Fluid flow near the Earth's core surface derived from geomagnetic field models with constraint of radial dependence

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Earth's core surface flow models have been estimated from geomagnetic field models to understand a realistic geodynamo mechanism, to investigate the thermal structure at the core surface, and to constrain the effect of core-mantle boundary (CMB) on the fluid flow. In most of core surface flow models, magnetic lines of force are considered to move as if they are frozen-in fluid elements when the advective time scale is much shorter than the magnetic diffusion time scale. This is called the frozen-flux hypothesis. Because of fundamental non-uniqueness, additional constraints have been imposed. It should be noted that thickness of a boundary layer at the CMB had been neglected. This suggests that flow models are estimated at the top of the free stream immediately beneath a thin boundary layer at the CMB.

In the meantime, we have examined contribution to temporal variations in the magnetic field near the core surface based on numerical MHD dynamo models. We have found that the effect of magnetic diffusion is more significant than that of magnetic induction inside the boundary layer at the CMB, and that the effect of magnetic diffusion is much smaller than that of magnetic induction. This means that the frozen-flux hypothesis does not necessarily hold when a significant boundary layer appears.

Hence we have presented a new approach to estimate fluid flow near the CMB from geomagnetic field models. We presume that both the magnetic diffusion and the viscous force are effective inside the boundary layer. That is, not only magnetic induction but also magnetic diffusion contribute to temporal variations in the magnetic field inside the boundary layer. Also the viscous force plays an important role there, and balance among the pressure gradient, the Coriolis force, and the viscous force is presumed. The magnetic diffusion is neglected as in the frozen-flux approximation below the boundary layer, and the flow is presumed to be in a geostrophic state there.

So far we have not constrained the radial dependence of fluid motion near the core surface, although the radial component of the magnetic field has been treated in form of a truncated Taylor expansion. When the radial dependence of horizontal components of fluid flow is expressed in terms of a second-order polynomial, a linear inversion problem is to be solved in the same way as that without any constraint. When the radial dependence is given by a profile as often found in boundary layers, a non-linear inversion problem must be solved.