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Wavefront Healing and Tomographic Resolution of Deep Mantle Superplumes

Jing Xue and Ying Zhou
Department of Geosciences, Virginia Tech, Blacksburg, VA 24061, United States (jingx87@vt.edu)

Seismic tomography revealed two large low shear velocity province (LLSVP) at the bottom of the mantle, one under Africa and the other under the southern Pacific. Traditional tomographic results show strong anti-correlation between bulk sound speed and S wave speed perturbations, supporting at least partially chemical origin of deep mantle superplumes. The core-mantle boundary regions are best sampled by core diffracted waves while wave front healing effects of diffracted waves have been ignored in traditional tomographic studies.

To investigate the resolution of deep mantle superplumes as well as the robustness of the anti correlation between bulk sound speed and S wave speed, we use Spectral Element Method (SEM) to simulate global seismic wave propagation in 3-D plume models at periods down to 10s. We measure frequency-dependent P-wave and S-wave travel time anomalies caused by 3-D plume structures using a multi-taper technique, and calculate bulk sound speed perturbations based on measured P-wave and S-wave traveltimes. The comparison between measured delay times and ray-theory predictions shows that different healing rates between P waves and S waves in thermal plume models can lead to significant artifact as anti-correlation between bulk sound speed and S-wave speed perturbations. The strength of this artifact depends on epicenter distance and wave frequency. The artifact in anti-correlation is also confirmed in tomographic inversions based on ray theory using Pdiff and Sdiff traveltimes measured from SEM seismograms. We show that resolutions of superplumes as well as artifacts in the anti-correlation are dependent upon the length scale of the anomalies, the frequency of the wave as well as source-receiver distribution. Finally we compare calculations based on finite-frequency theory and ray theory and show that different healing rates between P waves and S waves can be properly accounted for in finite-frequency tomography.