Introduction

We examine a method for generating broadband ground motions for a suite of San Andreas earthquakes (Mw 6.0-8.0) using a hybrid of empirical & deterministic methods of ground motion simulations. We use finite source models from past earthquakes resampled to a 0.5 km x 0.5 km grid to generate the earthquakes. The low frequency content (< 0.5Hz) of the ground motions are generated using a wave propagation software package called SPECFEM3D. This package incorporates the regional 3D-velocity structure (SCDC/CVM-H) with its resolution enabling the software to accurately propagate waves with periods greater than 2 seconds. The results for this period range have been extensively validated in previous studies. The low frequency will be superimposed with high frequency ground motions determined using empirical green's function (EGF) approach. The basic principle involving the EGF method is generating ground motions using seismograms from smaller earthquakes (sub-events) as green's functions for a large earthquake. The high-frequency motion for a given San Andreas earthquake scenario is generated using the following steps taken to best capture the path & local site effects:

1. Seismograms from actual historic events in the magnitude range 2.5-5.0 that have occurred along the entire rupture length of the given scenario are assigned to each subfault
2. For a given analysis site of interest, the seismogram recorded at the seismic station that is closest in distance is used.
3. Each of the seismograms is scaled by the ratio of assigned sub-fault moment to the sub-event moment.
4. The effect of geometric spreading & the delay in arrival of the waves is accounted for by additional scaling and shifting.
5. The earthquake records corresponding to the rupture of all the sub-faults participating in the given earthquake scenario are combined after due scaling and shifting.

The key advances in this work are the use of rupture scenario-specific events as EGFs & the utilizing of the data from small magnitude earthquakes (sub-events) as green's functions for a large earthquake. The high-frequency motion for a given San Andreas earthquake scenario is generated using the following steps taken to best capture the path & local site effects:

Method

Our procedure for simulation of the suite of San Andreas earthquakes consists of following steps:

1. Event Selection: For simulating ground motion at a particular site (Target Station) we assign a record from historic earthquake catalogue to every subfault. The selection process is done through an automated process that best match the path between subfault and target station. (Figure 6)
2. Summation Procedure: The record from each subfault is scaled and summed such that the results are consistent with Brune's 1970 spectral scaling law (Omega Square). We will be following a new variation of empirical green's function method (EQ 1).
3. Corrections: The records used as Green’s functions are scaled by the ratio of the station-subfault distance (R) to small event-record distance (Robs) (Figure 6) to account for geometric spreading. The records are shifted in time to adjust the arrival times for cases that the EGF’s travel path is different from the subfault-station travel path. Additionally the records are shifted randomly in time to remove any periodicity that can occur due to the rupture propagation pattern.

Analysis of EGF Selection

Traditionally the magnitudes of the selected EGFs is kept within 2-3 units of the Target events. We are exploring the possibility of using lower magnitude EGFs(Mw 2-5) for simulating large earthquakes (Mw 6). This can ultimately be a better utilization of the data available in the low magnitude range for ground motion simulation purposes.

Additionally, we are studying the performance of the use of different EGFs in simulation of ground motions with the goal of answering the following questions: “Given a magnitude of target event, the location of the station and the frequency band of interest, what is the best EGF to use?” Should we be using very low magnitude events with a perfect path representation or use the EGFs from different location following questions: “Given a magnitude of target event, the location of the station and the frequency band of interest, what is the best EGF to use?” Should we be using very low magnitude events with a perfect path representation or use the EGFs from different location?

Low Frequency Ground Motion

Selection Criteria: Selected source models (Table 1) are based on finite source models inferred from past earthquakes on vertically dipping right-lateral strike slip faults (Mw 6.0-8.0)

Resampling: To ensure that the source models are capable of generating a 2s wave, they are resampled to a finer resolution (0.5 km X 0.5 km or lower).

Mapping and Directivity: The resampled source models are then mapped to 5 equally spaced segments of the southern San Andreas fault. For each location, two unilateral rupture directivities are considered (north-to-south & south-to-north).

Ground Motion Simulations

Ground motions are generated at 450 sites located on a roughly 7 km X 7 km (1/16 degree) grid using SPECFEM3D. Figure 3 illustrates the east-west component of the peak ground displacement maps for the scenarios shown in Figure 2. (Data valid for frequencies < 0.5 Hz)

Data Analysis

The ground motions obtained from our simulations are used to examine the effects of parameters such as magnitude, distance, and directivity on ground motion intensity measures.

The data are compared against well studied ground motion prediction equations (GMPE) such as the ones developed by PEER.

Figure 4, illustrates a preliminary study on the variations in peak ground velocities (PGV) against distance for Ms 7.28 earthquake (data used in this analysis are obtain from SPECFEM3D). Additionally, in the same figure we have compared the results to the values obtained from GMPE (Campbell & Bozorgnia).

Figure 5, illustrates the PGV values against Magnitude for stations located at roughly 80 km from the earthquake and the results are compared against attenuation relations.

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References

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