Refining Earthquake Locations Along the Chilean Coast

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Abstract

It is difficult to locate earthquakes along subduction zones because of complex geology and lack of oceanic stations. We can avoid some of these problems by applying the cut-and-paste (CAP) method, which allows for timing shifts between phases, assuming a 1D model, and determines source parameters. If the travel times or lags of the phases due to path effects are known relative to a reference model, we can locate the events' centroid with surface waves without knowledge of the 3D velocity structure. Here, we explore several possible methods of relocating and some preliminary waveform modeling of the slab structure.

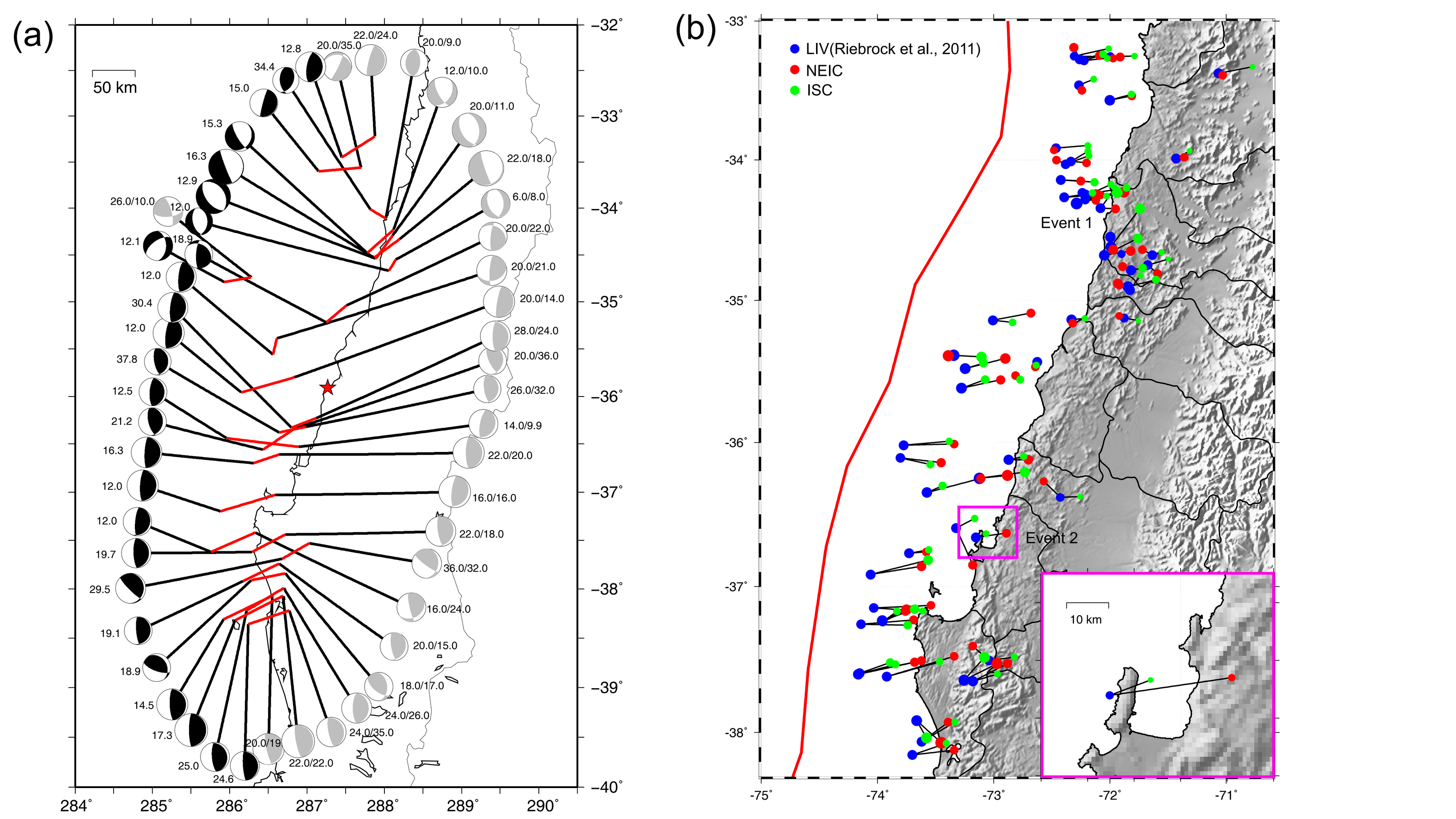
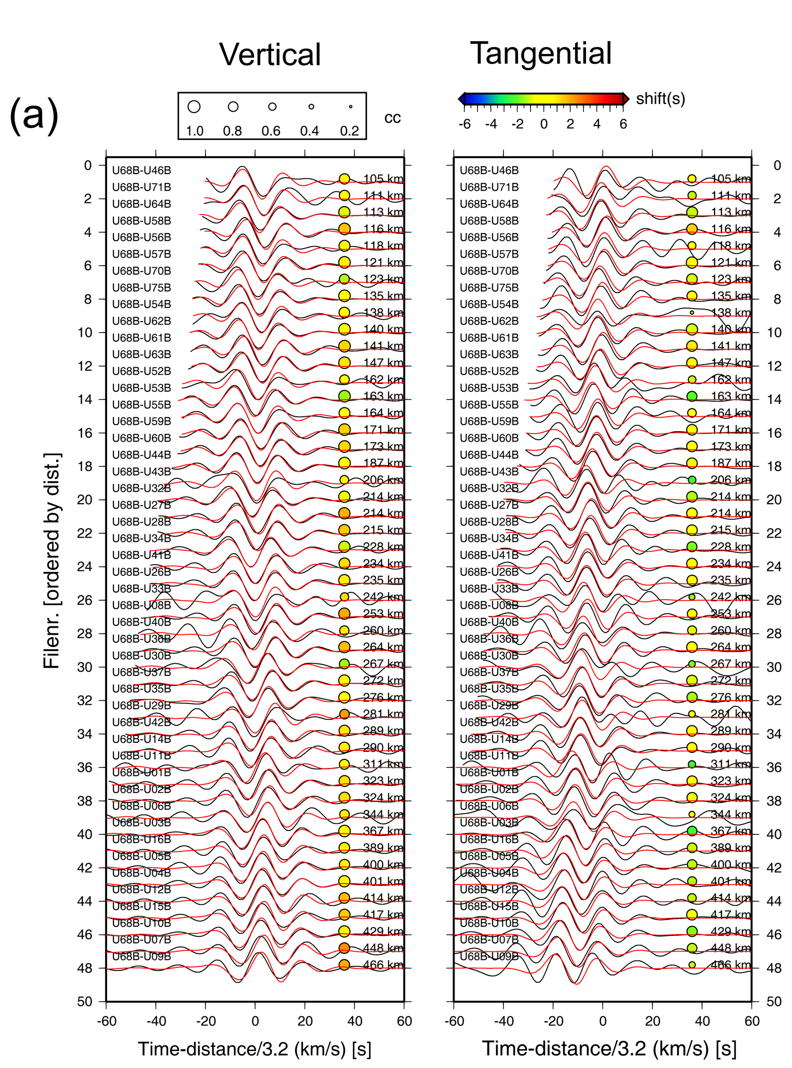


