Hunting for Ultra Low Velocity Zones using SKS and SKKS Differential travel time residuals

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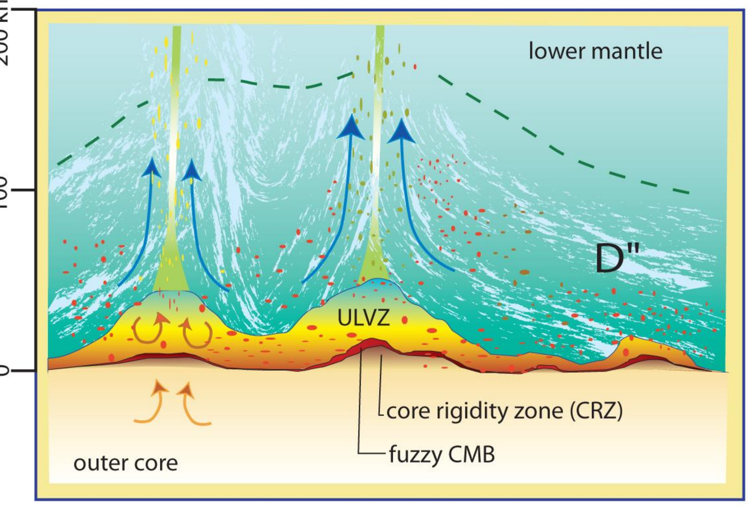
Introduction

Ultra-low velocity zones (ULVZ's) are characterized as localized thin (5-40 km thickness) layers at the CMB of strongly reduced seismic velocities but increased density. ULVZs influence multiple aspects of mantle dynamics and might be the source of mantle plumes, regions of core material invading the mantle, and/or geochemically distinct regions such as the remnants of a global magma ocean or currently undefined exotic material.



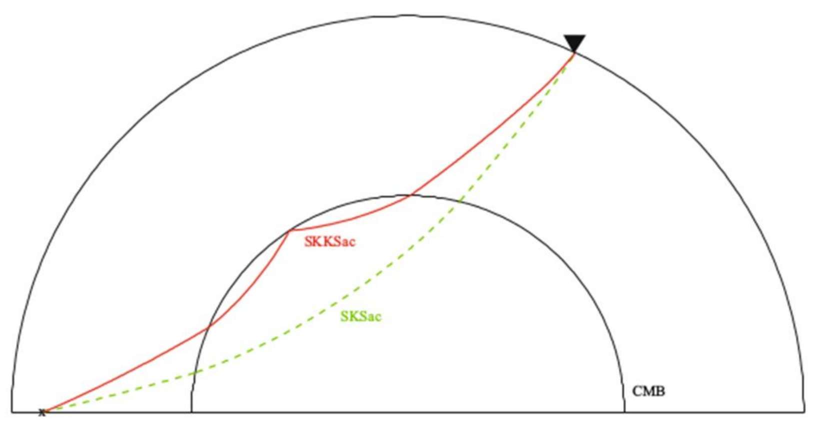


Figure 1 (left, top): ULVZs are thought to influence mantle dynamics and are potential plume roots near the core-mantle boundary (CMB). Moreover these zones in which Vp is reduced by ~10-15%, Vs is reduced ~30-45% and density is increased by ~10-15%, are commonly observed near the edges of large low shear velocity provinces (Image from E. Garnero Image Gallery). Figure 2 (left, bottom): In this study we employ SKS and SKKS waveforms to calculate SKS-SKKS differential travel time residuals. Because the raypaths are similar in the upper mantle it is assumed that observations highlight lower mantle/D" structure (Figure from Vanacore and Niu, 2011)

