Diffraction Patterns at Superplume Edges and Multi-path Detectors

Daoyuan Sun and Donald Helmberger, California Institute of Technology, Pasadena

Current tomographic models of the Earth display perturbations to a radial stratified reference model. However, if these are chemically dense structures with low Rayleigh numbers, they can develop enormous relief, perhaps with boundaries closer to vertical than radial. Several new methods have been developed to simulate 3D synthetics for such structures that involve both analytical and numerical techniques. The method we use approximates 3D effects by adding out-of-plane contributions from virtual receivers at neighboring azimuths with two related to the inner Fresnel zone, *Helmberger and Ni* (2005). Here, we develop a new tool for processing array data based on such a decomposition referred to as a multi-path detector which can be used to distinguish between horizontal structure (in-plane multi-pathing) vs. vertical (out-of-plane multi-pathing) directly from processing array waveforms. We demonstrate the usefulness of this approach by processing samples of S data from the Kaapvaal array in Southern Africa displayed below.

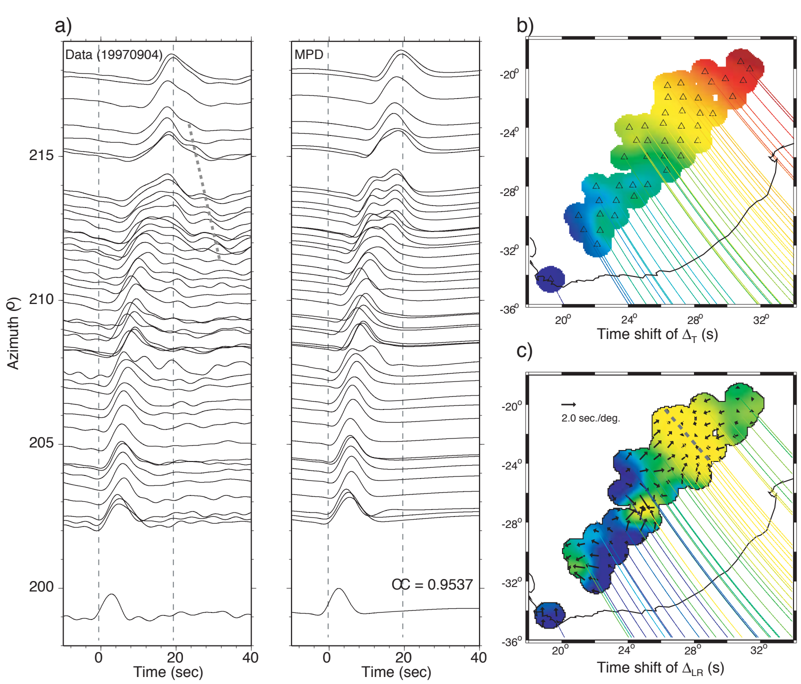
We generate a synthetic for a reference model using an empirical source S(t), and assume each recorded trace can be modeled by summing S(t) + S(t + Δ_{LR}). We define Δ_{LR} as the time separation which refers to the lag of the right half of the Fresnel zone relative to the left, or split time. The travel time of the composite (second column) relative to the reference model is defined as Δ_T. The Δ_T's are displayed in (b) along with the gradient of the Δ_{LR}'s in (c). Thus, if we neglect diffraction features as indicated by the dotted line, we can still distinguish between in-plane vs. out-of-plane effects. The gradient in Δ_{LR} constructed from the array forms a vector indicating a diffraction pattern as in optics. Note that in this case, the vectors are not purely in the azimuthal direction suggesting that there is some radial or depth sensitivity as well. However, the Superplume wall crossing is well defined where the gradient changes sign and occurs along the ray path specified by the dotted line. We demonstrate the usefulness of this approach in a series of modeling applications to slabs and plumes.

For further reading:

Helmberger, D. V. and Ni, S., Approximate 3D Body-Wave Synthetics for Tomographic Models, *BSSA*, **95**, No. 1, 212-224, 2005.

Sun, Daoyuan et al., Diffraction Patterns at Superplume Edges and Multi-path Detectors, submitted to *JGR*, 2008.

Sun, Daoyuan, Helmberger, D. V., and Gurnis, M., Chemical Piles and Deep Mantle Plumes, submitted to *JGR*, 2008.



Display of observed S waveforms arriving at the array for a Western Pacific event plotted as a function of azimuth. The observations (a) are aligned relative to PREM predictions. Thus recording near the top are about 14s late while the data at the larger azimuths are PREM-like. Waveforms near 212° are transitional in timing with both early and late arrivals. This type of multipathing can be used to form simulations, *Sun et al.* (2008) with results presented in the column labeled MPD.