The structure of mantle convection in super-Earths of various sizes

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The structure of convection in the mantle of super-Earths is one of the most important issues in studies of their thermal history and surface environment which is linked to the habitability of planets. In our past studies (Miyagoshi et al., 2014 ApJL, 2015 JGR), we showed that the effects of strong adiabatic compression substantially reduces the activity of hot ascending plumes and the efficiency of convective heat transport in massive super-Earths(about ten times the Earth's mass).
In this paper, we show that how convective structure changes as the mass of the planet increases. In the Earth-like size planet, hot plume activity is high, but the activity is reduced as the planet mass increases. When Mp (the planet mass divided by the Earth's mass) exceeds 4, hot plumes become faint compared with cold ones and their activity becomes negligible. The dimensional thickness of the lithosphere increases as Mp increases in spite of the increasing Rayleigh number. The rms velocity of thermal convection does not significantly depend on Mp. These results suggest that plate tectonics becomes harder to operate as Mp increases.
We also explored the initial transient stage of thermal convection in massive super-Earths. When the shallow mantle is initially hotter than expected from the adiabatic extrapolation from the deep mantle, as expected when the planet is formed from giant impact, transient layered convection continues for as long as several to ten billion years before it yields to a whole layer convection that occurs as the structure in the statistically steady state. Our results suggest that the interior of many of massive super-Earths may be still in the transient stage rather than the steady state now.

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