Trans-dimensional Bayesian inversion for a radially anisotropic S-wave velocity model in the crust and upper mantle: Application to the Australian continent

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The velocity structure and discontinuities in the upper mantle, such as Lithosphere-Asthenosphere Boundary (LAB) and Mid-Lithosphere Discontinuity (MLD), have been investigated through a number of seismological studies, in which both body and surface waves have been employed. Many studies using body waves have extracted information on the upper mantle from the later arrivals of teleseismic body waves by deconvolving the vertical component from the horizontal components, which produces "receiver functions". While they are good at constraining impedance contrasts across the discontinuities, they are not sensitive to the absolute velocity. In contrast, surface waves enable us to recover the absolute velocity, though sharp velocity jumps cannot be resolved due to their lower frequency content (< 0.05Hz). In view of such different sensitivities of receiver functions and surface waves, the joint inversions of body and surface waves will be the most effective approach to the accurate estimation of seismic velocity structures in the crust and upper mantle.

In this study, we develop a new method for non-linear joint inversion of Ps receiver functions and multi-mode Rayleigh and Love surface waves using trans-dimensional Bayesian formulation, following the earlier works by Bodin et al., (2012, JGR). This trans-dimensional approach allows us to constrain the complexity of earth model with little a priori information, in which the number of model parameters (e.g. number of layers) can also be treated as a part of unknowns. The reversible-jump Markov Chain Monte Carlo approach (Green, 1995, Biometrika) is used to sample models with variable dimension in proportion to the posterior distribution of the Earth models. Assuming that data errors follow the Gaussian distribution, we also estimate the variances of the data errors at the same time. Such an approach is called 'Hierarchical Bayes' (e.g. Malinverno and Briggs, 2004, Geophysics), in which the overfitting of the models can be prevented. Parallel Tempering method (e.g. Sambridge, 2014, GJI) is also incorporated in our inversions, which makes the model samplings more efficient enabling us to extend the parameter search ranges.

With this method, we jointly inverted the Ps receiver function, multi-mode Rayleigh and Love dispersion curves from Yoshizawa (2014, PEPI) for a radially anisotropic 1-D shear velocity model under Global Seismographic Network (GSN) stations in Australia. Our preliminary result for the WRAB station in the central Australia implies the existence of two MLDs with negative and positive velocity jumps at around 90 km and 150 km depths, respectively, and LAB at around 220km depth. The depths of MLDs are consistent with an earlier receiver function study by Ford et al. (2010, EPSL) and such multiple MLDs are also reported by another study in North America (Calo et al., 2016, EPSL). Our estimated LAB depth at 220 km is deeper than that from the earlier surface wave study (Yoshizawa & Kennett, 2015, GRL), in which the Lithosphere-Asthenosphere Boundary under cratons is supposed to be a smooth transition. Still, we can still see the common feature of strong radial anisotropy (SH>SV) in the asthenospheric depth below 220 km, indicating the effects of strong shear flow under the fast-moving Australian continent.

Keywords: Bayesian inversion, receiver function, surface wave, higher mode, lithosphere, asthenosphere