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Thermal Interaction of Mantle and Core Reproduced with Newly Developed Numerical Model
- Earth's Cooling Mechanisms Elucidated -

Overview

Dr. Masaki Yoshida and his colleague at Department of Deep Earth Structure and Dynamics Research, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC: Asahiko Taira, President) performed a series of high-resolution numerical simulations of Rayleigh-Bénard convection with a highly viscous outer layer and a low-viscosity inner layer in 2-D spherical-shell geometry. To investigate the dynamics of convection between the two layers, the heat transport efficiency of two-layer convection was evaluated. Also, the coupling modes between the two layers were directly analyzed using the temperature anomaly and deviatoric stress fields near the interface. Results show that the mechanical coupling mode is dominant in two-layer convection when the absolute viscosity contrast between the two layers is sufficiently small, and it weakens, becoming closer to the thermal coupling mode, as the viscosity in the low-viscosity inner layer decreases.

The thermal history and evolution of the Earth are considered to be controlled by convection in the mantle and outer core. Highly viscous mantle is thought to govern the convective motion in the low-viscosity outer core based on fluid dynamics theories. However, fundamental physics and dynamics have not been quantitatively resolved. A numerical model developed in this study demonstrated that the pattern of mantle convection is kept statistically in a steady state slowing cooling the Earth because of thermal coupling mode in two-layer convection and thermal boundary layer just below the core–mantle boundary becoming thicker than expected, which results in less heat flux from the core to mantle.

These results are expected to contribute to solving major issues in solid-earth science concerning thermal evolution history accompanied by plate tectonics and continental drift.

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The above results were published in the November issue of the *Physics of Fluids*.

Title: Numerical studies on the dynamics of two-layer Rayleigh-Bénard convection with an infinite Prandtl number and large viscosity contrasts
(http://dx.doi.org/10.1063/1.4966685)
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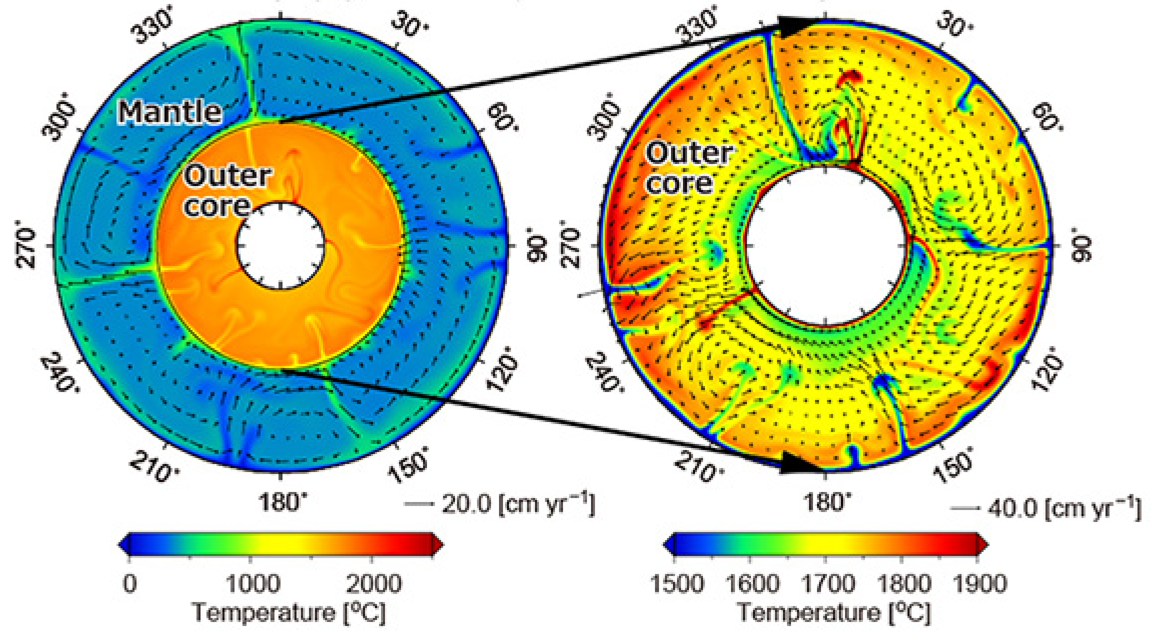
(a) Viscosity contrast: 10^{-1}



