

Synthetic Rayleigh Wave Tomography of the Northern Appalachian Mantle Anomaly (NAA)

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Recent studies have identified a slow velocity anomaly in the upper mantle beneath southern New England (USA) called the NAA. Here we investigate how this anomaly influences the propagation of fundamental mode Rayleigh waves. Exploring such wave propagation phenomena is challenging with real data due to Earth's heterogeneous structure which limits our ability to isolate the effects of a single anomaly. We utilize synthetic SpecFEM waveform simulations to study scattering, focusing, and phase velocity perturbations. Synthetic Rayleigh waveforms are windowed and Fourier transformed to obtain amplitude measurements. Phase velocities are determined using the three station phase difference method after Delaunay triangulation of the station array. We analyze three structural scenarios: two test models including a 200 km wide semispherical anomaly and a semisphere combined with a narrow cylindrical anomaly (stacked model), as well as a realistic 400 km wide anomaly specifically designed to closely replicate observed NAA parameters from real event data. Our simulations demonstrate velocity perturbations associated with the NAA across multiple periods. At short periods (32 s), amplitudes are lower, whereas at longer periods (100 s), amplitudes significantly increase, displaying a clear sign reversal directly above the NAA. Higher amplitudes uprange suggest wave focusing due to the slow velocity anomaly. Additionally, the anomaly exhibits a downrange displacement of approximately 100 km at 100s period, which decreases at 60s and is negligible at 32s. The shallow stacked cylindrical structure notably increases perturbations in the 32–50 s period range. The 400 km wide NAA model demonstrates realistic broader parameterization effects, aligning closely with observed real event data. This synthetic approach effectively isolates structural influences from mantle anomalies, improving our understanding of seismic wave propagation through the NAA and similar slow anomalies.