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Towards full-waveform inversion for upper-mantle discontinuities on the global scale

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We present a new methodology for imaging mantle discontinuity structure based on full-waveform inversion. Our focus is on the global seismic discontinuities around 410 and 660 km depth. High resolution images of these topographic structures are important for understanding the variations in temperature and/or composition in the mantle transition zone. Subsequently, the constraints from seismological models to mineral physics can be improved and lead to more consistent modelling of the mantle transition zone dynamics.

However, most of the current topographic maps of these discontinuities present shortcomings in the methods used, which are usually based on linearised ray theory. Additionally, the natural trade-off between mantle velocity structure and boundary topography is not properly accounted for. Simple corrections for the effect of the velocity structure are not enough. We therefore developed a new approach which overcomes these methodological limitations.

To develop the method, we computed synthetic seismograms using exact spectral-element wave propagation in 1-D and 3-D background models. Topography models of the discontinuities at 410 and 660 km are added to the background velocity models. We measured the misfit between waveforms with and without topography using cross-correlation travel-time and waveform differences. Sensitivity kernels of the measurements to boundary structure are computed with the adjoint method. Using a gradient descent algorithm, we performed iterative optimisations with the objective to retrieve the input topography of the 410 and 660.

The tests are performed in both background models resulting in the successful retrieval of the initial topography models. Starting from zero topography, our simple gradient based method converges to the input models in few iterations. Full-waveform inversion improves the inference of topographic maps because it incorporates exact sensitivity kernels and allows us to take into account the crosstalk between the parameters of boundary topography and velocity structure in a natural way.