Upper mantle discontinuities beneath Australia from trans-dimensional hierarchical Bayesian inversions using receiver functions and multi-mode surface waves

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Upper mantle structures under cratons have recently been investigated by many researchers using receiver functions and surface waves to clarify the nature of the Lithosphere-Asthenosphere Boundary (LAB) and Mid-Lithosphere Discontinuity (MLD). Majority of seismological studies of joint inversions using receiver functions and surface waves have employed dispersion curves of fundamental-mode only, but higher-mode information is essential for resolving the whole depth range of thick continental lithosphere (over 200 km) and its underlying asthenosphere.

In this study, we reconstructed radially anisotropic S wave models including multiple discontinuities in the upper mantle under seismic stations in Australia, using multi-mode surface waves and receiver functions in the framework of the Bayesian inference. We employed a fully nonlinear method of joint inversions incorporating P-to-S receiver functions and multi-mode Rayleigh and Love waves, based on the trans-dimensional hierarchical Bayesian formulation. The method allows us to estimate a probabilistic Earth model taking account of the complexity and uncertainty of Earth structure, by treating the model parameters and data errors as unknowns. The Parallel Tempering algorithm is incorporated for the effective parameter search based on the reversible-jump Markov Chain Monte Carlo method.

Multi-mode phase speed maps of surface waves developed by Yoshizawa (2014) are used to extract localized multi-mode dispersion curves. The use of higher-mode surface waves enables us to enhance the sensitivity to the depth below the continental asthenosphere, while the receiver functions allows us to better constrain the depths of discontinuities and velocity jumps. Synthetic experiments indicate the importance of higher-mode information for the better recovery of radial anisotropy in the whole depth range of the upper mantle.

The method has been applied to Global Seismographic Network stations in Australia. While the S-wave models in eastern Australia show shallow LAB above 100 km depth, those in central and western Australia exhibit both MLD and LAB. Also, seismic velocity jumps equivalent to the Lehmann Discontinuity (LD) are found in all seismic stations in Australia. The LDs under the Australian continents are found at the depth of around 200 - 300 km, depending on locations.
Radial anisotropy in the depth range between LAB and LD tends to show faster SH anomalies, which may indicate the effects of horizontal shear underneath the fast-moving Australian plate.