Figure 1. (a) A comparison of GCMT (black) and CAPt (grey) solutions of the aftershocks of the 2010 Maule earthquake. The numbers next to the beachballs are depth estimates. The first number (NEIC depth) and second (CAPt results) are included with the grey samples. The red lines indicate the difference in location. (b) Comparison of aftershocks location from three different catalogs (NEIC, ISC and LIV). Events enclosed in the magenta boxes are studied in Fig.3

Ambient Noise Study

A particular attractive approach for establishing path corrections for surface waves is ambient seismic noise (ASN) (Zhan et al., 2011), whose resolution is about 3 km. To do this we computed noise cross-correlations (NCC) between each station pair within the IRIS network (black triangles in Fig. 2b, Fig. 6), measured the lag of phases due to path effects relative to a 1D model, and developed them into tomographic maps (Fig. 2b).



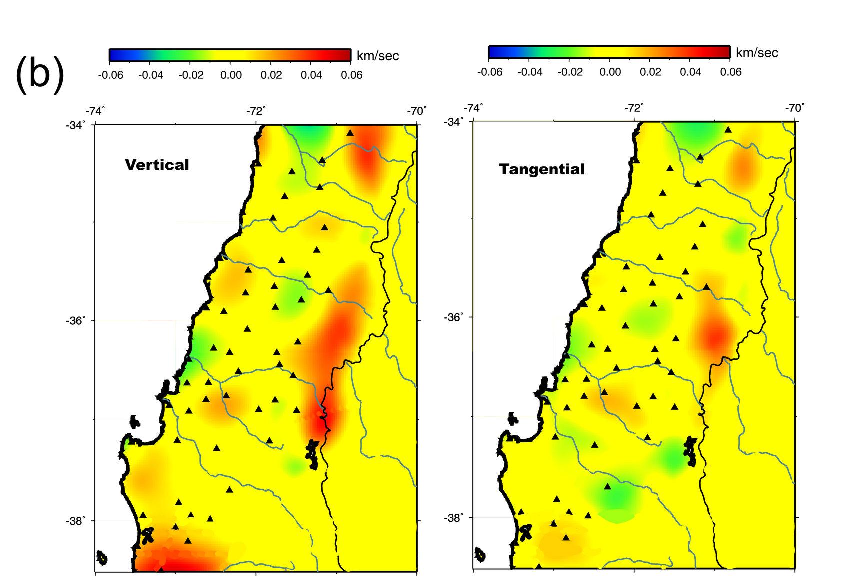


Figure 2. (a) A sample of comparisons between NCC and 1D synthetics. The waveforms are filtered to 15-100 sec, which is the same period band used for surfaces waves in regional CAP inversions. (b) Tomographic maps of the ASN surface wave velocity perturbation relative to the reference 1D structure.

Refining Earthquake Locations

With ASN path corrections for surface waves, we can deem the structure as 1D, and determine the events' centroid with Rayleigh waves. Another useful method proposed by Chu et al. (2011) is to determine water depth above the source using depth phases to control the off-shore distance. We compare results from these methods against those provided by Andreas Rietbrock (LIV) using a temporary amphibious network.

