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Global Scale Exploration Seismics: Mapping Mantle Discontinuities with Inverse Scattering Methods and Millions of Seismograms

R.D. van der Hilst (1), M.V. de Hoop (2), S.H. Shim (1), X. Shang (1), P. Wang (3), and Q. Cao (4)

(1) MIT, EAPS, Cambridge, United States (hilst@mit.edu), (2) Purdue University, Department of Mathematics, West-Lafayette, United States, (3) C.G.G. Veritas, Houston, United States, (4) Shell International E&P, Houston, United States

Over the past three decades, tremendous progress has been made with the mapping of mantle heterogeneity and with the understanding of these structures in terms of, for instance, the evolution of Earth's crust, continental lithosphere, and thermo-chemical mantle convection. Converted wave imaging (e.g., receiver functions) and reflection seismology (e.g. SS stacks) have helped constrain interfaces in crust and mantle; surface wave dispersion (from earthquake or ambient noise signals) characterizes wavespeed variations in continental and oceanic lithosphere, and body wave and multi-mode surface wave data have been used to map trajectories of mantle convection and delineate mantle regions of anomalous elastic properties. Collectively, these studies have revealed substantial ocean-continent differences and suggest that convective flow is strongly influenced by but permitted to cross the upper mantle transition zone.

Many questions have remained unanswered, however, and further advances in understanding require more accurate depictions of Earth's heterogeneity at a wider range of length scales. To meet this challenge we need new observations—more, better, and different types of data—and methods that help us extract and interpret more information from the rapidly growing volumes of broadband data. The huge data volumes and the desire to extract more signal from them means that we have to go beyond 'business as usual' (that is, simplified theory, manual inspection of seismograms, ...). Indeed, it inspires the development of automated full wave methods, both for tomographic delineation of smooth wavespeed variations and the imaging (for instance through inverse scattering) of medium contrasts. Adjoint tomography and reverse time migration, which are closely related wave equation methods, have begun to revolutionize seismic inversion of global and regional waveform data. In this presentation we will illustrate this development – and its promise – drawing from our work on inverse scattering of reflected SS and ScS/SKKS wavefields and reverse time migration of converted P and S waves. With SS and the wave conversions we study the upper mantle transition zone and with ScS/SKKS we image complex structures near the base of the mantle.