Teleseismic waveform complexity caused by ocean-crustal interaction

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Abstract

Heterogeneous source-side structure can cause waveform complexities at teleseismic distances. However, detailed waveform modeling of these complexities is computationally expensive. For the 2011 Tohoku-Oki earthquake sequence, the effects of two dominat source-side structures, the ocean and the subducted slab, are not well understood.Here we develop a new hybrid method (SEM+Ray theory) to study this problem. Our results show that the water layer has a stronger effect on the wave propagation than the subducted slab. The dipping ocean bottom can cause systematic bias in earthquake focal mechanisms, especially the dip angles. Better understanding of the ocean-crustal interaction also allow us to relocate the earthquakes accurately.

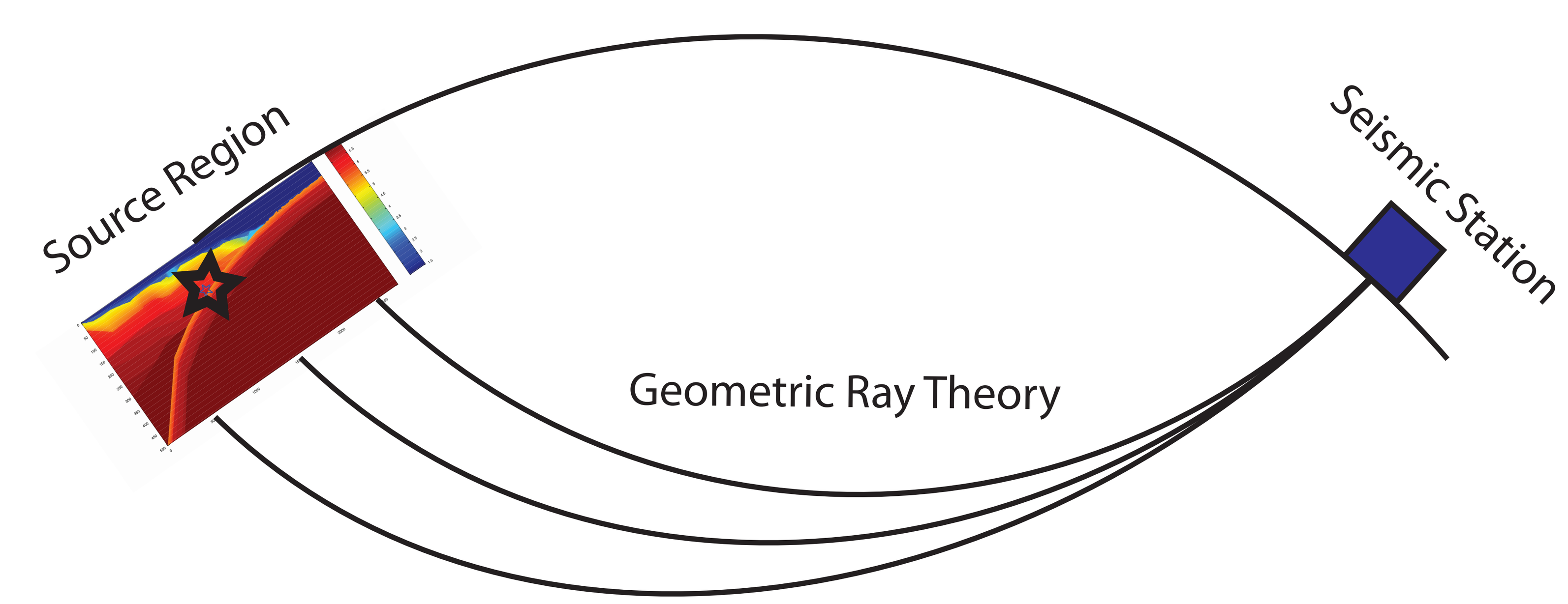
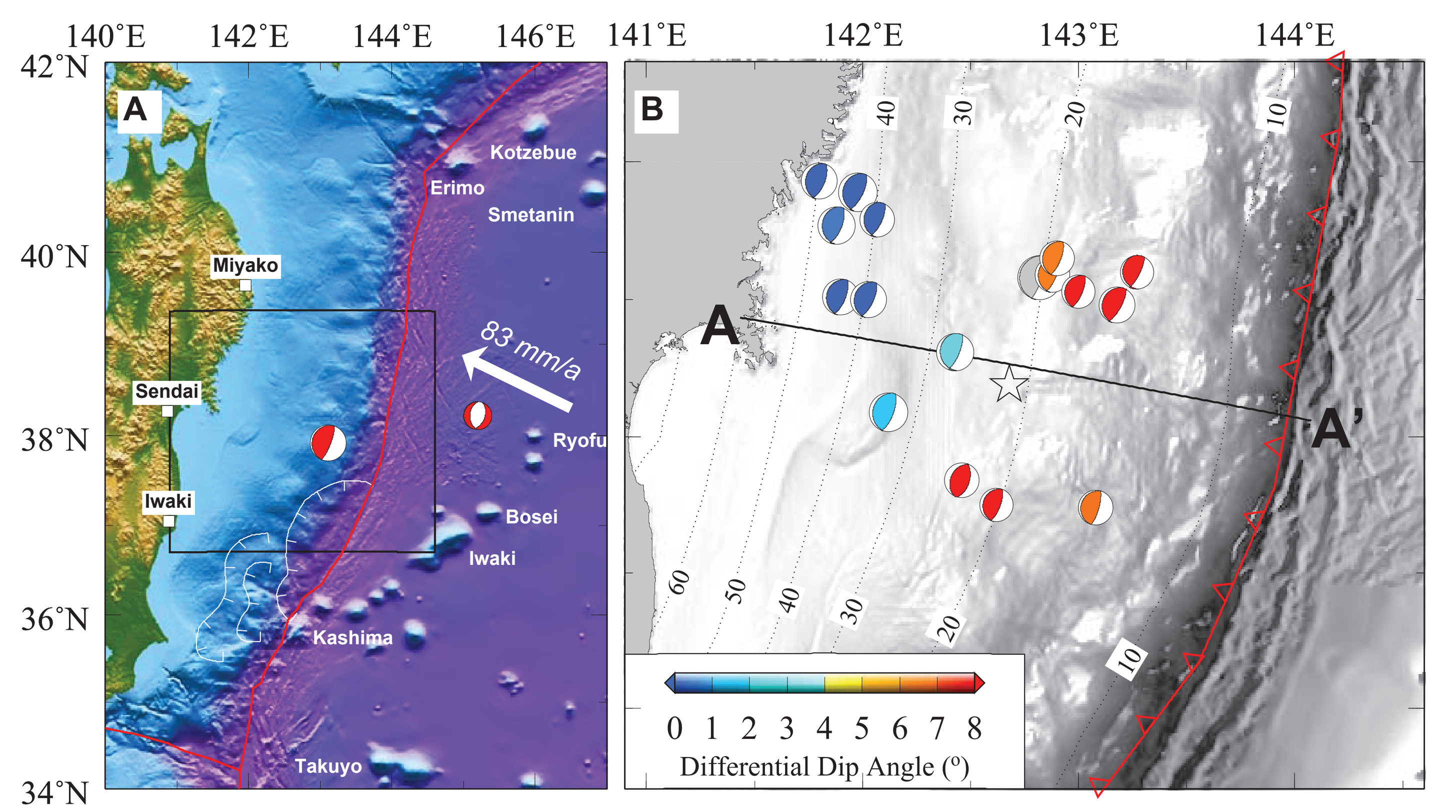


Figure 1. Illustration of the hybrid method. In the source region, we use the Spectral Element Method (SEM) to simulate the full wave propagation. The wavefield on the boundaries of the SEM region is interfaced into geometric ray theory using the Kirchhoff interfacing method.



