Imaging the Crust and Upper Mantle of the Western US from USArray, Part II

Shengji Wei[1,2], Laura Alisic[2], and Don V. Helmberger[2]
1,University of Science and Technology of China, Hefei, Anhui, 230026
2,Seismological Laboratory, California Institute of Technology, Pasadena, CA91125,USA

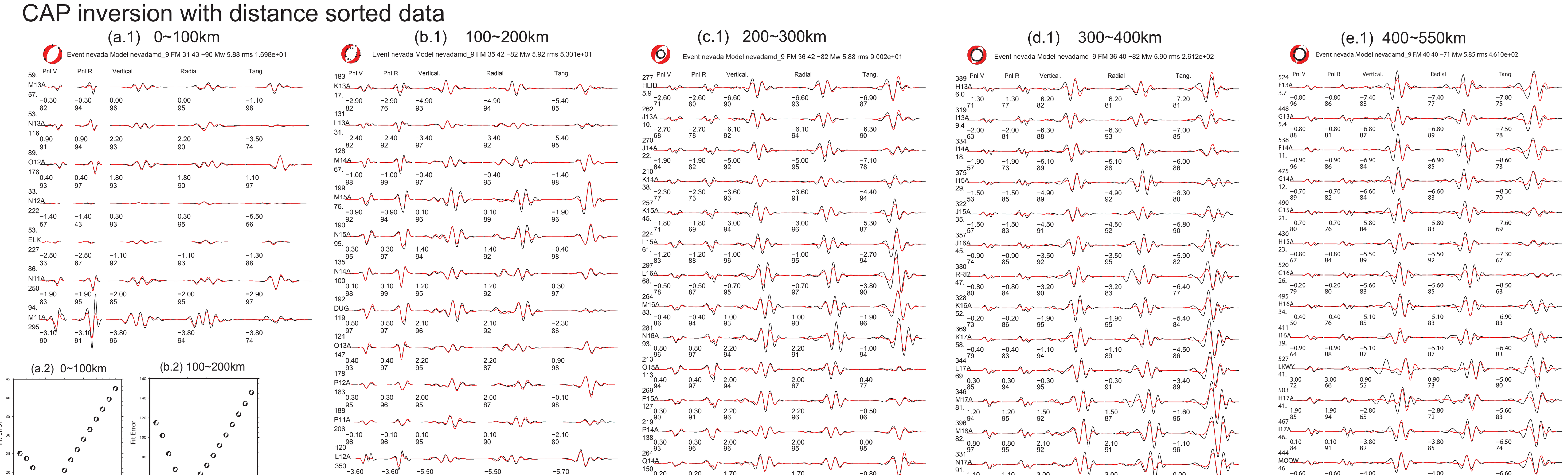
Abstract

The recent Nevada Earthquake (M=6) produced an extraordinary set of crustal guided waves. In this study, we examine the three-component data at all the USArray stations in terms of how well existing models perform in predicting the various phases, Raylaigh waves, Love waves and Pnl waves. To establish the source parameters, we applied the Cut and Paste Code up to distance of 550km for an average local crustal model which produced a normal mechanism (strike=35°,dip=41°,rake=-85°) at a depth of 9 km and Mw=5.9. Assuming this mechanism, we generated synthetics at all distances for a number of 1D and 3D models, using both the FK method and the spectral element code SPECFEM3D_GLOBE (Komatitsch and Tromp, 2002) with a shortest period of 6s. Specifically, the tomography model developed by Burdick et al (2008) is tested. This is a P-wave model implemented in the top 1000 km of the mantle as a perturbation to the 1D ak135 model. The Crust2.0 model (Bassin et al., 2000) is superimposed on this (see also Part I of this poster). The Pnl observations fit the synthetics for the simple models well both in timing(V_{Pn}=7.9km/s) and waveform fits out to a distance of about 550 km. Beyond this distance a great deal of complexity can be seen to the northwest apparently caused by shallow subducted slab material. These paths require considerable crustal thinning and higher P-velocities.To the northeast, the complexity may be caused by a relatively slow body in the Yellowstone area. Small delays and advances outline the various tectonic province to the south, Colorado Plateau, etc. with velocities compatible with that reported on by Song et al.(1996). Five-second Rayleigh waves (Airy Phase) can be observed throughout the whole array and show a great deal of variation(up to 30s). In general, the Love waves are better behaved than the Rayleigh waves.

