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# Dynamic Rupture Models Suggest High Fluid Pressures and Low Differential Stresses for the M 9.2 2004 Sumatra-Andaman Earthquake

Elizabeth Madden (1), Iris van Zelst (2), Thomas Ulrich (1), Ylona van Dinther (2), and Alice-Agnes Gabriel (1)

(1) Ludwig-Maximilians-Universität München, Geophysics, Munich, Germany, (2) ETH Zürich, Institute of Geophysics, Zurich, Switzerland

A major challenge in understanding the physics of megathrust earthquakes is constraining the initial stress field. The close relationship between initial stress and friction and any variations in fault geometry make unique determination of these parameters difficult. In addition, evidence for low effective stresses (e.g. Hardebeck, 2015; Husen and Kissling, 2001) seem incompatible with the occurrence of large megathrust events. Here, we present a series of 3D dynamic ruptures along the plate interface that hosted the 2004 M 9.1-9.3 Sumatra-Andaman earthquake. The dynamic rupture models are performed with SeisSol, which solves for dynamic fault rupture and seismic wave propagation. Use of an unstructured tetrahedral mesh allows for a realistic representation of both the non-planar slab interface and the bathymetry. First, we compare earthquake models under conditions of high versus low fluid pressure. The model with a low fluid pressure (hydrostatic) produces rupture velocities and slip magnitudes that are much too high. The model with a high fluid pressure (near lithostatic) produces the observed average 2.5 km/s rupture speed and slip magnitudes that match the observed GPS surface displacements. This suggests that earthquakes along the Sumatra-Andaman subduction zone operate under the conditions of low effective principal and differential stresses that result from high fluid pressures. For a third model, we use conditions from a 2D seismo-thermo-mechanical earthquake cycle model representing long term deformation at the latitude of the 2004 earthquake's hypocenter. Slip instabilities that approximate earthquakes arise spontaneously along the subduction zone interface in this model. We use the stress and material properties at the time of nucleation for a single earthquake as initial conditions for the dynamic rupture model. In order to produce a reasonable earthquake, fluid pressure must exceed lithostatic near the hypocenter. Because the effective principal stresses in the earthquake cycle model decrease exponentially with decreasing depth, high fluid pressure is not required everywhere along the subduction zone interface. This suggests that earthquakes along the Sumatra-Andaman subduction zone operate under the conditions of very low effective and differential stresses near the hypocenter, which may result from high fluid pressure there. The final surface displacements for all three models are compared as preparation for future work to use them as input for tsunami wave propagation models in the context of the ASCETE project, “Advanced Simulation of Coupled Earthquake and Tsunami Events".