Annual Reports for SCEC3

Using seismic noise for the purpose of improving shallow S-wave velocity models (2007-2011)

Constraining the evolving architecture of the Plate Boundary Zone through 3D Seismic Velocity and Anisotropy Mapping (2007-2010, collaboration with Prof. Paul Davis at UCLA)

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1. Summary

During the SCEC3 funding period, we were funded on two projects:

(1) Using seismic noise for the purpose of improving shallow S-wave velocity models from 2007 to 2011

(2) Constraining the evolving architecture of the Plate Boundary Zone through 3D Seismic Velocity and Anisotropy Mapping, in collaboration with Prof. Paul Davis at UCLA, for the period 2007 to 2010.

For the first project, we examined seismic noise and explored various approaches to improve shallow crustal structure in the urban Los Angeles region. Our main target was to test the SCEC CVM (Community Velocity Model) based on information that can be derived from seismic noise, using 150 broadband seismometers in the region. A method to improve the upper 5 km of the crust, based on Rayleigh-wave signals in noise, was developed and applied to the SCEC CVM. The results were submitted for publication in Geophysical Journal International (Paper 1 in our publication list). This study has led to the improvement of the upper 5 km of the SCEC CVM. This is an important extension beyond shallow layer corrections in SCEC CVM because it has implications to long-period oscillations (~10 seconds) in the Los Angeles basin. It is increasingly becoming important to understand such long-period oscillations in the basin because many high-rise buildings have resonant periods near 10 seconds.

For the second project, we worked on improving our understanding on the anisotropic structure of the crust and mantle in the region. This has relevance to the large-scale tectonics in the region as tectonic stresses tend to produce specific orientations in minerals. Our group at UCSB focused on surface wave analysis and derived Rayleigh-wave anisotropic pattern that was not obtained before. The fast axes of Rayleigh waves in southern California were determined from array analysis of broadband data and were in the azimuth 110^{o}-290^{o}, measured clockwisely from north. We attach a figure after the main text (Figure S). This azimuth is consistent with the sense of collision and the shear forces that arise in the transverse ranges of southern California. The source of anisotropy appears shallow and some parts of this signal may originate in the crust, although there must be strong anisotropic structure also in the upper mantle for the depth range about 33-100 km. Its relation to body wave signals (SKS) was summarized in paper 3 of our publication list.

2. Technical Description : Report for 2011

Method and Results

We finalized our inversion procedure for the ZH ratio (Rayleigh-wave ellipticity) data, derived from seismic noise. The important points are (1) there is specific signal for basin structure in this data and (2) collection of this type of data leads us to improve the S-wave velocity in the upper 5 km of the crust.

(1) Systematic variations in ZH ratio data

The ZH ratios (Rayleigh wave ellipticity) were measured from noise data at all available broadband stations in Southern California. The results at selected frequencies are shown in Figure 1. The four panels are 0.15, 0.20, 0.25 and 0.30 Hz.

The ZH ratio data in Figure 1 (top, four panels) show features that are clearly related to shallow geological features; the results at 0.15 Hz indicate that Rayleigh-wave particle motion are mostly flat in the LA Basin, particle-motion ellipse being elongated in horizontal direction in comparison to vertical (see orange and yellow circles). These small ZH ratios become larger at 0.20 Hz and disappear in higher-frequency maps. The bottom panel (Figure 1) shows the same results (0.15 Hz) from a 3D perspective. This figure contains interpolation of data in Figure 1 (top, left) using the wavelength corresponding to Rayleigh waves at 0.15 Hz. This figure depicts a special characteristics of the basin structure, mainly related to low S-wave velocity.

(2) S-wave velocity structure : Corrections to SCEC CVM

Examples of inversion at four locations of seismic stations are shown in Figure 2. Two stations in the basin structure (LAF and STS) are in the basin and are shown at top. Two stations from outside the basin are shown at bottom (CHF and SBPX). Each station has two panels, the top for the fit of ZH ratio data and the bottom for S-wave velocity structure changes. Both LAF and STS show the minimum in the ZH ratios about 0.15 Hz and that were fit by having very slow S-wave velocity in the upper 3-5 km of the crust.

In Figure 3, we show the geographic variations of S-wave velocity model for the Los Angeles basin region. The top panel is the starting model (SCEC CVM-H 6.2) and the bottom panel is the perturbation of S-wave velocity that are required to fit our data. There are newer models in this series of CVM but the S-wave velocity in the upper 5 km is not so different and the results will not differ as far as larger scale patterns are concerned.

