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Application of high-velocity friction experiments to the shear rupture of a fault in an elastic half-space

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We developed a physics-based model for earthquake rupture by numerically simulating shear rupture along a 2D vertical fault with the dynamic frictional strength of granite under high slip velocity. Recent experimental observations indicated that the steady-state frictional strength of silica-rich igneous rocks (granite, syenite, diorite) alternate between dynamic-weakening under low velocity ($V < 0.03$ m/s) and dynamic-strengthening under higher velocities ($V > 0.03$ m/s). This strength alternation was attributed to powder-lubrication (weakening), and powder dehydration (strengthening) (Sammis et al., 2011).
We used the dynamic friction law which was determined on samples of Sierra White granite under experimental velocities approaching 1 m/s (Reches and Lockner, 2010). We converted their observed friction-distance-velocity relations into an empirical friction model referred to as WEST (WEakening - STrengthening). For the simulation calculations, we used the spectral element code of Ampuero (web.gps.caltech.edu/∼ampuero/software), which computes the spontaneous rupture propagation along an anti-plane shear (mode III) fracture in an elastic half-space.
In the present analysis, the WEST friction model is used as the fault strength while keeping all other parameters (crust properties and stresses) the same as Version 3 of the Southern California Earthquake Center (SCEC) benchmark problem (Harris et al., 2004). This approach allows for direct comparison between the WEST rupture and the benchmark rupture with a fault of slip-weakening friction model (Rojas et al., 2008). We found the following differences between the ruptures of the two models: (1) WEST-based rupture occurs earlier at all observation points away from the nucleation zone; (2) WEST-based model has lower (∼ 35%) peak velocity and shorter rise-time; and (3) WEST-based rupture shows rich, frequent alteration of slip velocity, and consequently, the simulated rupture is more complex in stress drop, displacements, and friction recovery. We discuss the significant contribution of this experimentally-based friction model to the understanding of rupture models with emphasis on slip-pulse behavior.