Multi-mode surface wave tomography with trans-dimensional hierarchical Bayesian inversion: application to Australia

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Seismic surface waves are primary information sources for three-dimensional mapping of the crust and upper mantle. Most of the structural mapping for shear wave speed models in the crust and upper mantle has been based primarily on the linearized inversions of surface wave dispersion data. Such linearized inversions, however, involve intrinsic limitations, such as the influence of *a priori* constraints and the entrapment into local minima. With the increasing computational power, a fully nonlinear approach based on the model parameter search with the Markov chain Monte Carlo method is now feasible.

In this study, we employ the trans-dimensional hierarchical Bayesian (TDB) inversion to construct a new 3-D radially anisotropic S wave model in the Australian upper mantle, which requires almost no subjective *a priori* information. We use multi-mode phase speed maps in Australia by Yoshizawa (2014), and the local dispersion curves of multi-mode Love and Rayleigh waves are inverted for extracting the probability density functions of radially anisotropic S wave model. This process is repeated for all the grid points in our target region, which eventually produce a 3-D shear wave model.

The TDB approach requires significant computational power compared with the classical linearized inversions, i.e., several thousand times more CPU time is required in our case to evaluate more than a million models. Still, it enables us to flexibly parameterize the model parameters (i.e., the number of layers in this case, and data uncertainties can also be handled properly through the hierarchical Bayesian approach.

Through the comparisons of our new 3-D model from TDB approach with our earlier 3-D model from a conventional linearized inversion, we have found that the large-scale features are mostly consistent between these models. However, our new TDB model shows the enhanced strength of heterogeneity and well-resolved spatial distribution of seismic anisotropy, which well reflects the past and current tectonics of the continental upper mantle. In particular, the vertical change in shear wave speeds can be well constrained in the TDB model by the use of the trans-dimensional parameterization, and the data fit to dispersion curves are improved by the use of the hierarchical Bayes approach.

Keywords: surface wave, tomography, Bayesian inversion, anisotropy, Australia