Some clear systematic features can be recognized in Figure 3 (0- 5km). Generally, slow S-wave velocity region defines the LA Basin (indicated by red in the top panel) and the bounds of the basin correspond to known faults; for example, the red region (the basin) is bounded by the Santa Monica fault to the north, and the Palos Verdes fault to the west. The eastern edge is not clear but the perturbation map shows a clear fast velocity zone, trending in the north-south direction at about longitude 242.2 degrees (117.8 degrees west). The perturbation map indicates that the eastern edge of the basin has sharper velocity contrast than the SCEC CVM indicates.

Overall, SCEC CVM (CVM-H 6.2) contains most important geological patterns but S-wave velocity in the upper 5 km needs to be perturbed as much as 50 percent in some regions. These changes obviously have implications to ground motion amplification, especially at the time of major earthquakes.

These results were submitted for publication (paper 1 in the attached publication list).

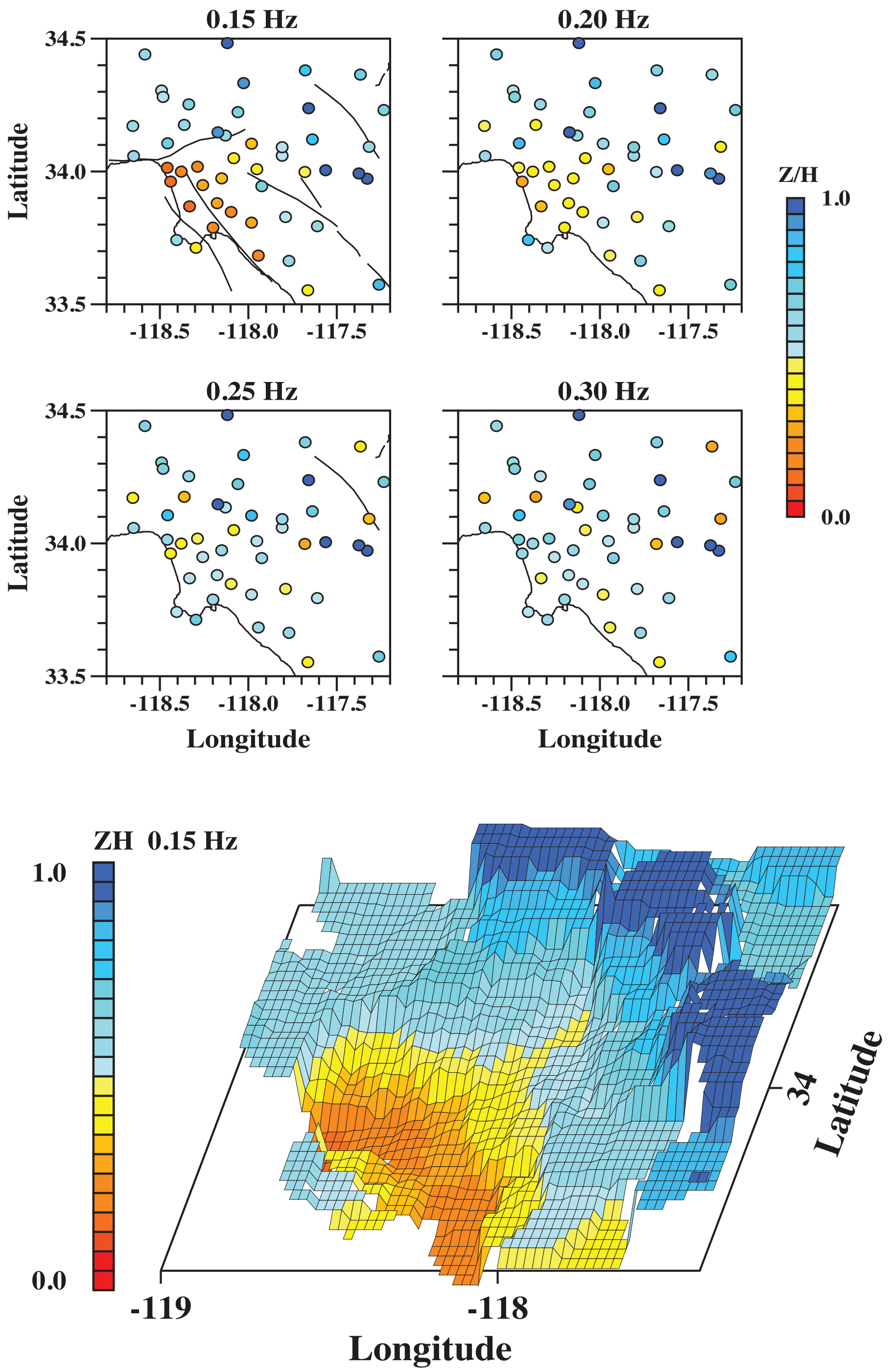

Figure 1: (Top)Four panels show the ZH ratio data at frequencies 0.15, 0.20, 0.25 and 0.30 Hz. The basin shows flat particle motions at 0.15 Hz by red and orange circles that get weaker at 0.20 Hz and disappear for higher frequencies. (Bottom) Interpolated ZH ratios at 0.15 Hz are viewed in 3D perspective. It depicts the specific feature of the LA Basin.

