Rayleigh and Love wave tomography of the western United States from ambient seismic noise using USArray

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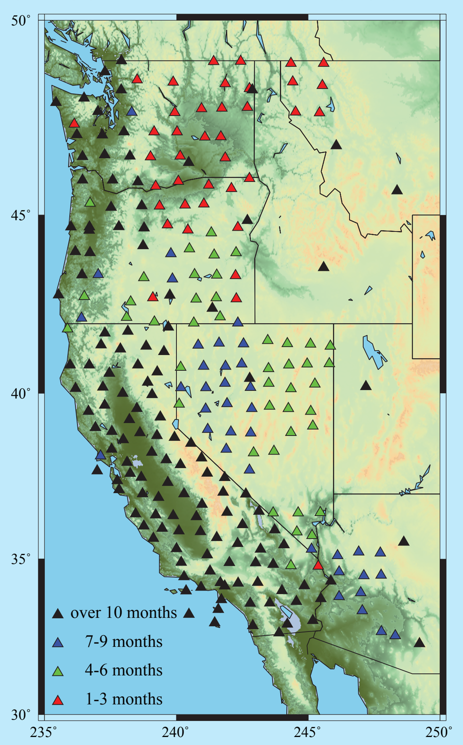
Abstract

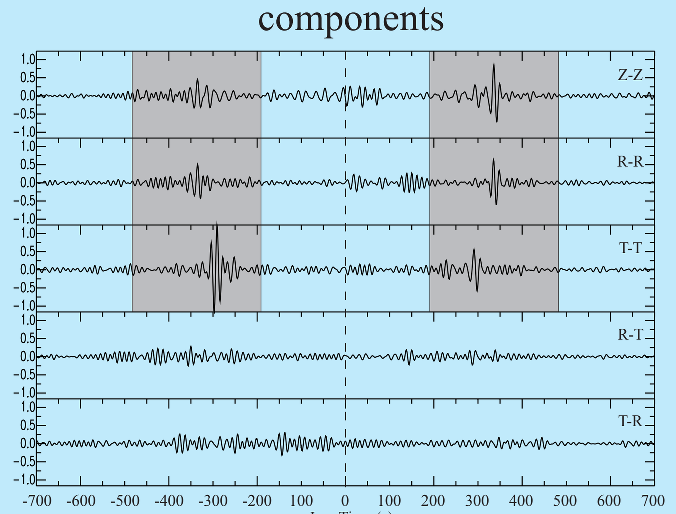
We present the current results of Rayleigh wave and Love wave tomography in the western United States using ambient seismic noise observed from the EarthScope/USArray Transportable Array and regional networks. All available three-component time series have been cross-correlated to yield estimated empirical Rayleigh and Love wave Green's functions. Phase velocity dispersion curves for both Rayleigh and Love waves between 5 and 40 sec period are measured for each inter-station path by applying frequency-time analysis and are then used to invert for Rayleigh and Love wave speed maps. The significant velocity variations observed on the short period maps suggest that it may not be appropriate to use straight ray theory in these inversions. To investigate both the off-great-circle and finite-frequency effects, we apply a 2D finite difference wave propagation simulation combined with the adjoint method. We investigate the effects on ray geometry, travel time measurement, and tomography.

