Geophysical Research Abstracts
Vol. 21, EGU2019-11205, 2019
EGU General Assembly 2019

Numerical modeling of earthquake rupture on thrust faults with dynamically activated off-fault fracture network

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Seismic hazard assessment rests on the distance from the rupture zone to population centers, and on the magnitude estimation. The latter is controlled by the area ruptured along the fault plane and by the amount of slip accommodated during the earthquake. While progress has been made to estimate the ruptured area, the determination of how much slip occurs during an earthquake remains a major issue in improving hazard assessment. This is particularly true for thrust events, where traditional scaling relationships between seismic moment, area and slip fail, due to lack of understanding of the fault mechanical behavior close to the surface. Thrust faults are commonly known to produce larger slip, damage and ground acceleration as the rupture approaches the free surface. Preliminary work from Gabuchian et al. [2017] supports a novel solution which simply built on the natural asymmetry of the geometry of reverse faults. Combining numerical and experimental simulations, they showed that, when propagating up dip toward the free surface, the earthquake rupture induces large deformation, especially rotation of the hanging wall, the region above the fault.

In this work, we take advantage of new numerical algorithms for dynamic modeling of earthquake rupture to describe more carefully the physical mechanisms behind the free surface effect. We use enhanced numerical algorithms for earthquake rupture recently developed by the Los Alamos National Laboratory. The numerical method behind these algorithms is called combined finite-discrete element method (FDEM) and can effectively reproduce earthquake rupture nucleation and propagation. It also captures the rich, and complex, deformation of the surrounding media, as it reproduces the dynamically activated off-fault fracture network. We first use this new numerical tool to better characterize rupture propagation on a dipping fault with dynamically-generated coseismic damage. Through a systematic analysis of case studies, we investigate the effect of the fault geometry, friction parameters and damage properties in the rupture evolution. We then use this numerical model to predict surface displacements and ground motions. These predictions will next serve as synthetic data when comparing with recorded surface deformation from past earthquakes.