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Investigating the visibility of mantle plumes with seismic arrays

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Mantle plumes may play a major role in the transport of heat and mass through the Earth, but establishing their existence and structure using seismology has proven challenging and controversial. Previous studies have mainly focused on imaging plumes using waveform modelling and inversion (i.e. tomography). In this study we investigate the potential visibility of mantle plumes using array methods, and in particular whether we can detect seismic scattering from the plumes. By combining geodynamic modelling with mineral physics data we compute "seismic" plumes whose shape and structure correspond to dynamically-plausible thermochemical plumes. A full-waveform simulation, sending seismic waves through the plumes, generates synthetic seismograms. We analyse the seismograms with array methods to investigate potential seismic scattering from the plumes. At periods longer than 15 seconds, we do not detect scattering. However we do see several out-of-plane arrivals that are consistent with an apparent bending of the wavefront around the plume conduit. These arrivals are less obvious and less strong at shorter periods, consistent with the expected changes in the waves' behaviour at higher frequencies. We also detect reflections off the iron-rich chemical pile which serves as the plume source in the D" region, indicating that D" reflections may not always be due to a phase transformation. We suggest that slowness-backazimuth analysis may be a useful tool to locate mantle plumes in real array datasets. However it is important to consider waves travelling in all directions and at different frequencies, in order that any out-of-plane energy can be correctly interpreted.