ShakeOut and its effects in Los Angeles and Oxnard areas

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Abstract

Three-dimensional simulations of earthquakes have given a deeper understanding of wave propagation and site effects in urban regions. In this work we study the impact of a potential major earthquake on the San Andreas Fault with significant seismic hazard in the Greater Los Angeles Basin. We present results for the ShakeOut simulation—a rupture beginning near Salton Sea, California, heading 270 km northwest along the fault, that produces a Mw 7.8 earthquake in a geographical region which includes all major populated areas of Southern California and northern Mexico, in a 600 km by 300 km by 80 km volume, for a maximum frequency of 1.0 Hz and a minimum shear wave velocity of 500 m/s. For the material model, we use a discretized version of SCEC's CVM4 velocity model, called CVM-Etree. The simulation was performed at the Pittsburgh Supercomputing Center using Hercules, a finite element octree-based, parallel software developed by the Quake Group at Carnegie Mellon University. Hercules implements a highly efficient end-to-end algorithm for solving the wave field in highly heterogeneous media due to kinematic faulting. We verify our results by comparing synthetic seismograms computed with a parallel finite difference code by Robert Graves (URS) for a similar scenario earthquake, for a maximum frequency of 0.5 Hz and minimum shear wave velocity of 500 m/s. We focus our analysis of the results of the 1.0 Hz ShakeOut simulation on the Los Angeles Basin area, and the Santa Clara River Valley and Oxnard Plain. We examine the site effects present in these two areas and their proneness to capture and amplify seismic waves due to their geological features. Results show a direct correlation between the amplification levels and the local soil and basin profiles.

