LLNL-TR-687657

A Kinematic Rupture Model Generator Using Irikura's Recipe

A. Pitarka

April 1, 2016

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

A Kinematic Rupture Model Generator Using Irikura's Recipe

Arben Pitarka

Final Report

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. This is contribution LLNL-TR-687657

Introduction

In this project we developed GEN_SRF4 a computer program for generating kinematic rupture models, compatible with the SRF format, using Irikura and Miyake (2011) asperity-based earthquake rupture model (IM2011, hereafter). IM2011, also known as Irkura's recipe, has been widely used to model and simulate ground motion from earthquakes in Japan. An essential part of the method is its kinematic rupture generation technique, which is based on a deterministic rupture asperity modeling approach. The source model simplicity and efficiency of IM2011 at reproducing ground motion from earthquakes recorded in Japan makes it attractive to developers and users of the Southern California Earthquake Center Broadband Platform (SCEC BB platform). Besides writing the code the objective of our study was to test the transportability of IM2011 to broadband simulation methods used by the SCEC BB platform. Here we test it using the Graves and Pitarka (2010) method, implemented in the platform. We performed broadband (0.1-10 Hz) ground motion simulations for a M6.7 scenario earthquake using rupture models produced with both GEN_SRF4 and rupture generator of Graves and Pitarka (2016), (GP2016 hereafter). In the simulations we used the same Green's functions, and same high frequency approach for calculating the low-frequency and high-frequency parts of ground motion, respectively.

Ground Motion Simulations Using the IM2011 and GP2016 Rupture Generators

We tested the performance of IM2011 in conjunction with the Graves and Pitarka ground motion simulation method by comparing ground motions simulated with the IM2011 and GP2016 rupture models. We considered ground motion from a M6.7 scenario earthquake on a dipping strike slip fault, at hard-rock stations. The fault mechanism and rupture parameters are summarized in Table 1. The stations distance from the fault surface projection varies from about 1 km to 11 km. Figure 1 shows the fault trace and stations distribution. The rupture is bilateral and it extends from 3 to 19 km in depth.

The kinematic rupture models generated with IM2011 and GP2016, named Mod10 and S1, respectively, are shown in Figure 2. Based on the Irikura's recipe, Mod10 has two asperities. No attempt was made to select the GP2016 model that has the slip distribution closest to Mod10.

The low-frequency part (0.1-2 Hz) of ground motion was calculated using synthetic Green's functions computed with an FK method. Table 2 describes the flat-layered velocity model used in the simulations. The sub-faults dimensions used in the low frequency simulations were 0.2 x 0.2 km, and those in the high frequency simulations were 2 km x 2 km. The crossover frequency between deterministic and stochastic parts of the simulated ground motion was set at 1 Hz. Many studies have assumed that the transition between the deterministic and stochastic characteristics of ground motion occurs at 1 Hz, partly due to computational limitations in wave propagation computation. However, it is expect that for the source contribution the transition between the coherent and incoherent summation vary with magnitude. Figure 3 compares time histories of low frequency part of ground motion velocity computed with both rupture models at 16 selected stations. Figure4 compares the BB time histories of the computed acceleration. Given the fact that no attempt was made to select a GP2010 slip model with characteristics that are the closest to Mod10, the similarities between the velocity and acceleration time histories produced with the two rupture models is very good. The RotD50 spectral acceleration goodness-of-fit plots for Mod10 and S1 averaged over all 32 stations is shown in Figure 5. The largest difference between the simulated ground motions is observed in the period range 1-2 Hz. At these frequencies the details of the slip model and rupture propagation do matter, and since the slip distributions obtained with the two rupture generators are very different such discrepancy is expected. The overall favorable comparison of the acceleration response spectra on a broad period range demonstrates that IM2010 and GP2016 rupture models produce equivalent ground motions. More simulations are needed to investigate systematic differences between the two kinematic rupture generators.

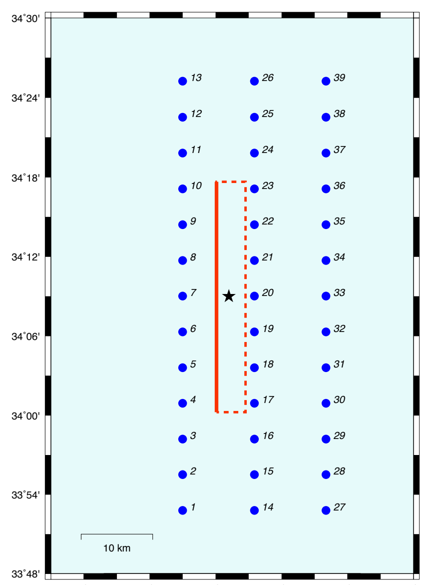

FIG.1. Map of station locations (blue circles) and fault trace (red rectangle). Star indicates the rupture initiation location projected on the free surface.

