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Seismic rays in realistic heterogeneous mantle structures

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The highest resolution tomographic models of the upper mantle available to date have been derived using ray theory and travel time inversion. Nonlinearity in the inversion is tackled by iterative linearized approaches, where rays are first traced in a starting, usually one-dimensional, reference model, and then re-traced in iteratively updated models using approximate two-point boundary value methods (ray bending). The effect of the starting model can therefore remain along the iterations. We adapt a finite difference first-arrival travel time calculation scheme (Podvin and Lecomte, 1991) to work on spherical geometry, and apply it to realistic structures for the European and Mediterranean region. We show that, although wave velocity anomalies in the upper mantle are generally quite smooth, they can cause very significant ray deflection, that can confuse the correct attribution of the delay accrued along a ray. Three-dimensional models deriving from linearized travel time tomography, although very successful in modelling observed travel times, and in imaging large scale geologic features, may in part still be suffering from distortion and amplitude bias due to this difficulty in tracing rays. This points to the importance of a reliable reference model. Although the question of a reliable starting model is often treated as a 1D problem, it is in fact three-dimensional, as differences in velocity profiles (and depth of discontinuities) can vary significantly along the upper mantle transect connecting source to receiver, and also off-azimuth.