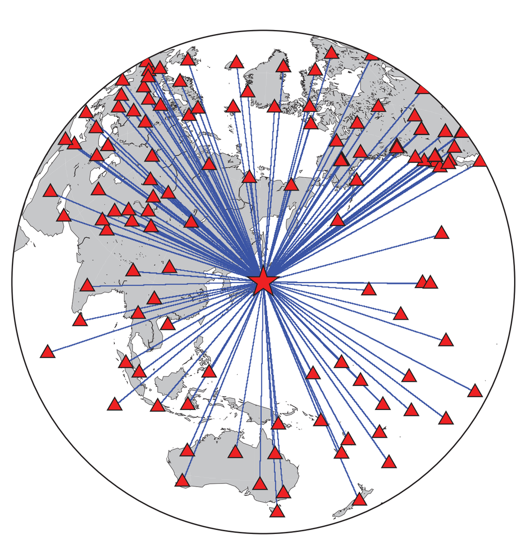


Figure 2. Geometry of the subducted Pacific Plate and relationship to geological features and slip-release of the Great Tohoku-Oki event. (A) Topography and bathymetry map of northeast Japan with identified seamounts. The WPhase moment tensor solution of the 2011 Tohoku-Oki earthquake is shown as red beachball. (B) Correlation between earthquakes with anomalous dip angles and large slip area of the Tohoku-Oki earthquake. Blue contours show the slip distribution model and dashed contours indicate the depth to plate interface based on Simons et al. 2011.

Figure 3. Distribution of teleseismic stations (FDSN+GSN) used in this study. Note the good azimuthal coverage.

Conclusion

We develop a new hybrid method to study the effect of source-side structures. We show that
1. 3D source side structure, especially the water layer can cause systematic bias in earthquake focal mechanisms. Teleseismic SH waves are much more strongly affected than P waves.
2. Teleseismic P waves and its coda due to ocean-crustal interaction can be used to relocate earthquakes accurately. Preliminary results show that USGS locations may be biased to the west by 20km.