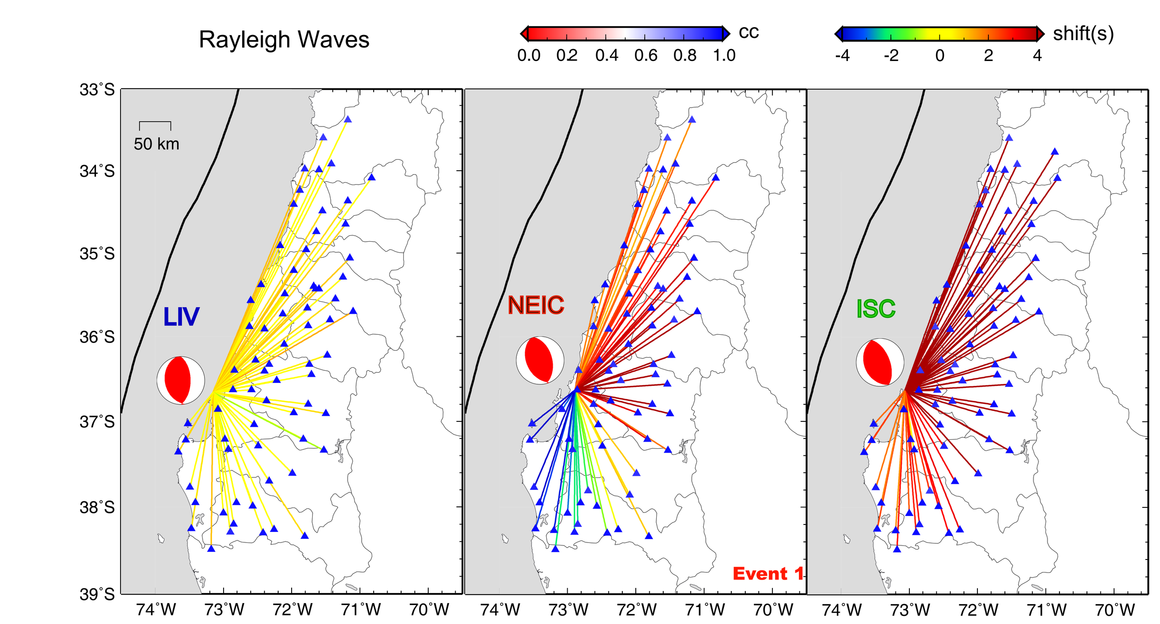
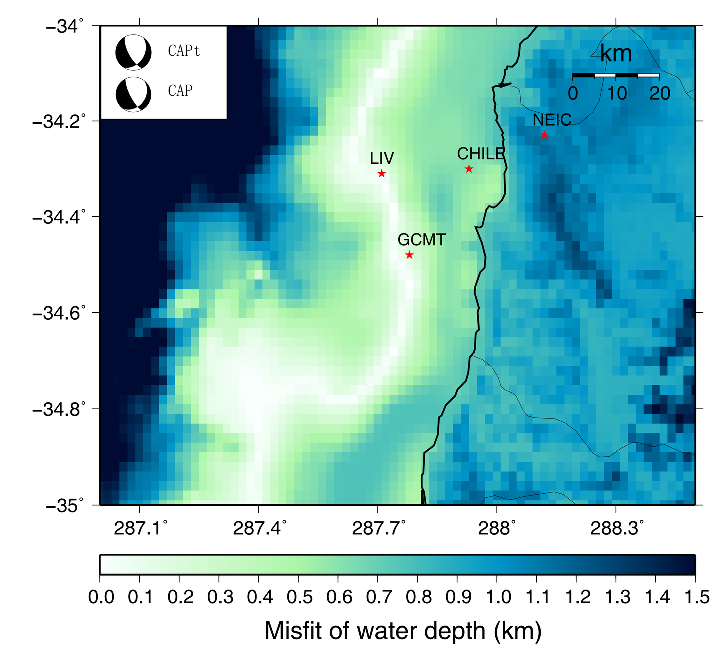


Figure 3. Spider diagrams of CAP inversions for Event 2 (Fig. 1b, Fig. 5) using different catalogs. The lines connecting the source and stations are colored by time shifts needed to align the velocity data and synthetics for Rayleigh waves (filtered to 15 -100 sec) . The stations(triangles) are colored by the cross-correlation coefficients. Red lines means actual travel time is longer than theretical in that path. It may indicate slow structure or the source location should be further away, or errors in origin time.

Figure 4. Mmap showing the misfit between ocean bathymetry and water depth determined by water phases (Chu et al., 2011) for Event 1 (Fig. 5). White color shows small misfit, which means favorable locations. Locations from other groups are also plotted for comparison.



