3D Simulations of Earthquakes on Parallel Offset Faults with Homogeneous Stress Conditions

Kayla A. Kroll¹, Keith B. Richards-Dinger², James H. Dieterich², David D. Oglesby²

¹ Atmospheric, Earth, and Energy Division, Lawrence Livermore National Laboratory, Livermore, CA, USA
² Department of Earth Science, University of California, Riverside, Riverside, CA, USA

Several recent large earthquakes, (e.g. 2002 Mₘ 7.9 Denali, AK, 2010 Mₘ 7.2 El Mayor-Cucapah, Mx, and the 2016 Mₘ 7.8 Kaikoura, NZ events) have ruptured up to a dozen fault segments. Understanding how ruptures are able to jump across geometrical complexities is of critical importance for estimates of seismic hazard and earthquake forecasting, as earthquake magnitudes are strongly affected by total rupture length. Large event clusters such as the Landers-Big Bear-Hector Mine sequence in CA and the 2011 cluster in Christchurch, NZ are of additional concern in forecasting and hazard analysis. Here, we employ two earthquake rupture codes (FaultMod & RSQSim) to investigate the characteristics of rupture propagation (e.g. stress drop, slip, renucleation location, and jump distance) across parallel strike-slip faults with uniform initial stresses at increasingly larger offsets. We also explore the possibility that time-dependent nucleation effects inherent to rate-state friction cause individual fault segments to slip as part of a large event cluster, rather than in a single jumping rupture at larger offsets. We perform this analysis for fault systems classified by high (relative fault strength S=0.49) and low (S=1.25) initial stress states.

We show that results from RSQSim compare favorably with those from FaultMod. We find that the average slip is inversely related to offset in both simulations. However, slip is largely asymmetric in FaultMod, with more slip on the nucleating fault compared to the receiver fault. Average source and receiver fault stress drops in both methods vary considerably with larger offsets. Receiver fault renucleation locations lie within lobes of increased static stress for extensional and compressional offsets. For models with S=1.25, the maximum jump distance is ~0.5 km for both simulation methods. For models with S=0.49, FaultMod simulations jump larger offsets (~3km) than those produced with RSQSim (~2km). However, when large event clusters are considered in RSQSim, the jump distances increase and are nearly equal to those in FaultMod. These results indicate that 1) RSQSim is capable of producing ruptures similar to those of the fully dynamic simulations, 2) rupture characteristics vary as a function of offset, and 3) time-dependent nucleation allows for larger jump distances. This work suggests that large event clustering due time-dependent rupture effects should also be considered in earthquake forecasts and seismic hazard analysis.

Prepared by LLNL under Contract DE-AC52-07NA27344.