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Global surface-wave tomography: a comparison between ray and finite-frequency theory

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In global seismic tomography, almost all inversions thus far have relied on ray theory. Ray theory is valid at high frequencies where wavelengths are short compared to the size of the heterogeneous structure of the Earth. Particularly for surface waves at longer periods, we need to go beyond this approximation. Finite-frequency theory is expected to perform well even for heterogeneities of approximately the same size as the wavelength. Thanks to important progress in high-performance computing (HPC), it has become feasible to apply finite-frequency sensitivity kernels in global scale inversions. Still, it is unknown how well ray theory and finite-frequency theory compare with one another especially for surface wave tomography; a systematic investigation on global-size scales with a realistic source/receiver distribution is lacking.

In this study, we focus on phase-velocity inversions of intermediate to long-period surface waves. We use the source/station distribution of a real phase-anomaly measurement database to investigate the resolution limit of ray-theoretical and finite-frequency inversions. Our synthetic datum is calculated by cross-correlating waveforms obtained numerically from a membrane model which accounts implicitly for all nonlinear propagation effects; our experiment differs, in this sense, from the classical checkerboard test where synthetic data are computed in a linear model. Employing HPC facilities, we are able to iterate the inverse scheme with finite-frequency sensitivity kernels calculated in a heterogeneous Earth via the adjoint wavefield method. Our results show a clear improvement for high harmonic degree when finite-frequency theory is used to invert phase-anomaly measurements of long-period surface waves.