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Searching for ultra low velocity zones on the core-mantle boundary beneath the Aleutian subduction Zone

a) b)

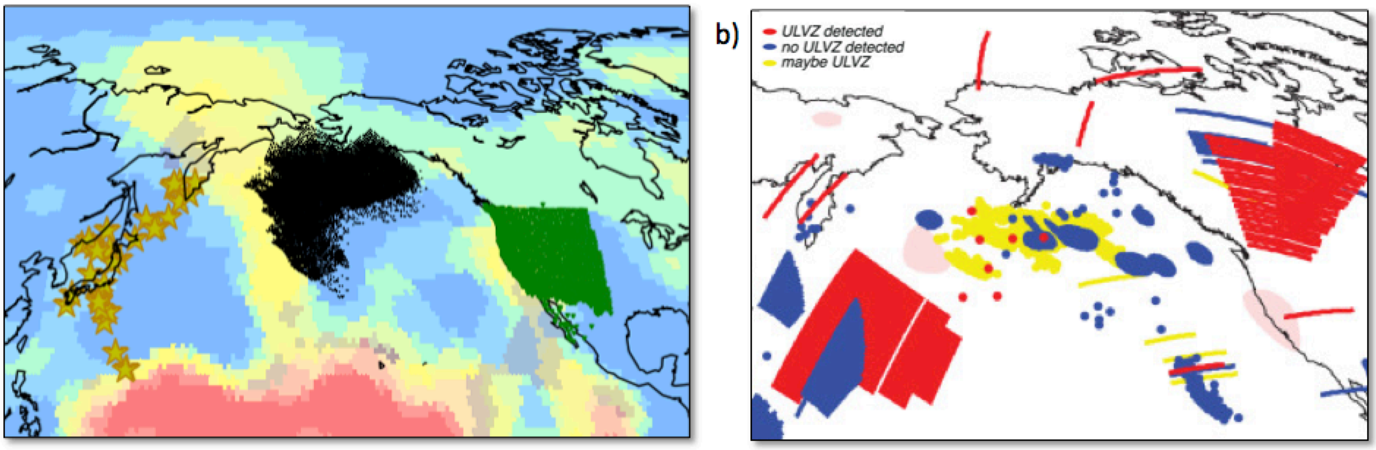

Figure 1: a) Events (yellow stars), seismic stations of the US array (green triangles) and bounce points on the CMB of ScS phases (black dots), suggested for use in this project. Coloured background shows a vote map (Lekcic et al., 2012) of several tomographic models with red colours showing regions where many models agree on slow velocities on the CMB, identifying the Pacific LLVP, and a potential northwards branching arm. b) From Yu and Garnero (2018), map of previous studies results on searching for ULVZ beneath the Aluetian subduction zone.

1. Background

Ultra low velocity zones (ULVZs) are poorly understood features that sit on the core-mantle boundary. ULVZs show seismic wave speed reductions of tens of %, and are small in scale - 100s of km wide by tens of km high and are often defined by a sharp top (Yu and Garnero, 2018). ULVZs have been linked to larger scale core-mantle boundary CMB structures known as large low velocity provinces (LLVPs), and have been suggested to preferentially be found at the edges of and maybe within them. The physical significance of ULVZs is still not known, with proposed hypothesis including: the presence of partial melt (Yuan and Romanowicz, 2017), basaltic piles (Pradhan et al., 2015), or remnants of a basal magma ocean from earlier in Earth history (Labrosse et al., 2007).

On the CMB beneath the Aleutian subduction zone, numerous small-scale studies have suggested the precence of some ULVZ material (Vidale and Benz, 1992, Revenaugh and Meyer, 1997, Castle and Van Der Hilst, 2000, , Persh et al., 2001, Hutko, 2009, Rost and Thomas 2010). However data coverage is usually extremely limited meaning only small areas are explored in each study. Different studies also used a range of different methodologies of varying sensitivity. Perhaps unsurprisingly given this variation in the approach different papers have come to a range of conclusion as to the presence or absence of ULVZ material in this region (Yu and Garnero, 2018), Figure 1b.

The deployment of the USArray (a network of 100s of seismic stations that slowly moved across the United States from 2012-2015) provides a huge new data set with which to investigate this region, Figure 1. The large footprint of the array will allow a wide area of the CMB to be searched in detail using consistent methods. This project will assess the presence of ULVZ material in this region, explore its association with a suggested northerly extension of the Pacific LLSVP and where possible make measurements of observed ULVZ properties to help understand its origin.

