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The limitations of staggered grid finite differences in plasticity problems

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Most crustal-scale applications operate at grid sizes much larger than those at which plasticity occurs in nature. As a consequence, plastic shear bands often localize to the scale of one grid cell, and numerical ploys — like introducing an artificial length scale — are needed to counter this. If for whatever reasons (good or bad) this is not done, we find that problems may arise due to the fact that in the staggered grid finite difference discretization, unknowns like components of the stress tensor and velocity vector are located in physically different positions. This incurs frequent interpolation, reducing the accuracy of the discretization. For purely stress-dependent plasticity problems the adverse effects might be contained because the magnitude of the stress discontinuity across a plastic shear band is limited. However, we find that when rate-dependence of friction is added in the mix, things become ugly really fast and the already hard-to-solve and highly nonlinear problem of plasticity incurs an extra penalty.