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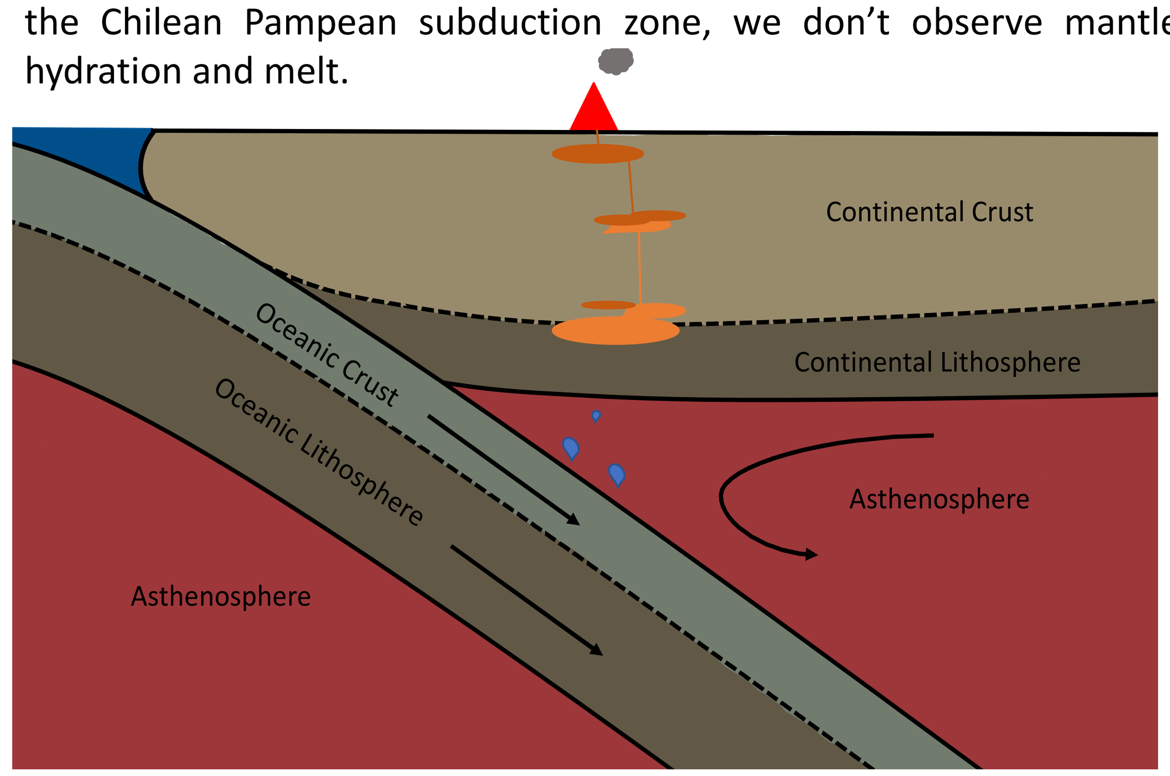
Subduction Zones

Earth is the only terrestrial planet known to have plate tectonics and subduction zones. A majority of the world's total seismic movement, including earthquakes, volcanoes, and tsunamis, are generated at subduction zones (Stern, 2002). They are also important interfaces for the circulation of crust, mantle, and ocean materials through our tectonic system (Tatsumi, 2005). In a normal subduction zone, thin, dense oceanic crust descends under less dense continental crust. As the plate subducts, it releases fluid in the form of a flux which hydrates the mantle and generates magma (Stern 2002). However, in the Chilean Pampean subduction zone, we don't observe mantle hydration and melt.



Above: diagram of a normal angle subduction zone. Compare with the flat slab subduction zone, far right

Flat Slab Subduction

The area of flat slab subduction on the Chilean coast, known as the Chilean-Pampean flat slab region, has been identified and studied since the 1970s (Ramos et al., 2009). In this region, the Nazca plate descends at a normal subduction angle of 30°, before flattening to a sub-horizontal angle between 200 and 400 km inland. The slab then returns to a normal subduction angle beneath the continental plate (Anderson et al., 2007). The flat slab subduction at this latitude is commonly attributed to the subduction of the Juan Fernandez Ridge, a volcanic seamount chain (Yáñez et al., 2002).

