Sensitivities of Finite-Frequency Traveltime and Amplitude to Elastic and Anelastic Structures

Li Zhao[1] and Po Chen[2]
1. Institute of Earth Sciences, Academia Sinica, Taiwan
2. Lamont-Doherty Earth Observatory, Columbia University, U.S.A.

Abstract

In seismic tomography, phase delays and traveltimes of seismic waves have been used extensively to image the laterally heterogeneous elastic structures of the Earth. Recent theoretical advancements in seismology have also introduced the so-called finite-frequency traveltimes into seismic tomography. Finite-frequency traveltimes are usually measured by the waveform cross-correlation technique and as a result anything that affects the waveforms can contribute to the traveltime measurements and ultimately affects the tomography model. The Earth's intrinsic attenuation has a large impact on the waveforms because it reduces the amplitudes of seismic waves in a frequency-dependent manner. However, the amplitudes of seismic waves have not been sufficiently exploited in tomography. The difficulties in utilizing amplitudes in structural studies are two folds. The amplitudes of seismic waves are often affected by structural variations in a very nonlinear fashion and as a result the amplitudes are not robust data for tomography inversions. Moreover, the amplitudes of seismic waves are affected by not only the anelastic attenuation, but also by the elastic structures through focusing/defocusing and scattering. We are developing a consistent and comprehensive approach to the inversion of frequency-dependent traveltime and amplitude anomalies for the Earth's elastic and anelastic structures. We adopt a consistent definition for the frequency-dependent traveltime and amplitude anomalies and measure both from the same cross-correlation between the synthetic and recorded seismograms. Frequency-dependent anomalies can be obtained from narrow-band filtered cross-correlagrams. We also assure a consistency in interpreting the measurements in terms of structural variations by linearly relating the frequency-dependent phase-delay anomalies to both the elastic parameters to account for scattering and the Q values to account for physical dispersion; and at the same time linearly relating the frequency-dependent amplitude anomalies to the same elastic parameters and Q values to account for scattering and attenuation. We present examples of full-wave 3D sensitivity kernels for these linear relationships computed by coupled normal-mode summations, as well as results of an experimental Q tomography using regional Rayleigh waves in East Asia.