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スーパー地球のマントル対流シミュレーション: 熱伝導率の深さ依存性と断熱圧縮の効果
Numerical experiments on mantle convection of super-Earths with variable thermal conductivity and adiabatic compression

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Recently, many extra-solar planets have been discovered by improved observation technologies. Some of these planets, called super-Earths, have small masses (up to 17 times the Earth's) and high mean density (>5000 kg/m3). Numerical modeling of mantle convection of super-Earths plays an important role in studying the occurrence of plate tectonics and the surface environments on these planets. On the other hand, when considering mantle convection of super-Earths, it is also important to take into account the difference in (hydrostatic) pressure in the mantles. Since super-Earths have high inner pressure, there must exist a strong change in physical properties and the effect of adiabatic compression. While the effects of physical properties have been intensively studied so far, those of adiabatic compression have not been well studied in the previous models of mantle convection of super-Earths. Here we conduct numerical experiments of thermal convection of highly compressible fluid in a two-dimensional rectangular box whose thermal expansivity and conductivity are dependent on depth, viscosity is dependent on temperature, in order to elucidate the mantle convection on super-Earths.

Our numerical experiments showed the change in convecting flow patterns depending on the temperature-dependence in viscosity, regardless of the depth-dependence in thermal conductivity. When a viscosity is sufficiently dependent on temperature, horizontal flow becomes dominant in the mantle, with a very weak activity of hot plumes from the base of the mantle. This flow pattern is quite similar to the "stratosphere" in the field of meteorology. In addition, we found that the occurrence of "stratosphere" is enhanced for a strong depth-dependent thermal conductivity. One reason for this is that high conductivity at depth significantly reduces the difference in temperature between the basal thermal boundary layer and isothermal core. Our study therefore suggests that the depth-dependent thermal conductivity is one of the most important agents which control the mantle dynamics of super-Earths.

キーワード: スーパー地球, マントル対流, 断熱圧縮, 熱膨張率, 熱伝導率, 粘性率
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