The cross-correlations and the phase travel time measurements

The EarthScope/USArray stations operated between Nov 2005 and Oct 2006

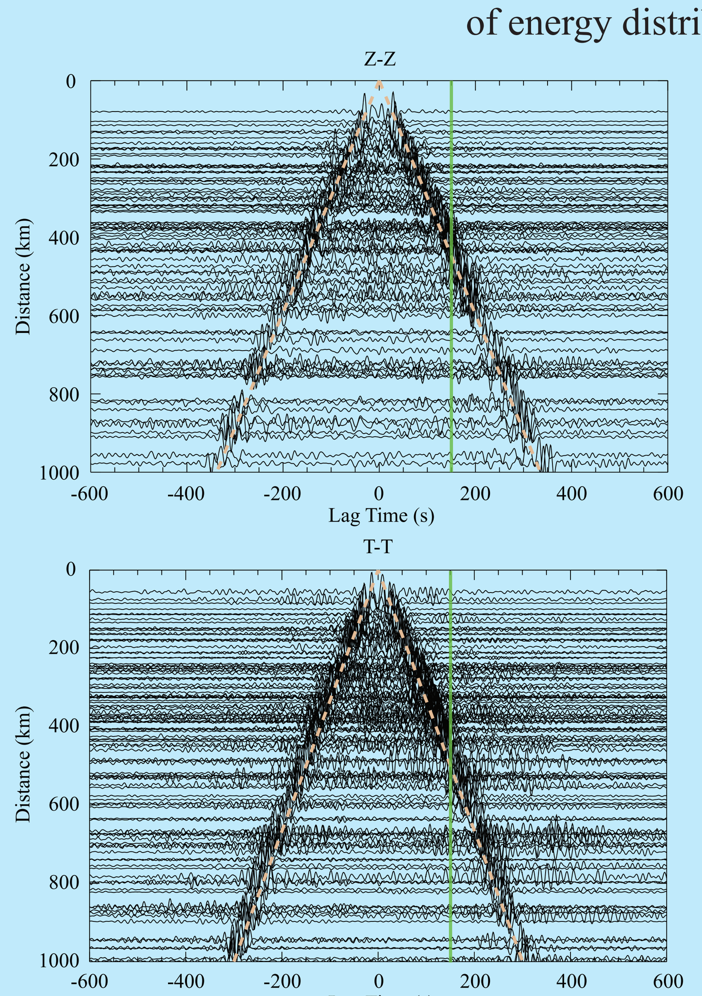


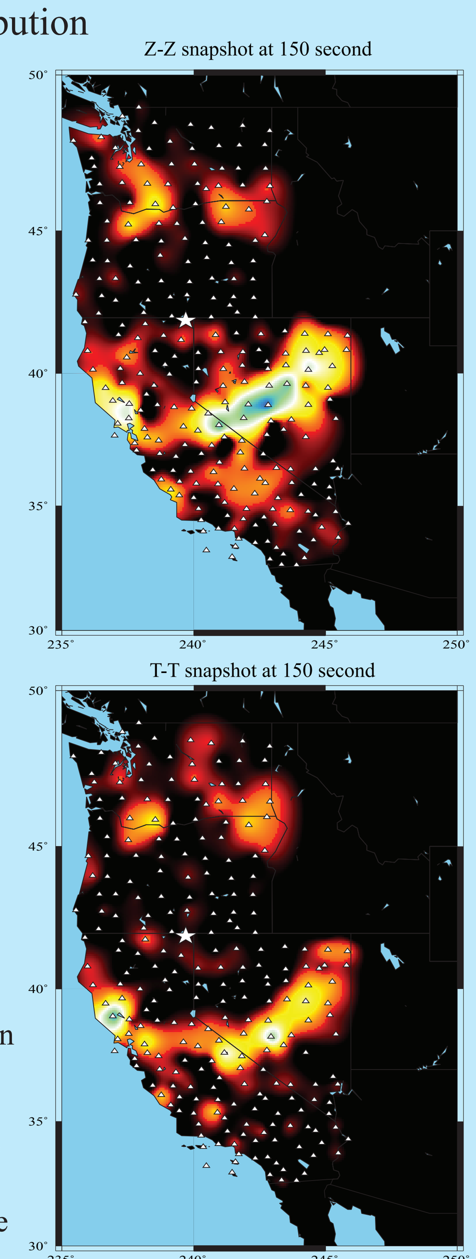
The cross-correlations between different components



The 10-25 sec band-pass filtered cross-correlation observed between two EarthScope/USArray TA stations, 116A (Eloy, Arizona) and R06C (Coleville, California). The prediction windows used for SNR analysis, defined for arrivals with velocities between 2 and 5 km/s, are marked in gray.

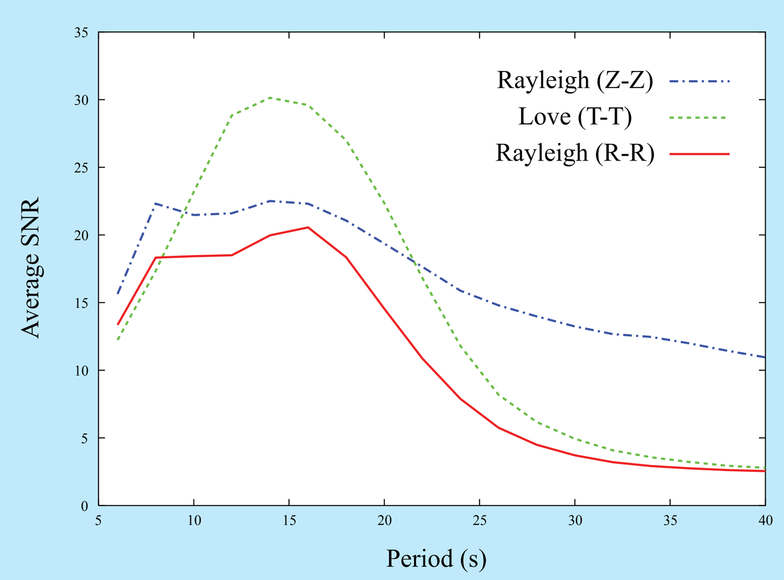
The Z-Z and T-T cross-correlation record sections and the snapshots of energy distribution





