Towards simulating sequences of seismic and aseismic slip across scales: Initial benchmarks and future directions

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Numerical simulations of the earthquake cycle have made great progress over the past decades to address important questions in earthquake physics and fault mechanics. However, significant challenges in bridging multiscale interactions between long-term tectonic deformation, aseismic fault slip, earthquake nucleation, and dynamic rupture still remain. In this study, we present results from GARNET, a newly-developed numerical library to simulate sequences of seismic and aseismic slip across scales. This finite difference code utilizes a fully staggered spatially adaptive rectilinear grid. Furthermore, it incorporates an automatic discretization algorithm and combines different physical ingredients, including a visco-elasto-plastic rheology and quasi- and fully dynamic formulation of inertial effects into one algorithm. While PETSc and Kokkos libraries are included for parallel computing, an adaptive time stepping is integrated into the algorithm to resolve both long- and short-time scales, ranging from years to milliseconds during the dynamic propagation of earthquake rupture.

Here we present results from two benchmarks (BP1 and BP3) based on the community code-verification effort for Sequences of Earthquakes and Aseismic Slip (SEAS) by the Southern California Earthquake Center (SCEC). BP1 benchmark is a 2D antiplane problem, with a 1D planar vertical strike-slip fault obeying rate-and-state friction, embedded in a 2D homogeneous, linear elastic half-space. The fault has a shallow seismogenic region with velocity-weakening friction and a deeper velocity-strengthening region, below which a relative plate motion rate is imposed. A periodic sequence of spontaneous, quasi-dynamic earthquakes and slow slip are simulated in the model. In the BP3 benchmark we consider full inertial effects during the dynamic rupture and we investigate its influence on earthquake behaviour and patterns. Results from these two benchmarks represent the first step towards more advanced seismic cycle models, which will help to enhance our understanding in earthquake physics.
