Seismic Tomography: Methodology, Results, and the Latest Developments

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Determining the structure of Earth's interior is one of the most fundamental pursuits in Earth science. Seismic tomography is the premier tool in this endeavor, since seismic waves sample the Earth directly. Wave speeds yield valuable information about the structure, and by inference the composition, temperature, and evolution of Earth's interior. Using high-resolution, accurate seismic images it is possible to shed light on such issues as the length scale of mantle convection, the mechanisms of heat transfer from the core to the surface, or the interaction between the deep Earth and surface processes such as plate motion and deformation. Does the mantle convect as a whole or is it layered? Do mantle plumes exist? What is their contribution in delivering Earth's heat to the surface? What are the origins and correlation length scales of mantle heterogeneity? What are the nature and role of geochemical reservoirs? Is there an undifferentiated reservoir in the lowermost mantle? Answering such questions requires a contribution from seismic tomography — a technique by which the three-dimensional distribution of wave speeds in the Earth is reconstructed from travel-time or waveform anomalies. In this presentation I will discuss the methods of seismic body and surface wave tomography, starting from first principles, parameterization schemes and inversion techniques, to ongoing developments such as finite-frequency sensitivity approaches and adjoint methods. As a method, seismic tomography is borrowed from medical tomography; there, as here, accurate reconstructions depend vitally on the even distributions of sources and receivers. I will devote attention to theoretical and practical approaches to evening out global ray path coverage, and discuss the implications of the current status of such efforts with regards to the uncertainty of our knowledge of the structure and the evolution of the Earth's deep interior.