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Fluid flow near the Earth's core surface derived from geomagnetic field models with constraint of radial dependence (2)

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Fluid flow models near the Earth's core surface have been estimated from geomagnetic field models, since they provide information on a realistic geodynamo mechanism. Furthermore, they are useful to investigate some natures at the core-mantle boundary (CMB) like the thermal structure. Most of core flow models estimated so far have relied on the so-called frozen-flux hypothesis, in which magnetic lines of force move as if they are frozen-in core fluid elements. In this case, or for a time scale much shorter than the magnetic diffusion time scale, the magnetic diffusion term can be neglected in the induction equation. It is known that flow models thus estimated are fundamentally non-unique, and additional constraints, like a steady flow and a tangentially geostrophic flow, have been imposed. It should be noted that these flow models correspond to the top of the free stream immediately beneath a boundary layer at the CMB. That is, thickness of a boundary layer had been neglected, although the flow must vanish at the CMB on the no-slip boundary condition, in reality. In other words, the effect of radial shear flows on the magnetic field has been neglected.

In the meantime, we have examined contribution to temporal variations in the magnetic field near the core surface. Below the boundary layer at the CMB, the magnetic diffusion is much smaller than the magnetic induction as presumed in the frozen-flux approximation. Inside the boundary layer, however, the magnetic diffusion is found to be more significant than the magnetic diffusion. This means that the frozen-flux hypothesis does not necessarily hold when a significant boundary layer appears at the CMB.

Hence we have presented a new approach to derive fluid flow near the CMB from geomagnetic field models by taking a boundary layer into account. The temporal variation in the radial component of the magnetic field arises from the magnetic diffusion only because of no-slip condition at the CMB. Inside the boundary layer, we presume that the magnetic diffusion as well as the magnetic induction contributes to temporal variations in the magnetic field, and that the viscous force plays an important role. Below the boundary layer, we presume that the magnetic diffusion is neglected as in the frozen-flux approximation, and that the flow is geostrophic.

So far the radial component of the magnetic field has been treated in form of a truncated Taylor expansion. On the other hand, the radial dependence of horizontal components of fluid flow has been expressed in terms of a second-order polynomial. The radial dependence can be given by a profile as often found in boundary layers. In fact, dynamics of the boundary layer can be represented in terms of the boundary layer compatibility condition. We therefore attempt to use the condition to constrain the radial dependence of the flow to be derived from geomagnetic field models.