Simulated Wave Propagation for the Mw5.4 Chino Hills, CA, Earthquake, Including a Statistical Model of Small-Scale Heterogeneities

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This research was enabled by the National Center for Atmospheric Research (NCAR) Computational and Information Systems Lab (CISL) compute resources. The simulation was run on Yellowstone, a 1.5-petaflops computing system with 72,288 processor cores. The entire run took 2 hours 22 minutes, and used 13125 cores with a mesh size of 3500x2500x1500.

Discussion:
As ever-increasing computational resources allow earthquake scientists to push the frequency limits of deterministic ground motion estimates higher, understanding small-scale, near-surface heterogeneities becomes paramount. The variation of the soil amplification over short distances (from tens to hundreds of meters) is important for the design of smaller structures, including lifelines. These small-scale heterogeneities may significantly affect ground motion in geologic basins, and are not included in state-of-the-art Community Velocity Models (CVMs). The density of current (and expected future) direct and indirect measurements of these heterogeneities is insufficient to capture their variation in sedimentary basins. SCEC researchers are working to improve ground motion simulations for California by developing more realistic small-scale models of the earth's near-surface structure.

We have generated statistical models of seismic velocities and densities in agreement with the results of the analysis of near-surface measurements and integrated these models into the most recent SCEC CVMs. The effects of the near-surface heterogeneities on ground motion and scattering are tested using simulations of 0-2.5 Hz wave propagation for the 2008 Mw 5.4 Chino Hills, CA earthquake in a 56 km x 40 km subset of the SCEC CVM 4.0. The 29 July 2008, M 5.4 Chino Hills, California, earthquake was the largest seismic event in the Los Angeles area since the 1994 Mw 6.7 Northridge earthquake. This earthquake was very well recorded on hundreds of seismic stations. The mainshock occurred at a depth of 14.7 km and the epicenter was located in Chino Hills, approximately 28 miles east-southeast of downtown Los Angeles. The earthquake was felt by many people throughout the Los Angeles basin and the surrounding areas, although there was very little damage. We assume a minimum Vs of 200 m/s with a grid spacing of 16 m in all directions, calculated using the finite-difference code AWP-ODC. A fractal distribution of near surface heterogeneities with a Hurst exponent of 0.1 and σ=10% is added to the near-surface sediments.

The simulation including the statistical model of the heterogeneities shows several new and interesting results. For example, the wavefield is markedly incoherent, broken up into parts of variable scales, as expected from the fractal statistics. The waves linger for more than one minute in the model area. When compared to strong-motion seismic data from the Chino Hills earthquake, the results tend to predict the duration of ground motion better than the results in the same CVM, but without the statistical model of the heterogeneities, dependent on the relations for the anelastic attenuation.

The visualization compares two simulation results showing velocity magnitude at the earth's surface for the 29 July 2008, M5.4 Chino Hills, California earthquake.

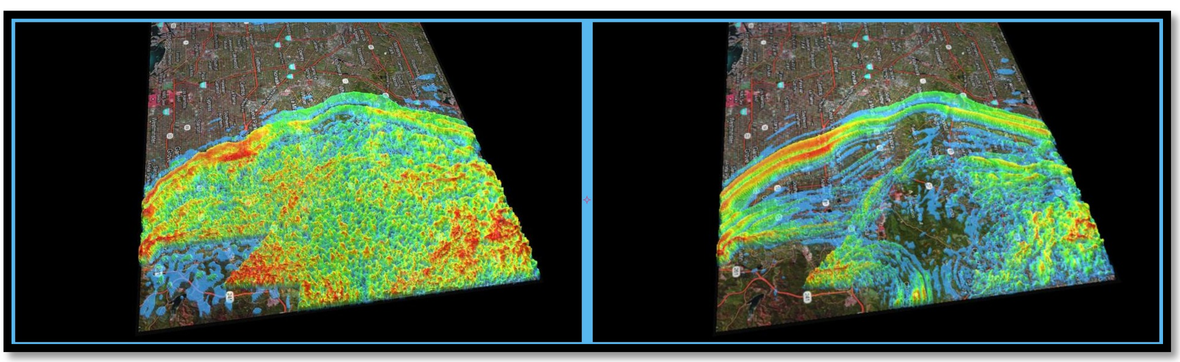

Figure 1

For the two simulations shown in Figure 1, all differences can be attributed to the impact of the small-scale heterogeneities as well as anelastic attenuation. The animation on the right shows a Chino Hills simulation with unmodified SCEC Community Velocity Model (CVM-S v11.2). The animation on the left shows a Chino Hills simulation that uses a modified version of CVM-S v11.2 that contains more realistic small-scale complexities.

The animations show that the more complex velocity structure used in the left simulation, clearly impacts the ground motion distribution, the levels of peak ground motion, and the duration of shaking. The next scientific step is to compare both simulation results against observed data for this event to determine which velocity model most closely reproduces the observed ground motions for this earthquake.

Visualization Resources:

- NCAR Command Language (NCL) Version 6.1.0 [Software]. (2012). Boulder, Colorado: UCAR/NCAR/CISL/VETS. http://dx.doi.org/10.5065/D6WD3XH5
- AutoDesk Maya

Visualization Link:
http://www.vis.ucar.edu/~scheitln/AsdSC12movies/JordanASD2.1920x1080.mov