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Testing the seismic signature of upper-mantle plumelets: application to the Northern East-African Rift

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Several recent seismic and numerical studies proposed that below some hotspots secondary smaller-scale upper mantle plumelets rise from a regional thermal boundary layer below 660, fed by a (potentially offset) deeper plume source. Such plumelets may help explain hotspot complexities like simultaneous activity of nearby volcanic centres. We recently found tomographic evidence of several small upper-mantle upwellings, spaced by several 100 km, rising through the transition zone below the northern East-African Rift system. To better test this interpretation, we perform synthetic resolution tests using 3D dynamic models of such upper mantle plumelets. The thermal structures are converted to seismic velocities using a mineral physics approach that accounts for the sensitivity to temperature, composition and phase, including anelastic effects. Synthetic resolution tests are then conducted for the same P- and S- data distribution and inversion parameters as our original teleseismic traveltime tomography, a technique that is very commonly applied below hotspots. The models predict simultaneous plumelets in different stages of their evolution, resulting in seismic structure that looks substantially more complex than the simple vertical cylinders that are often anticipated. Recovered ratios of relative velocity anomalies RS,P (=dlnVS/dlnVP) display significant scatter due to differences in P and S resolution, even if input ratios are within a tight thermal range, implying that RS,P is of limited use for distinguishing between thermal or compositional structure. Finally, we find that for reasonable upper-mantle viscosities, the synthetic plume tomography is similar in scale, variability of anomaly shape, and vertical correlation variation to the actual P and S tomography of the Northern EAR, providing further support for the existence of upper-mantle plumelets below the region.