Geophysical Research Abstracts
Vol. 16, EGU2014-10204, 2014
EGU General Assembly 2014

Mechanical Erosion of the Seismogenic Zone by Creep from below on Rate-and-State Faults

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To increase our understanding of how earthquakes nucleate on frictionally-locked fault patches that are loaded by the growing stress concentrations at their boundaries due to aseismic creep, we run numerical earthquake cycle simulations on elastic, infinitely long strike-slip faults endowed with rate-and-state friction. We model the boundary between the locked and creeping sections at the base of the seismogenic zone as an abrupt transition from steady-state velocity-strengthening behavior at greater depth to velocity-weakening at shallow depth. Due to computational expense, most previous numerical simulations have been limited to modest ratios of the size of the velocity-weakening region H to the nucleation length scale L_∞ [Rubin & Ampuero, 2005]. In our quasi-static 1D fault model (with radiation damping), we can explore the behavior of simulations with H/L_∞ of up to a few hundred, well beyond previous simulations and arguably more relevant to major faults. As this ratio grows, we observe that between large (surface-rupturing) earthquakes, an increasing number of creep fronts march into the seismogenic zone from the velocity-strengthening region. Once the creep fronts reach a distance of at least $2L_\infty$ from the boundary, most nucleate and grow into seismic events. To understand the conditions that control whether these events grow into surface-rupturing earthquakes or reach only a fraction of the distance to the surface, we derive expressions for the recurrence interval based on fracture mechanics energy balance arguments. The predicted recurrence intervals depend on the chosen state evolution law and are insensitive to the rate-state (a-b), both in apparent qualitative agreement with simulations. The predicted recurrence intervals are consistently smaller than we observe, perhaps as a result of the relative infrequency with which the creep fronts nucleate seismic events. To investigate this further, we will be adding heterogeneous material properties near the transition to encourage more frequent nucleation.