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Exploring seismic small-scale heterogeneities in the lower mantle using PKP precursors

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Small-scale heterogeneities in the lower mantle can scatter seismic energy that can be observed as precursor to PKP phases. Global observations indicate that these scattering heterogeneities could be on the scale of ∼10 km with ∼0.1% velocity variations in the deep mantle. The scattering could result from heterogeneities in seismic velocity and/or CMB topography. Other explanations in the past include remnants of ancient subducted slabs or ultra-low velocity zones (ULVZs). However, the primary source of these small-scale heterogeneities and relationships with seismic structures remain elusive.

Here we investigate regional variations in precursor amplitude to aid the interpretation of the source of scattering. For one path, we analyze PKP precursors from earthquakes in the Aleutian Islands and Kamchatka Peninsula recorded by seismic arrays in Antarctica, and find that these heterogeneities extend ∼400 km above the CMB and are distributed between 30° and 45°N in latitude. The scatterers exhibit lateral variations with P-wave velocity perturbations of 1.0–1.2% in the center (160–180°E) while ∼0.5% in the west and east (140–160°E, 180–200°E), possibly due to subducted materials. For a second path, we collect PKP precursor waveforms from earthquakes in South America which are recorded by seismic arrays in Australia. By analyzing the slowness and scatterer location, we obtain the spatial distribution of these scatterers in the lowermost mantle east of Pacific LLSVP. We further constrain the geometry and velocity variations of these strong seismic anomalies using waveform modelling. Our results show that these seismic scatterers could be interpreted as localized, patchy ULVZs, with P-wave velocity reductions of ∼8% and thicknesses of ∼30 km.

To extend the coverage of precursor observations, we now examine a global data set of PKP precursors in individual seismograms and array data, to better constrain scatterer locations, scattering magnitudes and sources of scattering. We find strong variations of scattering amplitudes in many different paths. This helps to determine the relationship between regional variations in scattering amplitudes and timing of precursors with seismic structures in the mantle.