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A new approach for surface wave tomography II: application to the Australian region

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We propose a new three-stage inversion scheme working with multi-mode phase speed maps for retrieving 3-D images of the Earth's upper mantle using surface waves, which compensates for deficiencies in the conventional approaches to surface wave tomography. This is a very efficient method for obtaining 3-D models considering various effects of surface wave propagation, i.e., the finite frequency of surface waves and polarization anomalies for multiple modes as a function of frequency. We have applied the three-stage approach to reconstruct a new 3-D upper mantle model for the Australian region.

First, vertical components of Rayleigh waves observed at global networks (IRIS and GEOSCOPE) in the Australasian region as well as the portable networks operated by the seismology group in the Australian National University (SKIPPY and KIMBA arrays) are analyzed by fitting cross-correlograms as secondary observables to obtain path-specific 1-D shear wavespeed profiles. Phase speed dispersion up to the third higher mode is estimated from these 1-D profiles over a frequency range depending on modes (fundamental mode: 40-150, 1st higher: 40-140, 2nd: 40-100, 3rd: 40-80).

The ensembles of the phase speeds for each mode are then inverted to construct multi-mode phase speed maps as a function of frequency. Linear inversions for phase speed maps are carried out by the LSQR algorithm using spherical B-splines as basis functions for a spatial parameterization. The phase speed maps are updated iteratively incorporating the effects of ray bending and the frequency-dependent influence zone around the propagation path. Finally, local phase dispersion curves are assembled from these multi-mode phase dispersion maps, and are inverted for local shear wavespeed structures, which finally form a 3-D Earth model.

We have derived several types of 3-D models using the same data set with different approaches to the inversion processes, e.g., updating the models with or without including the effects of off-great-circle propagation and the influence zone. All these models tend to show similar features at the large scale with some improvement at shorter scale for the models that take account of the influence zone and ray tracing. A striking feature in the models with the influence zone is that the velocity structures are smoothed horizontally due to including the effects of finite frequency. Ray-path bending at the frequency range of interest seems not to be critical for the improvement of the models since two-point ray shooting experiments suggest that the actual ray paths are, in general, very close to the corresponding great-circle. Even if we only consider the influence zone around the great-circle without any effects of ray bending, the finite-frequency models show a high degree of resemblance. Therefore, we may conclude that the effects of the finite-frequency have more impact on the improvement of the 3-D models.