Annual Report, 1999

Ground Motion Validation Studies on the Southern California 3D Velocity Model

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Introduction

One of the objectives of SCEC is to develop integrated 3D velocity and subsurface structure models of the Los Angeles basin region. While there has been important progress toward this goal, there still remains significant uncertainty in the current models and hence it is necessary to validate these models and quantify the uncertainty they intorduce when predicting "scenario" earthquake ground motions. Using Version 1 of the SCEC 3D Seismic Velocity Model we have calculated ground motions in the San Bernardino and Los Angeles regions for the Landers and Northridge earthquakes, and compared the results with recorded motions.

Landers EQ

Extending on our earlier work, we have performed 3D finite difference simulations of the Landers earthquake, concentrating on the ground motion response in the near fault region, including the San Bernardino basin area. These simulations are reliable down to 2 seconds period, however, we use a denser grid mesh (0.25 km) and lower minimum shear velocity cutoff (0.5 km/s) than our earlier work.

In the near source area, the SCEC V1 model is laterally homogeneous, and is characterized by a generally smooth increase in velocity with depth. The background surface shear velocity of this model is 2.7 km/s. Our simulation uses the multiple time window, heterogeneous rupture model of Wald and Heaton, with a seismic moment of 8 x $10^2 6$ dyne-cm. The ground motions predicted with this model are generally similar to the observed waveforms; however, the amplitudes are noticeably smaller. To test the sensitivity of the response to the near surface velocity structure, we performed simulations with two alternative models. The first is a modification of the SCEC V1 model, which uses a sharp gradient in the top 2 km to reduce the surface shear velocity to 1 km/s. The second model is that used by Wald and Heaton, and has a surface shear velocity of 2 km/s with a large jump in velocity at 1.4 km depth. All three models are quite similar below 3 km depth. Both of the alternative models come much closer to the observed amplitudes. These results cannot distinguish between the sharp gradient model and the discrete layer model; however, we prefer the gradient model since it will produce much less of a wave guide effect for more distant stations. The SCEC V2 model will include a modification of the background model to more accurately represent the near surface velocity structure.

The San Bernardino basin is characterized by a sharp northern boundary which parallels the San Andreas fault (Figure 1). Sediment thickness is about 1 km throughout the basin. Currently, mainshock recordings are available at only three sites in the basin; svd, sb2a and ehos. Additional sites should become available shortly. Figure 2 compares recorded and simulated waveforms at these three sites. We have rotated the horizontal motions into components oriented perpendicular to (220°) and parallel to (310°) the northern basin margin. The 310° component shows significant amplification, suggesting preferential trapping and amplification of an SH type mode at the basin edge. The overall match to the observations is quite good at svd and sb2a, while at ehos, the simulation tends to underpredict the peak motions. Profiles of simulated motions taken along the section A-A' indicate that strong surface wave energy is created at the basin margin, particularly on the 310° component (Figure 2). The large amplitude surface waves begin to dissipate before reaching station ehos. This suggests that the basin structure may need modification (e.g., sloping bottom), in order to prolong the propagation of the edge generated surface waves.

Northridge EQ

Ground motions in the Santa Monica/West LA area were strongly amplified by basin-edge effects during the Northridge earthquake, leading to the high concentration of structural damage in this area. Graves et al. (1998) developed 2D velocity models which explain both the long-period (T > 1 sec) and higher frequency (2-6 Hz) patterns of ground motion amplification. Here, we compare the Graves model cross sections with those taken along similar profiles from the Version 1 SCEC 3D Seismic Velocity Model.

Both the Graves model and the SCEC V1 model use the geologic cross sections from Wright (1991) to provide structural constraints. The general features of the geology are captured by both models, however, more detailed characteristics, such as the location and dip of the northern strand of the Santa Monica fault are not faithfully represented by the SCEC V1 model. In addition, noticeable artifacts (vertical velocity bands) are seen in the SCEC V1 model. Once identified, these can easily be corrected using the rule based scheme.

