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Viscoelastic modelling of grounding line migration

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Tides play an important role by moving ice shelves and modulating the flow of ice streams even far upstream the grounding line. The grounding line as the boundary between the shelf and the ice sheet plays a crucial role in the mass balance and general stability of an ice sheet. It has been observed to migrate in response to tidal forcing, but the exact mechanisms and consequences are not yet understood in detail.

On short timescales, as present in tidal forcing, we need to account for the viscoelastic character of glacier ice and choose a Maxwell model as an appropriate rheological representation. A viscoelastic full stokes ice flow model was implemented in the finite element software COMSOL Multiphysics. We investigate the influence of tides on the dynamics of ice sheet–ice shelf systems and grounding line migration by means of numerical modelling.

In our model we are able to identify two processes, which control ice flow variations with tides. Uplifting of the ice shelf leads to retreat of the grounding line and therefore less area of the ice base is in contact with the bedrock. This leads to smaller basal shear stress, resulting in an increase in flow velocity. Additionally high tide causes increased normal stress at the ice – water boundary, which slows the ice flow. When forced with the S_2 (12 h) and M_2 (12.42 h) tidal constituents, we observe a non-linear interaction, which leads to a perturbation of the horizontal flow velocity close to the M_{sf} (14.76 d) constituent. By not including tides and viscoelasticity into ice models we commit significant errors for the estimation of the flux across the grounding line and the resulting mass balance. For our experimental setup this error depends on the elastic parameter and we obtain a maximal error of 3.75%. We also observe a general retreat of the grounding line due to tidal forcing. This implies that tides possibly lead to a different equilibrium of the grounding line position.