The ways the subducting flat slab interacts with the continental plate and a possible asthenospheric wedge are still poorly understood.

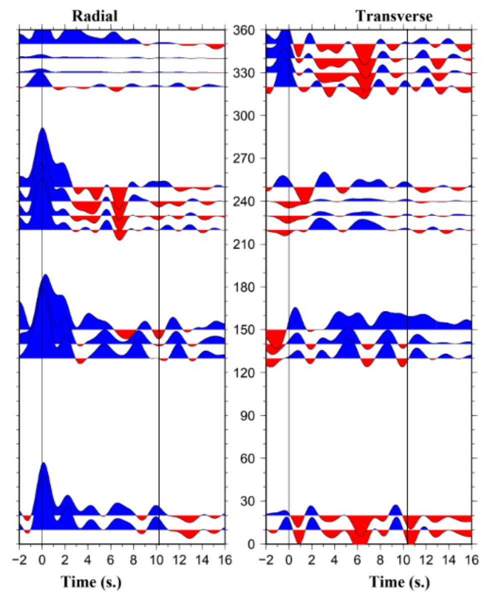
This area of flat slab subduction is notable for an absence of volcanism, which is a common feature of subduction zones. Seismically, the region is characterized by low seismic activity and an anisotropic anomaly. A seismically anisotropic medium will display a reversal of fast and slow velocities. In a horizontal subduction zone, a reversal every 90° is the most common (Park and Levin, 1997). Because the anisotropy correlates to this seismically inactive region and to certain mineralogical and structural features, the study of anisotropy in Chilean-Pampean flat slab region will teach us about the composition of the region and how its components interact.

The purpose of this study is to constrain anisotropy within the flat slab region. While previous studies have focused on the presence of anisotropy north of the flat slab region, we use seismic stations from the south to further define the boundaries of this seismic anomaly.

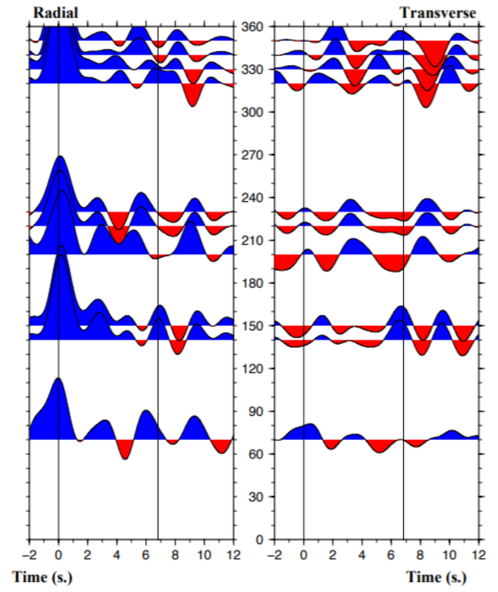
Observations

Receiver functions (RFs) are an important tool that can be used toward understanding the structure of subducting slabs. RFs are sensitive to both vertical (radial) and horizontal (transverse) changes in velocity. This gives us a sense of the geometry of the subducting plate on the radial, while also allowing us to see any changes in wave speed within each of the layers on the transverse. Lines drawn in each of the RFs presented here represent the subducting slab.

