Validate Tomography with Broadband Waveform Modeling: An Example at La Ristra Transect in the southwestern United States

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1 Motivation and Introduction

Travel time tomography has been the main tool for seismologists in developing mantle structure and studying regional tectonics. Standard practice for geodynamists is to convert the velocity anomalies into temperature and density and fit geophysical observables such as topography and gravity. However, tomographic models produced by smooth, damped inversions usually underestimate the amplitude and sharpness of the velocity structure. To validate these tomographic models, it is important to propagate seismic waves through them and compare synthetic waveforms with obvervations directly, which enable us to enhance and sharpen these models.

Here we illustrate an example using the Rio Grande Rift PASSCAL observations in the southwestern US. The La Ristra passive experiment was designed to cross the Rio Grande Rift system and study the tranition in mantle structure from Great Plain to Colorado Plateau (Fig. 1). Ray-based body wave travel time tomography (*Gao et al.*, 2004) indicated a linear, south-east dipping slab-like fast velocity anomaly under the western edge of the Great Plain. They interpreted it as a downwelling lithosphere produced by a small scale convection (Fig. 3). We take advantages of the dense linear array and examine data from two deep events in south America.

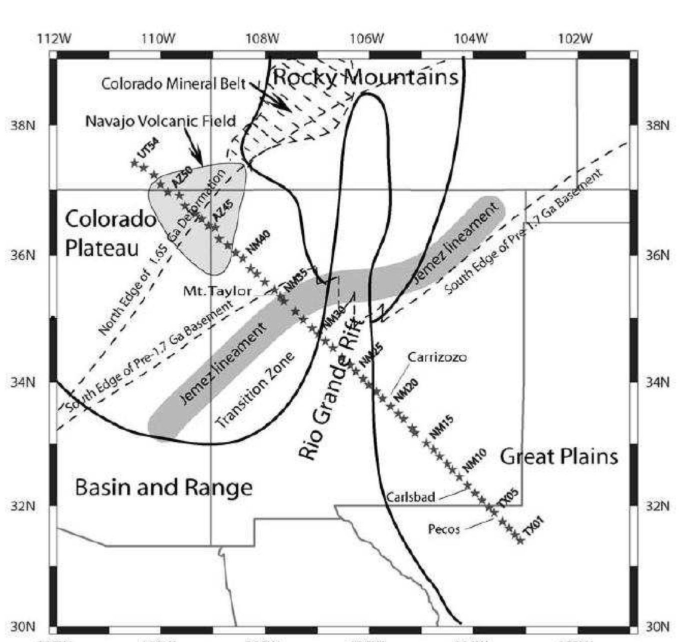

Figure 1: Geological setting at La Ristra Transect. (From *Gao et al.* (2004).)

After deconvolving the source wavelet from the raw data, deconvolved waveforms of both events consistently show that P and S waveforms are severely distorted at stations across the slab boundary by a factor of 2-3. The waveform amplitude also diminishs in proportional to the wavefrom broadening. The waveform shape becomes simple again for stations near the center of the rift. We implement the tomography model into the 2-D finite difference scheme (*Vidale et al.*, 1985; *Helmberger and Vidale*, 1988). Preliminary result shows that amplifying the tomography model by a factor of 3 starts to produce the waveform distortions observed.

2 Tomography beneath Rio Grande Rift

Gao et al. (2004) inverted S wave travel time anomaly and obtained a 2-D tomographic image underneath the La Ristra Transec, which transverses the Rio Grande Rift. One interesting feature in their model is a linear fast velocity anomaly beneath the edge of western Great Plain dipping to the south (Fig. 2). P wave tomographic image also reveals similar feature. As tomographic image often blurred and smooth the solution, it is critical to validate such result with real broadband waveform.