The ShakeOut

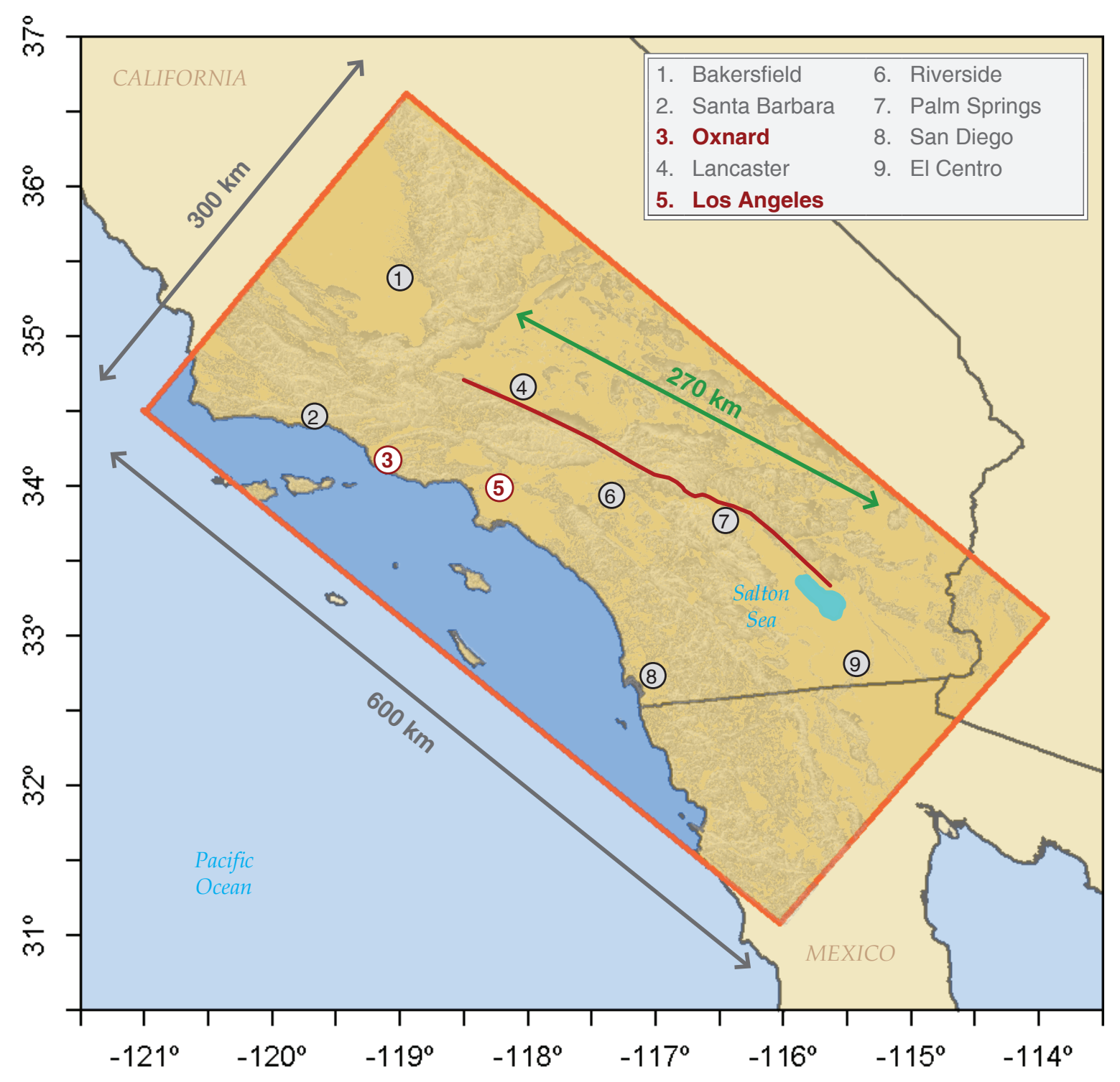

Figure 1. *ShakeOut region and fault line. Dimensions and main cities included.*

Together with SCEC and as part of the PetaSHA project, we have participated in the definition of an area of interest that covers all major cities in Southern California. Figure 1 shows the selected region and the main cities within it. Through this region pass some of the most prominent quaternary faults. Among them we have selected a portion of the San Andreas fault to simulate the rupture over an extension of 270 km, starting near Salton Sea and ending west of Lancaster, California. The rupture was defined together with a team of the US Geological Survey (USGS) in a joint effort with SCEC [1] and is shown in figure 2.