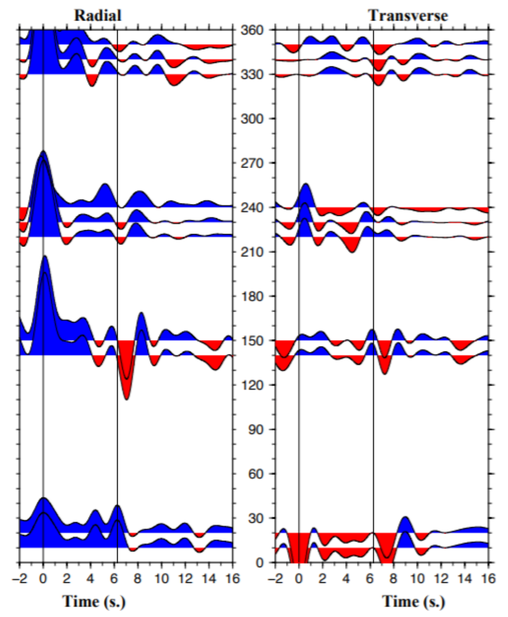
Station: BO02



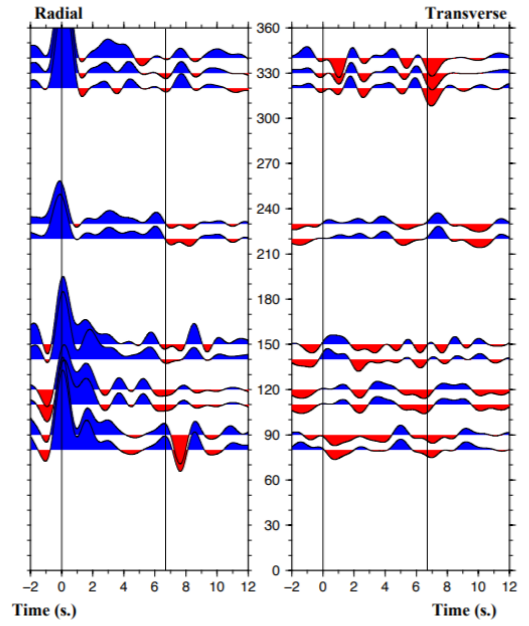
Station: CO02

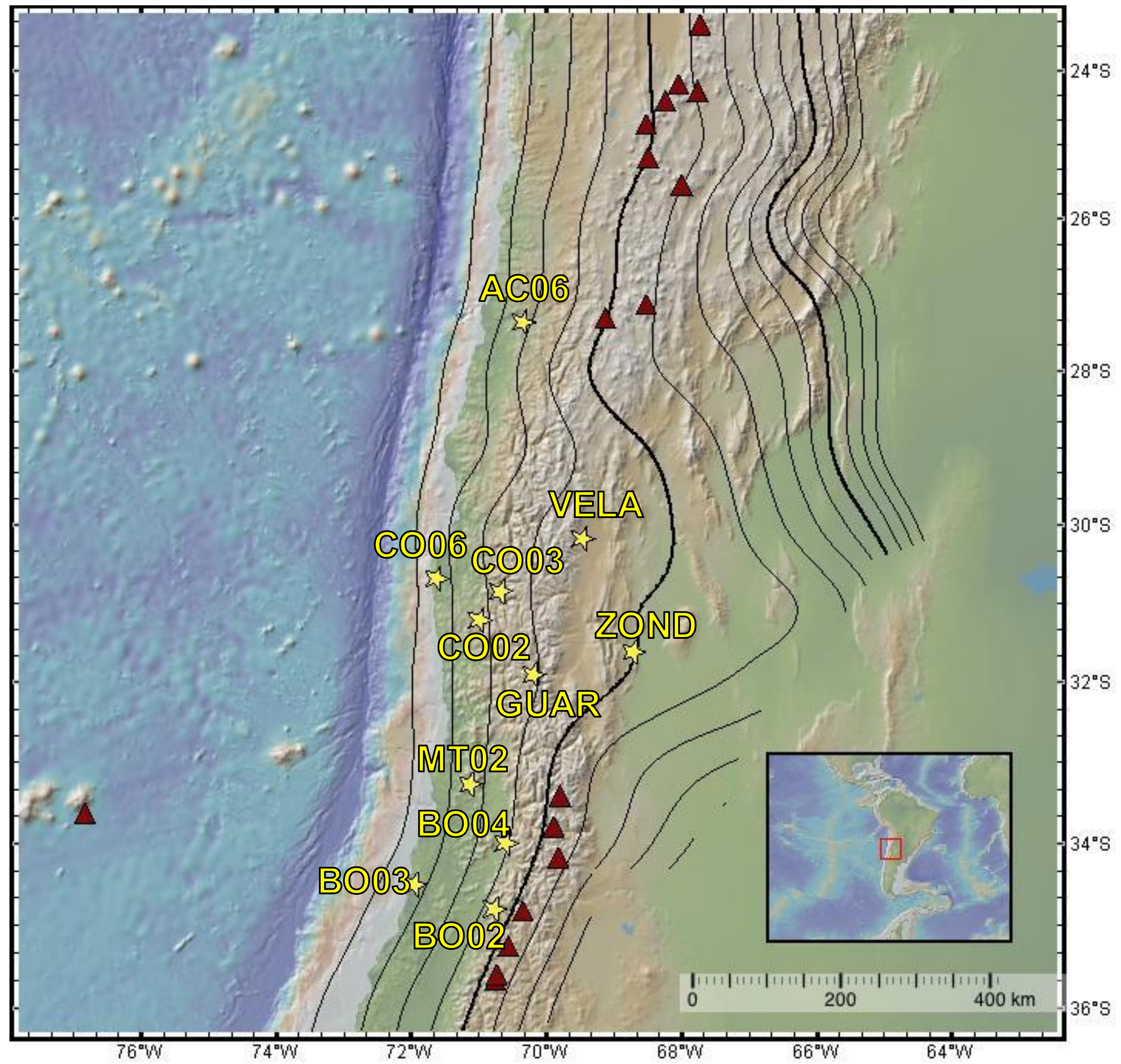


Station: MT02

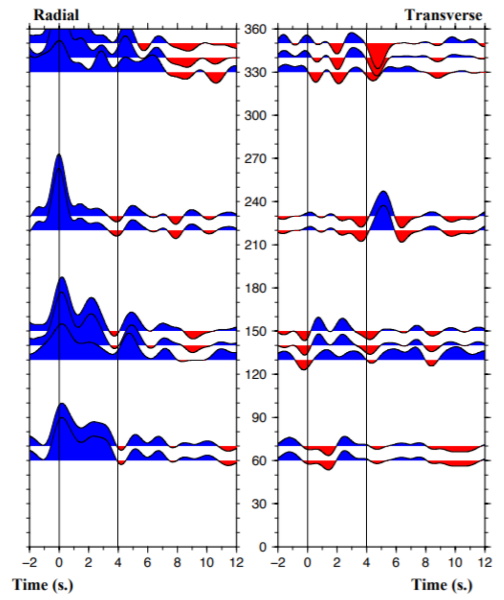


Station: AC06

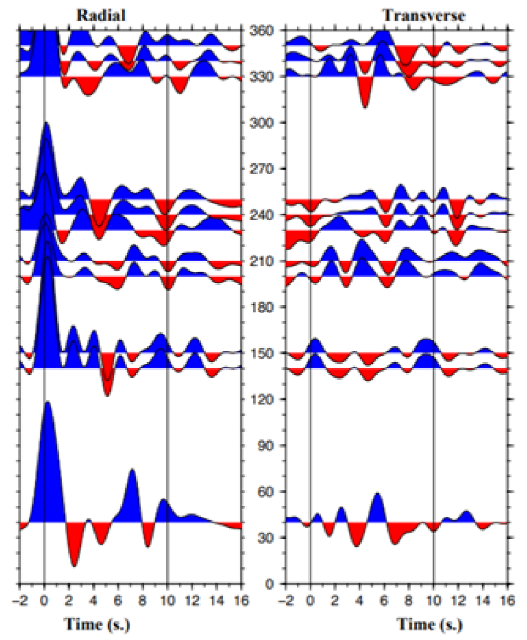




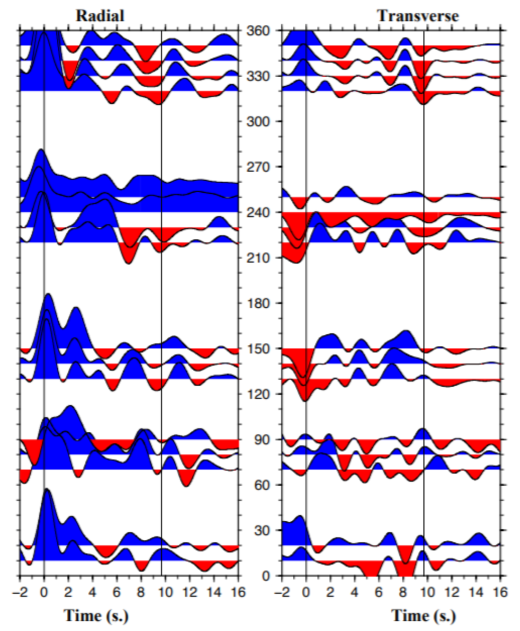
