High-Resolution Source Parameters Using Calibration from Ambient Seismic Noise

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Abstract

Several new methods have been developed to retrieve local Green's functions based on the cross-correlation of ambient seismic noise (station-to-station) and conventional (source-to-station) inversions. The latter methods provide the most broadband results but require accurate source parameters for phase-delay recovery which depends on the starting model. Considerable progress is being made in providing such information from 3D modeling,Tape et al.(2008), using Adjoint Tomography. But to match waveforms for the recent Chino Hills event still requires shifting synthetics to align on data. This means that it is difficult to use 3D simulations to refine source locations in near-real time. We can avoid the 3D problems by applying the CAP method and storing shifts from past events, Tan(2006), and/or using ASN, Shapiro et al.(2005), to predict lags for surface waves. Here, we directly compare results from CAP predictions with ASN results using stations near the Chino Hills event. We use the same South California seismic model as used in the Library of Earthquakes to generate Green's functions for noise(single force) for comparison with ASN correlations and allow CAP delays. We apply these delays or corrections to determine precise Centroid locations.

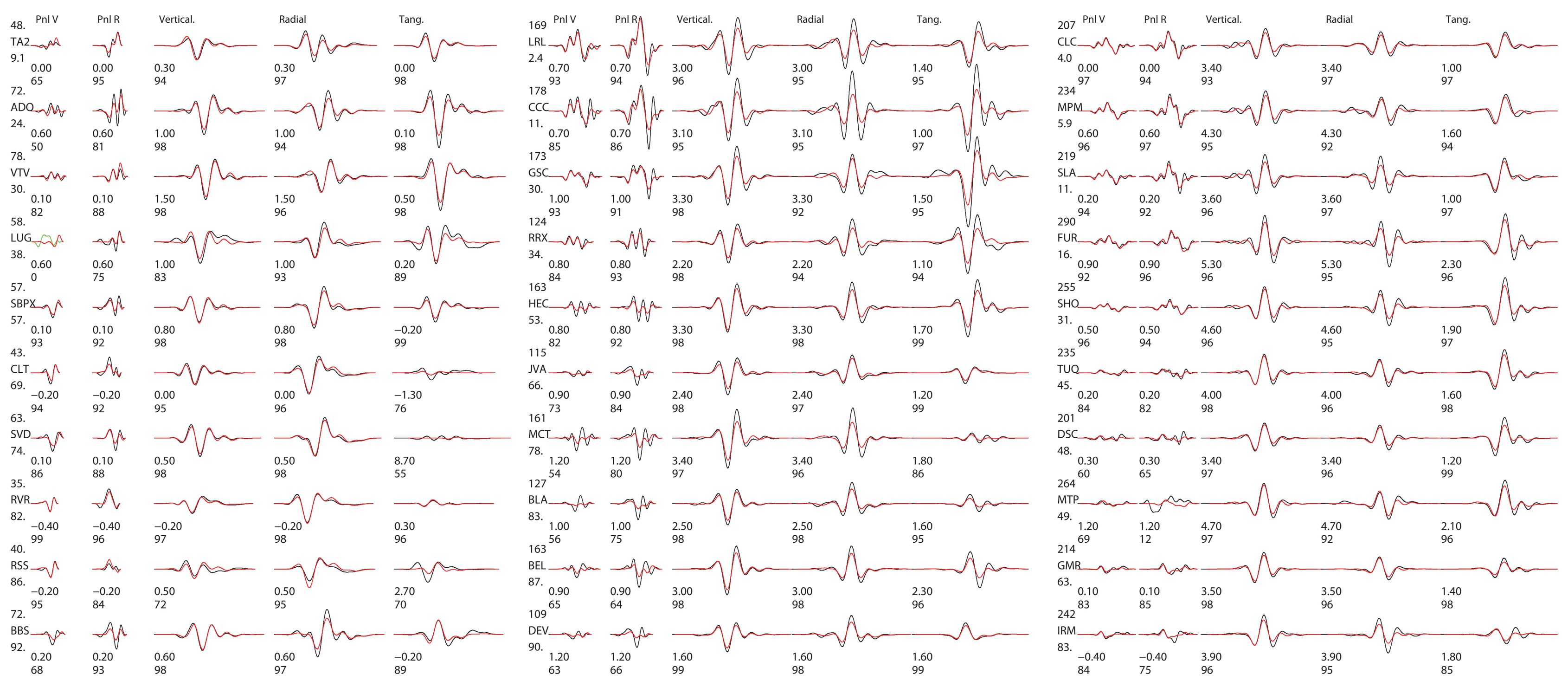

Fig. 2. Comparison of synthetic(red) and data(black) for the Chino Hills event, name of station is at the left of each seismogram, number above station name is epicenter distance in kilometer and below is azimuth. The number on the lower left of the seismograms are the time shifts(upper) and cross-correlation coefficients in percent(lower). Positive time shifts indicate slow paths. Pnl waves are filtered with bandpass(0.02~0.2Hz) and surface waves are filtered with (0.02~0.1Hz), a Standard South California Model(SoCal) is used.

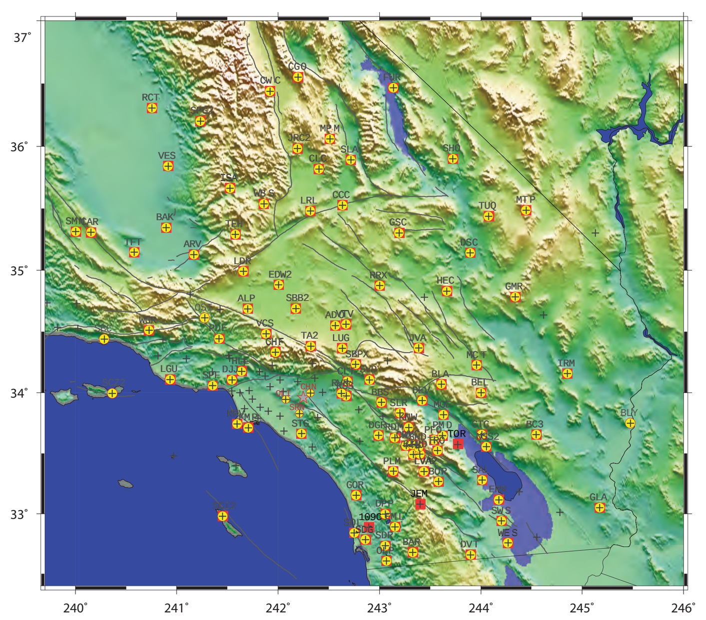

Fig.1.
Station and event locations. Stations at local distance, black-crosses represent the TriNet stations which are available for Chino-Hills event; yellow circles are stations used in ASN, in which three small yellow circles are source stations; red square symbols are those stations used in CAP inversion.