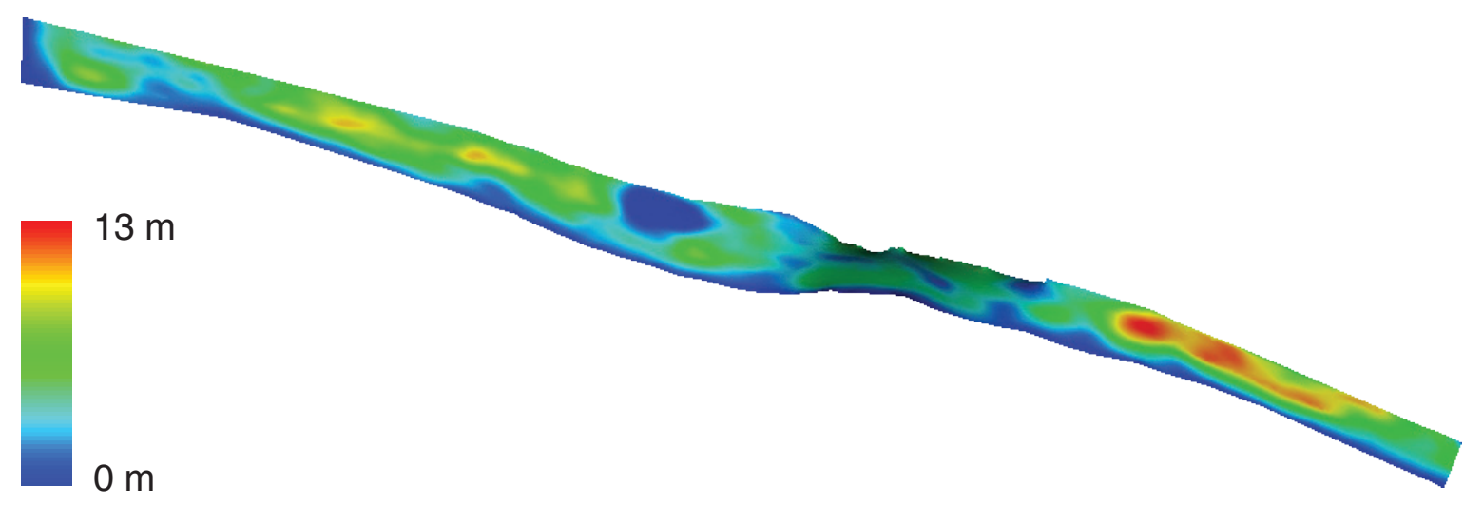

Figure 2. *ShakeOut slip magnitude.*

Verification of results

Figure 3 shows a comparison between our results and the synthetics obtained by Robert Graves [2] for a simulation of $f_{max} = 0.5$ Hz and $Vs_{min} = 500$ m/s. In general, both results agree satisfactorily. Differences arise around 60–70 s after the first wave arrival. This is around 80 s of simulation for the NSS station, 150 s for USC and 175 s for USB. These discrepancies are attributable to differences in the material model, solution method and meshes. Our results are obtained with Hercules, a finite element toolset that uses an unstructured octree-based mesh with material properties associated to the elements. Graves solves the wave field by means of the finite difference method using a regular mesh with properties associated to nodes. Both implement similar damping, but Graves acquire the material properties from SCEC-CVM4 while we used a discrete version of it, called CVM-Etree (tera1Hz.e) [3].