Station: CO06



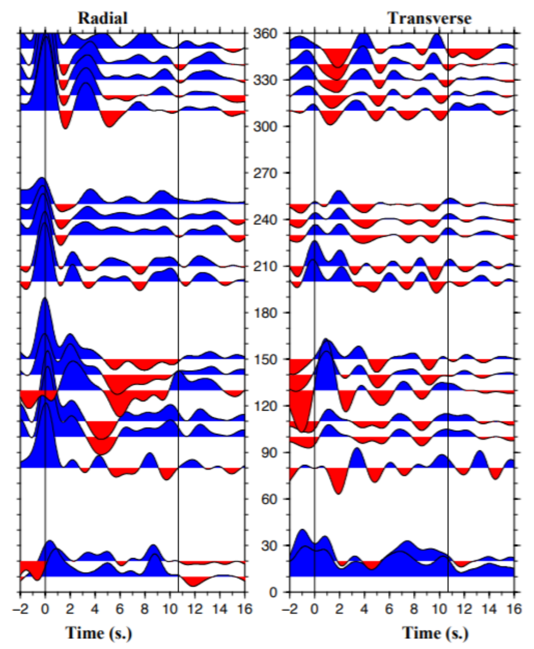
Station: GUAR



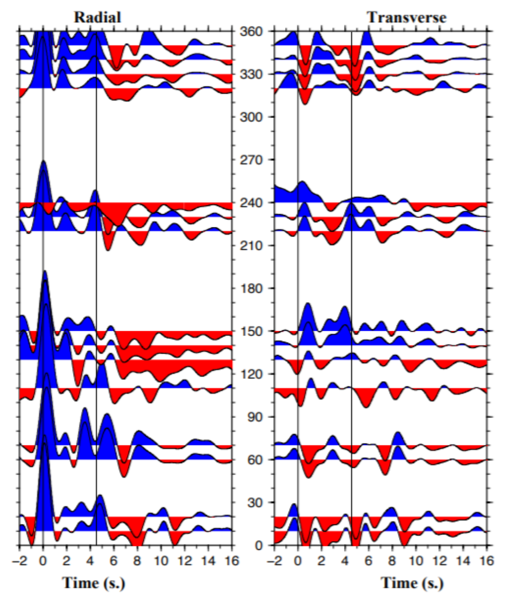
Station: BO04



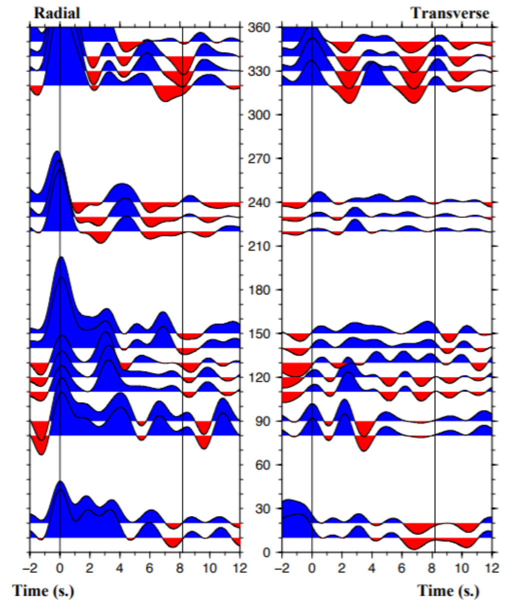
Station: VELA



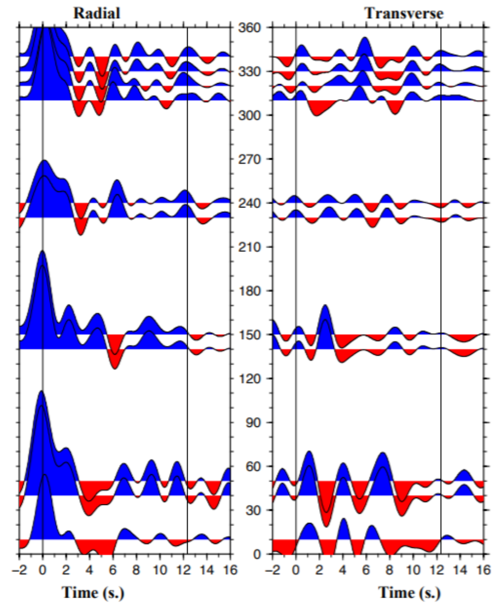
Station: BO03



Station: CO03



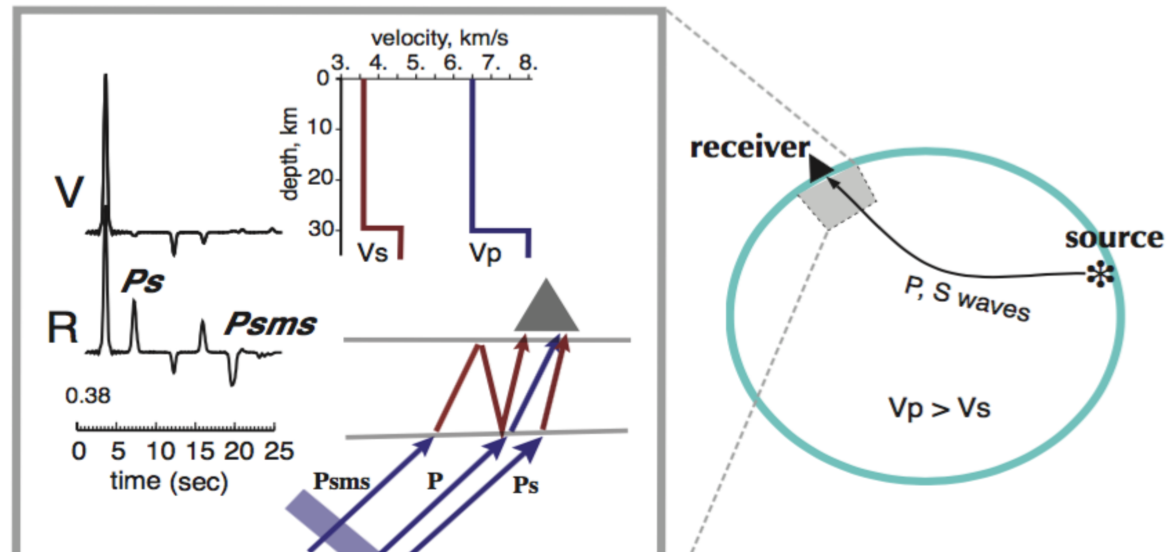
Station: ZOND



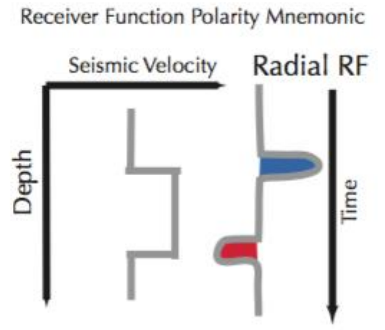
Methods

We used temporary seismic stations from the southern area of the flat slab region to create Receiver Functions (RFs). RFs are used to examine the structures beneath the station; in this study, we are looking for signs of anisotropy. The location of the flat slab is plotted on the RFs as a black line using a contour map of the flat slab region and assuming a two-way travel time of 8km/s.

To create a RF, we use teleseismic earthquakes of at least 5.3 magnitude. Using these earthquakes ensures that the seismic waves travel through with enough energy to record lateral velocity changes.



