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Ground Motion Modeling (PG&E, Group B)

Investigator: Dr. Kim B. Olsen, Institute for Crustal Studies, UC Santa Barbara

We have simulated 0-1 Hz elastic finite-fault ground motion for the 1979 M_L 5.9 Coyote Lake earthquake in the south Bay area, California (Figure 1). The simulation was carried out in order to plan the USGS deployment of seismic stations in the south Bay area. We used the slip distribution from slip inversion by Liu and Helmberger (1983). The earthquake was simulated in two different models, namely the 3-D crustal model developed by Brocher et al. (1997), and a 1-D (reference) model defined by the velocity and density profile of the 3-D model at a nearby rock site.

The amplification caused by the crustal model is partly controlled by the 3D basin structures, partly by site-specific impedance and resonance effects. The latter refer to the differences in velocities and densities between the two models in the area where the basin is located. To separate the contributions due to the 3D basin structure from the local amplification effects we carried out a series of 1D simulations where the models were given by the velocity and density profiles of the 3-D model. The source was a vertically-incident SH wave. We then use the distribution of 1D amplification factors as a transfer function to separate out the 3D basin effects.

Figure 2 shows the 3D/1D horizontal peak velocity ratios, divided by the transfer function accounting for the 1-D vertical wave propagation. The maximum ratio is 6, obtained above sediments just east of the southern tip of the Bay (see Figure 2). Notice how the amplification is displaced slightly to the north relative to the location of the sedimentary basins. This is in agreement with the amplification patterns from individual scenarios from the SCEC phase 3 study (chapter 4), and caused by increased ground motions in the 'rear' ends of the basins due to wave guide effects (Olsen, 1999). It is possible that the ratios in Figure 2 are overestimated due to the omission of anelastic attenuation in the simulations. A similar study for the Los Angeles basin (see progress report by Olsen, 1998) suggests that anelastic attenuation can reduce long-period peak velocities by up to a factor of two. The average reduction due to the attenuation for basin sites in the LA study was 14%.

We have also used 2-D simulations of 2-Hz elastic and visco-elastic ground motions along a profile perpendicular to the Calaveras fault (Figure 3) to estimate the effects of anelastic attenuation (see Figures 4-5). We used $Q_s = 0.1 \cdot V_s$ (V_s in m/s) and $Q_p = 1.5 \cdot Q_s$, and the minimum shear-wave velocity was 310 m/s. The main effect of the attention was to reduce the duration of the ground motions by up to a factor of 3.

As a step towards verifying the 3-D FD simulation code we have compared 2-Hz FD finite-fault synthetic seismograms from a 1-D crustal model to those from a simulation using the DWFE code (see Figure 6) as well as to data. We find a satisfactory fit between the synthetic seismograms from the two numerical methods considering differences in the source insertion procedure, and between the FD synthetics and data.

We have received three-component recordings at 40+ sites in the South Bay area for the August 12, 1998 M_L 5.4 earthquake near San Juan Bautista from Dr. Allan Lindh. We have corrected the data for instrument response and computed 2-6 hz peak velocity amplification, relative to a reference site (Figure 7). The amplification pattern, which is not corrected for distance, shows a general correlation with the basin areas, with larger amplification above deeper sediments within the basin to the northeast, while this correlation is less significant in the basin to the southwest. The amplification tends to increase towards the northeast.

References and SCEC publications

Brocher, T.M., E.E. Brabb, R.D. Catchings, G.S. Fuis, T.E. Fumal, R.C. Jachens, A.S. Jayko, R.E. Kayen, R.J. McLaughlin, T. Parsons, M.J. Rymer, R.G. Stanley, and C.M. Wentworth (1997). A crustal-scale 3-D seismic velocity model for the San Francisco Bay area, California, *EOS* Transactions **78**, F435.

Liu, H-L, and D.V. Helmberger (1983). The near-source ground motion of the 6 August 1979 Coyote Lake, California, earthquake, *Bull. Seis. Soc. Am.* **73**, 201-218.

Olsen, K.B. (1999). Site amplification in the Los Angeles basin from 3D modeling of ground motion, chapter 4 of SCEC phase 3 report, to be submitted to *Bull. Seis. Soc. Am.*