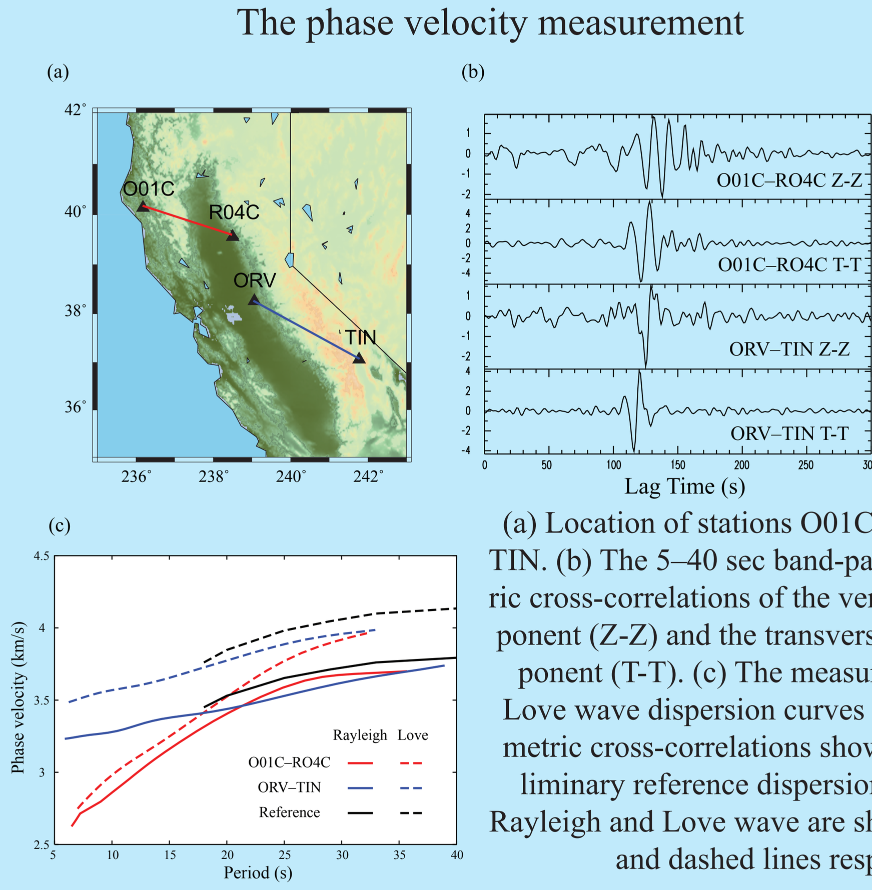
The 10-50 sec band-pass filtered record section centered at station MOD (Modoc Plateau, California). The dashed lines in Z-Z and T-T indicate the 3.0 km/s and 3.3 km/s move-out, respectively. Snapshots are constructed based on the envelope functions of the 10-20 sec band-pass filtered cross-correlations centered at MOD. A minimum curvature surface fit to the amplitude of the envelope function at the time of the snapshot at each station is applied.

