Numerical experiments on mantle convection of super-Earths with variable thermal conductivity and adiabatic compression

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We conduct a series of numerical experiments of thermal convection of highly compressible fluid in a two-dimensional rectangular box, in order to elucidate the mantle convection on super-Earths. The thermal conductivity and viscosity are assumed to exponentially depend on depth and temperature, respectively, while the variations in thermodynamic properties (thermal expansivity and reference density) with depth are taken to be relevant for the super-Earths with 10 times the Earth's. Our experiments showed the change in convecting flow patterns depending on the depth-dependence in thermal conductivity and the temperature-dependence in viscosity. This is largely due to the change in the thermal state in the convecting mantle, whose interplay with the adiabatic temperature change in turn reduces the activity of hot plumes from the base of the mantle. In particular, for the cases with strong interplay, we found that a "deep stratosphere" of stable thermal stratification can form at the base of the mantle where the fluid motion is insignificant. We also found that the presence of "deep stratosphere" not reduces but enhances the overall heat transport through the mantle, although it weakens the vigor of mantle convection. Our finding may further imply that the absence of intrinsic magnetic fields on massive terrestrial planets is not a corollary of the lack of plate tectonics on their surfaces.

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