Results and Interpretation

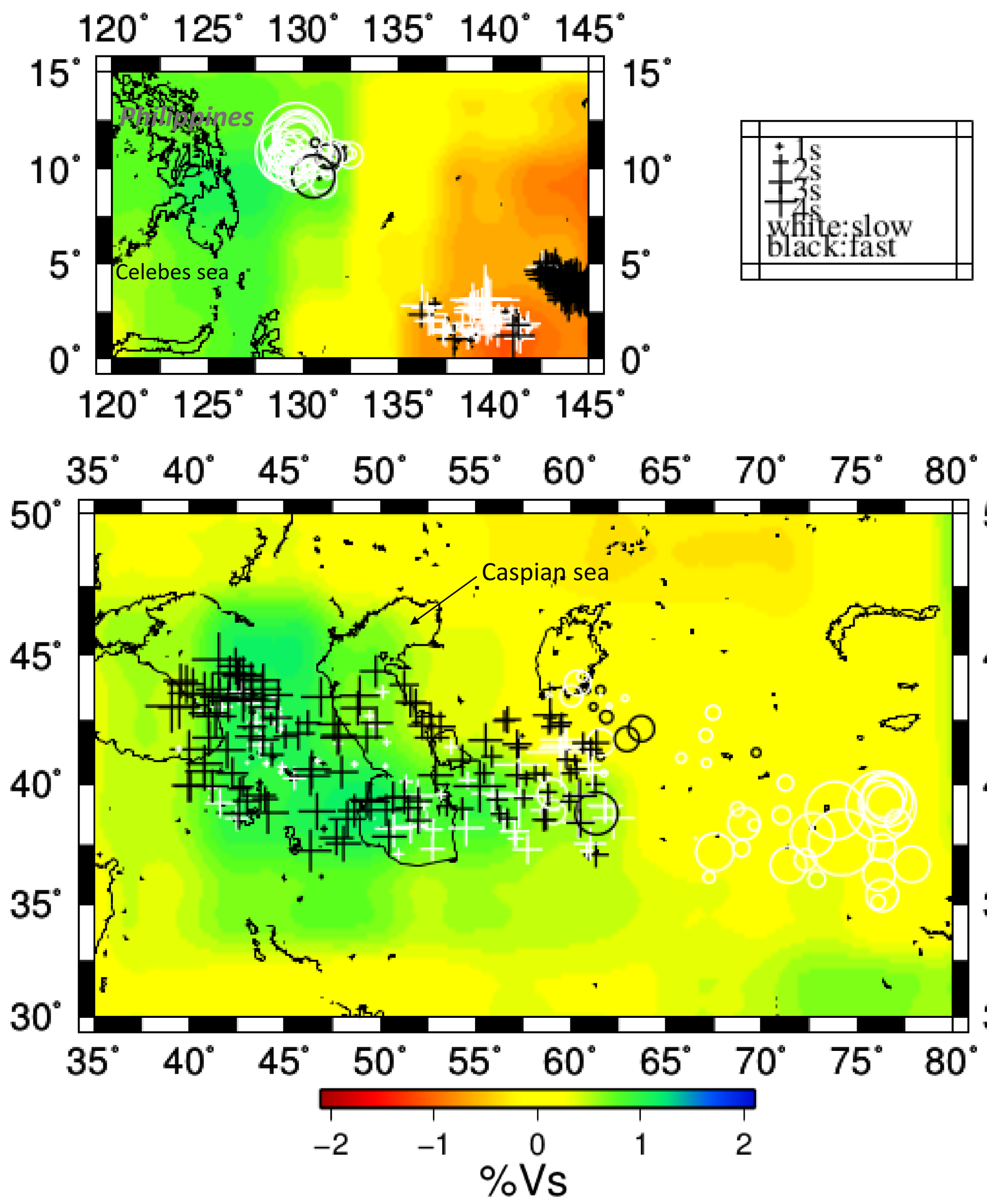


Figure 5 (left). The results of the differential travel time residual calculations for the SKS/SKKS CMB entry points (top) and exit points (bottom). Points are plotted where the path indicated by the statistical analysis (2008-SKS, 2009-SKS and SKKS, 2010-SKS). The white symbols represent regions with a negative differential travel time whereas black symbols indicate positive differential travel time residuals. Negative travel time residuals indicate low velocity zones along the SKS raypath or high velocity along the SKKS raypath. Positive residuals indicate the high velocity anomalies along the SKS raypath or negative velocity anomalies along the SKKS raypath. Here the white cluster of + symbols is interpreted as an ULVZ on the entry side. The black cluster of + symbols is interpreted as a possible high-velocity anomaly on the exit side. Alternatively the high velocity signal may be due to raypath multipathing within the West Pacific slab graveyard. The background is Grand's Tomography model (Grand, 2002).

