Validation of the UCSB Multi-Segment Kinematic Rupture Simulation Method Against Recorded Ground Motion for Several Events Constraints

Principal Investigator: Ralph Archuleta and Jorge G. F. Crempien
Earth Research Institute
University of California, Santa Barbara

Abstract
The main objective of this work is to determine rules to prescribe kinematic rupture models on multiple segment faults such that the generated ground motions resemble the ones reported by recordings on strong motion sensors and ground motion prediction equations (GMPE’s). As a secondary objective, we have determined that the ground motion between-events variability increases when considering multiple fault segments.

Intellectual Merit
We have proposed a kinematic rupture model to compute ground motion from kinematic rupture models with multiple fault segments. The model we validated so far is the 1999 Hector Mine earthquake.
We have also determined that the between events variability increases when multiple faults segments are numerically modeled to rupture.

Broader Impacts
The correct development of this kinematic rupture model will allow to compute ground motions for crustal fault systems with complex geometries, such as the San Andreas fault and other.

Problem Setup
The first step to compute ground motion from kinematic rupture models is to prescribe for each fault segment a hypocenter, the geometry that best represents the geologically or tectonically determined fault. In this particular research, we have chosen crustal faults that have ruptured multiple faults segments and that also complies with hopefully several strong ground motions recordings, to later compare the synthetic ground motions to the observed ground motions. After several trials, we came up with a set of rules, which we impose to prescribe kinematic rupture on several fault segments:

- First, we partition the seismic moment to scale directly with the area of each fault segment. This is not necessarily true; however, we deem this a good start to later vied the contribution to ground motion when this condition is further relaxed.
- The kinematic rupture simulation is done with prescribed correlation models. We use a von Karman model for spatial correlation, such that the slip correlation length is equal to the model proposed by of Graves (SCEC 2005), which is specified as the following:
  \[
  \text{Log}(\text{slip}_{dx}) = \left(\frac{M_w}{2} - 2.0\right) \quad \text{and} \quad \text{Log}(\text{slip}_{dy}) = \left(\frac{M_w}{2} - 2.0\right)
  \]
  over the entire fault
segments. It is important to note that the correlation length is constant and the same at each fault segment, which is magnitude dependent.

- We chose the order and rupture initiation points on each fault segment. For the case of strike-slip earthquakes, the subsequent fault segments initiate rupture at 0.5 km from the fault edge, at a down-dip distance of 7.5 km, the midpoint of a 15 km crustal faults.
- The rupture initiation on each fault segment is given by the time the rupture front of the previous fault segment takes to reach the edge, plus the time the S-waves take to reach the subsequent rupture hypocenter. For this, we need to check the rupture propagation front on each fault segment and each scenario.

Main Results

1999 Hector Mine Earthquake

Based on the 1999 Hector Mine earthquake, we modeled three fault segments (based on the work of Ji et al, 2002), which represent mainly the Lavic Lake and Bullion faults which are shown in Figure 1a. We chose to compute ground motion at stations within 50 km away from the fault segments as shown in Figure 1a. The stations we chose are Amboy, Hector, Joshua Tree and Twentynine-Palms. The computed synthetic ground motions, from 30 kinematic rupture

Figure (1): (a) In red we can see the map projections of the fault segments we considered in this preliminary modeling of the 1999 Hector Mine earthquake. On each colored inverted triangle, we show the location of very close stations to any portion of the fault segments that ruptured. (b) We show in grey lines the synthetic ground motions (response spectra) for 30 rupture scenarios at stations Amboy, Hector, Joshua Tree and Twentynine-Palms. Each colored line on the plots represents the observed response spectra at each station.
scenarios are shown win gray solid lines in Figure 1b. The colored solid lines correspond to the recorded strong ground motion at each station. There are stations in which ground motion in under and over-predicted, but overall, all observations are within the synthetic simulations.

**Between-Events Ground Motion Variability**

In Figure 2, we show the computed between-events standard deviations of response spectra (at each period) for the single fault kinematic rupture models (magenta) and the multiple fault segment kinematic rupture models (green). There is a great increase of the between-events standard deviation for the multiple-segment modeling approach with respect to the single fault approach. This is more evident for the lower than 1s periods.

**Conclusions**

We will continue the work with dynamic rupture simulations to explore moment partition, location of rupture initiation and timing for each fault segment for heterogeneous initial stress models. We will validate our ground motion synthetics with more earthquakes that ruptured several fault segments, such as the 1999 Chi-Chi earthquakes.

The between-events ground motion variability increases with the inclusion of the kinematic rupture of multiple fault segments, which we attribute to the fact that the rupture initiation and rupture jump from one segment increases the possible rupture models, which increases variability.

**References**