The average SNR for Rayleigh and Love waves



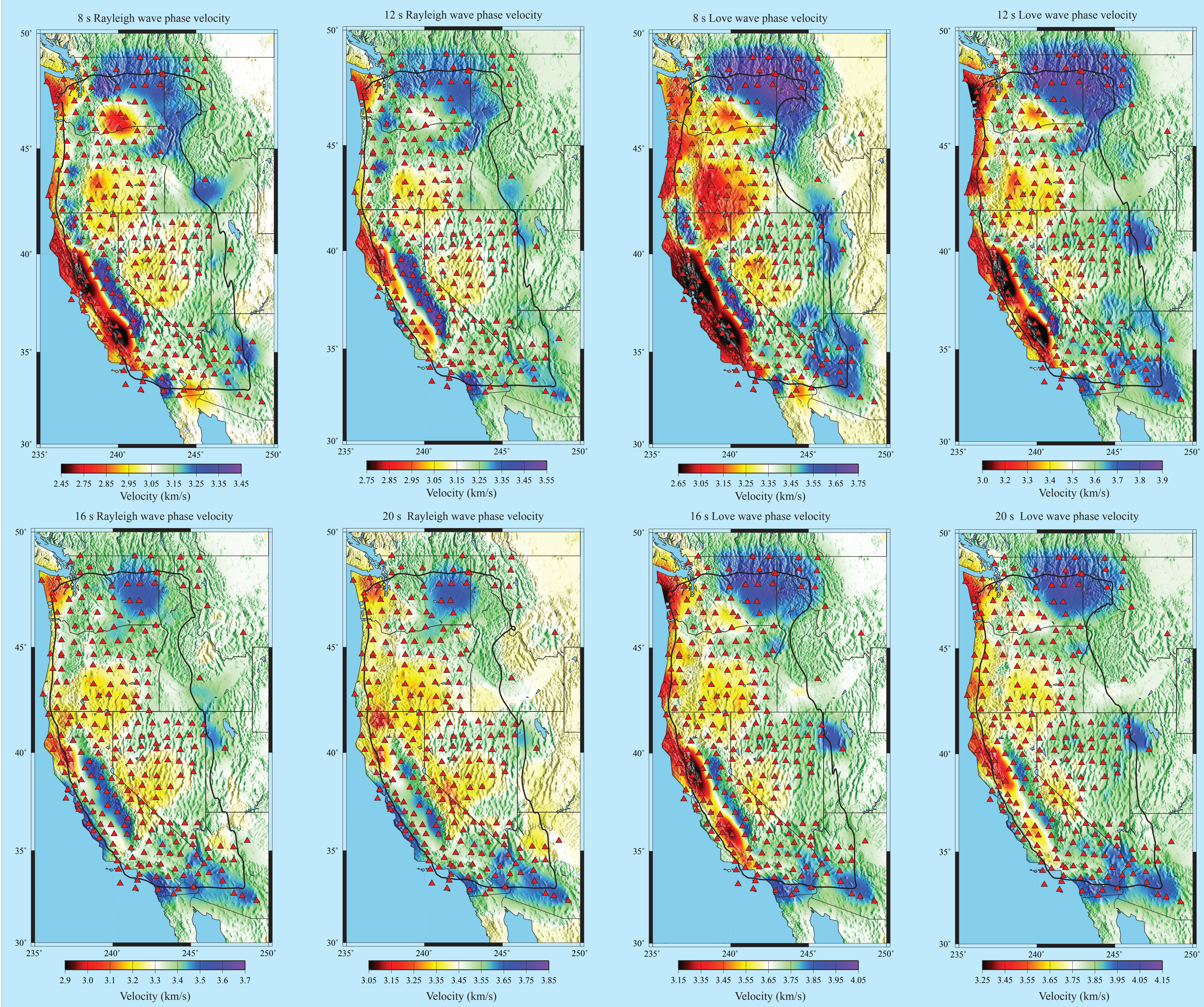
The Love wave signals are observed with higher average signal-to-noise ratio (SNR) than Rayleigh wave signals and hence can not be fully accounted by the scattering of the Rayleigh wave.

The phase velocity measurement



(a) Location of stations O01C, R04C, ORV, and TIN. (b) The 5–40 sec band-pass filtered symmetric cross-correlations of the vertical–vertical component (Z-Z) and the transverse–transverse component (T-T). (c) The measured Rayleigh and Love wave dispersion curves based on the symmetric cross-correlations shown in (b). The preliminary reference dispersion curves for both Rayleigh and Love wave are shown as black solid and dashed lines respectively.