Introduction

As an introduction to the Cut-and-Paste method , Zhu and Helmberger(1996), we conducted a test against synthetic data. We generated synthetics from four models as displayed with 5% and 10% variation in velocities. ie, fig. 4. These synthetics(now data) are then fit by the CAP method assuming an averaged 1D model where the Pnl are allowed to shift relative to the surface waves. These shifts simply correct for the timing issue, note that the amplitudes display some disagreement caused by the receiver functions. We recover the mechanisms just fine with this method. This method is applied to the Nevada data, where we perform the inversion as a function of range,0 to 100km, 100 to 200km,etc. Note the stability of the inversion from 100 and beyond where the three fault parameters strike,dip, slip and Mw vary only a few percent. The delays can be used to create a Tomography image, Tan et. al (2008), if the events are well located. Unfortunately, it appears this event is not that well located since stations to the south and north have a shift of a few seconds. The aftershocks likewise do not agree with these shifts as discussed later.Some of these issues will also clear-up when we add directivity to the main event. Furthermore, we have constructed record-sections along azimuths as denoted by the heavy red lines. Many sections compare quite well out to about 900km,even with this simple model of a uniform mantle.The most interesting profile is displayed along the sector 315 -330 degrees. In particular, note that the beginning portions of the Pnl wave train (H04A,G04A,etc) are indeed Pn-like while some stations, COR,TAKO,F03A,etc) are P-like (impulsive) indicating significant mantle structure. These 3D effects are presently being investigated where the same set of stations display interesting multi-pathing of teleseismic signals. Some preliminary runs of existing models with finite-difference and SEM do not explain these features. Better models now exist as represented at this meeting and will be tested on this data set. It appears that the 2D code (Vidale and Helmberger) will prove very useful for this purpose as suggested by the 1D comparison with FK results.

CAP inversion with distance sorted data



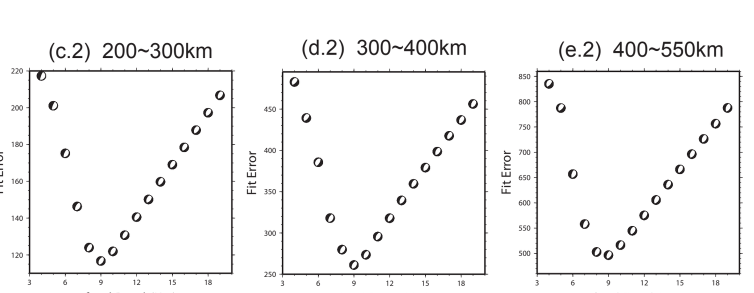


Figure 1.
According to epicenter distance, data within five degrees are sorted into five groups, as 0 to 100km as one group, 100 to 200km as another group, etc. “Cut and Paste” (CAP) modeling of Pnl and Surface waves has been done for each group of the data on the main Nevada Event. Name of station is at the left of each seismogram, number below station name is epicenter distance in kilometer and above is azimuth. The numbers on the lower left side of the seismograms are the time shifts(upper) and cross-correlation coefficient in percent(lower).Positive time shifts mean that the synthetics have been delayed or shifted to the right. Pnl waves are filtered with bandpass (0.02-0.2HZ) and the surface waves are filtered with (0.02-0.1HZ). This earthquake features a mostly dip slip mechanism . The focal depth is estimated to be around 9km. Note the stability of the inversion from 100 and beyond where the three fault parameters strike,dip, slip and Mw vary only a few percent. The delays can be used to create a Tomography image, Tan et. al (2008), if the events are well located. Figure a.1, b.1, c.1, d.1, e.1 are inversesion results of five groups of data. Figure a.2, b.2, c.2, d.2, e.2 are corresponding depth resolutions. Since Pnl is included in the inversion, CAP has a better constraint on depth. The velocity model(Figure 6.a) is from Song et al. (1996)'s paper, featuring a 34km deep moho in Nevada area.

