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Heterogeneity of the Earth's upper mantle, from waveform inversion of over one million broadband seismograms

Andrew Schaeffer (1,2) and Sergei Lebedev (1)

(1) Geophysics Section, Dublin Institute for Advanced Studies, Dublin, Ireland, (2) School of Geological Sciences, University College Dublin, Ireland

We present a new global, vertically-polarized shear speed model of the upper mantle. The model, *SL2013sv*, is constrained by a massive new dataset selected from more than one million successful waveform fits generated using the Automated Multimode Inversion of surface- and S-waveforms. The waveform inversion of each seismogram produces a set of linear equations describing perturbations in elastic structure within approximate sensitivity volumes along the source-receiver path, with respect to a three-dimensional (*3D*) reference model; structural information is extracted from fundamental modes in addition to overtones. These equations are then simultaneously inverted for a high-resolution, *3D* model of shear and compressional speeds and azimuthal anisotropy within the crust and upper mantle. From our total dataset, more than half-a-million seismograms were selected to constrain the final model, using elaborate outlier analysis. The selection of only the most mutually consistent equations strongly reduced the effect of errors in the data, enabling improvement upon past global model resolutions, resulting from significantly increased data sampling and redundancy.

In continental regions, lateral resolution approaches that of regional-scale studies, and good correlation can be observed with the surface expression of tectonics. In the oceans, spreading ridges are very well resolved, with the main anomalies closely confined near the ridge axis. Additionally, clear images of major subduction zones worldwide are captured, extending from shallow depths (in some cases, 150km depth) through much of the transition zone. We also briefly discuss the distribution of azimuthal anisotropy, which is well resolved globally, although over longer length-scales compared to isotropic heterogeneity.

Finally, the large size of our waveform fit dataset provides a strong statistical foundation to re-examine the validity field of the JWKB approximation (surface-wave ray theory), in addition to the quantification of the success rate of fitting using AMI. We conclude that, when selecting the correct portions of the seismogram on a case-by-case basis, the validity of the approximations is warranted in many cases, often at shorter periods than previously assumed. As a by-product of the waveform inversions, numerous phase and group velocity curves of the fundamental and first 15-18 higher modes of Rayleigh and Love waves have been measured. This large, new dispersion dataset and our new upper-mantle model offer complementary perspectives on the bulk heterogeneity of the Earth's upper mantle.