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Inverting full waveforms into 1D seismic (upper) crustal model by Neighborhood Algorithm: example from the Corinth Gulf, Greece

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Constructing seismic models of the Earth crust serves two major purposes: (i) helping to understand a geologic structure, and (ii) enabling investigations of earthquakes in terms of their location, centroid-moment-tensors, and/or slip-history on faults. We follow line (ii) where even good 1D models are still important. Should the 1D models be usable in seismic waveform modeling, the natural way is to derive them from full waveforms. We developed and tested a method in which full waveforms of an earthquake recorded in a network of local-to-regional stations are inverted into a 1D crustal model, optimally representing the seismic wave propagation. A single-point source approximation is used. The hypocenter position, origin time and a double-couple focal mechanism are fixed at previously determined values. The forward problem is solved by the Discrete Wavenumber method (Bouchon, 1981; Coutant 1989). The inverse problem is solved by the Neighborhood Algorithm (Sambridge, 1999), providing a suite of the well-fitting velocity models. The misfit function is the L2 norm of the difference between the observed and synthetic seismograms. The performance of the method is illustrated on the largest event (Mw 5.3) of the 2010 Efpalio earthquake sequence, Greece (Sokos et al., 2012). Broad-band data at 8 stations are used, spanning epicentral distances from 13 to 100 km. Several different parametrizations are tested. The most interesting results are obtained in the frequency range of 0.05-0.20 Hz for varying 7 layer thicknesses, their Vp and Vs. The corresponding waveform match (variance reduction VR$\sim$0.6) is significantly better than with the previously existing models of the region. It strengthens a chance to study some details of the space-time rupture process of future significant events in the Corinth Gulf. As revealed by the correlation and covariance matrices, the mutual trade-off between the thicknesses and velocities, as well as between Vp and Vs is negligible. The resolution decreases with depth. The best resolved is a significant Vs increase in the topmost 4 km; the Vp/Vs ratio in this layer is as large as $\sim$2 – 2.5. Several path-dependent (single-station) 1D models were also constructed whose main importance was the stability check. Investigation of lateral crustal variations would require more earthquakes.