A 3D Temperature Map of the Lower Mantle

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Seismic tomography maps regions of high and low velocity throughout the mantle. These maps reveal fast material under modern and past subduction zones which are most often interpreted as subjecting oceanic lithosphere. This fast velocity material takes on various morphologies as it collects in the lower mantle, but does appear to be concentrated above 1500 km depth and below 2400 km depth. Slow velocity regions are vertically continuous under the Pacific and Africa above the Large Low Shear Velocity Provinces (LLSVP) which are the slowest regions of the lower mantle. In order to better understand the material properties of these fast and slow regions, it is necessary to untangle the relative contributions of temperature, mineralogy, and composition on seismic velocity. We compute estimates of these derivatives using density functional theory with psuedopotentials to calculate the seismic velocities of lower mantle materials (e.g. perovskite and ferropericlase) for different Mg/Si ratios and Fe content. This methodology intrinsically takes into account the iron spin transition which causes a reduced seismic signal in ferropericlase in the mid mantle. We assign upper bounds on the temperature and composition assuming the entire seismic signal is due to only one of these effects. Since the compositional sensitivity is smaller than the temperature sensitivity, it takes a large change in composition to get the same seismic signal as a small change in temperature. Thus, there are many regions where the seismic signal is too large to likely be explained by composition alone. We then apply a set of different tradeoffs between temperature and composition that best explain the observed shear and compressional velocity in the lower mantle. In the lowermost mantle, we also incorporate the effects of the post-perovskite phase which increases the shear velocity in cold regions. The result is a 3D temperature map of the lower mantle. This temperature (and composition, although composition is more poorly constrained) map can be used to predict the stability of potentially hydrous phases in the lower mantle, constrain absolute temperature near the CMB assuming the existence of post-perovskite, and run models of mantle convection.