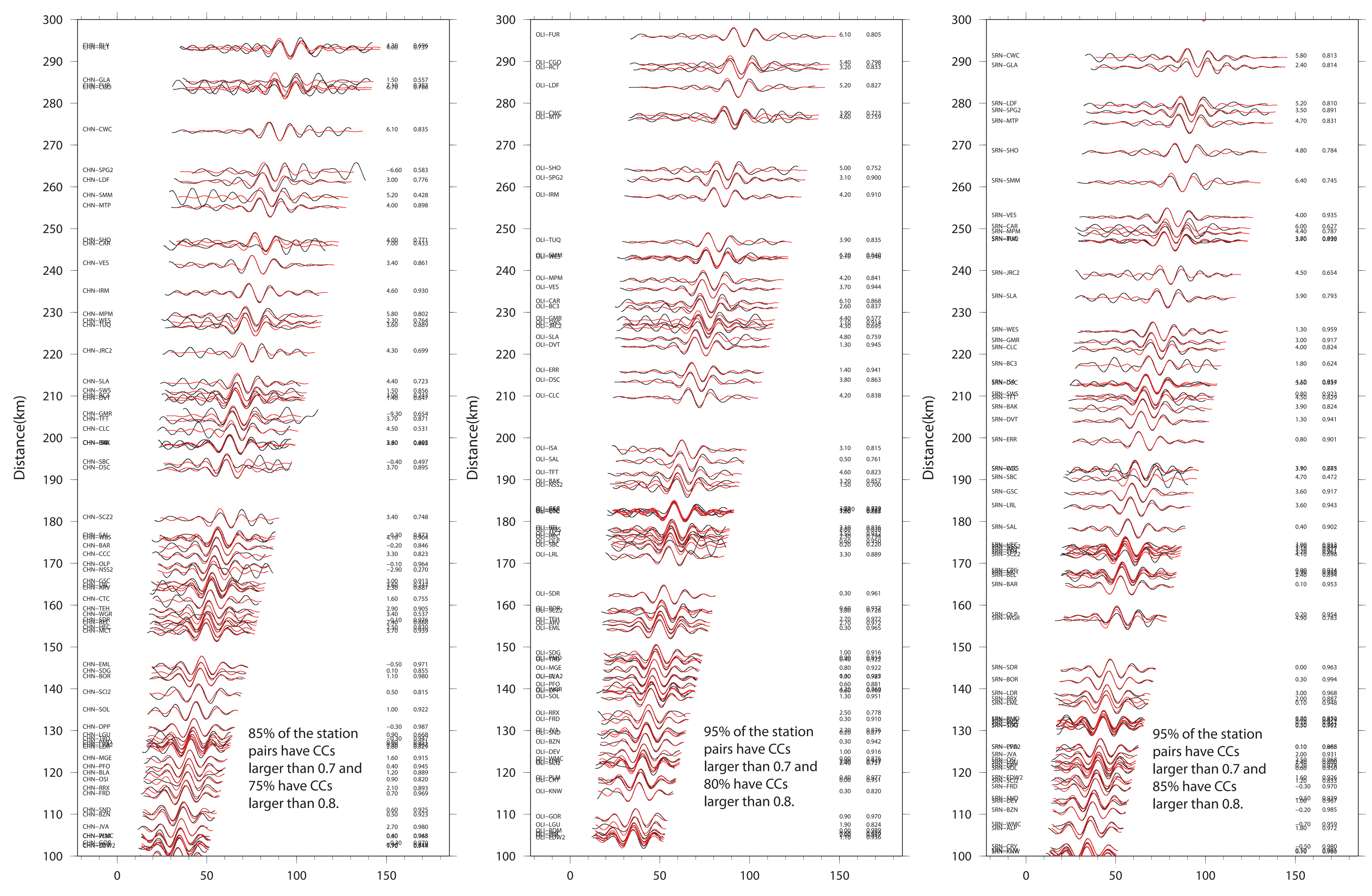

Fig. 3.
We compute Cross-Correlation Functions (CCFs) of Ambient Seismic Noise(ASN) between further away stations(big yellow circles) and close by stations(SRN, CHN, OLI shown as small yellow circles in the map). The CCFs(black line) are shifted to obtain maximum Cross-correlation Coefficients(CC) with single force Green's function between the two station from the same 1D Southern California Model as used in CAP. The resulting time delays and CC are shown on the right side of the seismograms. Most of the station pairs have CCs larger than 0.8. Both the CCFsand the Green's functions have been filtered between 10s and 50s. Note that most lags are similar between the pseudo-sources.