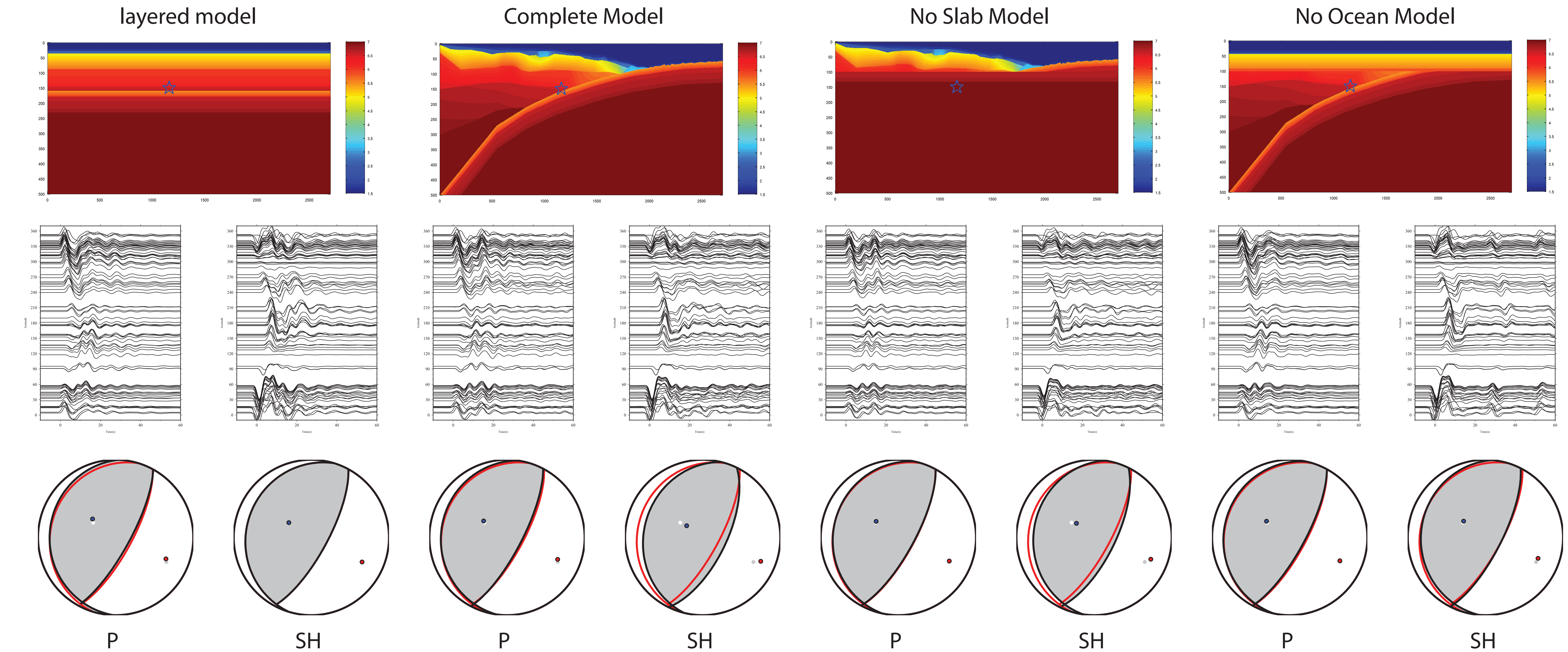
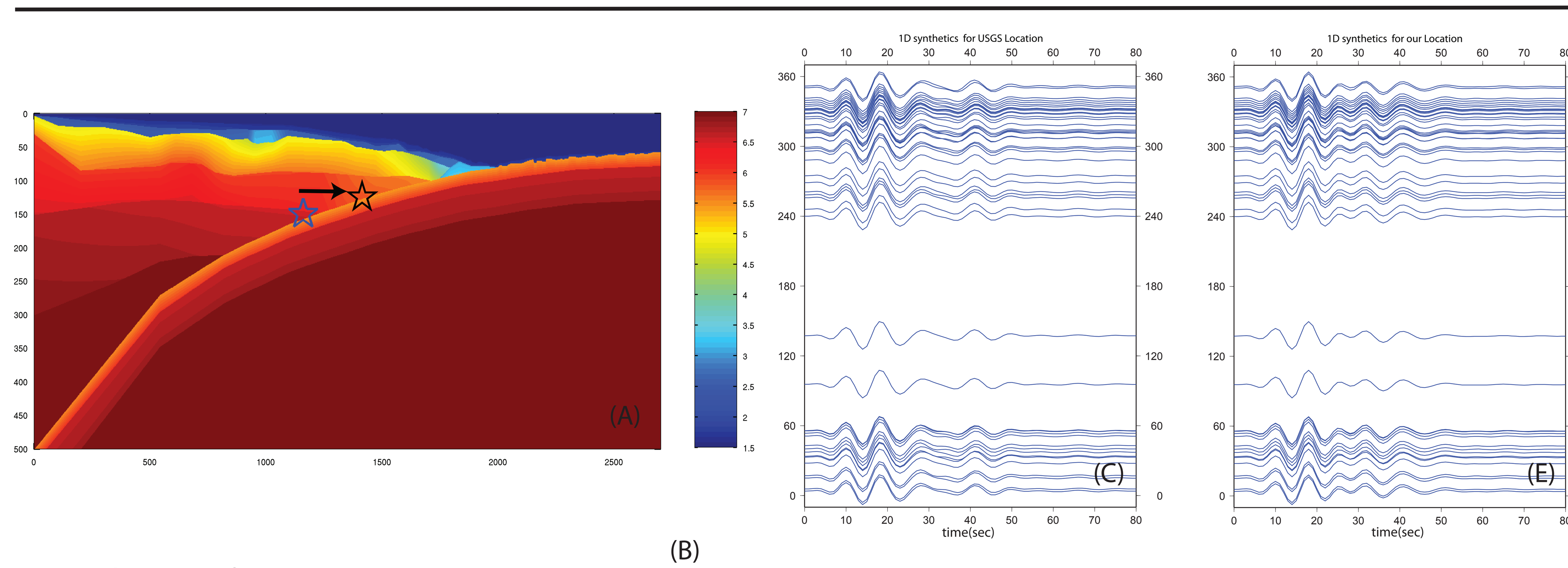


Figure 4. Synthetic seismograms from four different source-side models. A detailed 2D velocity model (complete model) is available from a seismic survey along AA' in Figure 2. A no-ocean model and a no-slab model are produced by replacing the water layer or the dipping slab with 1D structures. A 1D layered model is used as a reference. The inverted focal mechanisms with these synthetic data are shown in the bottom.



