The topography of the mantle seismic discontinuities beneath the Alaskan subduction zone

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Introduction

In the Alaskan subduction zone, the Pacific slab subducts underneath the North American Plate. Different seismic tomography models do not agree on the depth extent of the slab. Here, receiver function analysis is used to study the topography of the global mantle discontinuities, to gain more insight in the earth structure underneath Alaska. This research has been possible by the recent deployment of the USArray Transportable Array (TA) stations.

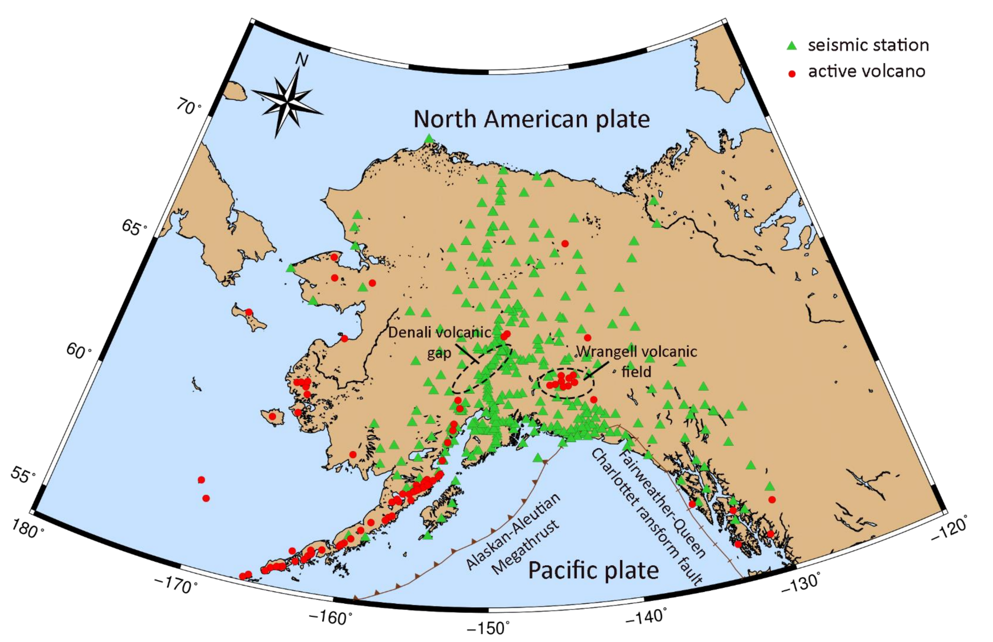


Figure 1: Map with the geometry of the Alaskan subduction zone. Distribution of stations in Alaska used in this study, are shown with green triangles.

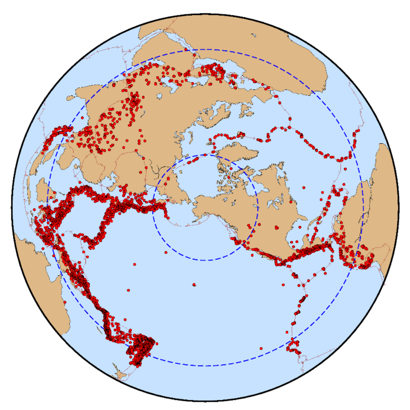


Figure 2: Distribution of events from 2000-2017 with M_w between 5.5 and 8.3, used in this study, shown with red circles, The blue contours define the epicentral distance range of 30° to 90° from the centre of Alaska. The final data set before quality control consists of 331079 event to station pairs from 375 stations across Alaska.

Seismic discontinuities

- The globally observed major seismic velocity discontinuities around depths of 410 and 660 km mark the top and the bottom of the mantle transition zone, the region that divides Earth's upper and lower mantle
- These discontinuities have been interpreted as polymorphic phase changes in the olivine system
- The phase transitions do not occur at the exact same depth everywhere, but vary depending on temperature, composition and water content
- For example, in colder regions like a subducting slab, an uplifted 410 and depressed 660, and thus a thicker mantle transition zone, are expected

