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Accounting for damage to model the influence of a pinning point on the grounding line dynamics

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The ice released from Greenland and Antarctic ice sheets into the ocean is the main cause of the current observed sea-level rise. Using the open-source finite-element code Elmer/Ice, a previous study (Favier et al., 2012) investigated the impact of a localised contact point between a floating ice shelf and the bedrock and showed its stabilizing effect on ice discharge.

The large amount of friction introduced locally by a pinning point induces a rapid decrease of ice velocities upstream the contact leading to an advance of the grounding line seaward until the grounded ice-sheet and the ice rise merge together. This causes a slow down of ice discharge which is consistent with observations on real ice-shelves. However, highly crevassed zones surrounding those pinning points are commonly observed, highlighting strong damage patterns which were not taken into account in Favier et al. (2012).
Damage has a strong influence on ice rheology as ice gets softer when damaged, therefore accelerating the ice flow. Recently, a damage model has been implemented within Elmer/Ice (Krug et al., 2014). In this model, damage is created in areas where the maximum principal Cauchy stress is higher than a stress threshold. Damage is then advected with ice flow and its impact on viscosity is taken into account by modifying the enhancement factor of Glen's flow law. Since high shear stresses predominate in the vicinity of pinning points, damage is likely to appear in those areas, making ice more fluid and thus lessening the stabilizing effect previously observed.
To check the validity of this hypothesis, the pinning point experiment is repeated taking damage into account. The impact of basal crevasses filled with sea water, which tend to counteract the compressive stresses due to cryostatic pressure and thus to promote damage formation under the shelf, is investigated as well.