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

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It is of importance to estimate fluid motion in the Earth's outer core to understand a realistic geodynamo mechanism. When the advective time scale is much shorter than the magnetic diffusion time scale, the diffusion term in the induction equation can be neglected for such a short time scale (Roberts and Scott, 1965). Then magnetic lines of force are considered to move as if they are frozen in fluid elements, and this is called the frozen-flux hypothesis. Solutions estimated on the basis of this method are fundamentally nonunique (Backus, 1968). Therefore, many flow models have been obtained from geomagnetic field models by imposing additional constraints.

There is another approach in which the induction and the Navier-Stokes equation are simultaneously solved by prescribing the radial dependence of poloidal velocity field (Matsushima, 1995). In this method, the magnetic diffusion is taken into account, and the velocity and the magnetic fields within the core are simultaneously estimated, although solutions are nonunique because of nonlinearity of the problem.

In the above approaches, thickness of a boundary layer at the core-mantle boundary (CMB) is neglected, since it is believed to be very small; that is, at the CMB, the so-called no-slip boundary condition is not taken into account, and fluid elements move there. The magnetic field then changes in time due to the advection. Such secular variations are the key to estimation of fluid motions at the CMB. However, as performed in numerical simulations of MHD dynamos, the velocity field must vanish at the CMB on the no-slip boundary condition. Fluid motions estimated so far should be those a little far from the CMB. In other words, we can know only the shear motion at the CMB.

We describe another approach to estimate fluid flow near the CMB from geomagnetic field models. We presume that both the magnetic diffusion and the viscosity are effective inside the boundary layer, and that they can be neglected outside the boundary layer. We apply the present method to magnetic field data taken from MHD dynamo models in a rotating spherical shell. We also compare our flow models with those so far estimated from geomagnetic field models.