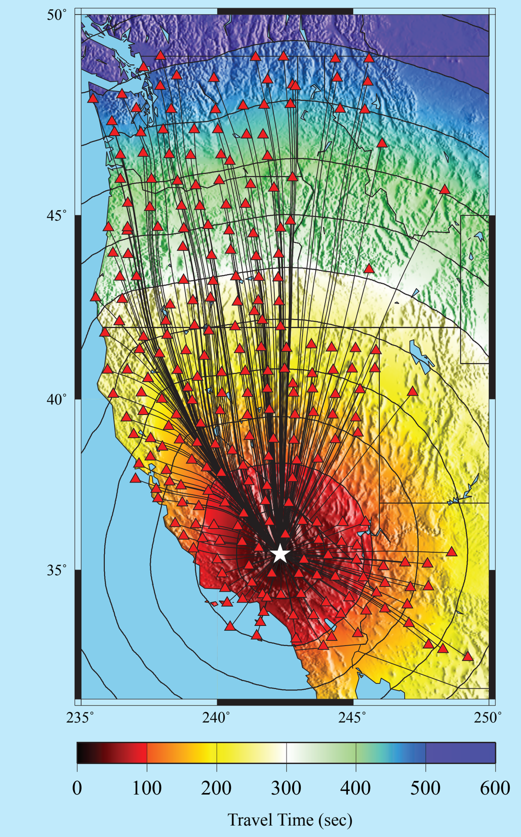
Prelimary result of straight ray tomography



The estimated Rayleigh and Love wave phase velocity maps at periods of 8 sec, 12 sec, 16 sec, and 20 sec. The 100 km resolution contour is shown for reference. The rms of the misfit travel time is between 0.9 and 1.6 second indicates good coherences of the measurements. The maps also show clear correlations with major geological structures such as the slow anomoly of the Central Valley and the fast anomoly of the Sierra Nevada.

