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Phase field viscoelastic fracture models for ice sheet dynamics

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Antarctic ice sheets grounded under the sea level can break apart if the ice cliffs at the edge of ice shelves collapse under their own weight. The process is known as the marine ice cliff instability and could lead to a rapid retreat of ice shelves, acceleration of the ice sheets, and subsequent increase in global sea levels.

A classical treatment of fracture by Griffith [3] introduced the energy release rate for brittle elastic materials, the energy required for crack propagation, and created the energetic fracture criterion. Unfortunately such theories are insufficient as they cannot reproduce curvilinear cracks, kinks, crack branching, crack arrest, or crack nucleation. One can overcome issues of the classical Griffith theory with a diffusive crack modelling by variational approaches based on energy minimisation [1, 4].

In this talk we present a thermodynamically consistent phase field viscoelastic fracture models relevant for ice sheet dynamics that allows to incorporate additional rheological properties such as creep. By identifying the relevant free energy and dissipation potential functions of interest one can derive relevant viscoelastic models. In the case of Maxwell rheology with Glen's flow law [2], one arrives at two possible systems, one better suited for short timescales and another for longer timescales.

We present robust adaptive numerical schemes that allow to treat both compressible and incompressible materials with pure Dirichlet or Neumann, as well as mixed boundary conditions. Computational experiments demonstrate the robustness of the numerical solvers and importance of inclusion of fracture mechanisms into ice sheet models.

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