Numerical experiments on thermal convection of highly compressible fluids: Influences for mantle convection of super-Earths

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We conduct a series of numerical experiments of thermal convection of highly compressible fluids in a two-dimensional rectangular box heated both from within and below, in order to study 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. From our experiments we identified a distinct regime of convecting flow patterns induced by the interplay between the adiabatic temperature change and the spatial variations in viscosity and thermal conductivity. That is, for the cases with strong temperature-dependent viscosity and depth-dependent thermal conductivity, a "deep stratosphere" of stable thermal stratification is formed at the base of the mantle, in addition to thick stagnant lids at their top surfaces. In the "deep stratosphere", the fluid motion is insignificant particularly in the vertical direction in spite of smallest viscosity owing to its strong dependence on temperature. Our finding may further imply that some of super-Earths which are lacking in mobile tectonic plates on their top surfaces may have "deep stratospheres" at the base of their mantles.

Keywords: Super-Earths, mantle convection, adiabatic (de)compression

