



Imaging deep heterogeneity in the northern Apennines from reflected surface waves

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Late wave arrivals in the intermediate period coda of regional seismograms in the wider Alpine area can be associated with lateral reflection of surface waves at the northern Apennines mountain chain (Italy). Frequently, these coda waveforms are dominated by a characteristic package of late reflected Love waves, and smaller late Rayleigh waves may become visible after rotation of the seismograms to the instantaneous incidence direction. Here, we discuss a general approach to image lateral heterogeneity using an adjoint method and time reversal of the surface wave coda, and we attempt the characterization of the northern Apennines reflector in particular. To image the origin of reflected surface waves, we compute three-dimensional waveform sensitivity kernels for reflected waves numerically by the time correlation between the original forward wavefield and the corresponding back-propagating adjoint wavefield. The corresponding waveform adjoint source incorporates the reflected waves directly as waveform residuals, and is composed of the synchronized, time-reversed, three-component displacement coda seismograms applied at the receiver locations. We show event kernels for synthetic waveform examples, as well as for real coda observations from moderate earthquakes in the Southern Alps. Wave propagation (for synthetic seismograms, regular wavefield and adjoint wavefield) is simulated with the spectral element method, and a three-dimensional regional velocity and density earth model

is involved in the real data kernels. For both, synthetic and real data, we obtain clear images of the reflectivity associated with the Northern Apennines especially in kernels for density and S-wave speed, consistent with the fact that reflected Love waves represent the most prominent coda arrivals. Sensitivity kernels show a ~ 250 km long near-linear discontinuity between the Adriatic and Ligurian-Tyrrhenian lithospheric domains under the axial zone of the northern Apennines.