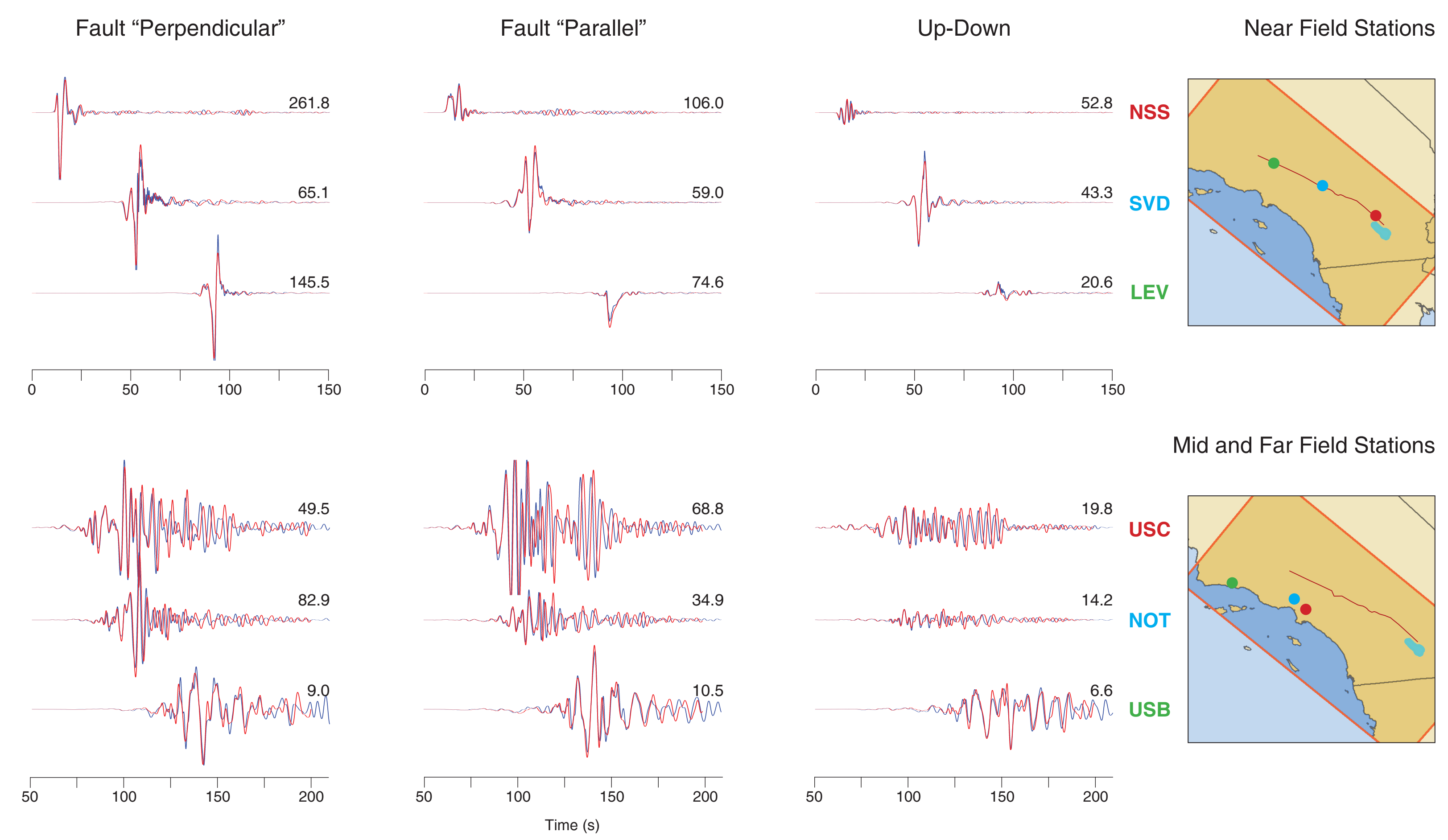

Figure 3. *Verification of results for a 0.5 Hz – 500 m/s simulation. Comparison between CMU-Hercules (—) and AWM-Graves (—) synthetics for locations in the near-, mid- and far-field. Peak values are shown on the right for each signal. Each station set is normalized to its maximum.*

Global response

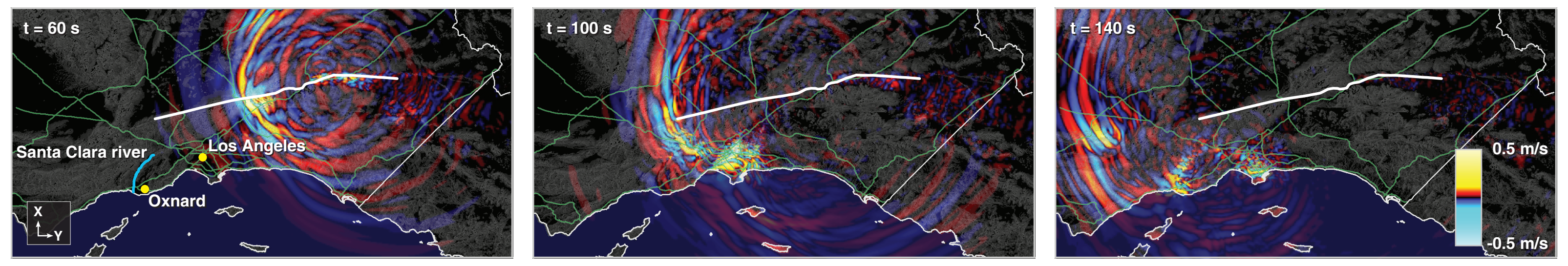

Figure 4. *Surface velocity (Y direction) throughout the region at different simulation times.*

