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Thermal versus elastic heterogeneity in high-resolution mantle circulation models with pyrolite composition: High plume excess temperatures in the lowermost mantle

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We study a new class of high-resolution mantle circulation models and predict their corresponding elastic heterogeneity. Absolute temperatures are converted to seismic velocities using published thermodynamically self-consistent models of mantle mineralogy for a pyrolite composition. A grid spacing of ∼25 km globally allows us to explore mantle flow at earth-like convective vigor so that modeled 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. Models with a large temperature contrast on the order of 1000 K across the core-mantle boundary, corresponding to a substantial core heat loss of up to 12 TW, result in elastic structures that agree well 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. In particular, high plume excess temperatures of +1000–1500 K in the lowermost mantle lead to significant negative anomalies of shear wave velocity of up to −4%. These are comparable to strong velocity reductions mapped by seismic tomography in the prominent low-velocity regions of the lower mantle. We note that the inference of a large core heat flux is supported by a number of geophysical studies arguing for a substantial core contribution to the mantle energy budget. However, effects of limited tomographic resolution may bear on our results. We discuss possiblities to extend our analysis by modifying geodynamic models so that they reflect uneven data coverage and damping. Possible approaches include the multiplication of model parameters with the resolution operator associated with tomographic inversions [e.g., Ritsema et al., 2007].