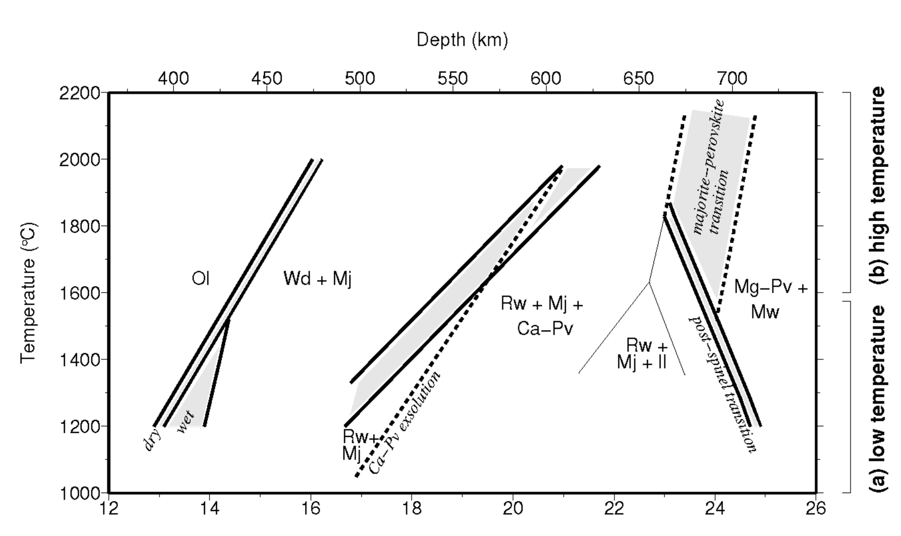


Figure 3: Schematic cartoon summarizing the phase transitions occurring in the mantle transition zone as a function of pressure and temperature. As can be seen, the olivine phase transitions around 410 and 660 km depth behave opposite to temperature anomalies. Not only olivine phase transitions (thick solid lines), but also garnet phase transitions (thick dashed lines) occur at these depths. The olivine to wadsleyite phase transition around 410 km depth broadens as a function of water content, but only for low temperatures.

Results

Three cross sections are made showing stacked receiver functions that all cross the location of the subducting slab and sample areas with high data coverage.

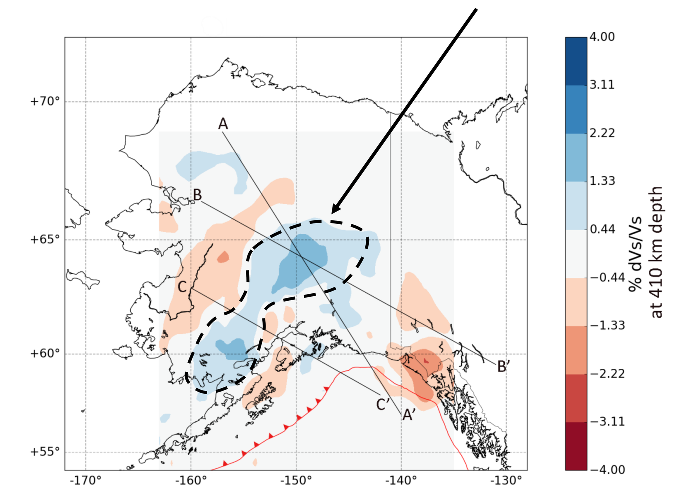


Figure 5: Locations of the three cross sections, plotted on top of the velocity model at 410 km depth. Location of the subduction zone at the surface is shown in red.

