Global P-wave tomography: on the effect of various mantle and core phases

Jianshe Lei[1]; Dapeng Zhao[1]

[1] GRC, Ehime Univ

During the last two decades, many 3-D Earth models have been produced that have greatly advanced our knowledge about the structure and dynamics of the Earth's interior. In these global tomographic studies different researchers have used different data sets extracted from the International Seismological Center (ISC) bulletins. However, the effect of the different mantle and core phases on the tomographic images is still unclear. In this study many checkerboard resolution tests and tomographic inversions have been conducted to investigate the influence of various mantle and core phases (P, pP, PP, PcP, Pdiff, PKPab, PKPbc, PKiKP, PKKPab and PKKPbc from the ISC data set) on the determination of the 3-D Earth structure.

Our results show that when only the direct P wave is used, the resolution is good for most of the mantle except for the oceanic regions down to about 1000 km depth, and for most of the D'' region. Adding the pP data, the result is almost the same. However, when PP is incorporated, the resolution is much improved beneath the oceanic regions in the upper mantle. PcP improves the resolution just beneath some continental regions, while Pdiff can improve the resolution of the whole mid-lower mantle. Adding PKP the checkerboard pattern is almost recovered in the whole lowermost mantle, and in the outer core except for the Pacific region. When PKiKP is used, the resolution is improved in the lowermost mantle and outer core. Because there are much fewer PKKP than other phases, it is not easy to find its effect visually. When all the phases are used, the checkerboard pattern is well recovered except for the upper mantle of some oceanic regions.

To see the effect of various phases on the images, here we show one example around the Pacific region. In the upper mantle and mantle transition zone after adding PP data the images are changed around Hawaii and west Pacific; when adding pP, PcP, Pdiff, PKP, PKiKP or PKKP, no significant differences are visible in the images of the upper mantle. In the lowermost mantle high velocity anomalies appear beneath north Pacific, and low velocity anomalies are visible in south Pacific and Toga regions when the direct P wave is used. After adding pP or PP data, the images are not changed significantly. After incorporating PcP or Pdiff, low velocity anomalies become more prominent beneath southern and northern Pacific. Adding the core phases, the images are changed considerably. In the outer core different phases also affect tomographic images significantly.

Our results indicate that later phases could provide vital information not provided by the direct P data, which enable us to gain new insights into important issues of geodynamics. For instance, a new finding is achieved by comparing the models with and without PKiKP. The models without PKiKP show that the Hawaiian hotspot originates from the south Pacific superplume. Some previous tomographic results also demonstrated low velocity anomalies exist beneath Hawaii but are limited in depth to the middle mantle. However, the models with PKiKP display a continuously slow anomaly beneath Hawaii in the whole mantle, indicating that the Hawaiian hotspot does originate from the CMB. This result is consistent with those from waveform modeling and recent tomographic studies (e.g., Russell et al., 1998; Zhao, 2004), but so far no tomographic images show such a continuously slow anomaly in the whole mantle. This indicates that later-arrival seismic waves are of great importance in better understanding the geodynamic processes of the Earth's interior.

References

Russell, S., Lay, T., Garnero, E., 1998. Seismic evidence for small-scale dynamics in the lowermost mantle at the root of the Hawaiian hotspot. Nature 396, 255-258.

Zhao, 2004. Global tomographic images of mantle plumes and subducting slab: insight into deep Earth dynamics. Phys. Earth Planet. Inter. 146, 3-34.