Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SIT040-13 Room:104 Time:May 23 17:30-17:45

On the influence of whole-mantle heterogeneity on teleseismic tomography

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Teleseismic tomography has become a powerful tool to determine the 3-D upper mantle structure under a region covered by a seismic network since this approach was firstly proposed by Aki et al. (1977). A basic assumption of teleseismic tomography is that the lower mantle is homogeneous, thus the use of relative travel-time residuals is assumed to remove the effects of earthquake mislocation and the structural heterogeneities outside of the study area, and the relative travel-time residuals from the teleseismic events only reflect the 3-D structure under the seismic network. However, global tomography studies have revealed various scales of structural heterogeneities in not only the upper mantle but also the lower mantle, such as deep subducted slabs and mantle plumes. Thus the whole-mantle heterogeneities would contribute partially to the observed relative travel-time residuals, and as a result affect the determination of 3-D velocity structure under the study area. However, so far no one has addressed this issue and it is unclear how much the whole-mantle heterogeneity would influence the teleseismic tomography. In this study we have investigated this problem for the teleseismic tomography beneath the Japan Islands. We used about 45,000 P-wave data from 360 teleseismic events recorded by the J-Array and Hi-net stations, in addition to about 230,000 P-wave arrival times from 1180 local shallow and deep earthquakes under the Japan Islands. We calculated theoretical travel times from each teleseismic event to the stations in Japan in a 3-D whole-mantle P-wave velocity model (Yamamoto and Zhao, 2010) and the 1-D iasp91 Earth model. We found that the differential travel time for the two models (T3d-T1d) is in the range of -0.3 s to +0.3 s, though it is -0.2 s to +0.2 s for most of the rays, which is equal to or larger than the picking errors of the teleseismic data (0.1-0.2 s). Therefore the effect of whole-mantle heterogeneity on the teleseismic residuals is significant and so it should be corrected. We have taken into account this effect and obtained a better 3-D P-wave velocity structure down to 700 km depth beneath the Japan Islands. Our results show that the Philippine Sea slab has subducted aseismically down to 300-500 km depth under SW Japan. Low-velocity (low-V) anomalies are imaged clearly in the central part of the mantle wedge above the subducting Pacific slab. The low-V zones exist not only under the Honshu land area but also extend westward beneath the Japan Sea. We also imaged low-V zones which seem to be caused by the deep dehydration of the Pacific slab at 300-400 km depths. A low-V zone is revealed at depths of 500-700 km in the mantle beneath the Pacific slab under Southern Tohoku and Kanto, which may reflect an upwelling flow from the lower mantle.

Keywords: teleseismic events, tomography, mantle, heterogeneity, slab