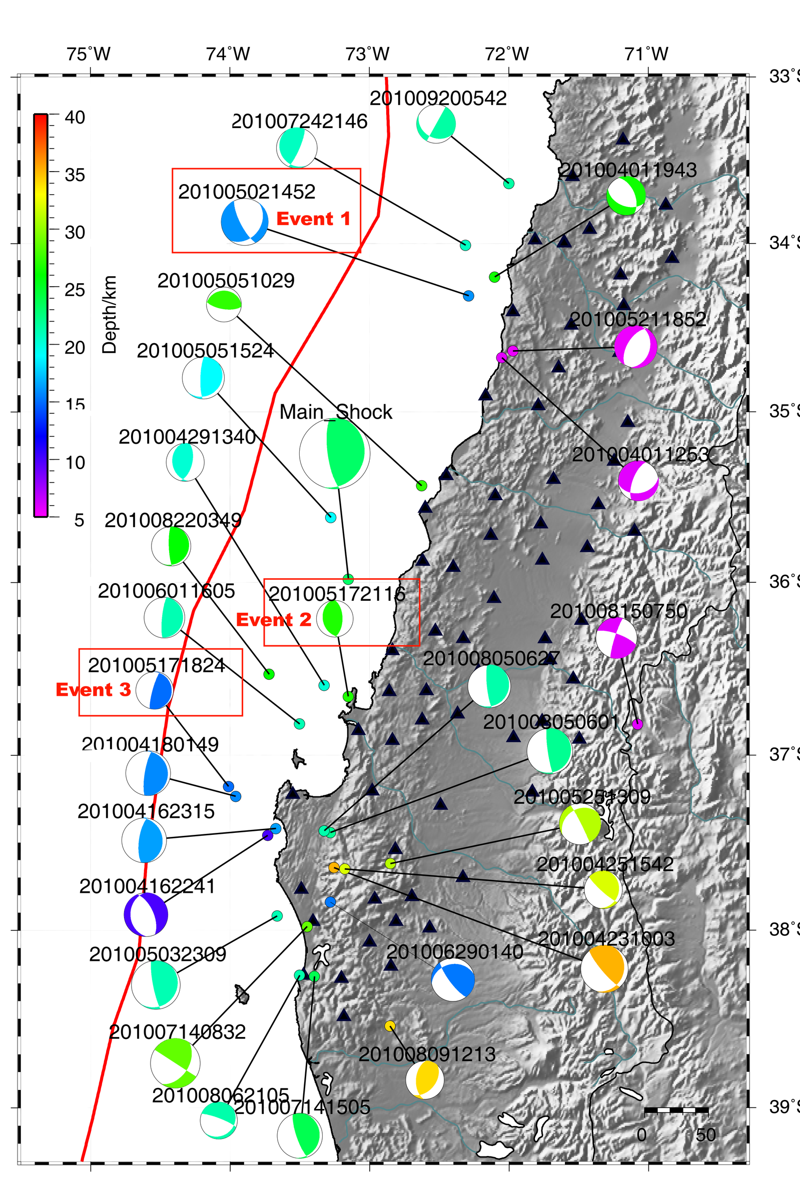


Figure 5. Mechanisms of aftershocks of the Maule Event (solution of the mainshock is from Global CMT) determined by regional CAP utilizing the above location refining approach. Events enclosed in red are studied in Fig 3, 4 and 6. The color of beachballs represents depth and the size indicates magnitude.

Preliminary Waveform Modeling of the Slab Structure

Most of the events show a strong travel time pattern caused by the fast dipping slab for this region (Haberland, Rietbrock et al., 2009). This feature is easily seen in the waveform patterns as well and appears sensitive to the oceanic-crustal waveguide.

