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Global Geodynamic Earth Models: Progress and Challenges

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Mantle Circulation models are a powerful tool to improve our understanding of deep Earth dynamics by integrating diverse observations that include seismic tomography, mineral physics, plate motion variations and gravity. Their comparison with seismic heterogeneity inferred from tomographic Earth models appears particularly promising. Here we focus on thermal variations as a key contributor to large-scale mantle structure and dynamics. We review our work on high-resolution mantle circulation models and use these models to predict elastic heterogeneity. Absolute temperatures of our models are converted to seismic velocities using published thermodynamically self-consistent models of mantle mineralogy for a pyrolite composition. A grid spacing of about 25 km globally allows us to simulate mantle flow at earth-like convective vigor so that modelled temperature variations are consistent with the underlying mineralogy. We concentrate on isochemical convection and the relative importance of internal and bottom heating in order to isolate the thermal effects on elasticity as clearly as possible. Remarkably we find that models having a high temperature contrast on the order of 1000 K across the CMB produce elastic structures that are in excellent agreement with tomography for a number of quantitative measures: These include spectral power and histograms of heterogeneity as well as radial profiles of root-mean-square amplitudes. High plume excess temperatures of +1000--1500 K in the lowermost mantle are particularly important in understanding the strong velocity reductions mapped by seismic tomography in low-velocity bodies of the deep mantle, as they lead to significant negative anomalies of shear wave velocity of up to $-$4¥%. We note that our results do not account for the curious observation of seismic anti-correlation, which appears difficult to explain in any case and will require further improvements in the ability to map seismic heterogeneity to thermal and compositional variations. Our results underline the need to include mineral physics information in the geodynamic interpretation of tomographic models.

Keywords: geodynamics, deep earth structure and evolution, mantle convection