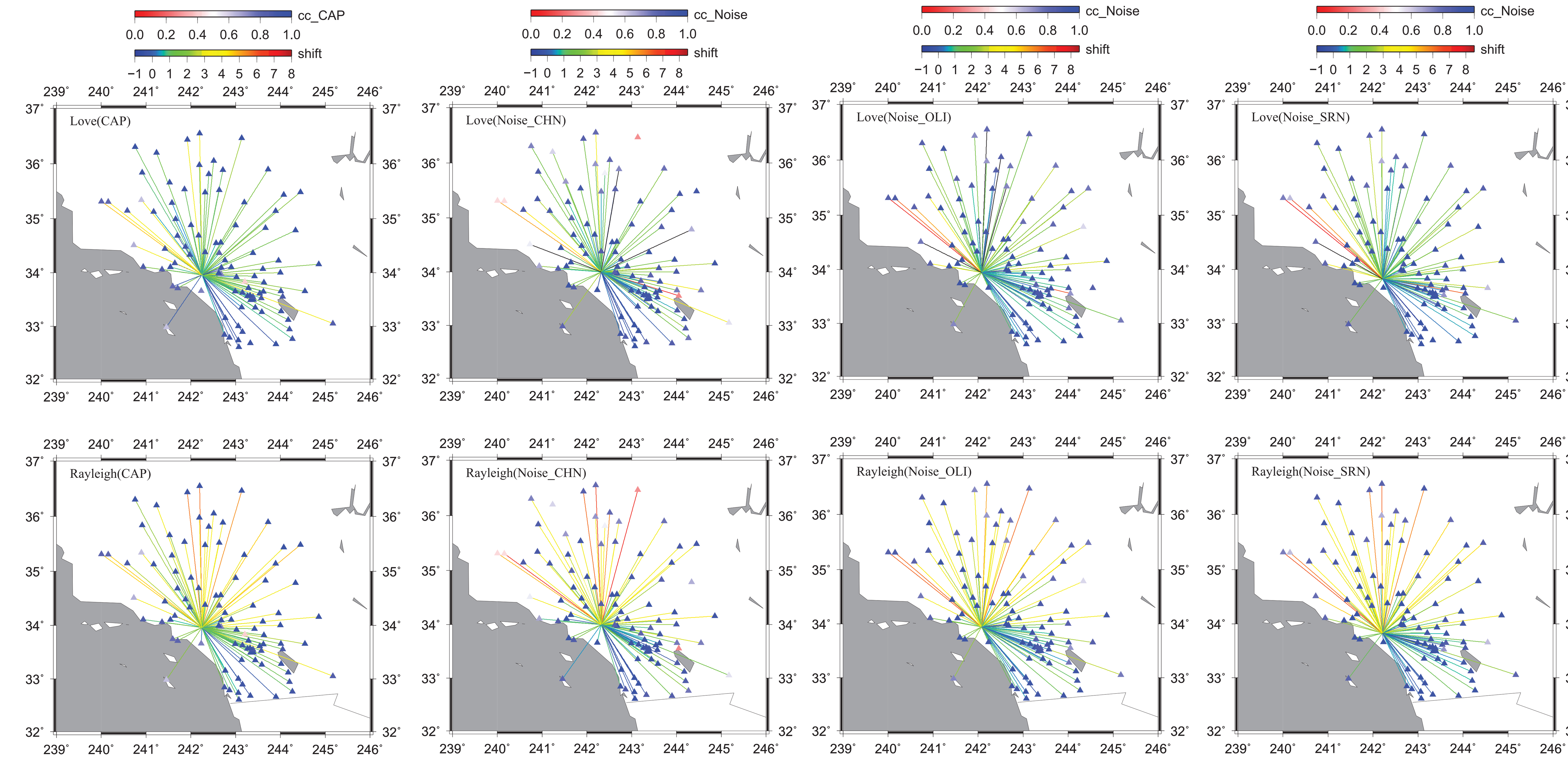

Fig. 4.
Time shifts of 10-50s surface waves with respect to Green's functions from the 1D South California Model. Stations are colored in cross-correlation coefficients between surface waves and Green's functions. Color of paths shows the time shifts obtained from CAP inversioin and ASN cross-correlation functions, using CHN, OLI and SRN as source stations. Note the similarity in delays for the three pseudo-sources (stations CHN, SRN, OLI), except for some interesting paths displayed as black lines in Fig. 1. Moreover, note the similarity between delays derived from the above CAP routine which are usually within one second. This means we can use the time shift s from ASN to calibrate the paths, then relocate the earthquake!