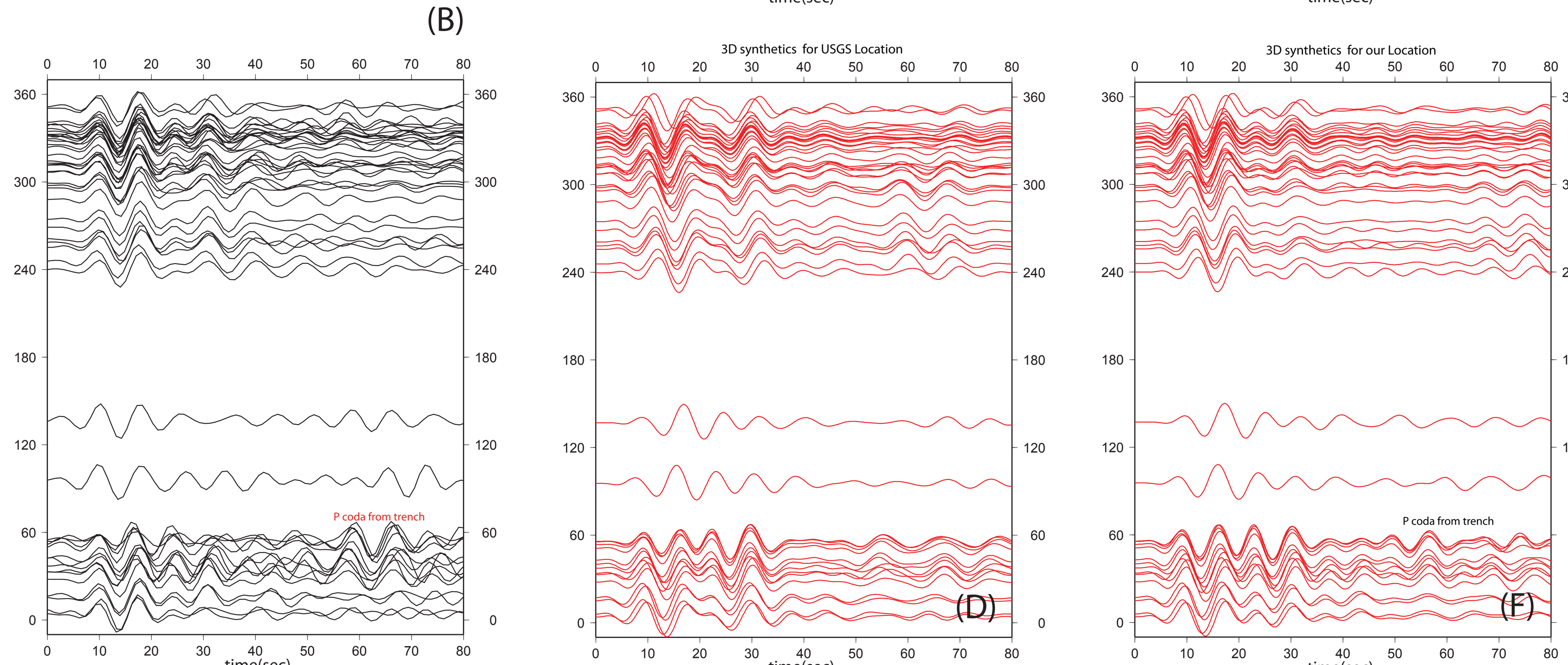


Figure 5. Relocation of a Mw6 event (Figure 2A) inferred from teleseismic waveform modeling. (A) The blue star is the location USGS gave while the black is the location we proposed. (B) Record section of telesiesmic P waves (0.08-0.15Hz band-pass) from stations shown in Figure 2B. (C) 1D synthetics for USGS's location. (D) 3D synthetics for USGS's location. (E)1D synthetics for our location. (F) 3D synthetics for our location.