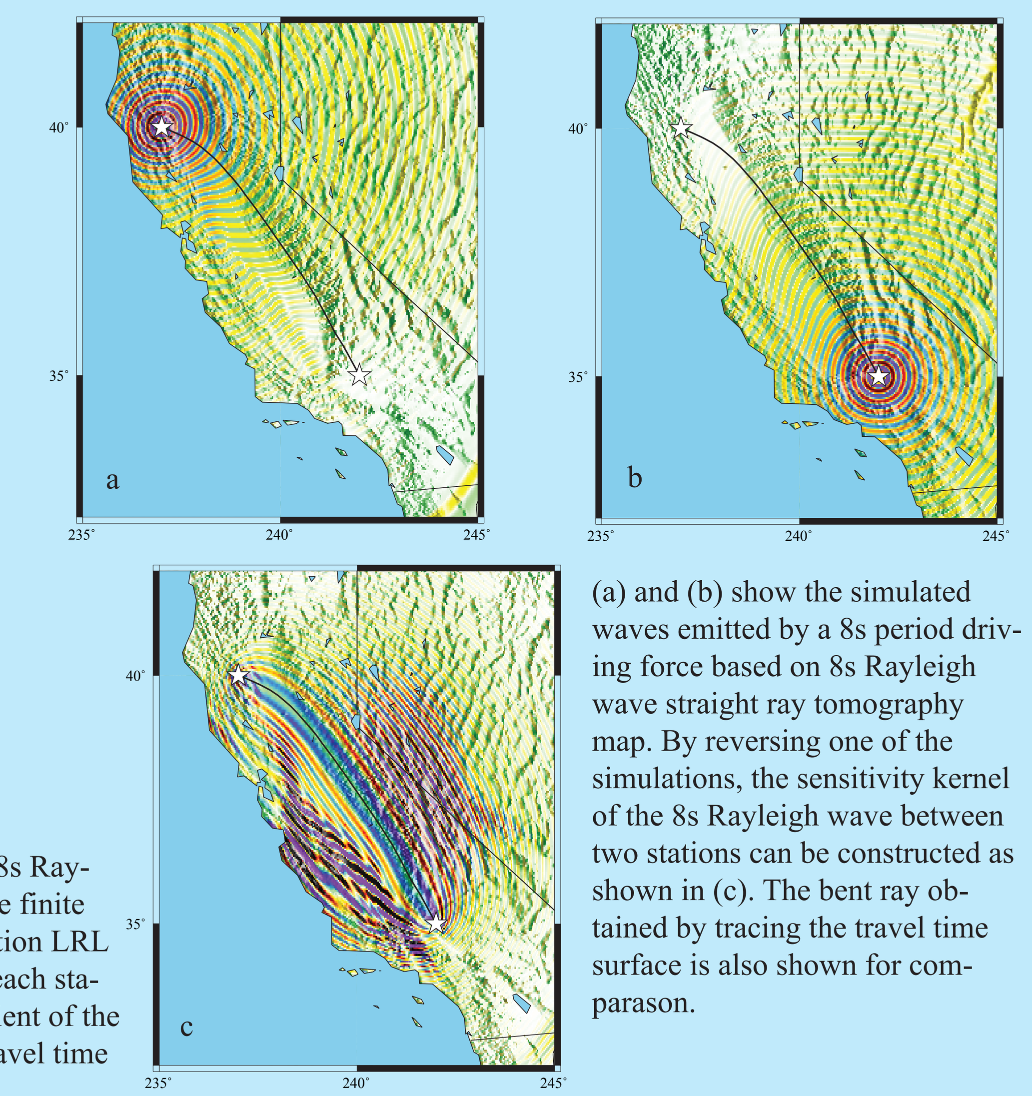
Prelimary result of bent ray tomography

The travel time map and the bent paths



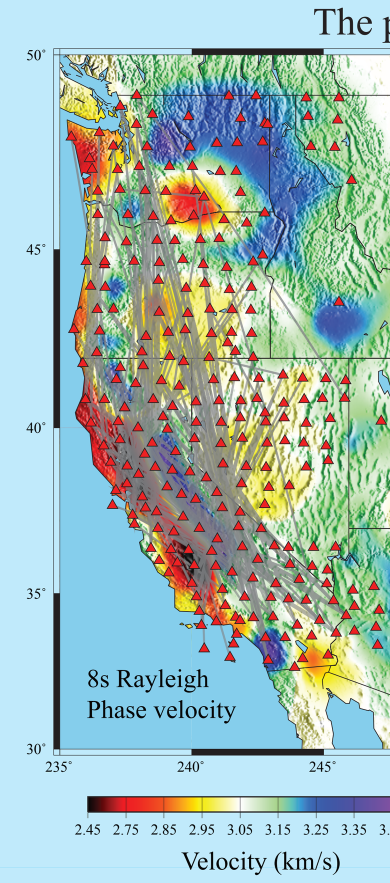
The travel time map is calculated based on the 8s Rayleigh wave straight ray tomography map and the finite difference method. An impulse is applied at station LRL at t=0 in the simulation. The bent ray between each station and LRL is determined by tracing the gradient of the travel time surface. Contours with 50 second travel time interval are also shown.

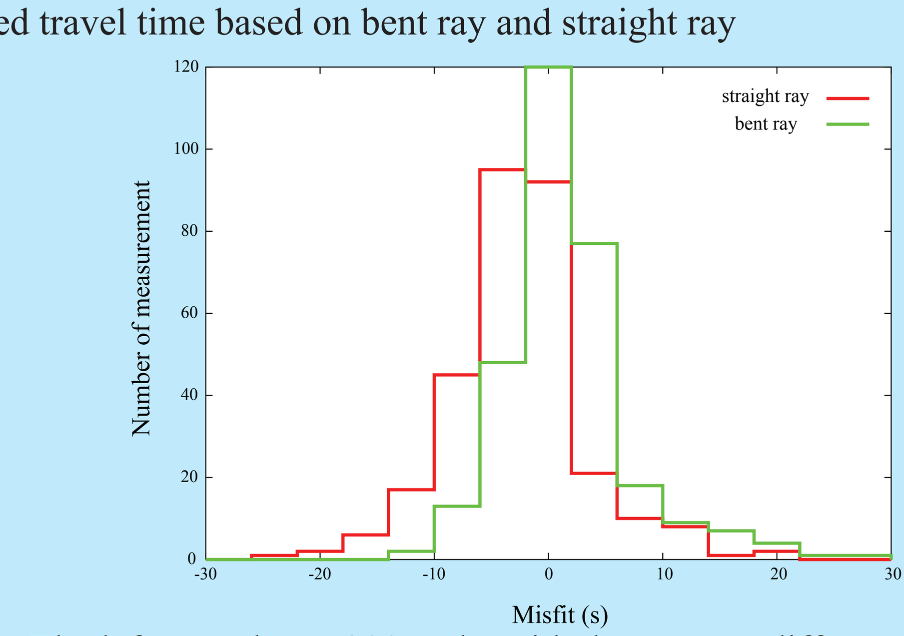
The sensitivity kernel based on the adjoint method



(a) and (b) show the simulated waves emitted by a 8s period driving force based on 8s Rayleigh wave straight ray tomography map. By reversing one of the simulations, the sensitivity kernel of the 8s Rayleigh wave between two stations can be constructed as shown in (c). The bent ray obtained by tracing the travel time surface is also shown for comparason.

