Observations of the Earth's major mantle discontinuities using ScS reverberations
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Introduction
The Earth's mantle is characterized by a few large global seismic velocity discontinuities, as well as several regional smaller ones. These velocity discontinuities are generally caused by mineral phase changes and they are influenced by anomalies in temperature, composition and water content. A range of seismic techniques has been used to successfully observe the global transition zone discontinuities at 410, 520 and 660 km depth (Figure 1). The combined results of different data types can connect these seismic observations with mineral physical phase changes. The main observation from Figure 1 is that the 410 is visible in all data types, the 660 shows more complexity. The goal of this study is to add ScS reverberation data, and compare the findings of these different data types, in order to better understand phase transitions in the Earth’s mantle.

Figure 1: Histogram of depth at which robust reflectors are found in (a) SS precursor data (b) PP precursor data and (c) PP precursor function data. PP and SS precursor data are taken from Deuss et al. (2006) and receiver function data is from Andrewhs and Deuss (2008). Figure from Deuss et al. (2013).

Method
ScS phases are horizontally polarized shear waves, and the relative ScS phases reflected between the surface and the core mantle boundary are denoted as ScS1h or ScS2h, where n denotes the number of core mantle boundary reflections. These phases are called zero-order reverberations or precursors in this study. ScS phases that reflect one or more times from a discontinuity are called first and higher order reverberations or daughter phases. Figure 2 shows parent phase ScS1h with its two first order daughter phases reflected from the 660.

A reflection from a discontinuity decreases the amplitude, but leaves the waveform of the daughter phases unchanged. Therefore, the waveforms of and around the parent phase can be used to look for arrivals of reflections. This is done by decomposing the parent phases from the seismograms to look for their post and precursors, similar to Wang et al. (2017). We use the iterative time domain deconvolution method described by Ligoria & Abers (1999).

Figure 2: Ray paths for parent phase ScS1h and two daughter phases for a discontinuity at 660 km depth. The daughter phases will arrive as precursors with a smaller amplitude and similar waveform.

Take home message
- ScS reverberations can be used to constrain the depth of mantle discontinuities.
- The first results show a simple 410 and a more complex 660 signal, in accordance with what is seen with other data types.
- Regional variations in discontinuity depth can be mapped by stacking data with common reflection points.

Next steps
- Decide on the best quality control mechanism.
- Map regional differences in discontinuity depths and transition zone thickness, e.g. by stacking windows with reflection points in the same area. Figure 7 shows two example events and their reflection points on the 660.

Figures
- Figure 1: Histogram of depth at which robust reflectors are found in (a) SS precursor data (b) PP precursor data and (c) PP precursor function data. PP and SS precursor data are taken from Deuss et al. (2006) and receiver function data is from Andrewhs and Deuss (2008). Figure from Deuss et al. (2013).
- Figure 2: Ray paths for parent phase ScS1h and two daughter phases for a discontinuity at 660 km depth. The daughter phases will arrive as precursors with a smaller amplitude and similar waveform.
- Figure 3: Transverse component seismograms (a) and corresponding synthetic (b) trace for the 10-12 2009 event, recorded by station IC.MDJ (c-i). For every time window (blue) the parent phase is decomposed from the rest of the window. Corresponding decomposed traces are shown in black.
- Figure 4: (a) Time to depth converted deconvolved traces for five windows in a synthetic trace. (b) Depth stack for 51 synthetic traces recorded by IC.MDJ. The major discontinuities in PREM can be seen in the depth stack.
- Figure 5: (a) Depth stacks for different SNR, shown in left upper corner. Right upper corner indicates the windows used in every depth stack. (b) Distribution of events recorded between 2001 and 2010 with 4k between 5.6 and 8.5 and minimal depth 200 km, shown with red stars. The green triangle indicates the location of station IC.MDJ.
- Figure 6: (a) The data from Figure 5(b) is divided into three clusters. (b) Histogram showing the amount of events for each cluster: (c) Depth stacks for the same data as Figure 5, but now divided into three back azimuth ranges.
- Figure 7: Location of the reflection on the 660 for the 5 different windows for two example events travelling to a station.