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Determining the seismic expression of thermo-chemical whole mantle plumes

Elinor Styles (1), Hannah Smith (2), Saskia Goes (1), Peter van Keken (2), and Jeroen Ritsema (2)
(1) Imperial College London, London, UK (elinor.styles03@imperial.ac.uk), (2) University of Michigan, Ann-Arbor, USA

To evaluate the nature of mantle plumes using seismic methods, it is necessary to determine the morphologies of physically realistic thermal and thermo-chemical plumes, how they decrease seismic velocity in the deep mantle, and whether plume-like low-velocity structures are detectable with current seismic methods and data.

Here we follow an multi-disciplinary approach to studying the seismic expression of plumes that relies on two steps. (1) We convert a range of thermal and thermo-chemical whole-mantle dynamic plume models, with Earth-like characteristics, into synthetic seismic signatures and account for the large uncertainties in density and elastic parameters of the constituent minerals and in anelasticity using several recent databases. (2) To allow for comparison between our (high-resolution) synthetic models and (low-resolution) tomographic images of the mantle we must account for the limited spatial resolution of tomographic images. We accomplish this by convolving the modelled seismic plume structure with a resolution operator for the global shear wave models S20RTS and S40RTS.

Our results indicate that, despite the factor 2 to 3 decrease in thermal sensitivity of seismic velocities with depth and decreased seismic resolution in the lower mantle, lower-mantle plume 'tails' should be detectable in global tomography for whole mantle thermal plumes with a reasonable excess surface temperature (200-300K, as constrained by petrology) and widths as predicted by dynamic models. Anomalous plume chemistry may cause variations in magnitude of seismic anomalies (up to a factor of 1.5) and morphology that may be distinguishable from the seismic expression of a purely thermal plume. We compare the predicted signature of a number of thermal and thermo-chemical dynamic plumes with tomographically imaged structure beneath major hotspots to constrain the presence or absence and character of the underlying plumes.