Above: RF diagram explaining how RFs are generated from wave data

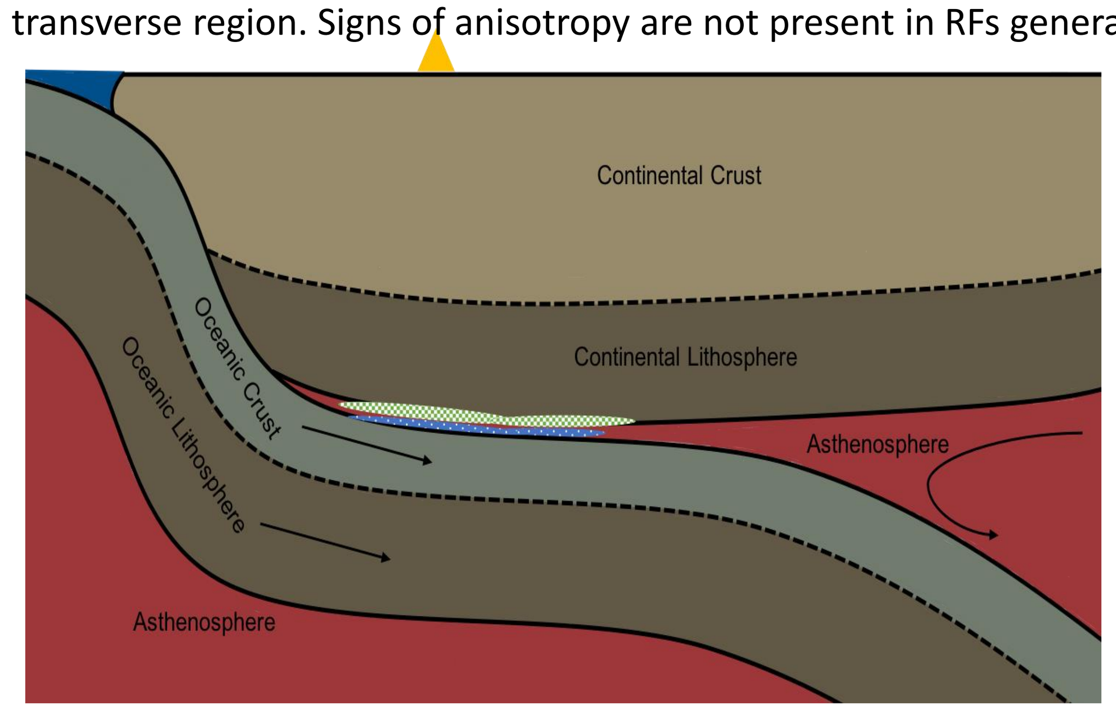


Above: example of change in velocity on a RF. In an anisotropic medium, amplitude is four-lobed (changes polarity twice along the back-azimuth)

Implications

In total, 17 viable RFs were generated in the area south of the flat slab, of which 12 are pictured at left. The central figure displays the location of the stations along the flat slab region and along the contours of the slab. Because many of the stations used were temporary stations, which are only active for an average of two years, many of the RFs lack full back-azimuthal coverage.

The two northernmost stations, AC06 and VELA, display some weak evidence of anisotropy in the transverse region. Signs of anisotropy are not present in RFs generated further south in the region.



The absence of anisotropic signal is best observed in stations with better coverage, such as BO04 and CO03, but is clear in all pictured RFs.

Based on the generated RFs, we conclude that there is some anisotropy in the transition out of flat slab subduction, but no anisotropy further south in the region.

Future Work

In this study we have focused mainly on stations on the southern half of the flat slab in order to supplement a previous study that focused on the northern stations. Going forward, we will combine the two to create a map describing the anisotropy in the region and how it changes from north to south.

Relevant References

Anderson, M. et al. (2007). Geometry and brittle deformation of the subducting Nazca Plate, Central Chile and Argentina. *Geophysical Journal International*, *171*(1), 419-434.;Bar, N., Long, M., Wagner, L., Beck, S., Zandt, G. and Tavera, H. (2019). Receiver function analysis reveals layered anisotropy in the crust and upper mantle beneath southern Peru and northern Bolivia. *Tectonophysics*, 753, pp.93-110.; Barazangi, M., & Isacks, B. (1976). Spatial distribution of earthquakes and subduction of the Nazca plate beneath South America. *Geology*, *4*(11), 686-692.; Gutscher, M. (2002). Andean subduction styles and their effect on thermal structure and interplate coupling. *Journal Of South American Earth Sciences*, *15*(1), 3-10.; Nikulin, A et al. (2019). Tracing geophysical indicators of fluid-induced serpentinization in the Pampean flat slab of Central Chile. *Geochemistry, Geophysics, Geosystems*, 20.; Ramos, V. et al. (2002). The Pampean flat-slab of the Central Andes. *Journal Of South American Earth Sciences*, *15*(1), 59-78.; Ramos, V., & Folguera, A. (2009). Andean flat-slab subduction through time. *Geological Society, London, Special Publications*, *327*(1), 31-54.; Yáñez, G. et al. (2002). The Challenger–Juan Fernández–Maipo major tectonic transition of the Nazca–Andean subduction system at 33–34°S: geodynamic evidence and implications. *Journal of South American Earth Sciences*, 15(1), pp.23-38.