Geophysical Research Abstracts
Vol. 18, EGU2016-15774, 2016
EGU General Assembly 2016

Spontaneous aseismic and seismic slip on evolving faults in a continuum-mechanics framework

Robert Herrendörfer, Ylona van Dinther, and Taras Gerya
ETH Zurich, Institute of Geophysics, Departement of Earth Sciences, Zurich, Switzerland
(robert.herrendoerfer@erdw.ethz.ch)

The convergent plate motion in subduction zones is accommodated both by seismic events as well as by aseismic transients and steady slip. To better understand the long-term conditions in subduction zones that govern which portion of convergence is released through seismic or aseismic slip, we need to simulate self-consistently these slip processes and the faults along which they occur.

For this purpose, we extended our continuum-based, visco-elasto-plastic numerical model in which cycles of earthquake-like ruptures were simulated through a purely slip rate-dependent friction, albeit at very low slip rates (van Dinther et al., JGR, 2013). To model a wider slip spectrum and to approach seismic slip rates, we implemented an adaptive time-stepping scheme (Lapusta and Rice, JGR, 2001) and an innovative invariant reformulation of conventional rate-and state dependent friction (RSF).

In a simplified subduction setup, we validate our new implementations by comparing our simulated stability transitions to those of conventional seismic cycle models. We show a general agreement of the transitions between the occurrence of decaying oscillations towards stable sliding, periodic aseismic events, complex periodic behaviour and seismic events.

To demonstrate the advantages of this continuum approach, we simulate the spatiotemporal evolution of a complex fault system beyond the megathrust within an otherwise visco-elastically deforming layered upper plate. Using the common assumption of zero cohesion in RSF applications, deformation localizes in fault-like shear bands, while the degree of localization depends on the choice of RSF parameters. Deformation strongly localizes for rate-weakening friction within the usual laboratory-determined range (a-b$\sim$ -1e-2), whereas for rate-strengthening friction it only localizes clearly outside of this range (a-b$\sim$1e-4). Furthermore, the existence of these faults is short-lived, because RSF describes only transient changes in fault strength. In nature, a crucial process during the fault development is permanent strain weakening. Including this missing process in the form of strain weakening of cohesion (and of friction if necessary) should allow for fault zones without residual strength, which remain permanent zones of weakness inside otherwise intact host rocks. On these mature fault zones, RSF can be correctly applied and seismic, transient aseismic or stable slip will likely occur spontaneously.