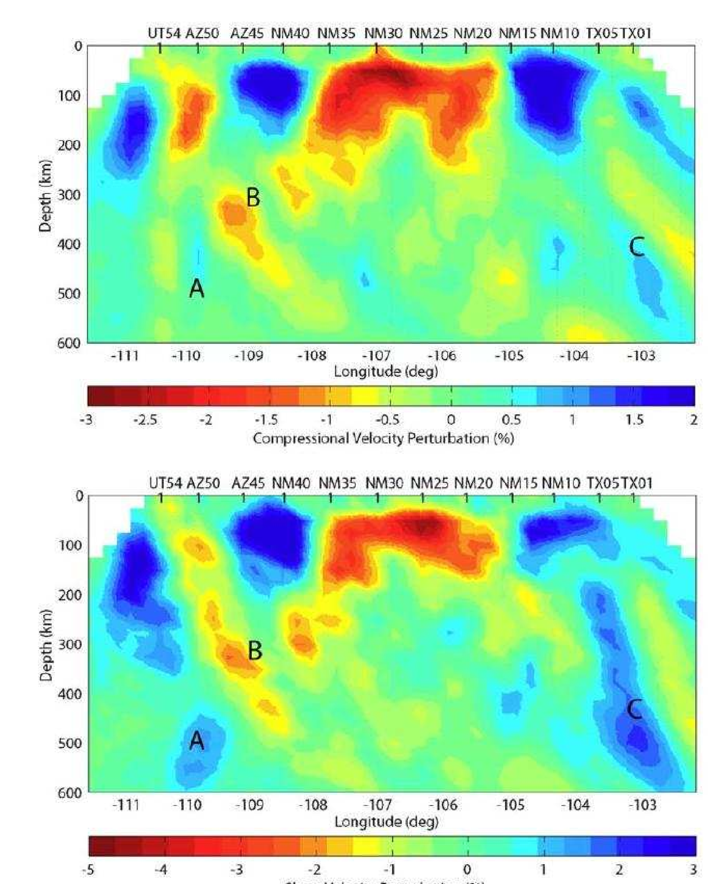

Figure 2: P and S wave tomography model. (From *Gao et al.* (2004).)

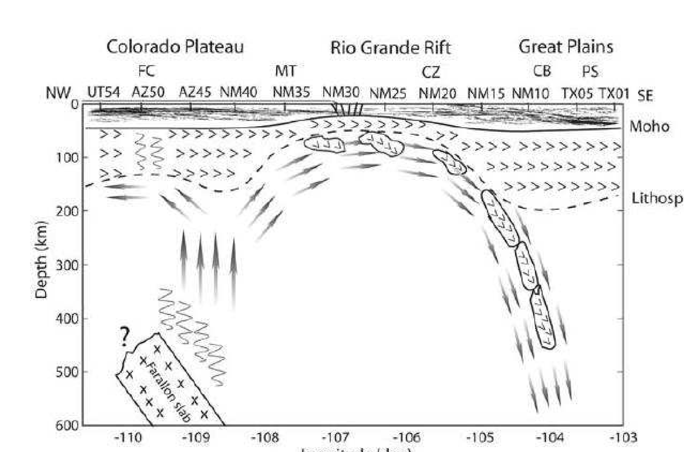

Figure 3: Hypothetis of a downwelling lithosphere due to edge-driven convection. (From *Gao et al.* (2004). FC is the Four Coeners regions, MT is Mount Taylor, CZ is Carrizozo, CB is Carlsbad, NM and PS is Pecos, TX.)

3 Broadband Waveforms Reveal Slab Diffraction

Slab diffraction effect has been discussed by several researchers (*Cormier*, 1989; *Vidale*, 1987). In these cases, waves generated by subduction zone earthquakes travel downdip both inside and outside of the slab and produce complicated and sometimes broadened waveform at teleseismic distances. However, the stations are relatively sparse and it is not easy to exam the detailed slab structure. In the current study, the dense La Ristra Transect gives great sampling on the mantle structure beneath the array. To exclude the waveform effect from structure near the source, we deconvolved the source wavelet. Although we only present an example to demostrate the complexities of waveforms, several other events coming from South America also present similar waveform broadening recorded by the same receiver at La Ristra Transect (Fig. 4 station NM12 - station NM19).