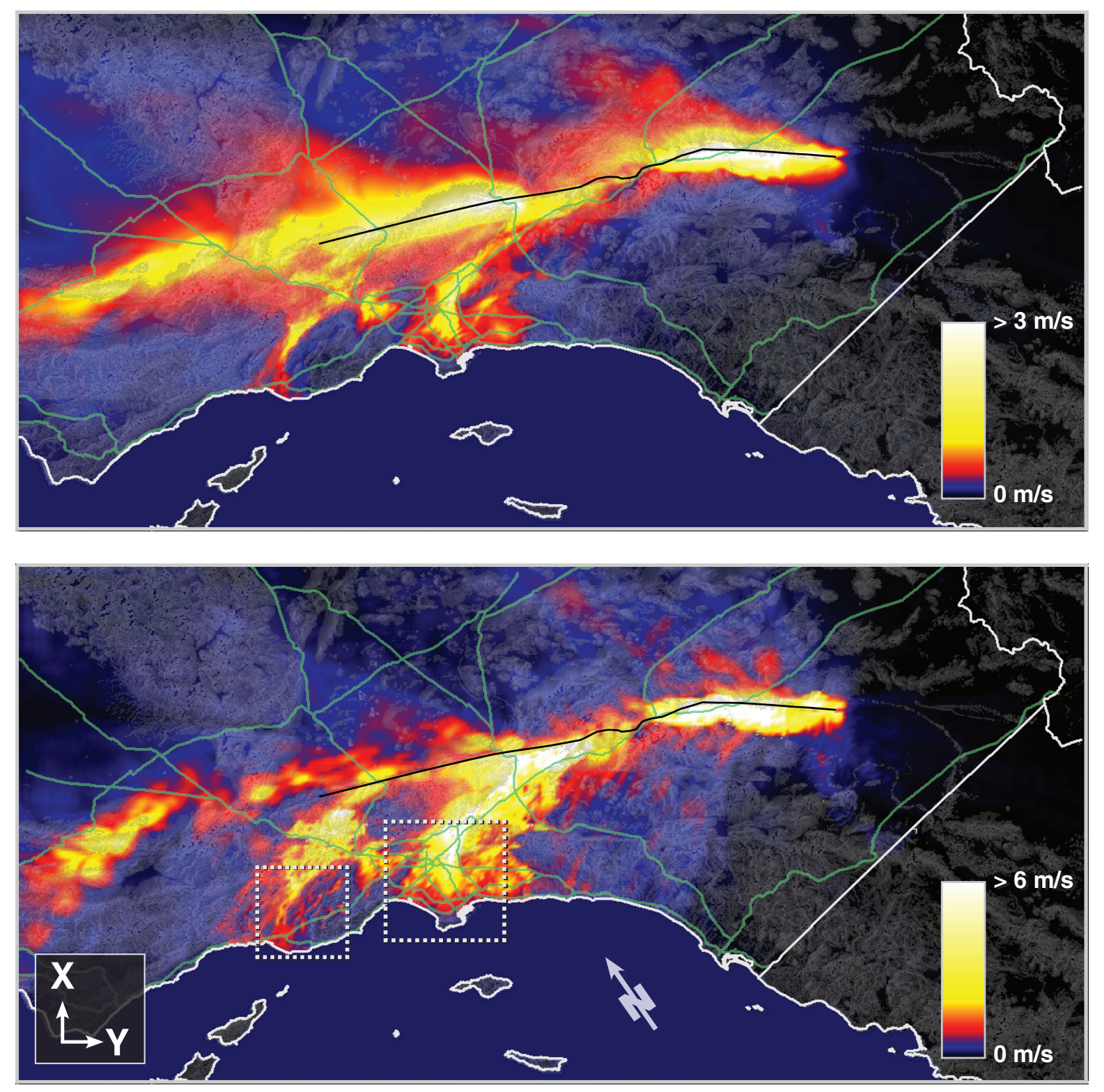

Figure 5. *Peak horizontal velocity (top) and horizontal response spectra for period T = 1.5 s in the Y direction (bottom).*

As waves travel through the region, they are trapped and amplified in basins and regions of especial geological conditions. Figure 4 shows how these phenomenon takes place in the Los Angeles basin and the Santa Clara river valley and the Oxnard plain for our simulation with $f_{max} = 1.0$ Hz. These to areas trap waves that keep vibrating after the main shock is gone. In the case of the Los Angeles area, this is mainly due to basin effects. In the Oxnard area, we believe waves are channeled by the Oak Ridge fault, which runs roughly parallel to the Santa Clara river. Figure 5 shows the peak horizontal velocity and horizontal response spectra in the Y direction ($T = 1.5$ s). Although maximum values concentrate around the rupture and extend northwest along the San Andreas fault, the local effects in the mentioned areas are visibly prominent. In the bottom part of figure 5 we have included two frames that enclose the regions of interest we explore in more detail in the next section. One can additionally identify a third smaller region of amplified response right between the two frames, it is the San Fernando valley.

Local response and site effects

Figure 6 shows in more detail the peak horizontal velocity and response spectra for the Oxnard and Los Angeles areas. Notice how the motion is amplified in the valleys. Specially along the Santa Clara river and the Oxnard plain and in the valleys between Pomona and Pasadena and Downtown L.A. and Long Beach. Also in the two small valleys north and south of Anaheim and northwest of North Hollywood toward San Fernando valley (not visible in the figure). These amplifications are clearly associated to site effects. We explore this in figure 7, which shows the surface response in the Y direction for points along a line streaming from the fault (near San Bernardino) to the Los Angeles area (ending at Santa Monica). On the right we have ploted a vertical cross section of the shear wave velocity of the material between the line. One can clearly associate the amplification of the surface response with softer soils and basin effects. Even for the case of the small basin between Fontana and Rancho cucamonga. Notice also the amplification at Monterrey Park and the lengthening of the response at Santa Monica.

