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Testing a rate-state model of earthquake probabilities

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It is now widely accepted that there is a clear causal link between co-seismic stress changes and subsequent earthquake occurrence, although the relative importance of various mechanisms remains a matter of intense study. From a seismic hazard perspective, one of the most difficult issues involves advancing from stress perturbations to changes in earthquake probabilities. While there are a number of possible models (e.g. ETAS, STEP, and simple Omori law + Gutenberg-Richter) for estimating such probabilistic hazard changes, the Dieterich (1994) approach is particularly appealing because it has been developed to directly compute the change in seismic rate (and hence earthquake probability) resulting from a sudden stress step.

The Dieterich model is based on robust laboratory experiments but it also relies on a number of unproven assumptions. Chief among these is the idea of a "uniform population of nucleation sites" which implies that such sites are both infinite and static, in other words that they don't change in time. This is clearly unphysical, however, as the population of earthquakes following a stress step will differ from that which would have occurred had the stress perturbation not occurred, and this in turn will modify the population of potential nucleation sites.

Here we investigate the changes in nucleation sites resulting from stress steps in a hybrid 3D seismicity simulation model. Rate-state friction is included using the discrete equations of Dieterich (1995) that assume that every element is in one of 3 states – completely locked, accelerating unstably towards failure, or actively slipping – and stress is transferred between elements and faults via a boundary element code. Initial results suggest that the population of nucleation sites, and subsequent seismicity, depend on the details of the earthquake-induced stress steps.