2. Methodology

The student will use S waves from large magnitude earthquakes reflected off the core-mantle boundary (ScS phases) to search of ULVZ signals, Figure 2ab. Using deep subduction zone events in Japan recorded at seismic stations on the western coast of North America (Figure 1), the students will generate a new dataset of S and ScS phase arrivals. ScS-S differential times will be used to identify regions of low seismic wave speed anomaly close to the CMB, Figure 1b. Such regions once identified will be searched for signals of small pre-/post-cursor phases arriving around the main ScS arrivals, which are set up when waves interact with a ULVZ with a sharp top, Figure 1cd. Such observations will be analysed using newly developed analysis methods recently applied to imaging of the Hawaiian ULVZ (Jenkins et al., 2021) to estimate the height and velocity contrast of identified ULVZs.

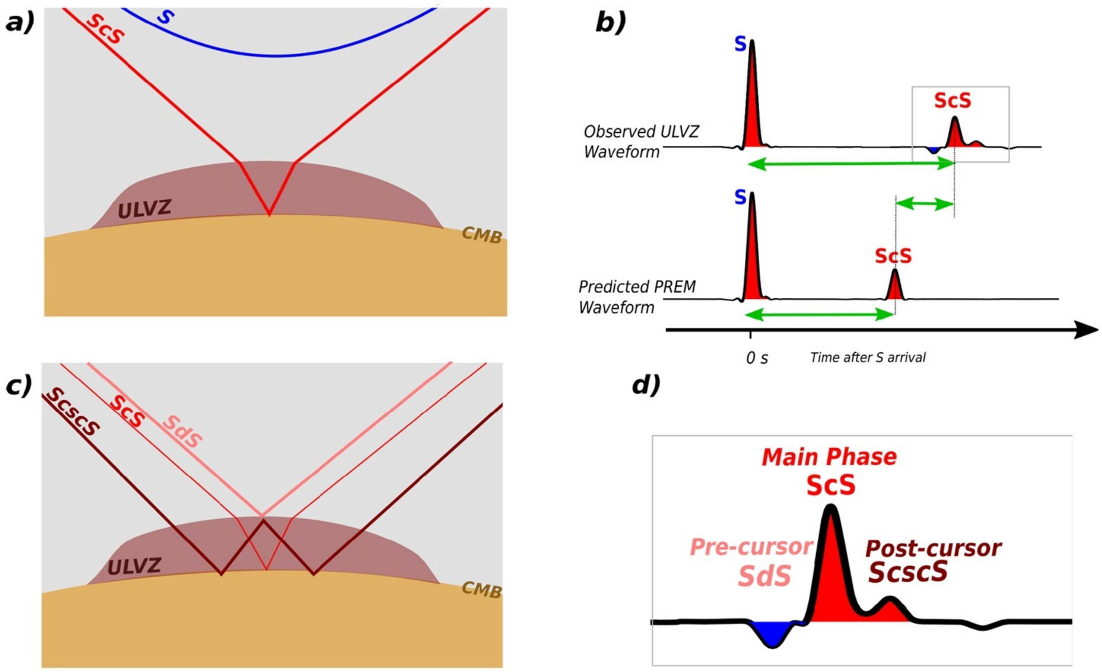

Figure 2) from Jenkins et al., (2021) a) Raypaths of direct S waves and core reflected ScS phases interacting with a ULVZ. b) Example of S and ScS arrival differences observed with and without the presence of an ULVZ. c) Cartoon diagram of the raypaths of pre/post-cursors around the main ScS phase generated by a sharp-topped ULVZ. d) Zoom-in around ScS arrival showing pre/post-cursors arrivals.

3. Training

The student will become part of a vibrant research culture in the department of Earth Sciences, in which ~80 postgraduate students work on a wide range of Earth Science research projects, where they will closely collaborate with the academic staff, postdoctoral researchers and fellows, and postgraduate students in Durham's Geodynamics and Geophsyics group.

Training will be provided in analysis of teleseismic earthquake data (Python programming, use of existing codes and potentially code development) as well as management of large datasets. The project is an opportunity for the student to become proficient in use of computer programming and large dataset analysis, giving them skills that will be useful for either continuing in academic research at PhD level or preparing for a data focussed role in industry.

References & reading

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