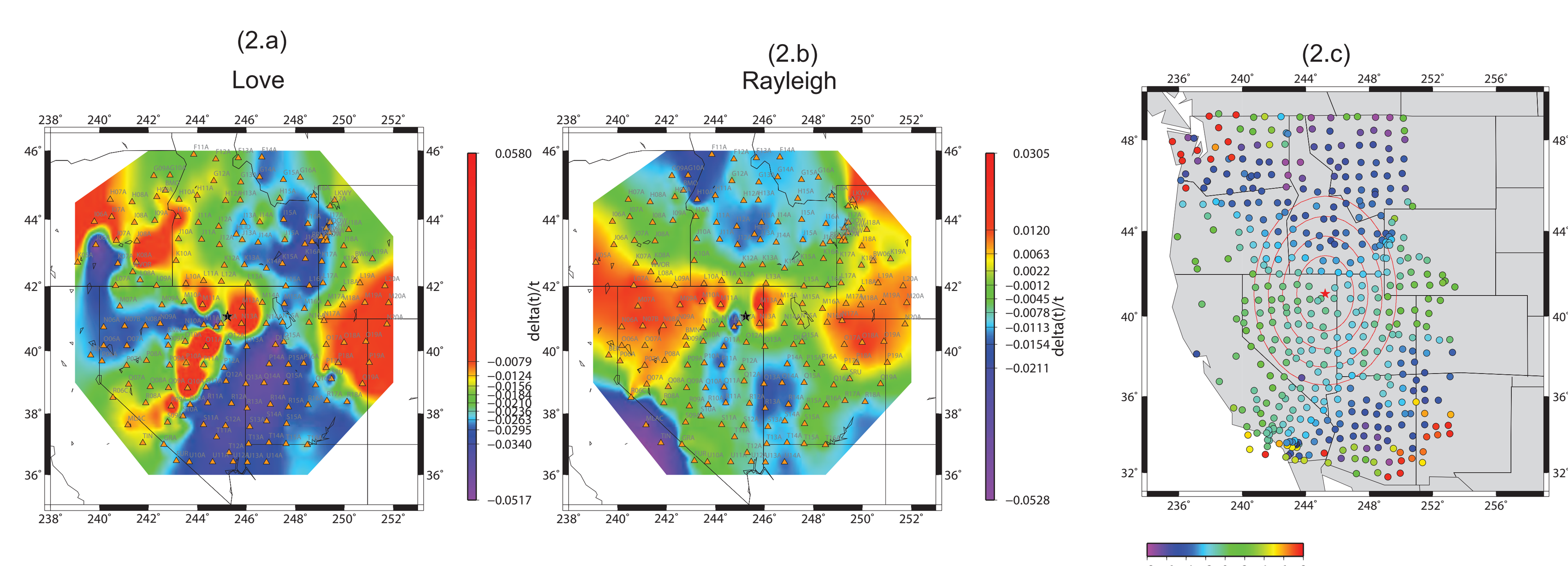


Figure 2
a). Relative time shifts between data and 1D synthetics of Love waves. Time shift of Love wave on each station is obtained in CAP inversion process(see fig. 1). This time shift is divided by the travel time of the Love wave which is measured to the maximum amplitude of Love wave.
b). Relative time shifts between data and 1D synthetics of Rayleigh waves. The delays can be used to create a tomography image, Tan et al (2008), if the events are well located.
c). Time shifts bewteen data and 1D synthetics of Rayleigh waves on all USArray stations. Shifts are calculated by cross-correlation technique.