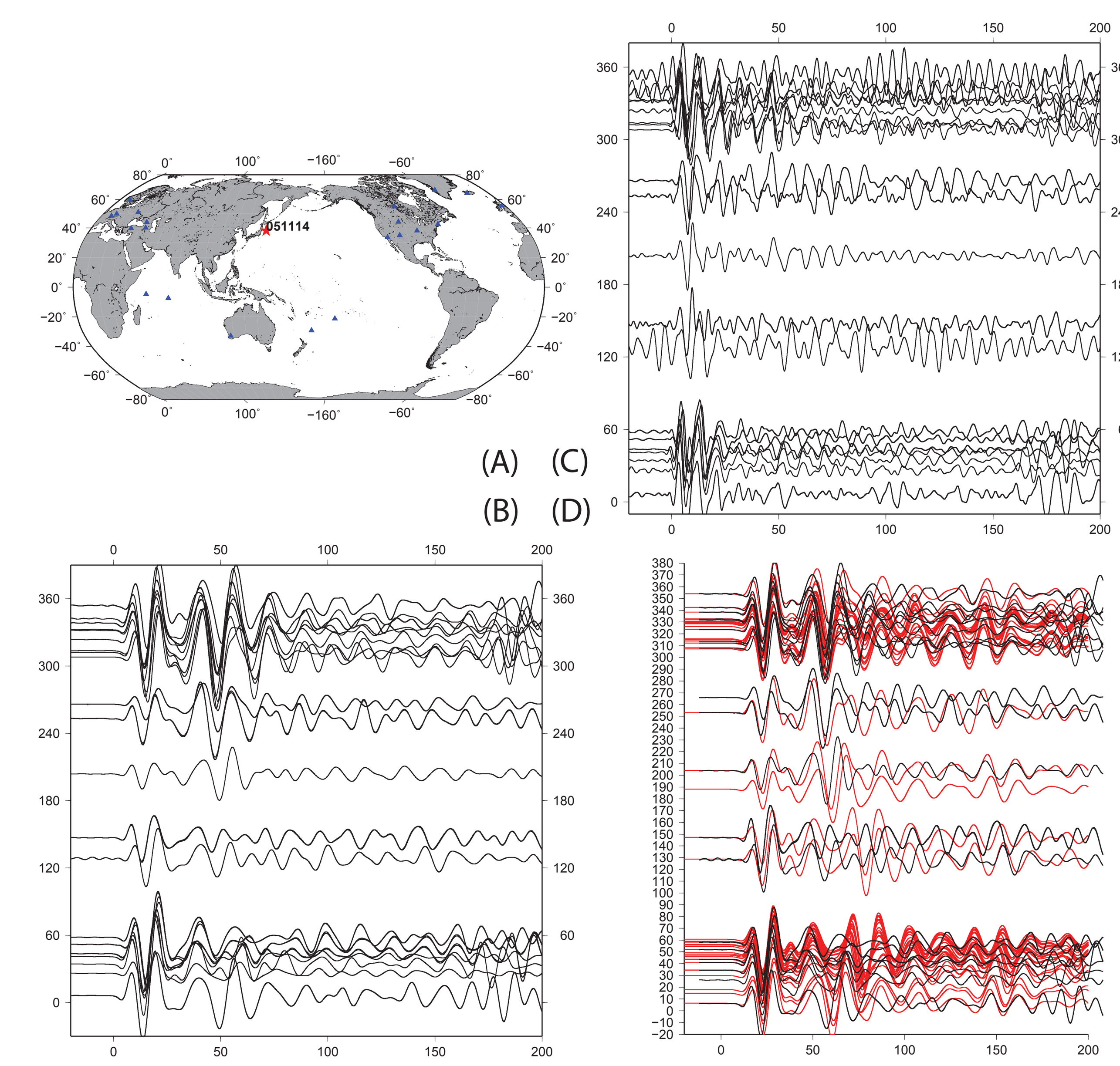


Figure 6. Observation for 2005/11/14 Mw7.0 outer-rise event (Figure 2A). (A) The global stations used in (B, C, D). (B)The 0.05-0.12Hz P wave record section aligned by AK135 travel time predictions. We can see the strong coda comparable with P wave for the azimuth around 360 degrees. (C)Higher frequency observed data. The coda is weaker. (D) 3D synthetics predict the strong coda well.