Rupture simulation in a temporally stochastic stress field

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In statistical seismology, we handle an earthquake sequence as a stochastic process. For example, temporal stochasticity determines the exact timing of earthquakes. In seismic wave propagation, we also consider the stochastic term to account for the scattering effect. In source physics of earthquake rupture, on the other hand, people assume deterministic physics. For example, we run a rupture simulation by prescribing conditions deterministically, including fault geometry, initial stress, and friction law. However, we never know such conditions perfectly in real faults, and therefore, the rupture would evolve as if it was a stochastic process. Hence, the consideration of temporal stochastic term is necessary to understand the earthquake rupture process better.

Here, we perform mode III rupture simulation under the existence of temporally stochastic external stress. Different strength drop and initial stress level result in various ruptures from both crack-like and pulse-like ruptures to slow ruptures. It becomes pulse-like for low initial stress conditions, which is consistent with the previous study with spatial heterogeneity (Zheng and Rice, 1998). In these conditions, rupture propagates by inertia while less slip occurs in the central part of the fault. Low strength drop and low initial stress conditions will result in slow earthquakes. In these conditions, rupture can propagate only by stochastic force. The stress concentration at the rupture front gets smaller as it advances, and the chance of the propagation gets smaller and smaller, resulting in decelerating rupture propagation. Our model is a realization of previous Brownian walk model for slow earthquakes (Ide, 2008; Ide and Yabe, 2018) in a continuum system. Compared to the simplified model with nearest-neighbor assumptions, our model has an advantage in explaining “pulse-like” tremor front as we observe.