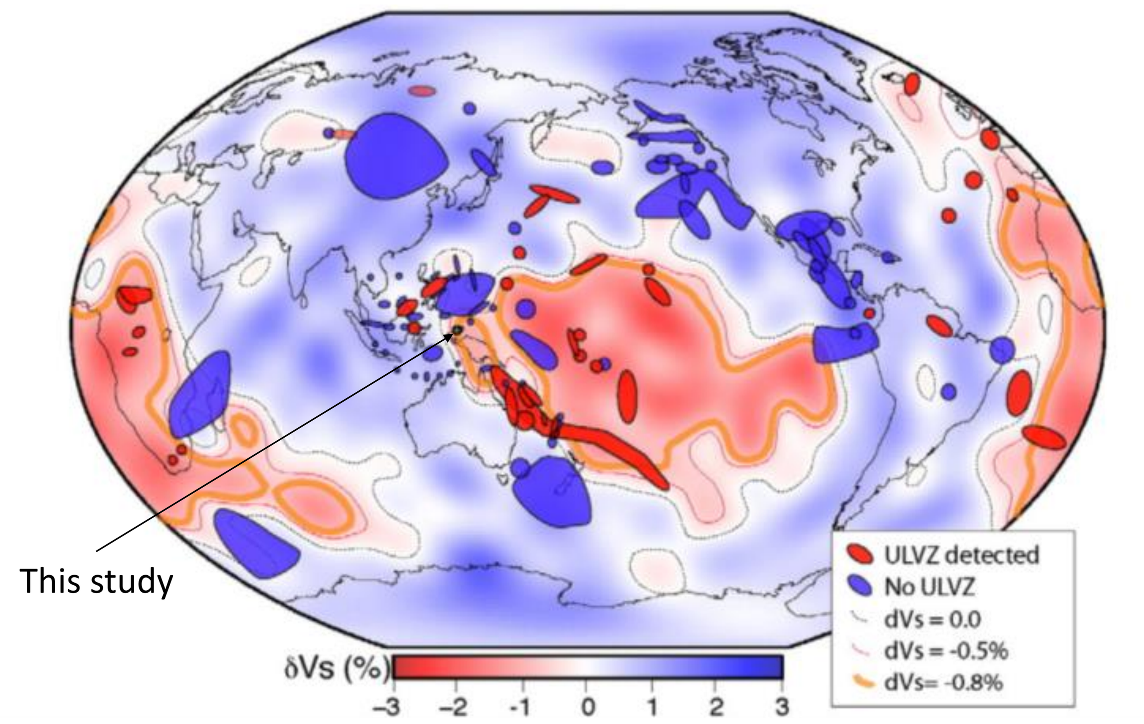


Figure 6 (above): The ULVZs identified in Figure 5 are quite concordant with other previous studies as they are located near edge of the Pacific Large Low S Velocity Province. Moreover the potential ULVZs in this study occur in a region that has contain mixed results of detection and non-detection from various seismic probes (e.g. ScP, PcP, SKS). The gray dots indicate the approximate locations of the ULVZs detected in this study where previous detections (red) and non-detections (blue) (Figure modified from McNamara et al, 2010).

Data

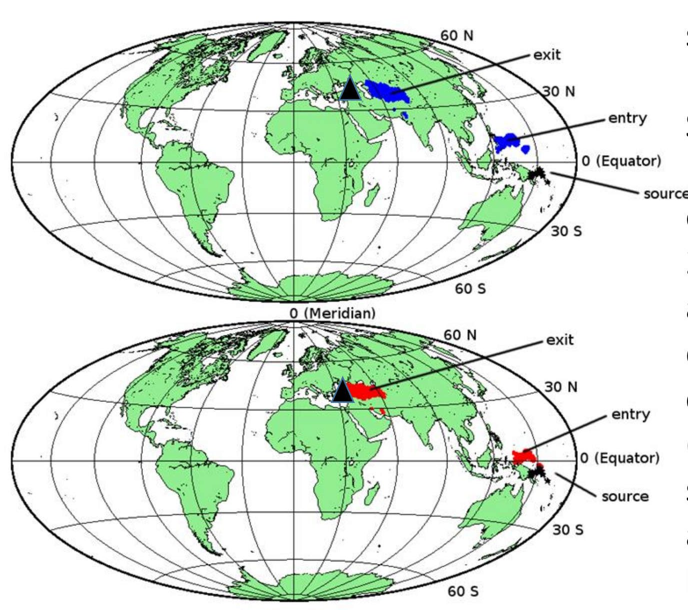


Figure 3. This study uses SKS and SKKS waveforms recorded in Anatolia by seismic networks managed by the the Kandilli Observatory and the National Seismic Array of Turkey (AFAD-DAD). Here we analyze three high quality events occurring in the West Pacific in 2008, 2009, and 2010. Additional analysis was limited by data quality. The distribution of entry and exit point coverage of SKS (Blue, top) and SKKS (red, bottom) for the data set. Black stars indicate events available for analysis between 2005 and 2010; the black triangle represents the approximate location of the seismic arrays.