(b) Viscosity contrast: 10^{-3}

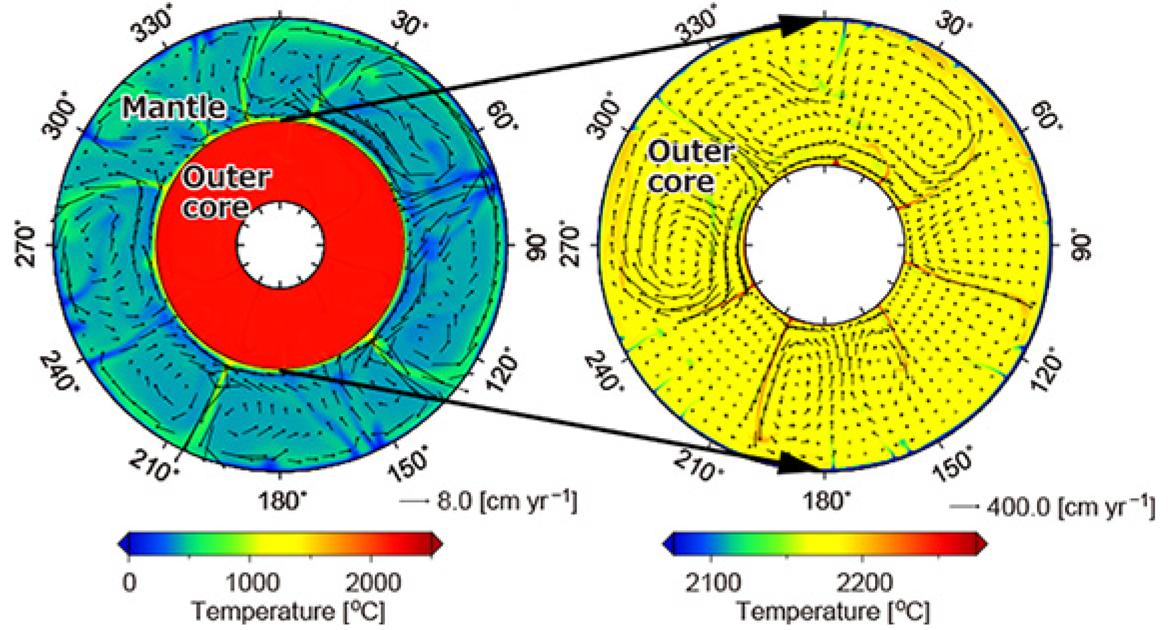


Figure 1. Snapshots of temperature and velocity fields in the mantle and the outer core (left panels) and the close-up views focusing on the interior of the outer core (right panels) with the ratio of outer core viscosity to mantle viscosity of 10^{-1} (a) and 10^{-3} (b).

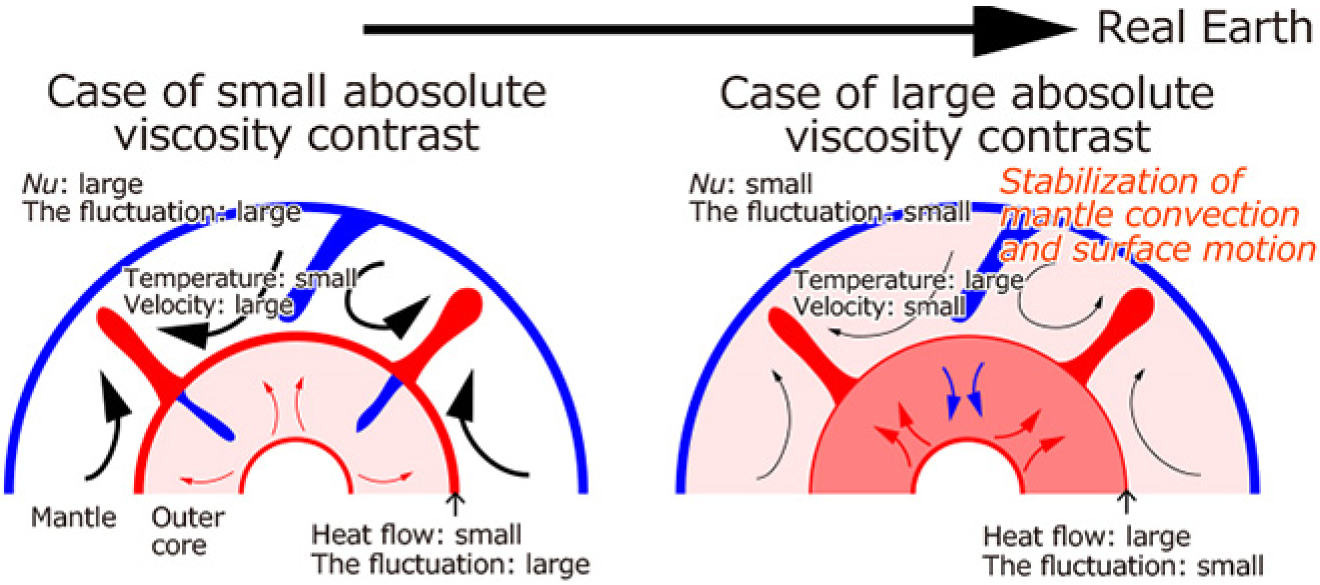


Figure 2. Schematic illustration of mantle convection based on simulations in this study. The right shows when the ratio of the outer core viscosity to mantle is small while the left shows when it is large (Nu= Nusselt number, which indicates the thermal transport efficiency). The blue color indicates low temperature and the red high one.

Simulation of Integrated Whole Solid-earth Thermal Convection System (Video)

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