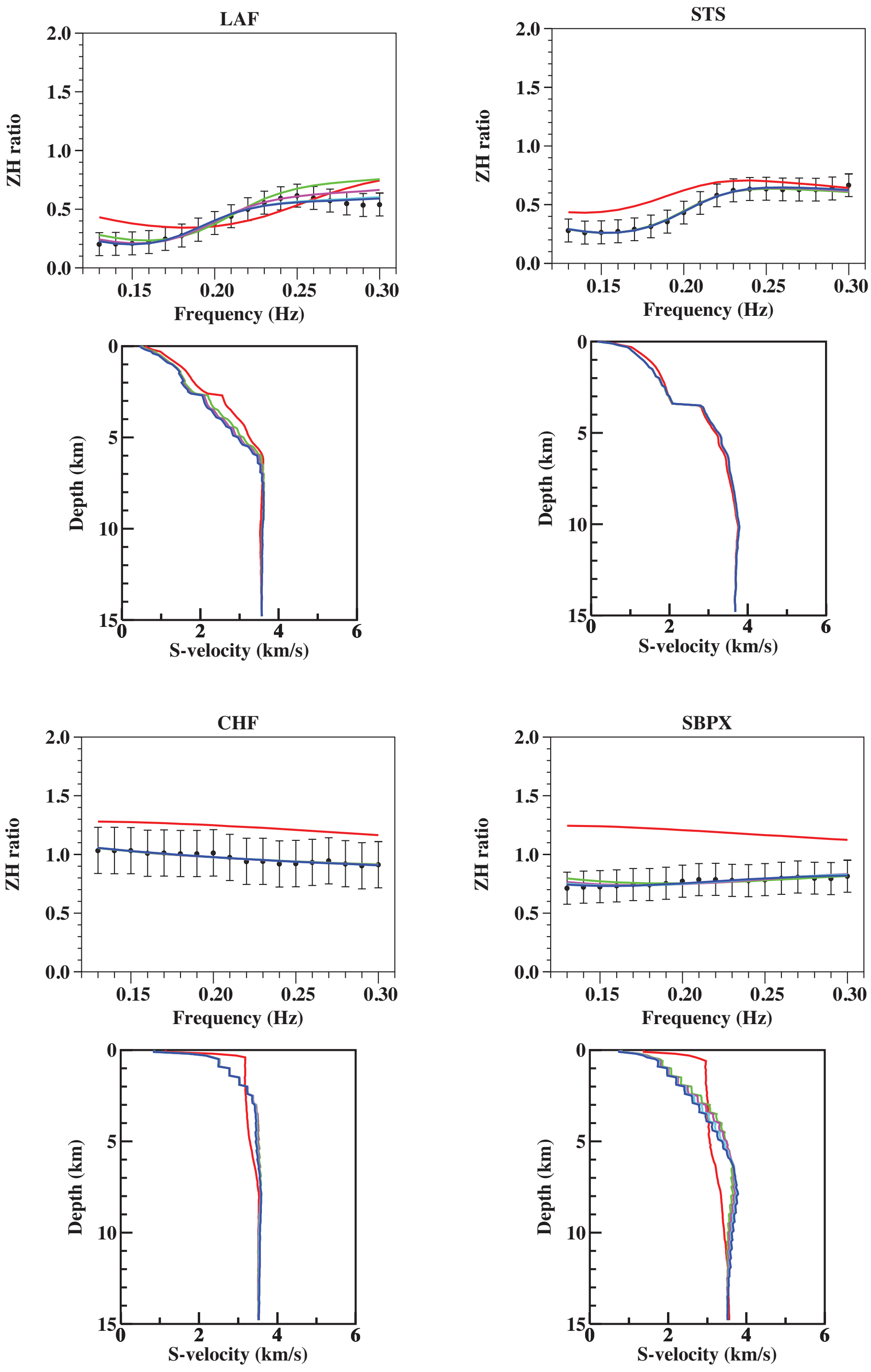

Figure 2: Example of inversion at four locations. Each case has two panels: the ZH ratio fit at top and S-wave velocity variations below it. Top two locations are in the basin (LAF and STS), both of which show small ZH ratios at about 0.15 Hz. Bottom two locations are outside the basin. Red lines are for the CVM-H 6.2, which was the starting model. Blue lines are for our final models. S-wave velocity structure in the upper 5-10 km is improved by our approach.