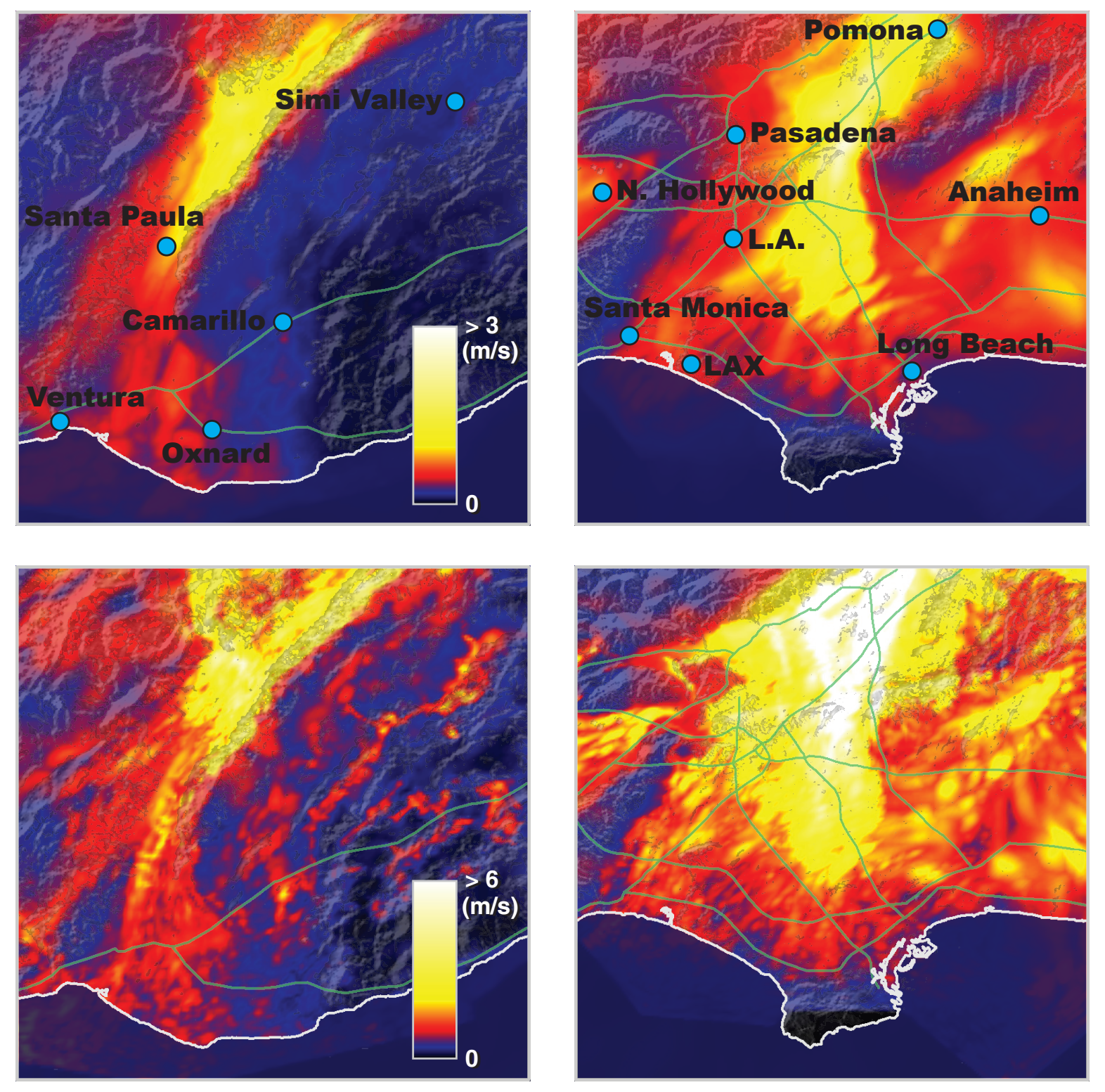

Figure 6. *Peak horizontal velocity (top) and horizontal response spectra for T = 1.5 s (bottom) for the Oxnard (left) and Los Angeles (right) areas.*