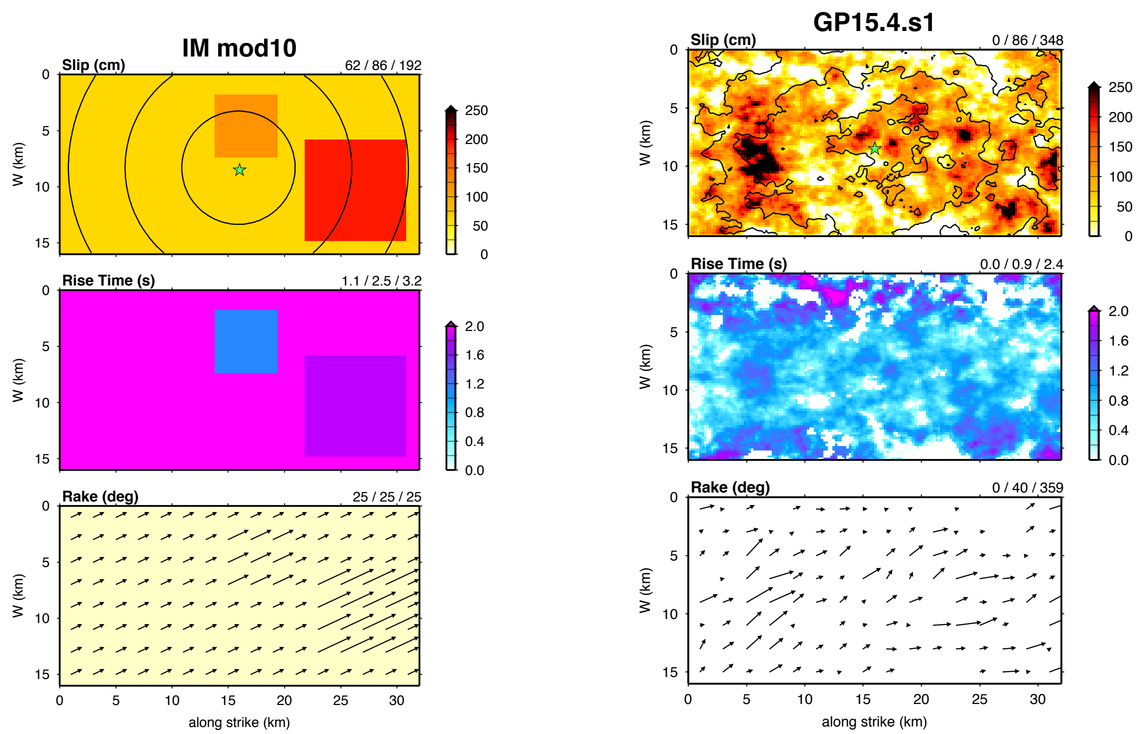

FIG.2. Kinematic rupture models for a M6.9 strike slip earthquake, produced with the IM2011 method (left panel) and GP2015 method (right panel).

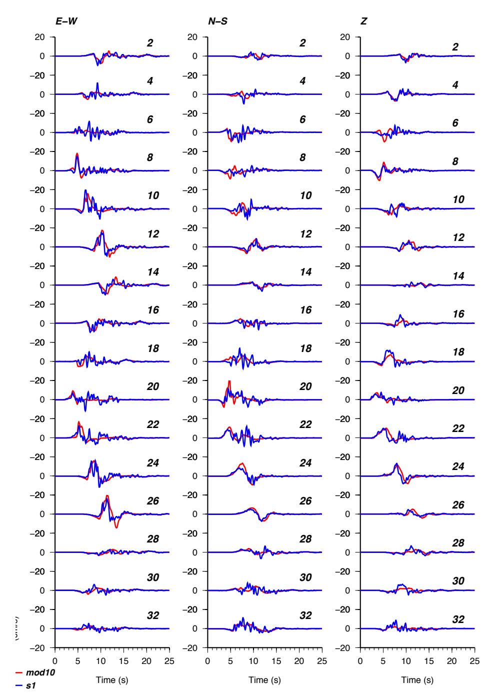

FIG. 3. Comparison of low-frequency (0-2Hz) velocity time histories simulated with the Mod10 (red traces) and s1 (blue traces) rupture models. Stations name is indicated on the left of each trace.