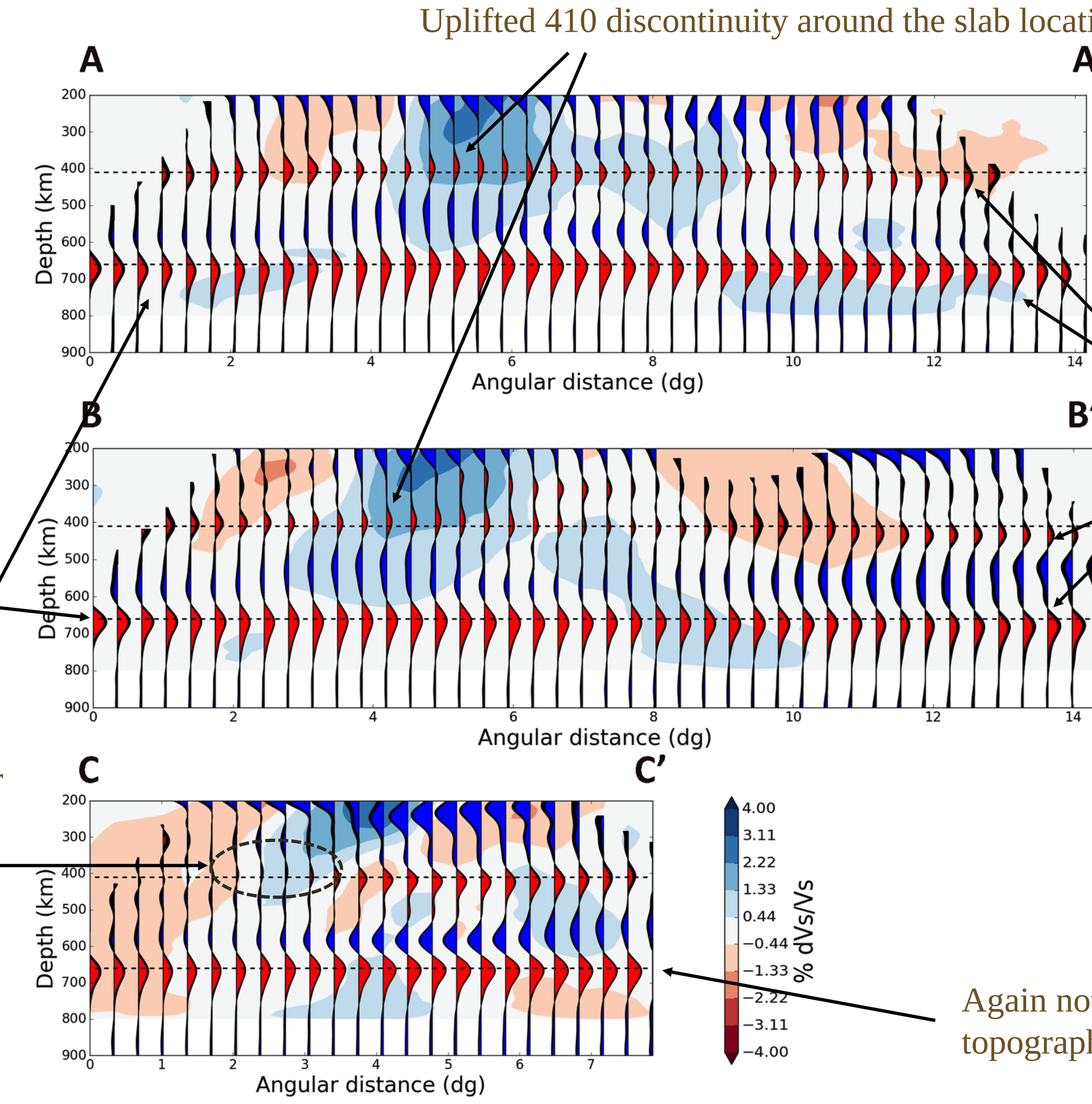


Figure 6: CCP stacked traces for the cross sections shown in figure 5. The 3D velocity model is plotted in the background. The large blue fast velocity anomaly is interpreted as the subducting Pacific slab.

The stacked receiver functions are used to make maps of the topography of the 410 and 660 and the transition zone thickness.

- Elevated 410 around the location of the slab, implying that the slab is penetrating through the 410 discontinuity
- Shallow part in the northeast, deep part in the southeast

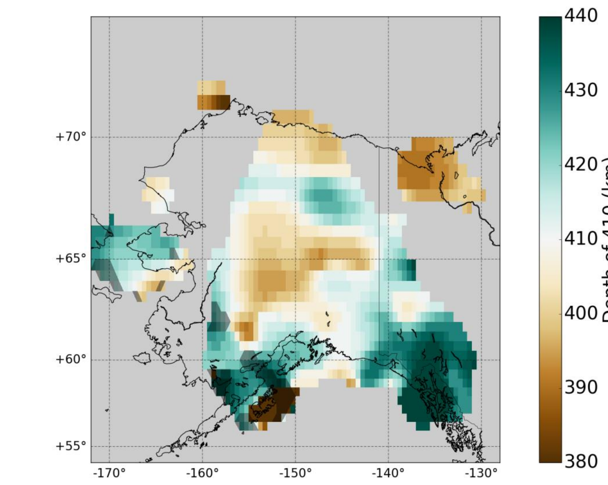


Figure 7: Topography of the 410 km discontinuity.