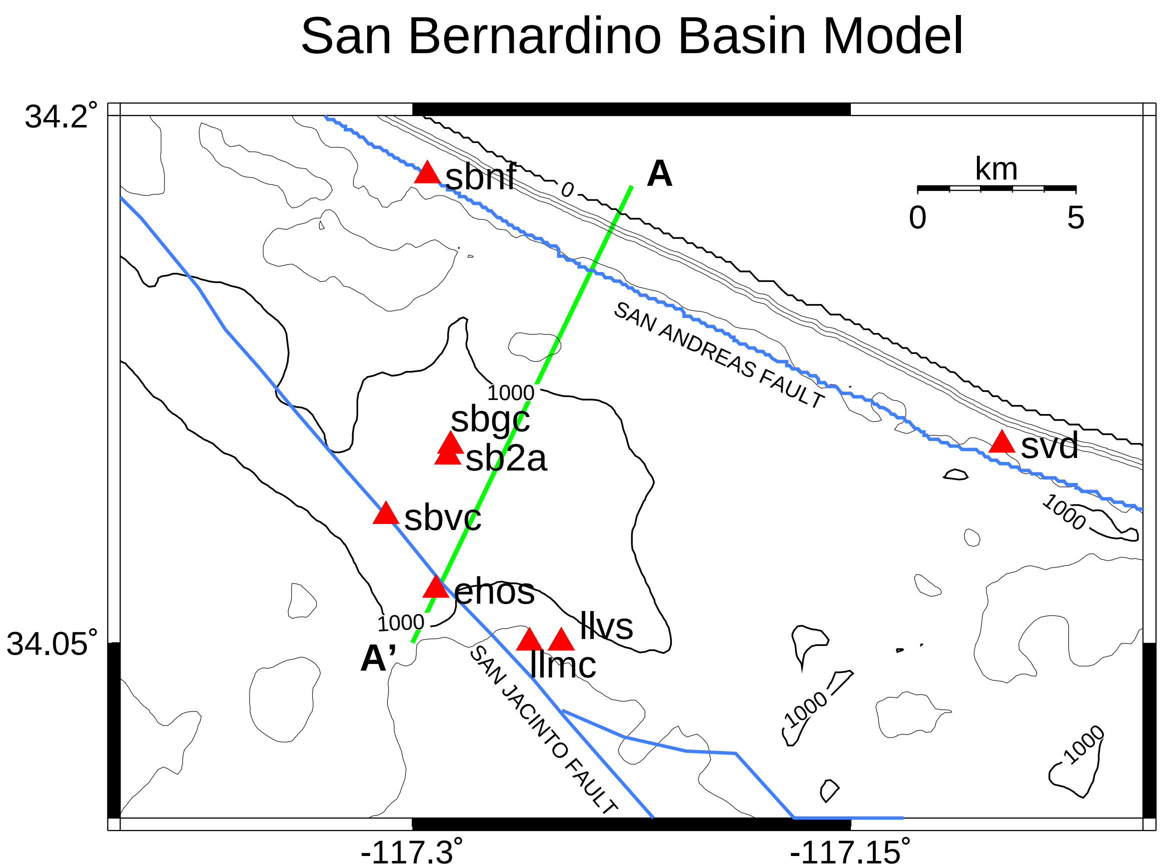
At periods greater than 1 sec, the ground motions predicted by the two models are fairly similar, and provide a reasonable match to the observed mainshock waveforms. At higher frequencies, the detailed resolution of the velocity structure becomes much more important. Figure 3 compares predicted spectral amplification factors (2-6 Hz) for the two models with the aftershock data recorded in the Santa Monica area. The data show a clear and abrupt increase in amplification for sites located at the fault scarp location. This pattern is matched quite well by the Graves model. The SCEC V1 model predicts a noticeably different pattern, with the strongest amplification occurring at the northernmost boundary of the basin sediments (2.5 km north of the fault scarp). Furthermore, along the fault scarp, the SCEC V1 model shows almost no amplification. These features suggest that 1) the seismic velocities north of the fault scarp in the SCEC V1 model are too low and 2) the geometry of the Santa Monica fault structure needs a more northerly dip (instead of vertical), which will tend to concentrate the amplification closer to the scarp.

Conclusions

One of the goals of this study is to emphasize the importance of calibration and validation of 3D earth models prior to use in ground motion estimation and prediction studies. We illustrate this is most suitably done with waveform modeling. This study has already contributed to this goal as development of the existing 3D model has taken these findings into consideration, and validation of updated models has been considered a more critical aspect to their overall development.

Publications

Graves, R. W., D. J. Wald and A. Pitarka (1999). Strong ground motion validation studies using version 1 of the SCEC 3D Seismic Velocity Model, *1999 SCEC Annual Meeting, Palm Springs, CA*, p. 64.



