Using Distant Sources in Local Seismic Tomography

Bruce R Julian, Gillian R Foulger
Earth Sciences, Durham University, Durham, County Durham, United Kingdom

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Seismic tomography methods such as the "ACH" method of Aki, Christoffersson & Husebye (1976, 1977) are subject to significant bias caused by the unknown wave-speed structure outside the study volume, whose effects are mathematically of the same order as the local-structure effects being studied. Computational experiments using whole-mantle wave-speed models show that the effects are also of comparable numerical magnitude (Masson & Trampert, 1997). Failure to correct for these effects will significantly corrupt computed local structures.

This bias can be greatly reduced by solving for additional parameters defining the shapes, orientations, and arrival times of the incident wavefronts. The procedure is exactly analogous to solving for hypocentral locations in local-earthquake tomography. For planar incident wavefronts, each event adds three free parameters and the forward problem is surprisingly simple: The first-order change in the theoretical arrival time at observation point B resulting from perturbations in the incident-wave time t_0 and slowness vector $\mathbf{s}$ is $\delta t_B \approx \delta t_0 + \delta \mathbf{s} \cdot \mathbf{r}_A = \delta t_A$, the change in the time of the plane wave at the point A where the un-perturbed ray enters the study volume (Julian and Foulger, submitted). This consequence of Fermat's principle apparently has not previously been recognized.

In addition to eliminating the biasing effect of structure outside the study volume, this formalism enables us to combine data from local and distant events in studies of local structure, significantly improving resolution of deeper structure, particularly in places such as volcanic and geothermal areas where seismicity is confined to shallow depths.

Many published models that were derived using ACH and similar methods probably contain significant artifacts and are in need of re-evaluation.