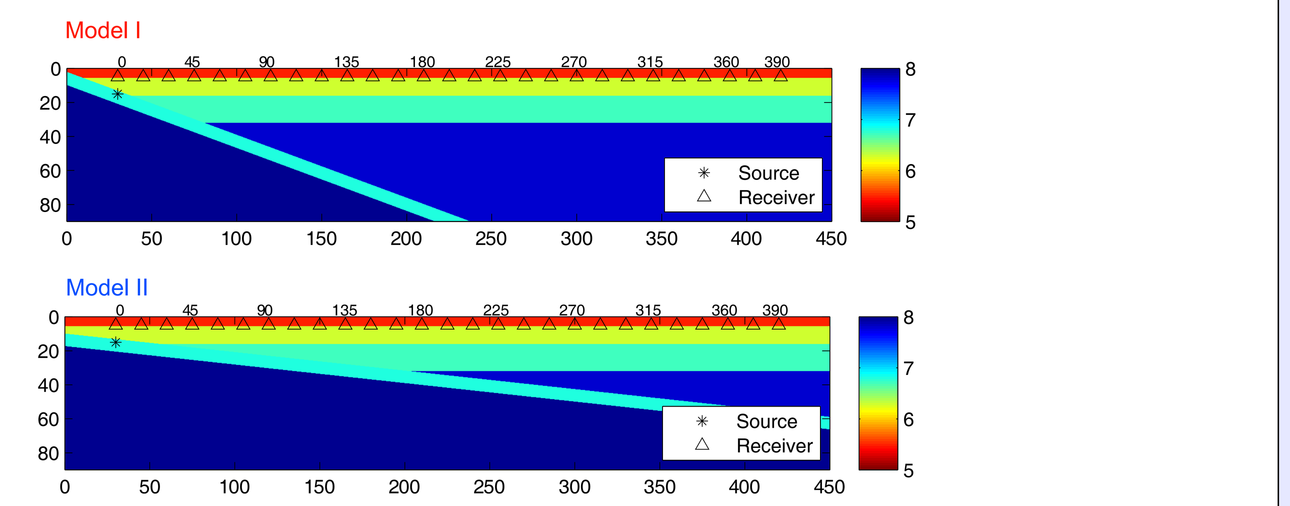


Figure 7. 2D models used in the Finite Difference (FD) modelIng. The different dipping angles in Model I and Model 2 are to simulate the slab structure at various azimuths.

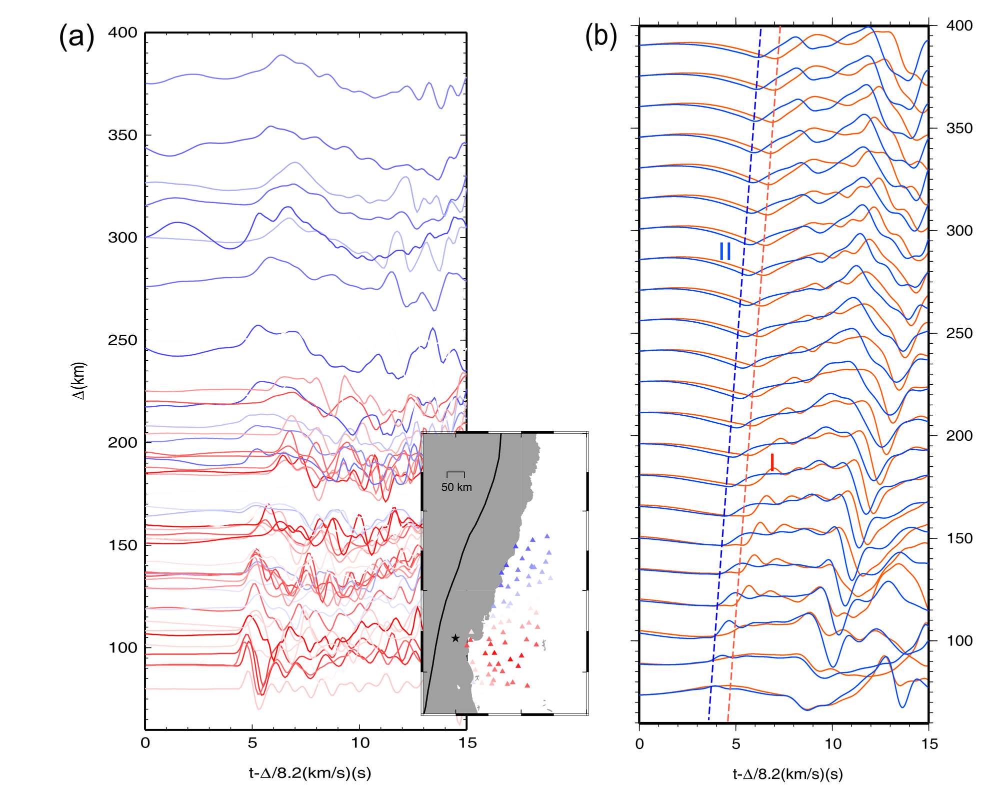


Figure 8. (a) Record section of vertical P-waves for Event 3 (Fig. 6). The waveforms are in displacement, and they are colored by azimuths as shown in the inset. It is notable that the red ones are slower while the blue/green ones are faster. The slow paths are mostly perpendicular to the trench where the dipping angle of the slab is large. (b) Synthetics from 2D FD modeling with models in Fig. 7. We can see for slow dipping slab structure the arrivals are earlier than the fast dipping slab case.