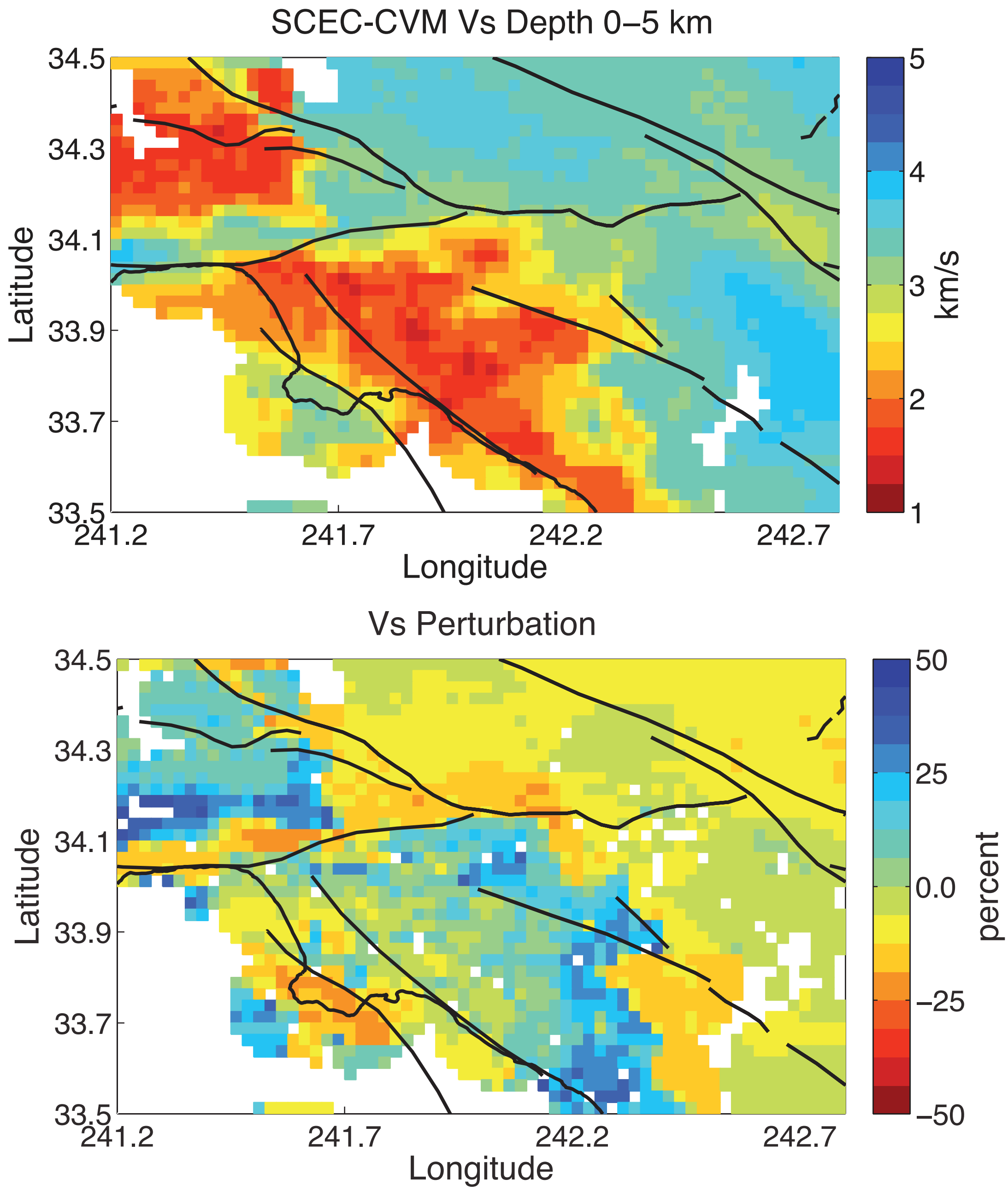

Figure 3: The SCEC CVM (top, CVM-H 6.2) and its perturbation that are required to fit our data (bottom). Average S-wave perturbations in the upper 5 km are shown. The low Vs velocity in the Los Angeles basin is bounded to the north by the Santa Monica fault and to the west by the Palos Verdes fault. Velocity perturbations in the bottom panel is such that to further enhance such features. Note that S-wave velocity in some areas need to be perturbed as much as 50 percent.

