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Fracture-induced softening for large-scale ice dynamics

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Shearing and expansive ice flow can result in fractures, which are carried with the flow downstream forming band-like structures. Those fractured zones affect the ice flow in the entire ice shelf, its stability and hence its buttressing effect on the upstream tributaries. We account for fracture processes by introducing a two-dimensional fracture density field in the large-scale prognostic Potsdam Parallel Ice Sheet Model (PISM-PIK) and define first-order criteria and rates for the initiation, growth and healing of fractures depending on the prevailing stress regime. The fracture density field provides a continuum mechanics approach of incorporating the macroscopic effect of fracture mechanics by determining a local softening factor, which reduces effective ice viscosity. Accordingly, flow simulations yield much more realistic flow patterns with large across-flow velocity gradients in fracture-weakened regions. This model framework is expandable to grounded ice streams as well as climate-induced enhanced fracturing. It further gives rise to an enhanced fracture-based calving model.