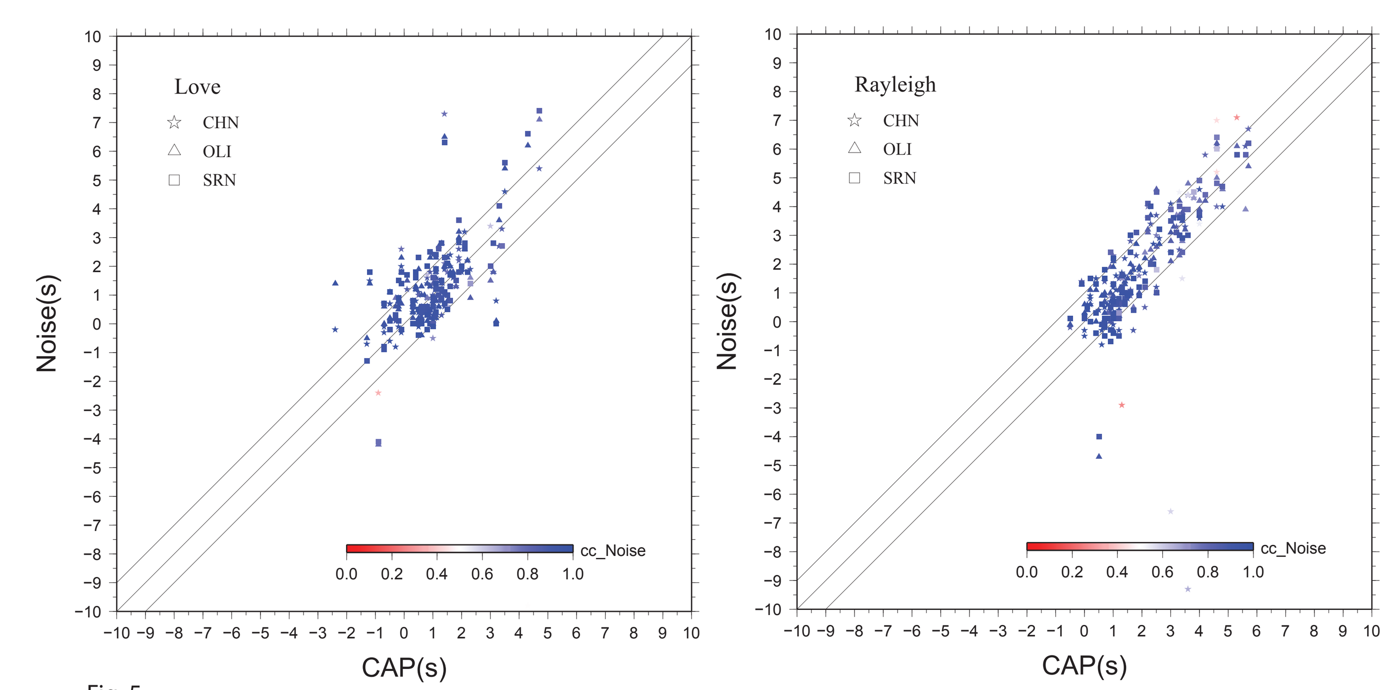

Fig. 5.
The relation between time delays from CAP and ASN. The left subfigure is for Love waves and the right subfigure is for Rayleigh waves. Results for different source stations CHN, SRN, OLI are shown by star, triangle and square, respectively. The color of the symbols shows the cross-correlation coefficients between noise cross correlations and Green's functions. The delays from ASN and CAP agree within 1 second for most paths, especially where CCs are better than 0.7.

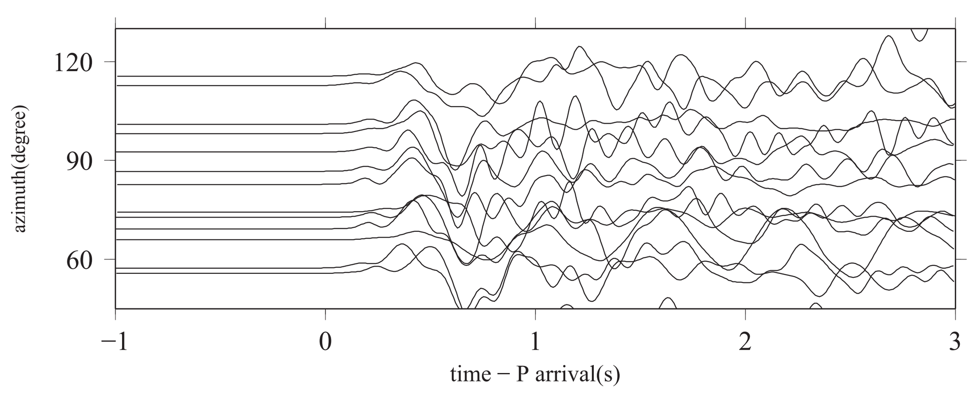

Fig. 6 . Many earthquakes larger than about Mw~4 have weak onsets that makes them difficult to locate by routine processing. This feature can be observed fro the Chino Hills event as displayed on the left.

