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Predicting lower mantle heterogeneity from 4-D Earth models

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The Earth's lower mantle is characterized by two large-low-shear velocity provinces (LLSVPs), approximately ∼15000 km in diameter and 500-1000 km high, located under Africa and the Pacific Ocean. The spatial stability and chemical nature of these LLSVPs are debated. Here, we compare the lower mantle structure predicted by forward global mantle flow models constrained by tectonic reconstructions (Bower et al., 2015) to an analysis of five global tomography models. In the dynamic models, spanning 230 million years, slabs subducting deep into the mantle deform an initially uniform basal layer containing 2% of the volume of the mantle. Basal density, convective vigour (Rayleigh number *Ra*), mantle viscosity, absolute plate motions, and relative plate motions are varied in a series of model cases. We use cluster analysis to classify a set of equally-spaced points (average separation ∼0.45º) on the Earth's surface into two groups of points with similar variations in present-day temperature between 1000-2800 km depth, for each model case. Below ∼2400 km depth, this procedure reveals a high-temperature cluster in which mantle temperature is significantly larger than ambient and a low-temperature cluster in which mantle temperature is lower than ambient. The spatial extent of the high-temperature cluster is in first-order agreement with the outlines of the African and Pacific LLSVPs revealed by a similar cluster analysis of five tomography models (Lekic et al., 2012). Model success is quantified by computing the accuracy and sensitivity of the predicted temperature clusters in predicting the low-velocity cluster obtained from tomography (Lekic et al., 2012). In these cases, the accuracy varies between 0.61-0.80, where a value of 0.5 represents the random case, and the sensitivity ranges between 0.18-0.83. The largest accuracies and sensitivities are obtained for models with $Ra \approx 5 \times 10^7$, no asthenosphere (or an asthenosphere restricted to the oceanic domain), and a basal layer ∼ 4% denser than ambient mantle. Increasing convective vigour ($Ra \approx 5 \times 10^8$) or decreasing the density of the basal layer decreases both the accuracy and sensitivity of the predicted lower mantle structure.

References:

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