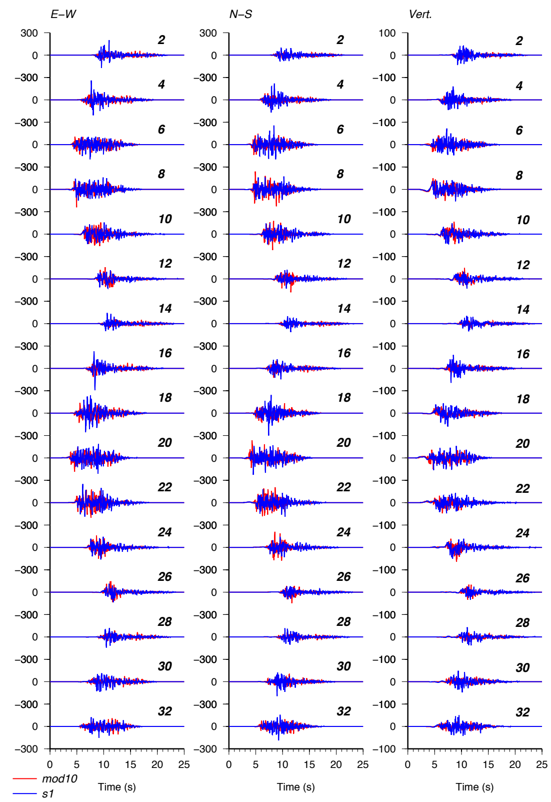

FIG. 4. Comparison of broadband (0.1-10 Hz) acceleration time histories simulated with the Mod10 (red traces) and s1 (blue traces) rupture models.

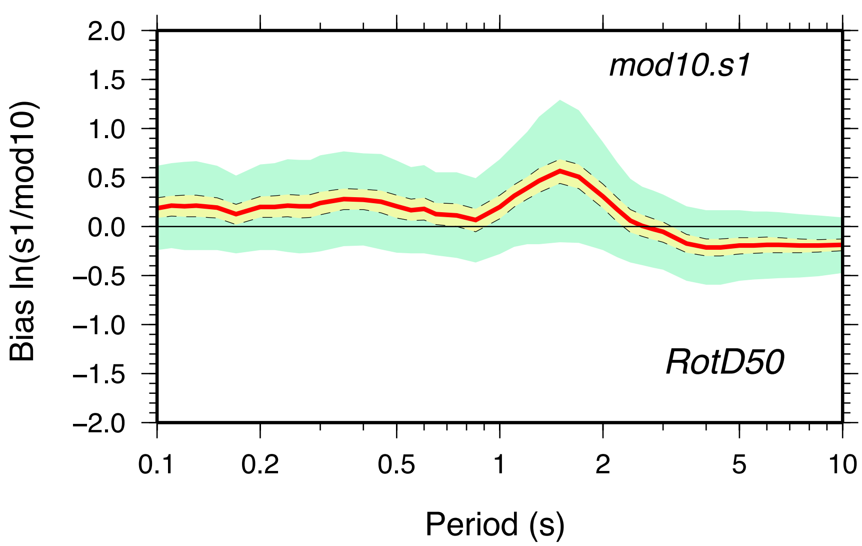

FIG. 5. Spectral acceleration goodness of fit for the M6.7 scenario earthquake simulations using the GP2015 (s1) and IM2011 (Mod10) rupture models.

TABLE 1: FAULT PARAMETERS FOR A M6.5 EARTHQUAKE RUPTURE SCENARIO

Fault Parameter	
Fault Length	32 km
Fault Width	16 km
Depth to Top of Fault	3 km
Shear Wave Velocity	3.5 km/s
Rupture Velocity	2.52 km/s
Strike	0^{o}
Dip	75^{o}
Rake	25^{o}

TABLE 2: 1D VELOCITY MODEL

Thickness (km)	**V_p (km/s)**	**V_s(km/s)**	**Density (g/cm^3)**	**Q_p**	**Q_s**
2.5	4.5	2.6	2.4	300	300
17.5	6.0	3.5	2.7	500	300
10.0	6.7	3.9	2.8	2000	1000
Half Space	7.7	4.4	3.2	2000	1000

References

IRIKURA, K, MIYAKE, H., "Recipe for Predicting Strong Ground Motion from Crustal Earthquake Scenarios", Pure Appl. Geophys. 168, (2011) 85-104.

GRAVES, R., PITARKA, A. "Broadband Ground-Motion Simulation Using a Hybrid Approach", Bull. Seism. Soc. Am., 100(5A), (2010) 2095-2123, doi: 10.1785/ 0120100057.

GRAVES, R., PITARKA, A. "Kinematic Ground Motion Simulations on Rough faults Including Effects of 3D Stochastic Velocity Perturbations", submitted to Bull. Seism. Soc. Am (2016).