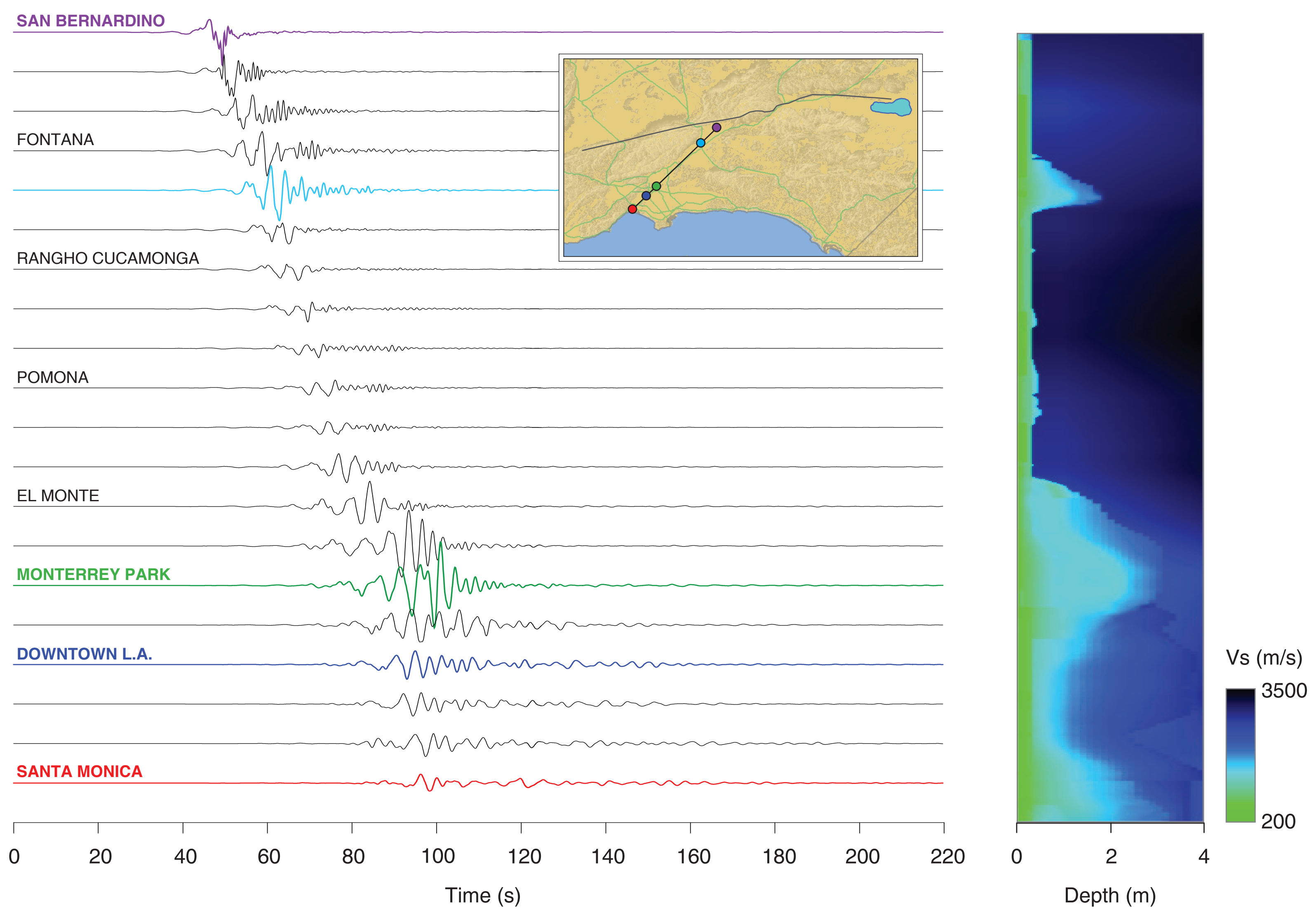

Figure 7. *Signals at selected locations (Y direction) along a line streaming from the fault to the Los Angeles area (left) and the shear wave velocity of the material on the vertical cross section along this line (right).*

References:

[1] Aagaard, B., K. Hudnut, L. Jones. SoSAFE Kinematic Rupture Model. USGS–SCEC internal document, 2007.

[2] Graves, R. Personal communication, URS, June–August, 2007.

[3] Taborda, R., J. Lopez, D. O'Hallaron, T. Tu and J. Bielak. A review of the current approach to CVM-Etrees. SCEC Annual Meeting, 2007.