A Survey of Earth’s Lowermost Mantle Utilizing Core-Diffracted Waves

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Abstract

We probe lowermantle structure with frequency-dependent measurements of core-diffracted wave phase slowness and amplitude decay rate from large earthquakes and earthquakes from the OBS array. Using strong constraints on the fine-scale radial velocity structure above the core-mantle interface in a sense sensuig to surface wave observables, we calculate synthetic seismograms. To estimate the relative arrival time and amplitude of both Pdiff and SHdiff for several test models, we perform simulations of the seismic signal for a range of frequencies with the aid of the 1D surface wave sensitivity kernels. These are compared to the observed data to estimate the slowness and amplitude decay rate of the seismic wavefield.

MOMA Data

The MOMA array was a linear transect of broadband seismometers deployed in 1995 to 1996 from Missouri to Massachusetts (USA). The array spanned 160 km, roughly equally spaced by 10 km, and was equipped with 900 seismometers. The array was deployed to study the elastic and anelastic properties of the mantle. The data were recorded in a time window centered on the coda of the earthquake, and the data were processed using a 20 Hz to 100 Hz bandpass filter.

Figure 2 (ABOVE): Earthquake in the Fiji region nearly along strike of the MOMA array. Pdiff/SHdiff waveforms may be due to a possible LVZ or just a slower than PREM region. This is known as diffracted wave profiling. Unfortunately the relative arrival time and amplitude of both Pdiff and SHdiff are difficult to separate due to the complexity of the seismic wavefield.

Figure 4 (ABOVE): Earthquake in the Fiji region nearly along strike of the MOMA array. Pdiff/SHdiff waveforms may be due to a possible LVZ or just a slower than PREM region. Note the deflections which are indicative of the D" region as they diffract about the Earth's core. The D" region is highly sensitive to the Earth's lowermost mantle.

Figure 5 (ABOVE): Popsa New Guinea event. Note the strong drop in slowness of Pdiff a strong resemblance to the NUVEL1 model of intraplate and tectonic slowness.

Figure 6 (ABOVE): A complex map of Fiji region. Note how Figure 4 is similar in both detail and seismicity of the wavefield.

Figure 7 (BELOW): Nearly perfect along-event from the Tonga region. Both the slowness and decay rate for Pdiff are almost perfectly linear. SHdiff shows an upturn, but the frequency range is limited.

Figure 8 (BELOW): Deep event from the Marianas. Pdiff dispersion at shallower depths compared to the Tonga region. Pdiff dispersion appears uncorrelated.

Synthetic Data

Several 3D models were proposed for the D" region, including a PREM radial velocity structure that is best fit by strong discontinuities at the base of the Earth. The slowness and decay rate of the seismic wavefield are highly sensitive to the uniqueness of the lowermost mantle.

Remarks

Significant slowness dispersion (% for several profiles is unlikely to be a result of intrinsic attenuation (expected to be 0.1% for a Qmu of 290).

Several profiles exhibit strong deviations in slowness that suggest non-PREM radial velocity structure that is best fit by strong discontinuous changes in seismic velocities in the lowermost mantle. Repeatability of 2 pairs of events indicates that the measurements are not affected by source effects for either the slowness or the decay rate. It is also indicative that our method is able to extract the slowness and decay rate reliably.

The lowermost mantle below the Northeast quadrant of the Pacific ocean displays lateral and radial velocity structure for both P and SH. Shdiff and Pdiff dispersion appear uncorrelated.