- Not such a significant signature of the slab at 660 km depth
- Could imply that the slab extends until somewhere in the MTZ or that the receiver functions are not able to image it at the 660

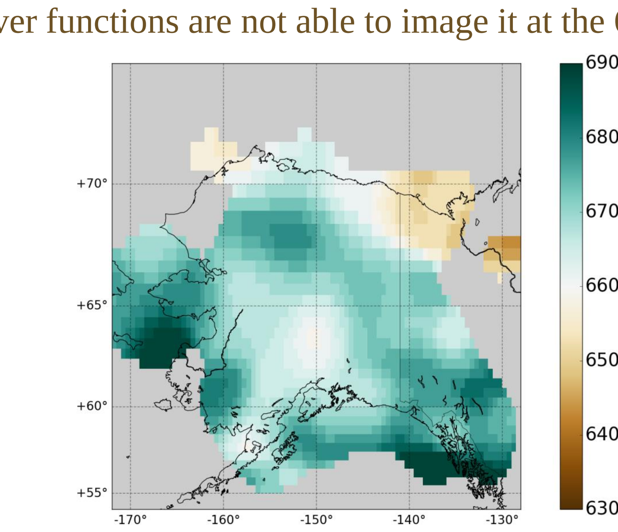


Figure 8: Topography of the 660 km discontinuity.

- Thickness of the MTZ varies considerable in the region
- The most prominent feature is the thicker part beneath central Alaska
- Thinner parts in the southeast and southwest

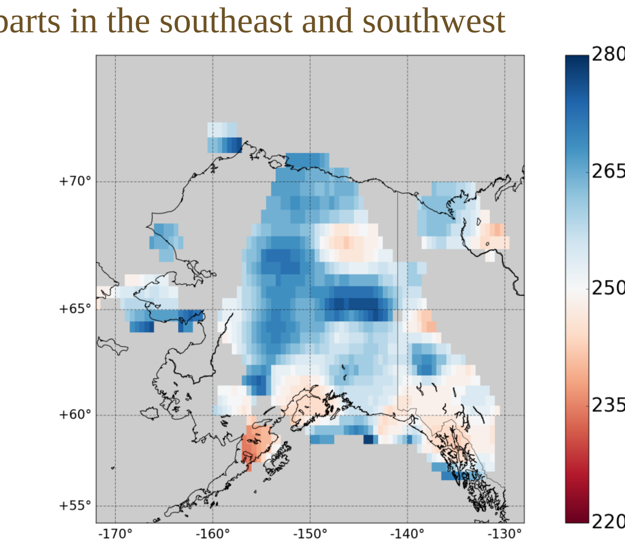


Figure 9: Transition zone thickness.

Methods

- Receiver functions use the fact that P to S conversion takes place when a seismic ray hits a discontinuity
- P660s and P410s have travelled as P-wave first, and only a small part as S-wave
- They arrive 40 to 70 seconds after the direct P-arrival

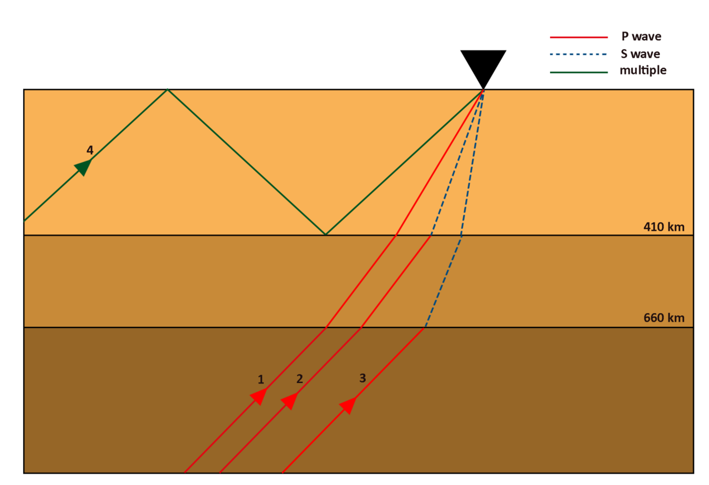


Figure 4: Ray paths of a direct P-wave (1), the two converted phases P410s (2) and P660s (3) and a multiple (4).

