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Fluid flow near the Earth's core surface derived from geomagnetic field models

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Estimating fluid motion in the Earth's liquid outer core enables us to understand a realistic geodynamo mechanism, to examine the thermal structure at the core surface, and to constrain the effect of core-mantle boundary (CMB) on the flow. Most of core flow models have been estimated from geomagnetic field models based on the frozen-flux approximation. In other words, the magnetic diffusion term can be neglected in the induction equation for a time scale much shorter than the magnetic diffusion time scale. Solutions thus estimated are fundamentally non-unique, and therefore many flow models have been obtained from geomagnetic field models by imposing additional constraints.

It should be noted that these flow models are considered to be those at the top of the free stream immediately beneath a boundary layer at the CMB. However, in reality, the velocity field must vanish at the CMB on the no-slip boundary condition, and a boundary layer does exist. This means that fluid motions estimated so far should be those a little far from the CMB. In other words, we can know only the radial shear of fluid flow near the CMB. This motivates us to examine some effects of a boundary layer on the magnetic field behavior.

We have then examined contribution to temporal changes in the magnetic field near the core surface. The effect of magnetic diffusion is found to be more significant than that of magnetic induction inside the boundary layer at the CMB. Below the boundary layer, however, contribution of magnetic induction to time variations in the magnetic field is larger than that of magnetic diffusion. This suggests that the frozen-flux hypothesis does not necessarily hold for cases in which a significant boundary layer appears.

Therefore, in this study, to estimate fluid flow near the core surface, we take a boundary layer into consideration. Because of no-slip condition at the CMB, the temporal variation in the radial component of the magnetic field is due to the magnetic diffusion only there. Inside the boundary layer, we presume that time variations in the magnetic field arise from both magnetic diffusion and magnetic induction. Below the boundary layer, the magnetic diffusion term is neglected in the induction equation as in the frozen-flux approximation. It is necessary to consider dynamics inside and below the boundary layer, in which the viscous force must play an important role. We therefore presume balance among the pressure gradient, the Coriolis force, and the viscous force in the equation of motion inside the boundary layer. Below the boundary layer, we presume that the flow is in a geostrophic state. We compare our flow models with those so far estimated from geomagnetic field models.