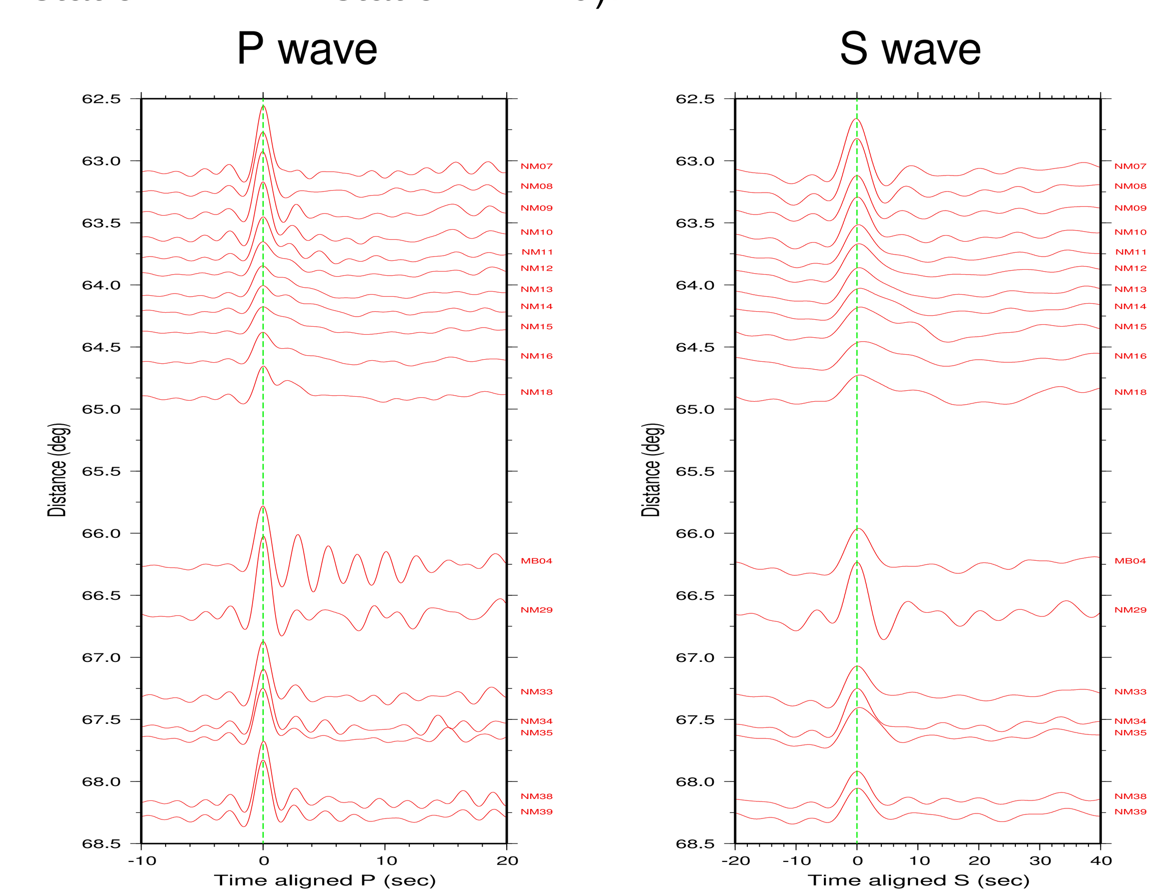

Figure 4: Deconvolved P and S waveform recorded by La Ristra Transect from event 990915 (depth=218 km) in South America. Note the distortion of waveform starts at 63.5° (station NM13 - station NM18). The absolute amplitude decreases in proportional to the broadening of waveforms.