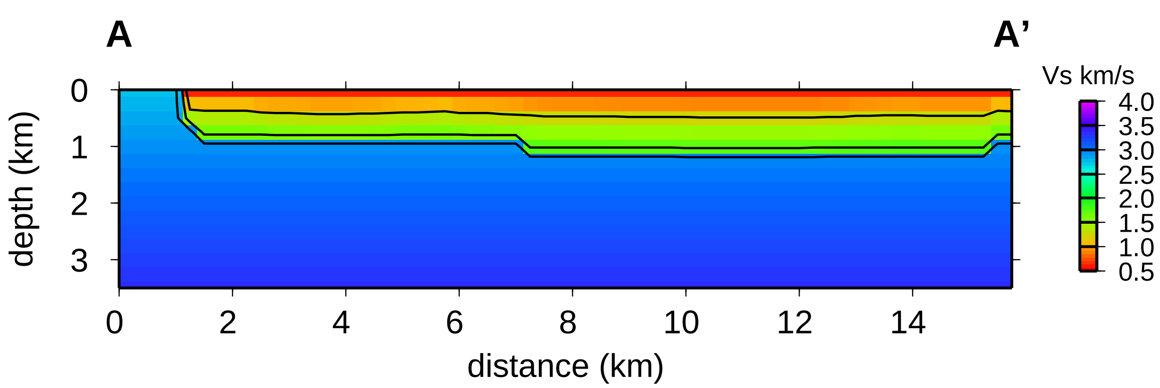


Figure 1: TOP: Map of the San Bernardino region showing strong motion stations (red triangles) which recorded the Landers mainshock. Also shown are contours of depth to basement from the SCEC V1 seismic velocity model. BOTTOM: Shear velocity cross section along profile A-A'.

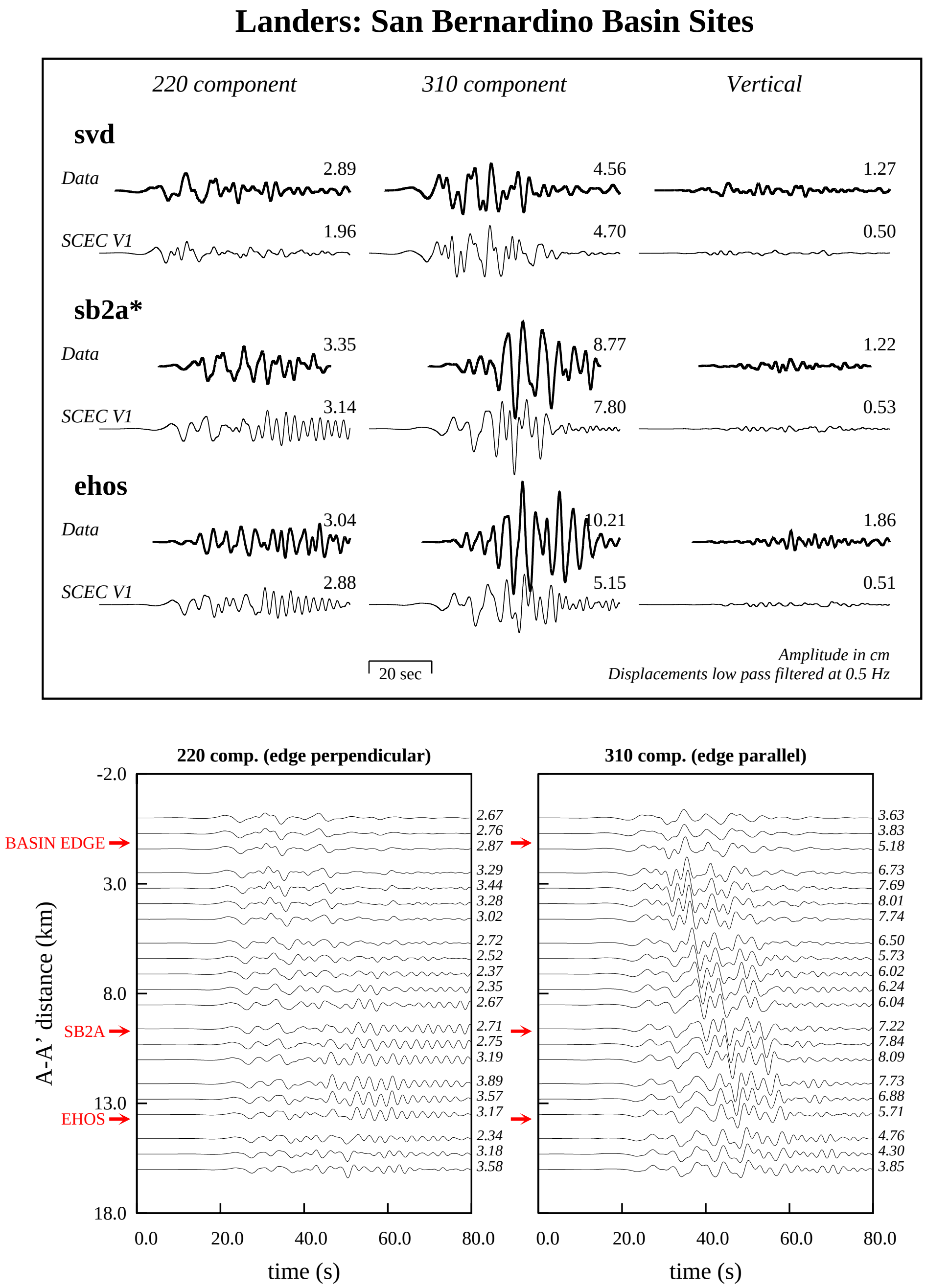


Figure 2: TOP: Comparison of observed and simulated ground displacements at San Bernardino area sites for which data are currently available. Station SVD is at the basin edge and stations SB2A and EHOS are over the deeper portion of the basin. At SB2A, the traces are aligned using the available trigger time. For SVD and EHOS, trigger times were not available, and the traces are aligned based on waveform. BOTTOM: Profiles of edge parallel and edge perpendicular synthetics along section A-A'.