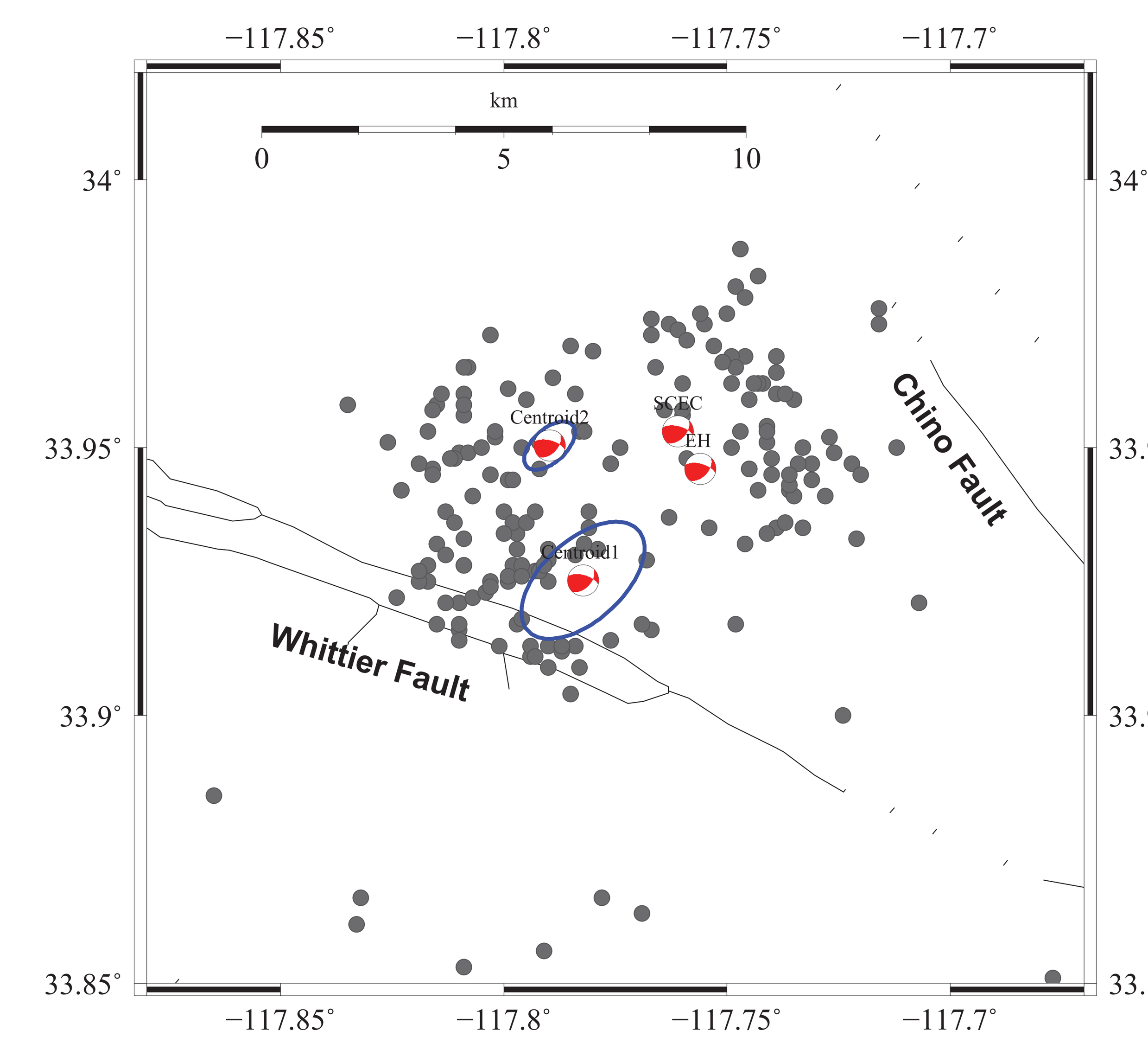

Fig. 7 .
Earthquake centroid located with time corrections from ASN. Beach balls marked with SCEC and EH are the epicenters from SCEC data center and Egill Hauksson, respectively. Centroid1 is the relocated centroid using long period (10-50s) Rayleigh and Love waves. Time shift corrections from ambient seismic noise are then used to locate Centroid2. The blue ellipses are the 95% confidence regions. It is obvious that the confidence region gets much smaller after correction. The gray dots are aftershocks until Dec 2008. The epicenters show that the Chino-Hills earthquake is in the middle of the Whittier fault and the Chino Fault. Noise-corrected centroid is closer to the Whittier fault. And the azimuth of centroid2 to EH epicenter is also very close to the strike of the Whittier fault. This is consistent with the preferred fault plane from a finite fault inversion (Shao, et al., in review, 2009).

Conclusion and Future Work

We have demonstrated the usefulness of ASN in calibrating surface wave paths. This method can give an independent estimation of earthquake centroid from the long period surface waves. It is especially useful in regions without well-determined 2D or 3D velocity models, but with a few seismic stations close to the source area (such as PASSCAL stations in South America and Tibet). These stations need not to be working during the earthquake, but only used to calibrate the paths. The well-located earthquakes near these stations can serve as reference to locate other nearby events.