I021-P003 Time: May 29 17:15-18:45

Thermal Evolution of the Earth with Convection Model based on Mixing Length Theory

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The thermal history of the Earth is supposed to have been essentially a cooling process. Convection is a main mechanism for the process and plays a substantial role in the structural evolution of the Earth. Most of the thermal history models for the Earth take the convective heat transport into account by adopting the method of the parameterized convection. The convection occurring in the Earth interior, however, has some complicated aspects, including a large variation of the viscosity, internal heating and phase boundaries. Especially, the temperature dependency of the viscosity affects strongly on the efficiency of the convective heat transport in the mantle. The parameterized convection needs to know the Rayleigh number of the convective region for the calculation of the efficiency of the heat transport. If the viscosity depends on the temperature, the representative Rayleigh number of the convective layer should be decided artificially. There is an alternative method to calculate the efficiency of the convective heat transport, which we have developed based on the concept of mixing length theory. This method needs only the local value of the various physical properties to calculate the efficiency of the convective heat transport. When using this method, the effect of the temperature dependency of the viscosity on the convective heat transport can be taken into account very easily, and the temporal change of the horizontally averaged temperature profile in the convective layer can be investigated by solving a mere thermal conduction problem. In this study, we firstly demonstrate that this method can calculate the efficiency of the convective heat transport correctly by comparison with the results in 2D box and 3D spherical shell simulations. Next we apply this method to the one-dimensional thermal history of the Earth, which contains the temperature dependency of the viscosity and internal heat generation in the mantle, and the solidification of the inner core.