4 Sharpening Tomorgaphy

After implement the 2-D mantle structure locally beneath the array, we propogate the waves from the source through a 1-D mantle structure TNA (*Grand and Helmberger*, 1984). We find the tomography model does not produce any waveform distortion. Amplifying the model by 2-3 times starts to see the waveform broadening (Fig. 5). In addition, the snapshot (Fig. 6) also demostrated multiple arrivals due to strong velocity anomaly of the downwelling slab.

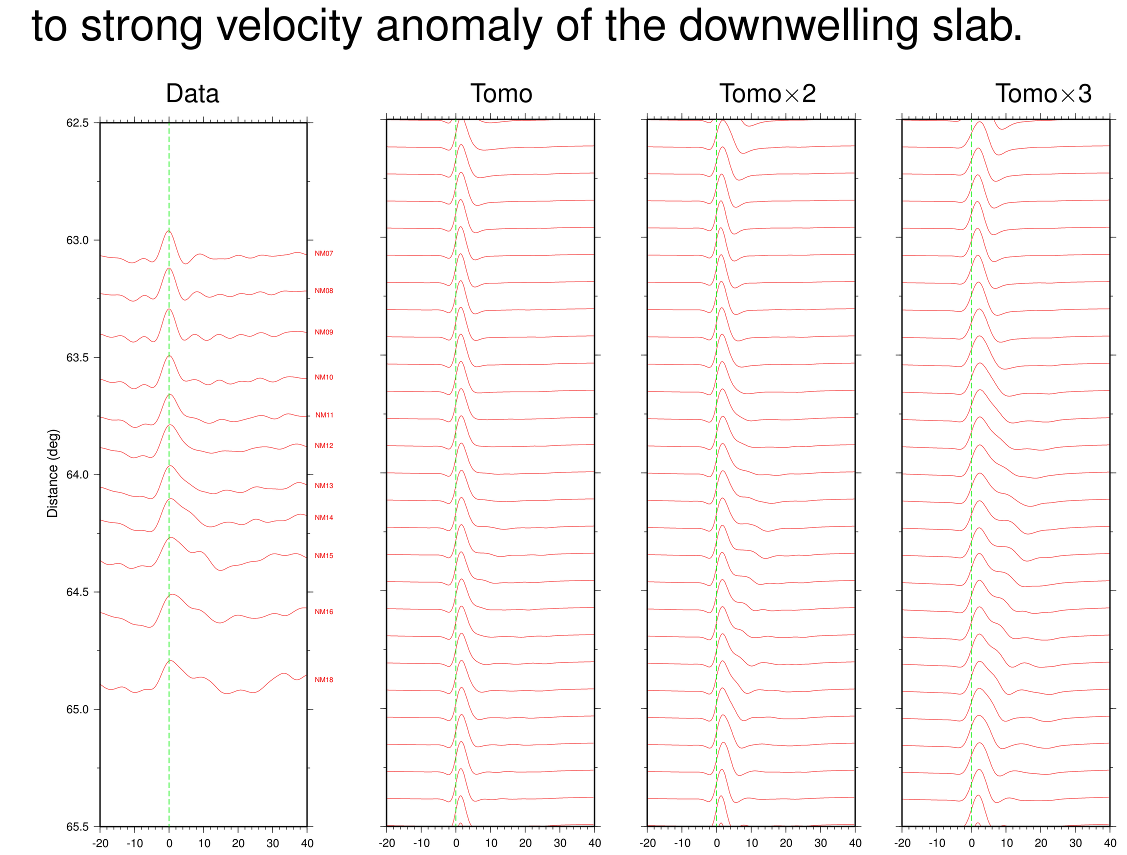

Figure 5: Comparison of data and synthetics.