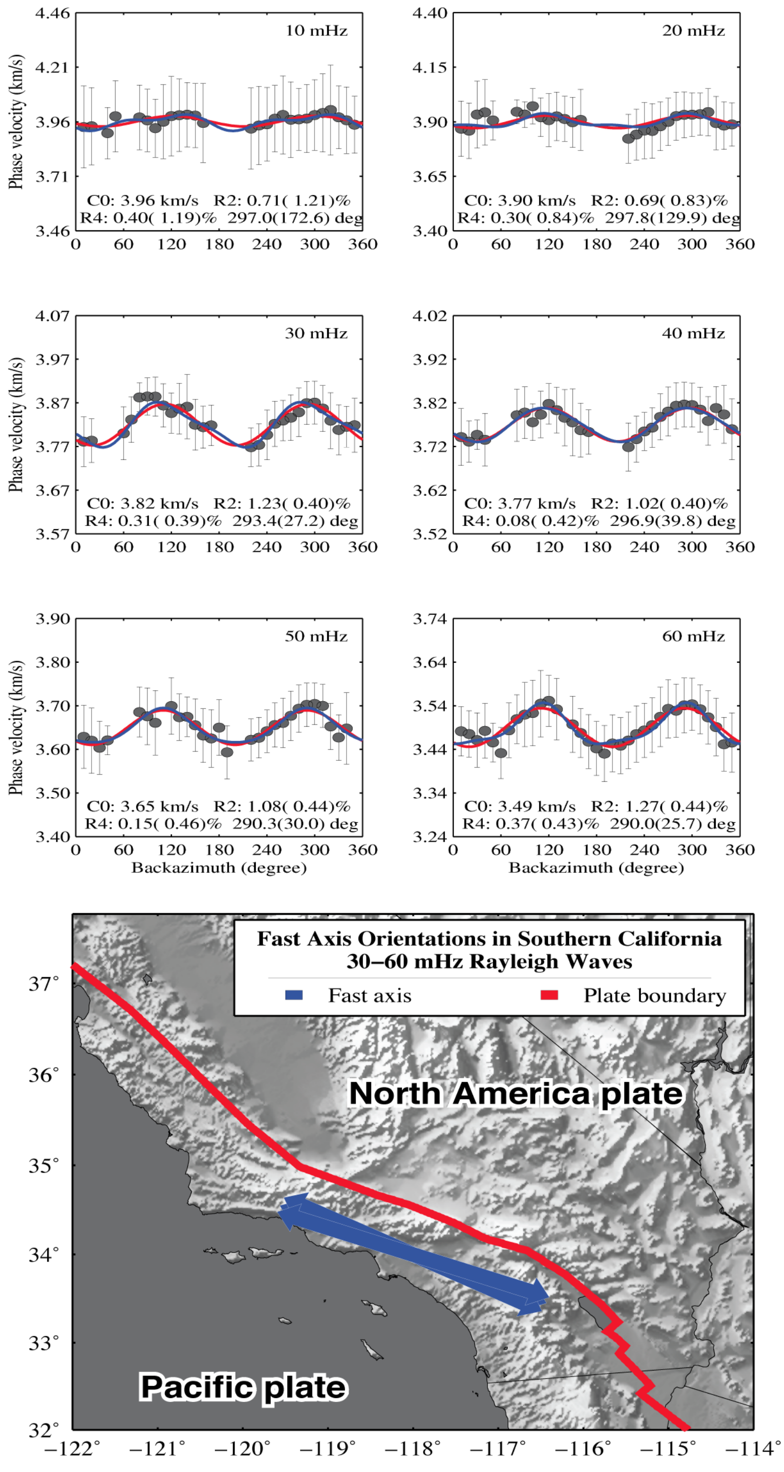

Figure S (referenced in the summary): Azimuthal anisotropy derived for Rayleigh waves in the region, based on an array analysis. Systematic fast axes are found in the azimuth 110-290 degrees from north (clockwise) for the frequency range 30-60 mHz but the size of uncertainties preclude such conclusion for lower frequency (10 and 20 mHz0 data. Fast axes directions are shown by blue lines in the bottom map. The full paper was published in Geophysical Journal International (Alvizuri and Tanimoto, 2011).

3. Bibliography (SCEC3)

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