Numerical Simulation of Earthquake Cycles: Implication for Earthquake Forecast

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Abstract

Seismic slip on plate boundaries is confined only at shallow seismogenic depths, and aseismic sliding at deeper parts continuously strains the seismogenic regions leading to seismic rupture. This process is adequately modeled with laboratory-derived rate- and state-dependent friction laws, which incorporate some important characteristics of rate, time, and slip dependence of rock friction. Numerical simulation studies using the friction laws have been conducted for the last two decades to understand complex seismic/aseismic sliding process, the variation of seismic coupling, sliding behavior preceding large earthquakes, etc. I review these simulation studies and discuss possible future developments with a target for earthquake forecasts. The friction laws predict that accelerating aseismic sliding inevitably precedes the occurrence of an earthquake, possibly generating precursory crustal deformation and seismicity changes. However, the magnitude of preseismic sliding depends on some constitutive parameters of the friction laws, which values are difficult to be constrained from available observation data. Accordingly, the detectablility of the expected precursory phenomena is uncertain. A more promising application of the model for earthquake forecasts is to evaluate the effect of stress perturbation caused by nearby earthquakes and the variation of aseismic sliding on coming earthquakes. Large interplate earthquakes occur at asperities, which are locked during interseismic periods and are loaded by surrounding aseismic sliding. When an asperity is ruptured, stresses are transferred not only by direct elastic interaction but also by accelerated aseismic sliding with some time delays. I demonstrate some numerical results that indicate that the interaction between asperities via aseismic sliding complicates earthquake sequence. I also discuss statistical characteristics of simulated earthquake sequences, which may be useful for long-term earthquake forecasts.