Geophysical Research Abstracts
Vol. 21, EGU2019-14287, 2019
EGU General Assembly 2019
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The temperature-dependent visibility of the 660-km discontinuity

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The absence of signals from the 660-km discontinuity in PP-precursors has been a topic of debate for several decades. Studies attribute this phenomenon to various factors: a small contrast in P-velocity or density across the post-spinel phase change in olivine, lateral topography of the interface, noise or irregular coverage in seismic datasets, or effects from transitions in the garnet mantle component. We propose a new resolution to this problem, incorporating new global seismic observations, a refined stacking approach, and modelling based on physical models of the Earth's interior. We use the most comprehensive handpicked global datasets of precursors to SS and PP to date [1], with 58,567 and 140,115 waveforms respectively. To avoid the effects of irregular coverage, and quantify uncertainties, we stack based on globally optimized tessellations of the Earth using Voronoi cells. For comparison, we predict seismic responses from mineralogical models using plane-wave matrix/reflectivity algorithms. While the 410 km discontinuity is unambiguously detected with both data types, the 660 km signal is typically absent in global PP data. Yet, we find numerous small regions where the P660P is present (5%). By inferring the temperature regime from the transition thickness and the depths of the 410- and 520-km discontinuities, we find that the P660P is dominantly detected in regions of high temperatures. Mineralogical models corroborate these findings. A weak P660P signal results from normal temperature conditions in a pyrolitic mantle (1300-1800 K), while a highly reflective interface results from anomalously high temperatures (> 1900 K). We furthermore demonstrate that analyses of reflectivity using Zoeppritz coefficients are too simplistic to recover this behaviour, explaining the deviation of our results from previous studies. A pyrolitic mantle with lateral variations of temperature successfully explains first-order global features of the PP and SS data. These results have implications for the convection and flow processes within different regions of the mantle, for example the stagnation of slabs at various depths, and deflection of upwelling material.

References

[1] Waszek, L., Schmerr, N., Ballmer, M. (2018): Global observations of mid-mantle reflectors with implications for mantle structure and dynamics. Nat. Commun., 9(385), doi:10.1038/s41467-017-02709-4, 2018.