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Mantle Dynamics Studied with Parameterized Prescription From Mineral Physics Database

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The incorporation of important thermodynamic and transport properties into mantle convection models has taken a long time for the community to appreciate, even though it was first spurred by the high-pressure experimental work at Mainz a quarter of a century ago and the experimental work at Bayreuth and St. Louis. The two quantities whose effects have yet to be widely appreciated are thermal expansivity α and thermal conductivity k, which are shown to impact mantle dynamics and thermal history in more ways than geoscientists have previously imagined. We have constructed simple parameterization schemes, which are cast analytically for describing α and k over a wide range of temperatures and pressures corresponding to the Earth's mantle. This approach employs the thermodynamics data set drawn from the VLAB at the University of Minnesota based on first-principles density functional theory [1] and also recent laboratory data from the Bayreuth group [2]. Using analytical formulae to determine α and k increases the computational speed of the convection code with respect to employing pre-calculated look-up tables and allows us to sweep out a wide parameter space. Our results, which also incorporate temperature and pressure dependent viscosity show the following prominent features: 1) The temperature-dependence of α is important in the upper mantle. It enhances strongly the rising hot plumes and inhibits the cold downwellings, thus making subduction more difficult for young slabs. 2) The pressure dependence of α is dominant in the lower mantle. It focuses upwellings and speeds them up during their upward rise. 3) The temperature-dependence of the thermal conductivity helps to homogenize the lateral thermal anomalies in cold downwellings and helps to maintain the heat in the upwellings, thus, in concert with alpha, helps to encourage fast hot plumes. 4) The lattice thermal conductivity of post-perovskite plays an important role in heat-transfer in the lower mantle and the Earth's heat budget history.

[1] www.vlab.msi.umn.edu
[2] Mantilake M., de Koker N, Frost D.J. and McCammon C.A., 2011. Lattice Thermal Conductivity of Lower Mantle Minerals and Heat Flux from Earth's Core. Proceedings of the National Academy of Sciences, 108, 17901-17904.