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On incorporating plasticity within numerical models of lithosphere deformation

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Numerical models for crustal- and lithosphere-scale deformation have become essential tools to explore tectonic processes such as continental breakup, subduction initiation, and the formation of mountain belts. These deformation processes are associated with stresses that often exceed the yield strength of rocks, thereby causing brittle failure and plastic deformation. This type of deformation is observed in nature, for example, as shear bands. In many geodynamic models plasticity is implemented using a stress-limiter that aims to locally reduce the shear viscosity such that stresses drop to (or below) the yield stress of the rock. This approach leads, unfortunately, to a highly nonlinear system of equations whose numerical solution often causes headaches.

We present different plasticity formulations that have been suggested over the last 15 years and show how, depending on formulation, implementation and/or parameter choices, the resulting deformation patterns may differ. Convergence behavior of the strain rate iterations and intermediate results during the iterations will be presented to illustrate how poorly converged results may cause a model calculation to evolve into unexpected directions. Several ad-hoc numerical details at the heart of various implementations of plasticity, for example how values at integration points can be handled, will be discussed. We look forward to discussions on how the current models can be improved, better compared, and better benchmarked.