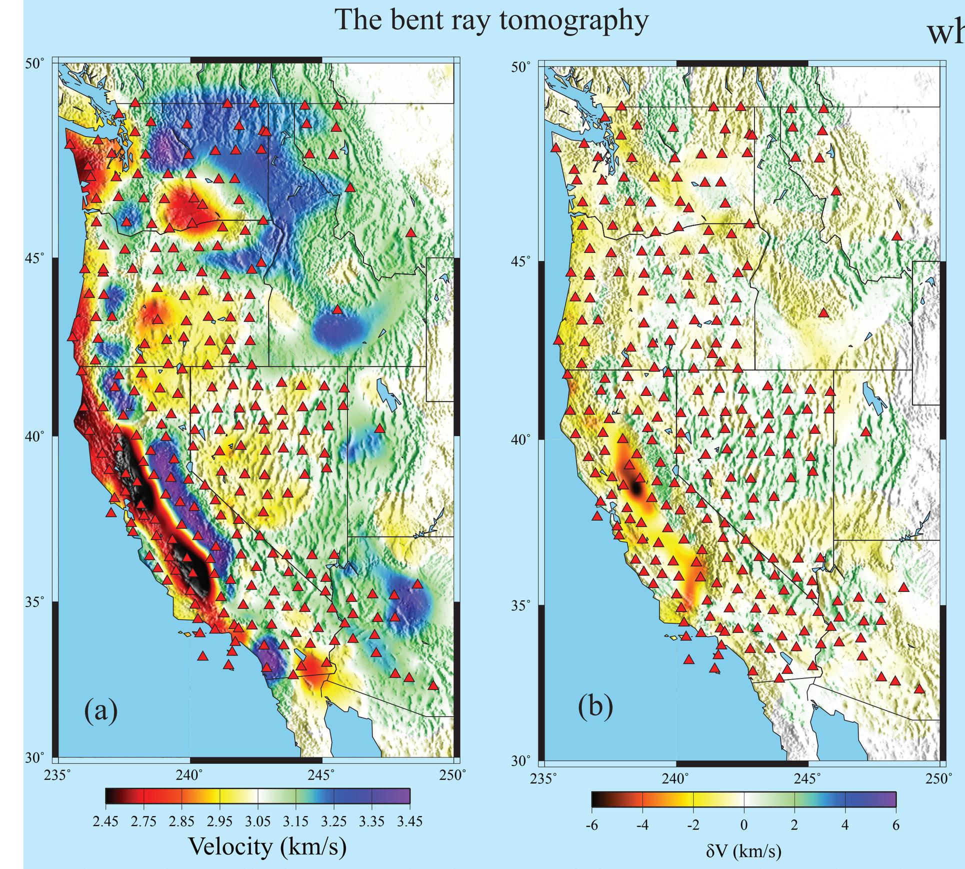
The predicted travel time based on bent ray and straight ray





The left map shows 300 paths with the greatest difference between the predicted travel time based on straight rays and bent rays. The histogram summarized the misfit between measured travel time and the predicted travel time for these 300 paths. The negative misfit for the straight ray indicates that the measured signals are consistently arrived faster than the prediction when straight rays are assumed.

The bent ray tomography



(a) shows the preliminary result of 8s Rayleigh wave speed map based on bent rays inversion. Overall it shows very similar features compared to the straight ray tomography and the rms of the misfit decreased by about 10%. (b) shows the percentage velocity difference between bent ray tomography and straight ray tomography. The slow anomalies near fast anomalies become even slower.

Conclusion

Here we show the preliminary tomography results of both Rayleigh and Love wave phase velocity between 8 and 20 second in the western US based on the ambient noise analysis. We investigate the off-great-circle propagation and the 2D surface wave sensitivity kernel based on 2D finite difference method combined with the adjoint method. A real phase speed map derived from the straight ray tomography was used to derive both the bent ray and the sensitivity kernel. The preliminary result on 8s Rayleigh wave indicates that the bent path assumption results in better data coherence and reduces the misfit by around 10%. The result also suggests that the velocity of a slow anomaly region near a fast anomaly is usually over predicted when a straight ray tomography is used. On going study is focusing on whether finite frequency effects are important in the tomography inversion and whether by using sensitivity kernel will further improve the coherence of the data set.

The preliminary result of stright ray tomographies presented here had been submitted to *GJI*. The most updated tomography maps based on the USArray can be found at *http://ciei.colorado.edu/~morganm/*