Eddy viscosity of core flow estimated from geomagnetic field data

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The molecular diffusivities of the Earth’ s core are very small, so that large-scale fields are diffused much more effectively by small-scale turbulence than by molecular processes. Therefore, geodynamo simulations have replaced the molecular diffusivities by the eddy diffusivities, of which values should appropriately adopted. It should be noted, however, that the eddy viscous diffusion, or the eddy viscosity, is not a property of the core fluid but of the core flow. Hence estimating the eddy viscosity from core flow models is very significant.

Fluid motions near the core-mantle boundary (CMB) cause the secular variation of the geomagnetic field observed above the Earth’ s surface. As an inverse problem, core flows can be inferred from geomagnetic field data, or spatial distributions and temporal variations of the geomagnetic field. Most of core surface flows are estimated by use of the diffusionless induction equation; that is, the frozen-flux approximation (Roberts and Scott, 1965) is adopted. The magnetic diffusion term in the induction equation can be neglected for a large-scale magnetic field with time scales much shorter than magnetic diffusion time. At the CMB, however, there exists a viscous boundary layer, where the magnetic diffusion cannot be neglected in temporal variations of geomagnetic field. Hence, Matsushima (2015) has devised a new approach to estimation of core surface flow; that is, the magnetic diffusion is explicitly incorporated within the boundary layer, whereas it is neglected below the boundary layer. Furthermore, core flows are assumed to obey a geostrophic balance or a magnetostrophic balance below the boundary layer.

To investigate relation between core surface flow and core-mantle coupling, a geomagnetic field model, COV-OBS.x1 (Gillet et al., 2015), from 1840 to 2015, has been used to derive a core surface flow model, which would contain any information on phenomena in relation with core-mantle coupling, such as the length-of-day (LOD), and spin-up/spin-down of core flows. A possible correlation between time series of the LOD and the axial component of global vorticity suggests any core-mantle coupling. The phase shift leading to the maximum correlation coefficient between the LOD and the axial vorticity is found to be about 18 years, from which the eddy viscosity can be estimated. Since other core-mantle coupling is not taken into account, such as electromagnetic coupling, the value could be a maximum one.

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