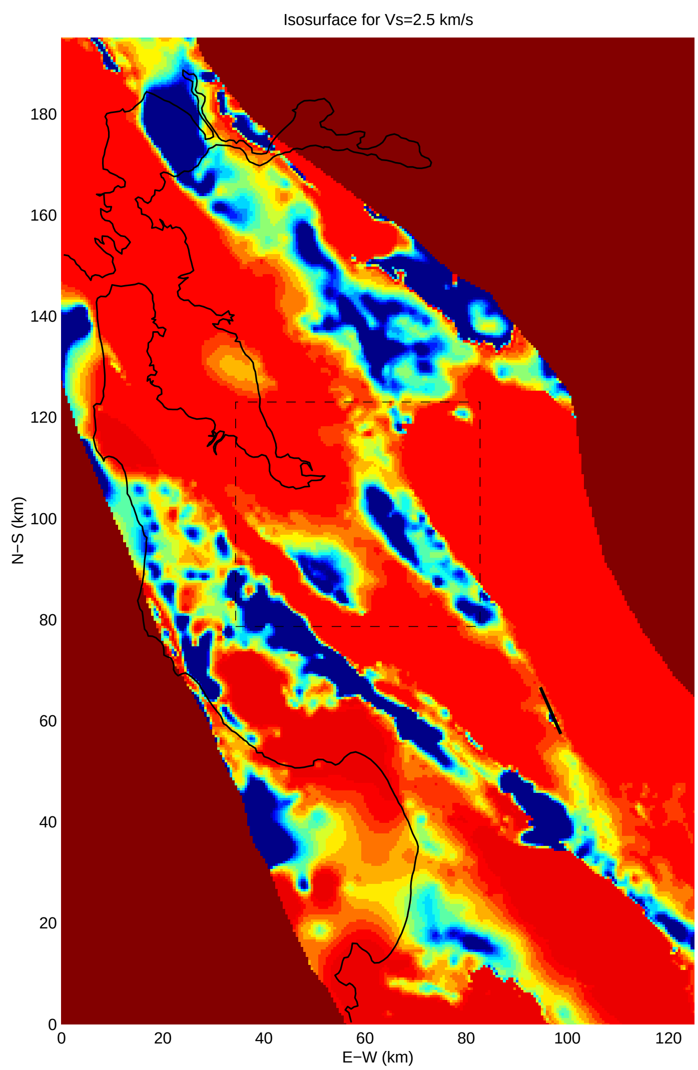

Figure 1: Image of the isosurface of an S-wave velocity of 2.5 km/s in the 3-D crustal model developed by Brocher et al. (1997). The solid line depicts the coastline. The area outlined by the dashed line depicts the South Bay area where we have simulated 3-D elastic ground motion for the 1979 M_L 5.9 Coyote Lake earthquake.

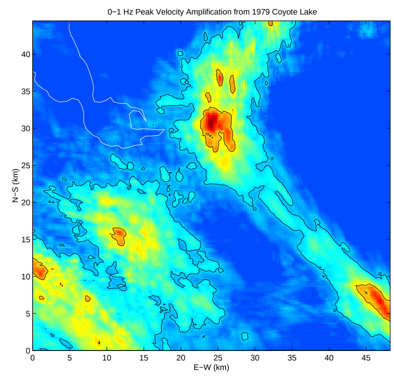

Figure 2: 3D/1D ratios of 0-1 Hz peak horizontal velocities for a finite-fault simulation of the 1979 M_L 5.9 Coyote Lake earthquake within the area shown in Figure 1. The contours represent peak horizontal ratios of 2 and 4. The ratios have been divided by a transfer function accounting for the amplification due to 1-D vertical propagation of SH waves at each site.

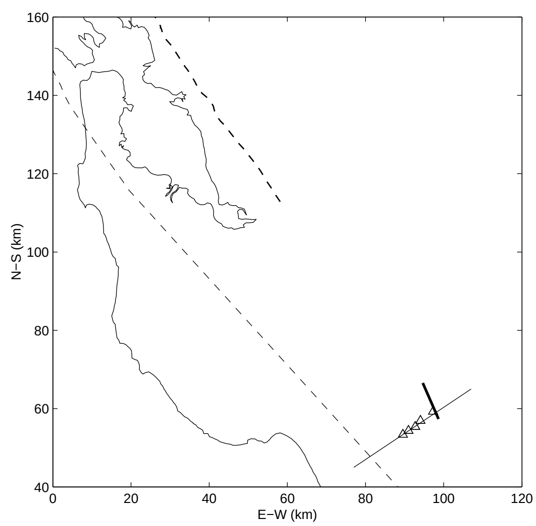

Figure 3: Location of profile used for the 2-D simulations with and without anelastic attenuation. The thick fault depicts the section of the Calaveras fault that ruptured during the 1979 Coyote Lake earthquake. The dashed lines depict the San Andreas and Hayvard faults. The triangles depict the location of the Gilroy array, from southwest towards northeast: g01, g02, g03, g04, and g06.