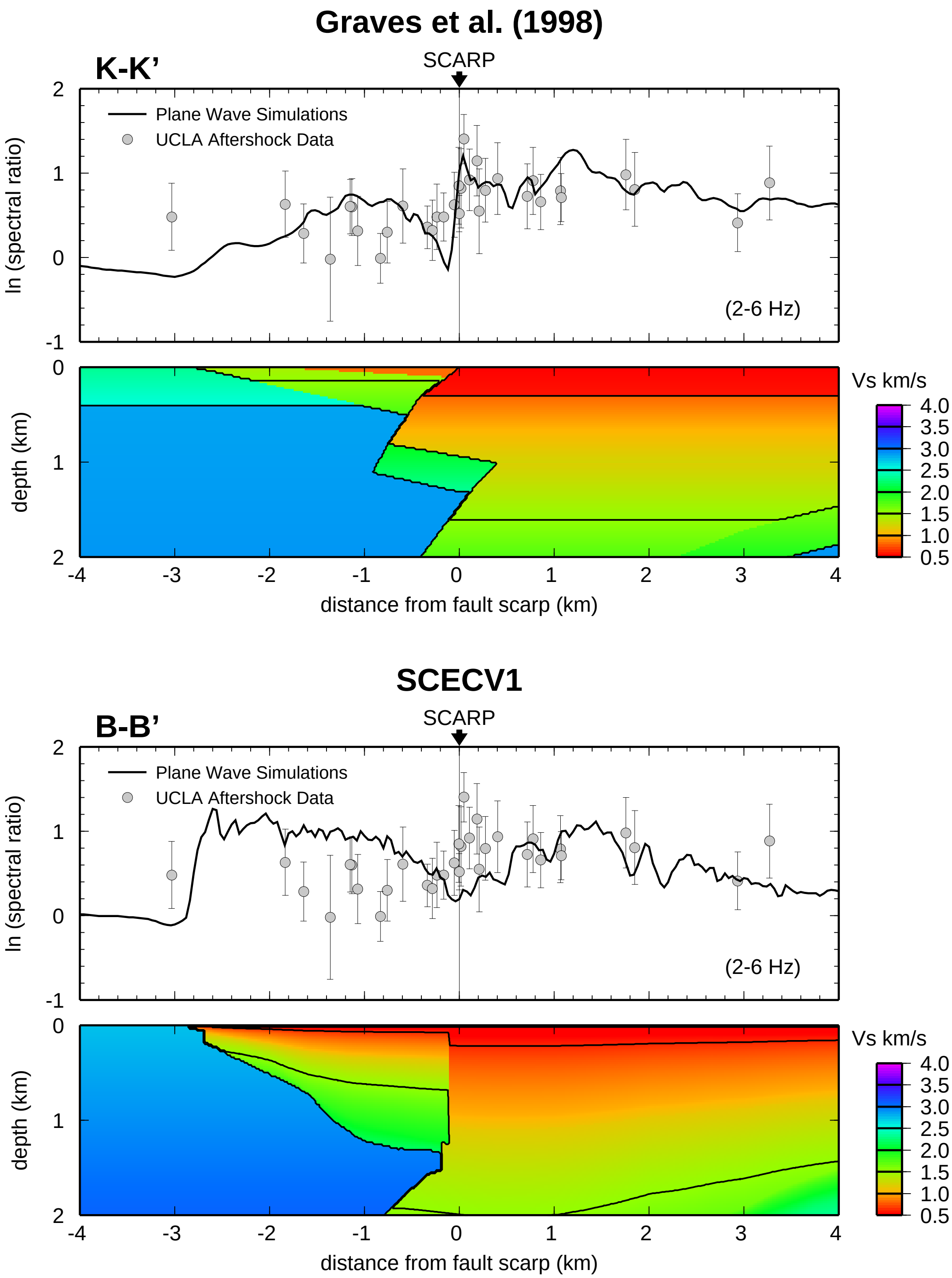


Figure 3: TOP: Comparison of observed and simulated (2-6 Hz) spectral ratios for the Santa Monica area using the Graves model (TOP) and the SCEC V1 model (BOTTOM).