Seismic ray path variations in a 3-D global velocity model

Jianshe Lei[1], Dapeng Zhao[1]

[1] GRC, Ehime Univ

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We have used a 3-D ray tracing technique (Zhao et al., 1992) to investigate ray path variations of P, PcP, pP and PP phases in the mantle with a 3-D global velocity model (Zhao, 2001). The results show that ray paths in the 3-D velocity model deviate considerably from the paths in the average 1-D model. For a PcP wave in Western Pacific to East Asia where the high-velocity (1-2%) Pacific slab is subducting beneath the Eurasian plate, the ray path difference between the 3-D and 1-D rays is about 25 km in horizontal direction and about 5 km in vertical direction. For a PcP ray in South Pacific where very slow (-2%) velocity anomalies (the Pacific superplume) exist in the whole mantle, the maximum ray path deviation amounts to 77 km. Ray paths of other phases (P, pP, PP) are also displaced by tens of kilometers. These results suggest that although the maximal velocity anomalies of the global tomographic model is only 1-2%, rays passing through those very heterogeneous regions can have significant deviations from those in a 1-D model because rays have very long trajectories in the global case. If the blocks or grid nodes adopted for inversion are relatively large (3-5 degrees) and only a low-resolution 3-D model is estimated, 1-D ray tracing may be feasible. But if fine blocks or grid nodes are used to determine a high-resolution tomographic model, 3-D ray tracing becomes necessary and important for the global tomography.

Zhao, D., 2001. Seismic structure and origin of hotspots and mantle plumes. Earth. Planet. Sci. Lett., 192, 251-265.

Zhao, D., A. Hasegawa, S. Horiuchi, 1992. Tomographic imaging of P and S wave velocity structure beneath northeastern Japan. J. Geophys. Res., 97, 19909-19928.