Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SIT05-P01 Room:Poster Time:April 28 18:15-19:30

Estimation of the lithosphere-asthenosphere transition from multi-mode surface waves

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The lithosphere-asthenosphere transition (LAT) is a key to the understanding of the present-day plate motion, but its seismological determination is not straightforward unlike material boundaries such as the Moho and core-mantle boundary. Some recent works on the LAT using body-wave receiver functions have revealed evidences for clear converted signals at the bottom of lithosphere, particularly in oceanic region. To the contrary, receiver functions normally do not show clear converted signals from the expected bottom of cratonic lithosphere at about 200 km depth, where surface wave studies indicate fast wave speed anomalies of the thick continental lithosphere.

In this study, we investigate a quantitative way to estimate the depth and thickness of the LAT from S-wave speed models derived from surface waves. Although surface waves are inherently not very sensitive to the sharpness of boundaries due to their long-wavelength features, the depth of LAT can be roughly estimated from the depth of either the negative peak of velocity gradient or the slowest shear velocity beneath the lithosphere. In this study, we consider that the former represents an upper bound of LAT and the latter a lower bound. The thickness (or sharpness) of LAT can be deduced from the differences between the upper and lower bounds.

We have performed synthetic experiments using several types of S-wave models including different smoothness (or sharpness) of LAT. Synthetic experiments using multi-mode surface waves (including up to fourth higher modes) result in a successful recovery of the smooth LAT (with a depth range over 50 km), which is expected at the base of the cratonic lithosphere. However, if we use the fundamental mode only, the recovery is unsatisfactory even for the smooth boundary, and the effects of the sharpness of boundary are almost indistinguishable in the recovered models. Surface waves have less sensitivity to a sharp boundary (with a transition thickness less than 25 km), but our experiments indicate that the estimated depth from the velocity gradient (upper bound of LAT) are found to be coincide well with the depth of sharp boundary, which may indicate the distribution of oceanic LAT can be well represented by the negative peak of vertical gradient in S-wave speed profiles derived from surface waves.

Keywords: lithosphere, asthenosphere, surface wave, higher mode