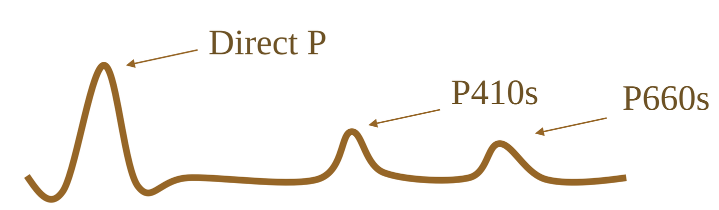
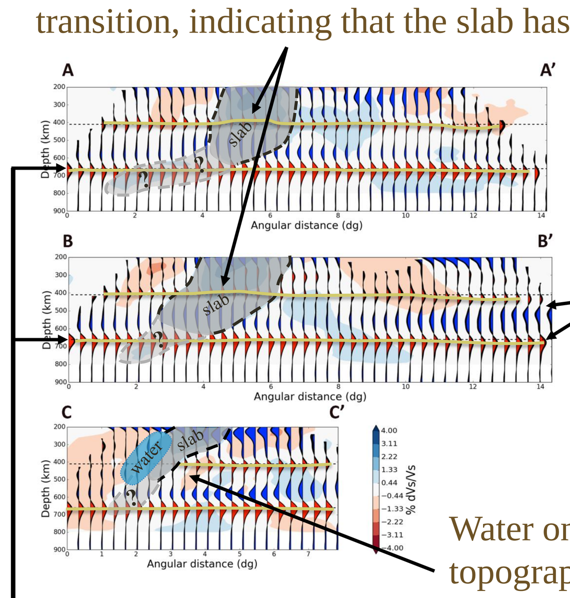


Figure 5: Example of a receiver function. The direct P and two converted phases are indicated.

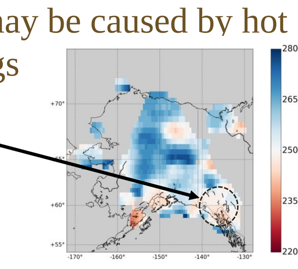
- After quality check 207410 radial receiver functions are used to make a common conversion point stack
- Regional velocity anomalies are accounted for by a regional tomographic velocity model (Burdick et al. 2017) and a crustal model (Laske et al. 2013)
- Smoothing is applied over an area twice the width of the Fresnel zone

Discussion and conclusions

The elevated 410 discontinuity and thicker mantle transition zone in central Alaska are describing the thermal interaction of the cold slab with the phase transition, indicating that the slab has penetrated through the 410



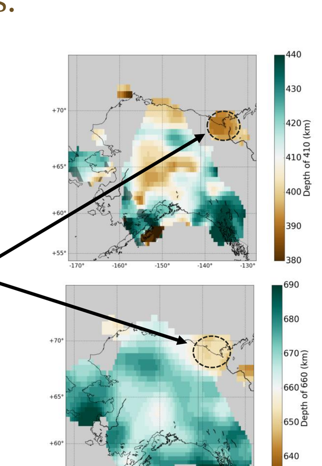
The area in the southeast corresponds to the location of a slab window, and thinning of the mantle transition zone may be caused by hot mantle upwellings



Water on top of the subducted slab, or too much topography on the 410 discontinuity, can cause diminishing amplitudes

The slab could have reached the 660 without the receiver functions being able to image it. A spreading zone between the Pacific and ancient Kula plate once existed and is now subducting as part of the Pacific plate. So, this part of the slab is likely to consist of young and thin, and therefore less cold, lithosphere. This causes less temperature variation and may not result in discontinuity topography as seen by receiver functions.

If velocity anomalies in the mantle are not corrected for accurately, they will cause highly correlated discontinuity depths. The region with an elevated 410 and 660 lies at the edge of the North American craton and outside the area of the velocity model used to correct the discontinuity depths. Therefore, the velocities in the upper mantle are likely to be undercorrected in this region



References and Acknowledgements

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