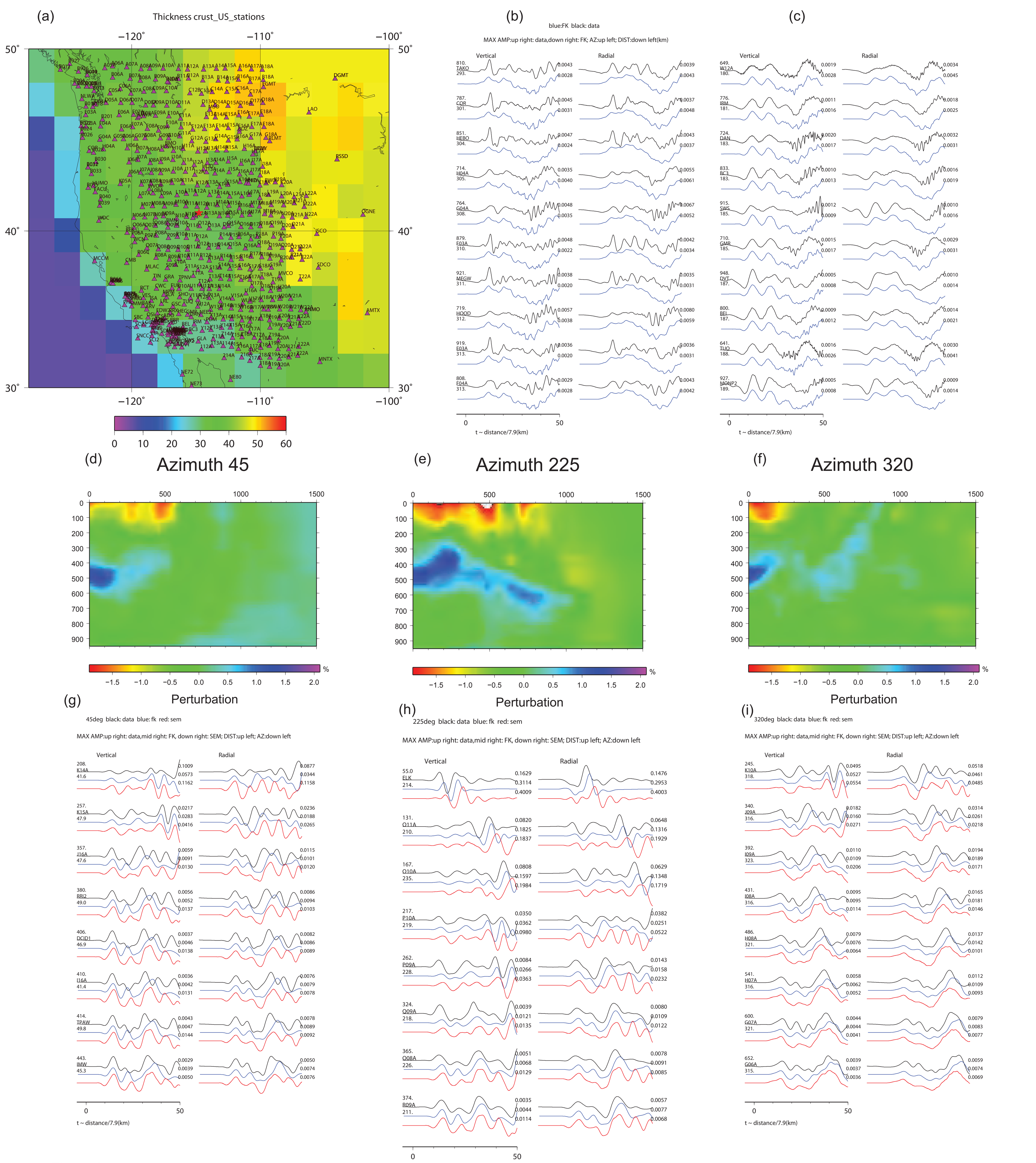


Figure 3.
(a). USArray station distribution and Crust2.0 model.
(b,c) Record-section of Pnl portion of data and 1D synthetic in northwest and southwest direction. Data in black, synthetic of 1D model in blue. Number on the right of each seismogram is peak amplitude. Many sections compare quite well out to about 900km (as show in c), even with this simple model of a uniform mantle.The most interesting profile is displayed along the sector 295~330 degrees. In particular, note that the beginning portionsof the Pnl wave train (H04A,G04A,etc) are indeed Pn-like while some stations, (COR,TAKO,F03A,etc) are P-like (impulsive) indicating significant mantle structure.
(d, e, f) 2D cross-sections through Burdick 3D P wave tomography model (2008), starting at source location towards azimuths 45, 225, 320.
(g, h, i) Data(black), 1D(blue,fk) , 3D(red,SEM) in the same azimuths as cross-sections, bandpassed between 6s and 60s.

Future Plans

To date, we have concentrated on developing a good 1D model to use as a reference. We have also assumed a point-source for the main event in the regional modeling. We intend to calibrate the stations at shorter periods (2Hz to 2s) as discussed in Tan and Helmberger(2006) and determine the mechanisms down to magnitude 2.
We plan to fine-tune the crust-mantle transition and upper mantle structure to explain Pn and strong variations in muliples that occur along Western Lines of stations. In short, we intend to test how well one can explain regional broadband records.