Event Date	Location (latº, lonº)	Depth (km)	Magnitude (Mw)
08/30/2008	(-6.15, 147.26)	75.0	6.4
05/12/2009	(-5.66,149.54)	89.0	6.1
03/20/2010	(-3.36, 152.25)	414.6	6.5

Table 1. Events used for the studies selected with higher magnitude for higher quality data.

Methodology

Differential travel time residual are calculated such that:

$$\delta T_{2K\text{-}K} = \Delta T_{2K\text{-}K\text{-}O} - (\Delta T_{2K\text{-}K\text{-}PREM} + \Delta T_{T2K\text{-}K\text{-}3DC})$$

Differential travel time residuals = Observed - (1D + 3D correction)

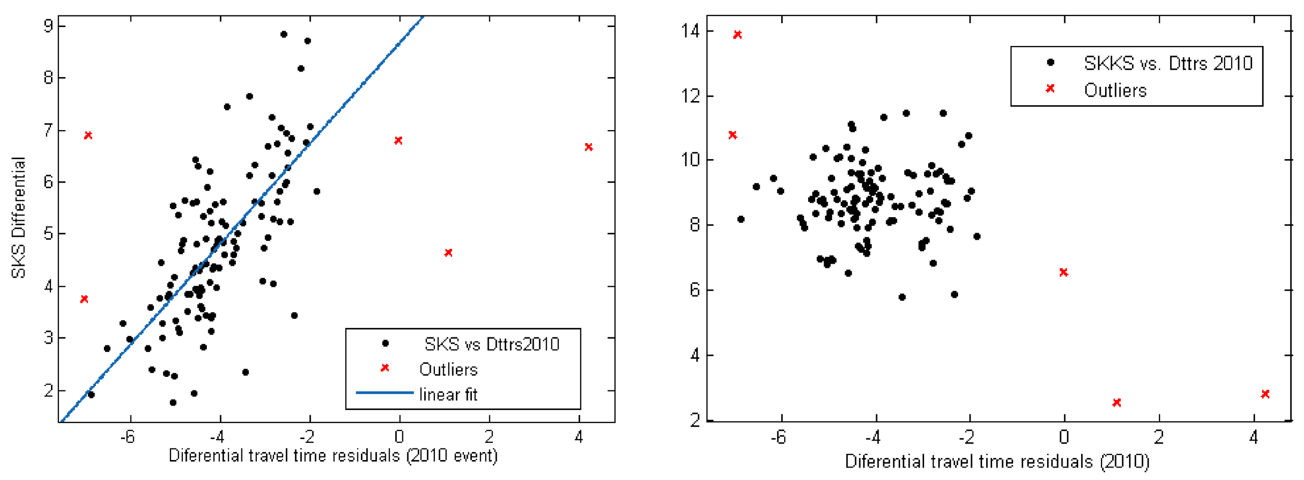


Figure 4: After the ∂T is calculated, we apply a statistical analysis to determine if an observed anomaly is sampled by the SKS or SKKS raypath. We employ the method used in Vanacore and Niu, 2011. We correlate the individual SKS and SKKS travel time residuals with the measured differential travel time residuals. If the values are well correlated, then this indicates that the velocity anomaly is located on that leg. Above we show an example from the event on 03/20/2010 Here the SKS leg (left) shows a strong correlation (R^2=0.4775) whereas the SKKS leg (right) is weakly correlated (R^2=0.0030). This indicates that the velocity anomaly detected by the differential travel time residuals is along the SKKS path.

Graph description	R-square values 1-D	R-square Values 3-D
SKS vs Diff residuals – 2010 event	0.34	0.48
SKKS vs Diff residuals – 2010 event	0.03	0.003
SKS vs Diff residuals – 2008 event	0.60	0.23
SKKS vs Diff residuals – 2008 event	0.14	0.29
SKS vs Diff residuals – 2009 event	0.53	0.51
SKKS vs Diff residuals – 2009 event	0.70	0.68

Table 2. Includes the statistical information from the plots for the 1D data and the 3D data.

Conclusions

- A possible ULVZ is identified near the edge of the Pacific Large Low S Velocity Province. This detection signal may additionally be influenced by fast velocities along the SKKS path (circles in Figure 5).
- A region of fast velocity in the lowermost mantle is identified near the Caspian sea. This region is coincident with a high velocity structure identified in the Grand (2002) tomographic model.
- To determine the validity of the interpretations future work employing additional phases such as ScP and PcP as well as more detailed modeling is required.

Any Questions? Ask me via e-mail: aldwin.vazquez@upr.edu

References

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