving events.
Ice responses to load in two ways: on long time scales ice reacts like a viscous fluid, and on short time scale like an elastic solid. As calving is a representation of the solid nature of ice, the elastic response is important and linear elastic fracture mechanics can be applied. However, gravity remains a long time load and hence, a viscous component needs to be taken into account as well. Therefore, we use a Kelvin-Voigt model for analyzing the transient response of an ice shelf to a calving event. In a simplified 2D-model the ice shelf is treated as a rectangular block, in which the gravity force is the only load in a first analysis. The stresses on the surface in the vicinity of the calving front are computed with the finite element software COMSOL. The boundary conditions are the water pressure at the front and bottom of the ice shelf and a constant displacement at the inflow. A stationary state will reappear until eventually the subsequent calving event occurs, the termination time is around 175days. Based on this time interval and the flow velocity of the ice shelf we estimate the calving rate.

Different parameter studies reveal the influence of geometry and material parameters on the stresses for an elastic material model. The literature and measurements at the Ekstroem Ice Shelf, East Antarctica, provides the relevant parameter range. Due to the depth-dependent water pressure at the ice front, a bell shaped distribution of stresses on the surface is found. For this reason the location of the maximal stress denotes the most likely position for a calving event and is arranged in between 0.65H and 0.85H, with H the thickness at the ice front. The results of these studies are compared to the results for two cross-sections of measured geometries of the Ekstroem Ice Shelf.