Observations of T-phase

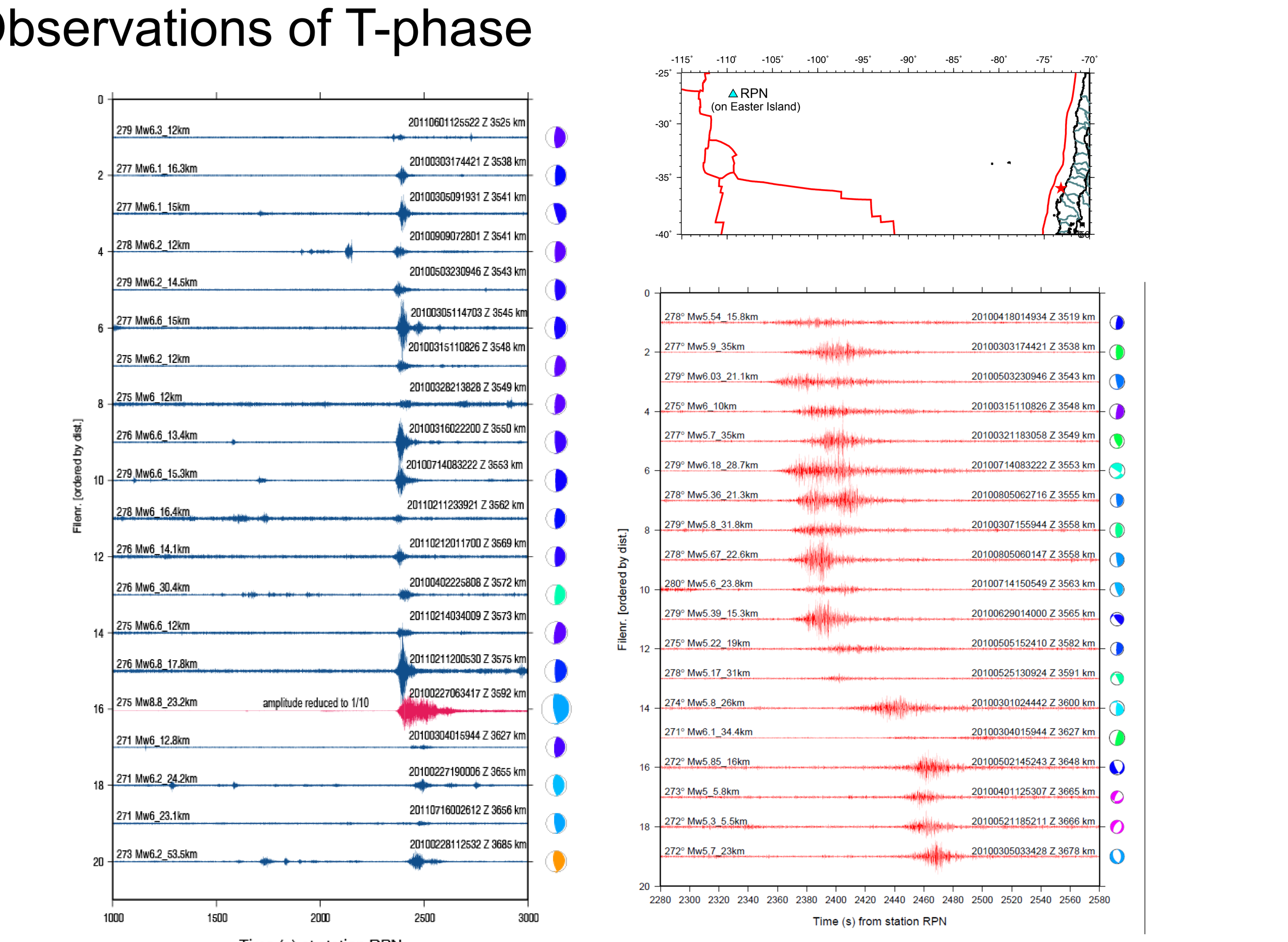


Figure 8. Another possible approach is to use the slow traveling T-phase. Some example observations of this arrival at Easter Island are displayed. On the left are some large aftershocks along with the main Maule event. On the right are events with our refined mechanisms and locations. The great variety of shapes is not well understood but we now have (thanks to Dunzhu Li) a code that can couple seismic waves into oceanic paths. It appears that depth is important as well as the coupling zone (local geology).