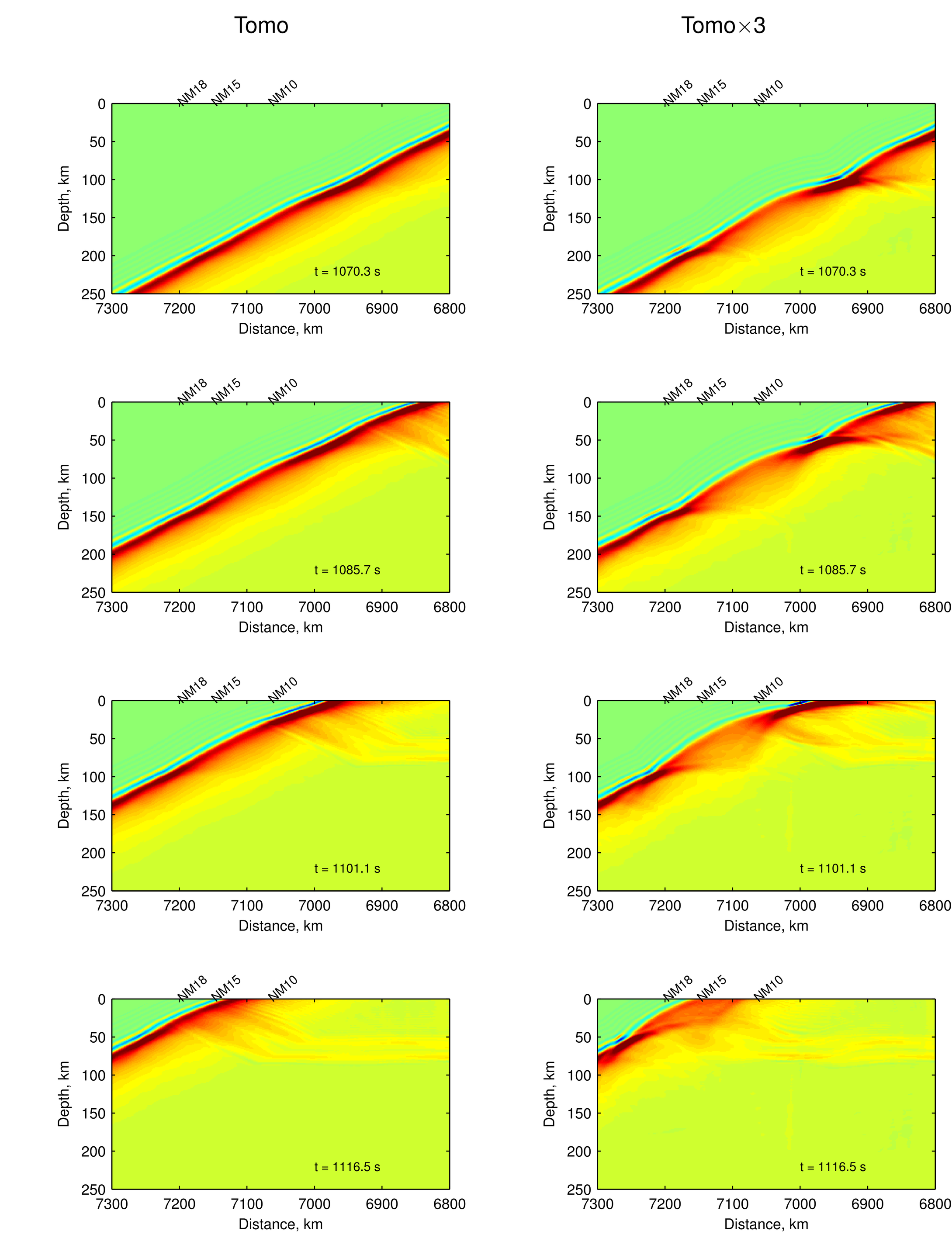

Figure 6: Snapshots. Left: Original Tomography. Right: Amplified Tomography by 3 times.

5 Future work

Modeling of P wave is under way. Besides, it is possible that the attenuation also plays some role in the S waveform complexity which is not included in the 2-D finite difference. Spectral element method (SEM) certainly provides promised solution in this topic.

References

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