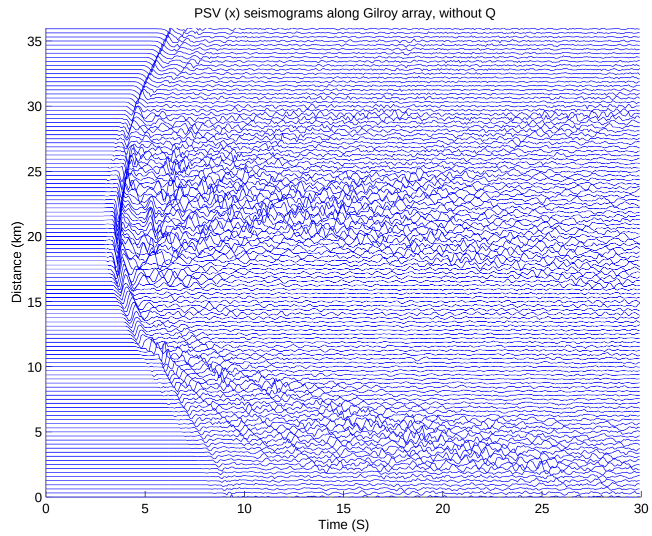

Figure 4: Horizontal component traces from a 2-D simulation along a profile perpendicular to the Calaveras fault in the crustal model generated by Brocher et al. (1997). The simulation did not include anelastic attenuation.

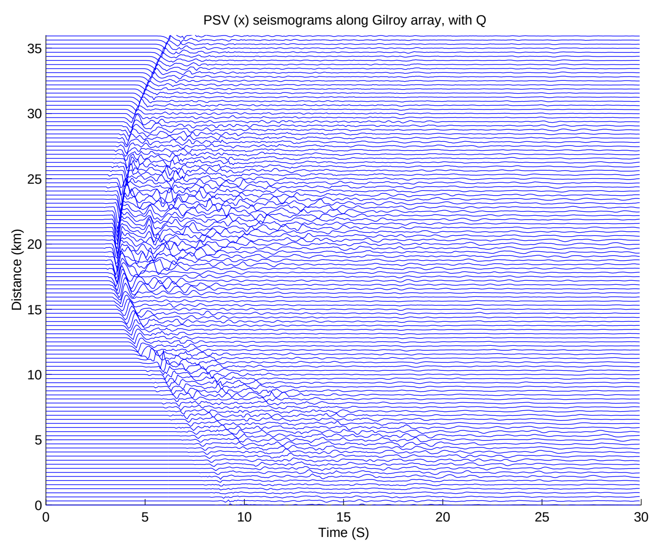

Figure 5: Same as Figure 4, but for a simulation including anelastic attenuation.

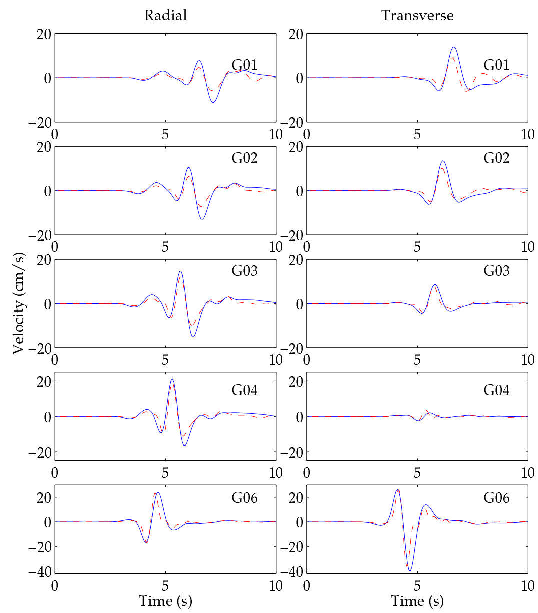

Figure 6: Comparison of finite-fault, finite-difference synthetics at Gilroy stations computed in the 1-D model by Liu and Helmberger (1983) using the finite difference method (red traces) and the DWFE method (purple traces).

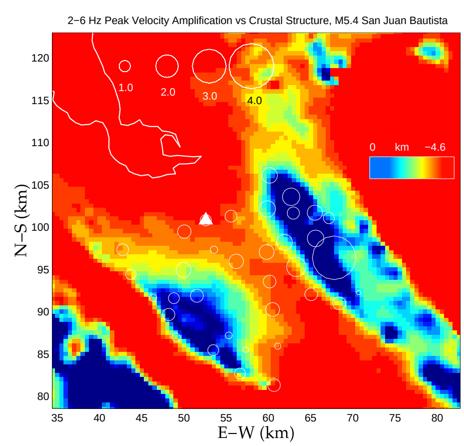

Figure 7: 2-6 hz peak velocity ratios in the South Bay area for the **M** 5.4 earthquake near San Juan Bautista. The reference station is depicted by the solid triangle. The amplification is superimposed on an image of the isosurface of a shear wave velocity of 2.5 km/s. The white contour depicts the San Francisco Bay.