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Coupling a geodynamic seismic cycling model to rupture dynamic simulations

Alice Gabriel (1) and Ylona van Dinther (2)

(1) LMU Munich, Geophysics, Department of Earth and Environmental Sciences, Munich, Germany, gabriel@geophysik.uni-muenchen.de, (2) ETH Zurich, Institute of Geophysics, Zurich, Switzerland

The relevance and results of dynamic rupture scenarios are implicitly linked to the geometry and pre-existing stress and strength state on a fault. The absolute stresses stored along faults during interseismic periods, are largely unquantifiable. They are, however, pivotal in defining coseismic rupture styles, near-field ground motion, and macroscopic source properties (Gabriel et al., 2012). Obtaining these in a physically consistent manner requires seismic cycling models, which directly couple long-term deformation processes (over 1000 year periods), the self-consistent development of faults, and the resulting dynamic ruptures. One promising approach to study seismic cycling enables both the generation of spontaneous fault geometries and the development of thermo-mechanically consistent fault stresses. This seismo-thermo-mechanical model has been developed using a methodology similar to that employed to study long-term lithospheric deformation (van Dinther et al., 2013a,b, using I2ELVIS of Gerya and Yuen, 2007).

We will innovatively include the absolute stress and strength values along physically consistent evolving non-finite fault zones (regions of strain accumulation) from the geodynamic model into dynamic rupture simulations as an initial condition. The dynamic rupture simulations will be performed using SeisSol, an arbitrary high-order derivative Discontinuous Galerkin (ADER-DG) scheme (Pelties et al., 2012). The dynamic rupture models are able to incorporate the large degree of fault geometry complexity arising in naturally evolving geodynamic models. We focus on subduction zone settings with and without a splay fault.

Due to the novelty of the coupling, we first focus on methodological challenges, e.g. the synchronization of both methods regarding the nucleation of events, the localization of fault planes, and the incorporation of similar frictional constitutive relations. We then study the importance of physically consistent fault stress, strength, and geometry input for dynamic rupture propagation in terms of rupture path and dynamics. On the other hand, it will provide the opportunity to compare slow earthquake akin events developing in quasi-static geodynamic model to fully dynamic ruptures in terms of coseismic displacements and stress changes.

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