High-resolution 3-D S-wave structure beneath North America using phase and amplitude of surface waves

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Majority of surface wave tomography have employed the phase information, which reflects the average phase speed perturbation along a propagation path. To the contrary, the use of amplitude anomalies of surface waves has been limited in tomographic studies, due to a variety of uncertain factors such as source mechanism, local amplification at receiver, elastic focusing/defocusing and anelastic attenuation. In the interstation analysis, the source term can be canceled out, so that we can focus on the effects of the elastic focusing/defocusing as well as the receiver amplification factors, with an appropriate correction for anelastic attenuation. In the framework of ray theory, the amplitude anomalies affected by the focusing/defocusing reflect the second derivatives of phase speed across the ray path, and thus the amplitude data are more sensitive to shorter-wavelength structure than the conventional phase data.

In this study, we employ a fully non-linear waveform fitting technique to measure interstation phase speeds and amplitude ratios simultaneously, based on a global optimization method. This technique is applied to observed seismograms of the high-density transportable array deployed in the United States (USArray) in the past decade, and a large-number of interstation phase speed and amplitude ratio data are collected. The typical interstation distances for measured dispersion data are less than 1000 km, which is much shorter than the average path length used in conventional single-station analysis and can be of help in improving the lateral resolution of the regional tomography models.

The measured interstation phase and amplitude data are inverted simultaneously for phase speed maps as well as local amplification factor at each receiver location. The phase speed maps derived from both phase and amplitude measurements exhibit better recovery of the strength of velocity perturbations, particularly for the smaller-scale heterogeneities. The spatial distributions of local amplification factors in the longer period are correlated well with the velocity structure in the upper mantle, indicating that the effects of local amplification can be isolated well from those of focusing in our joint inversion of phase and amplitude data.

Isotropic and anisotropic 3-D S wave speed models of North American continent are then obtained from the phase speed maps. Our isotropic 3-D S wave models from phase and amplitude data for Rayleigh waves emphasize local-scale tectonic features associated with conspicuous lateral velocity gradients; e.g., fast anomaly in the Colorado Plateau surrounded by slow anomalies, and slow anomaly in the New Madrid Seismic Zone encompassed by faster regions. Such local tectonic features with the size of about 200 km can hardly be identified in the conventional surface wave tomography, and thus the interstation amplitude ratio data can be of great help in improving the lateral resolution of velocity models in the upper mantle. Radial anisotropy models derived from the phase speed maps of Rayleigh and Love waves using only phase data, are also constructed. The results show faster SH wave speed anomaly than SV in the tectonically active regions in the western and central U.S., while the model exhibits faster SV wave speed anomaly than SH in the eastern region below 75 km depth.

Keywords: upper mantle, surface wave amplitude, North American Continent

