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# Fluid motions induced by horizontally heterogeneous Joule heating in the inner core of the earth

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The elastic anisotropy of the earth's inner core as revealed by recent seismic observations[1,2,3]is considered to originate from the alignment of texture formed along the solidification of the core[4,5] or alignment of the preferred orientation of crystals by plastic deformation of fluid motions[6,7,8,9]. The depth dependency of the anisotropy is difficult to explain by the solidification mechanism, whereas the various factors driving fluid flows in the inner core considered thus far do not appear to yield sufficiently strong stresses for generation of the elastic anisotropy[10]. In the present study, Joule heating of the magnetic field penetrating diffusively from the inner core boundary (ICB) is proposed as a possible source of inner core flows. Since the estimated bulk magnitude of Joule heating in the inner core is relatively small compared to the other thermal factors, such as secular cooling of the inner core, it is often neglected when considering thermal history or free vertical convection problems. However, the arguments in these problems implicitly consider heating to be uniform. When Joule heating varies horizontally even slightly, the induced horizontal temperature gradient would drive an overturning fluid motion (horizontal convection) through the torque associated with the buoyancy force.
Estimation using the expected values of the physical parameters in the inner core reveal that the proposed mechanism yields the velocity amplitude of $10^{-12}$-$10^{-10}$m/s. The amplitude of velocity caused by Joule heating is similar to or greater than that induced by other the factors considered thus far.
An analytic solution of a steady flow induced by Joule heating is obtained for any distribution of magnetic field imposed at the ICB. The model consists of the governing equations of a MHD Boussinesq fluid, which describes magnetic diffusion, the force balance of pressure, viscous and buoyancy forces, and the thermal balance of thermal diffusion, advection of basic temperature, and Joule heating. The boundary conditions at the ICB are assumed to be the zero tangential component of the stress field, the constant normal component of the stress field, and the zero temperature disturbance. Unlike the response to Maxwell stresses[10], the flow induced by this mechanism does not stop even when the system reaches a steady state. The flow field by this mechanism is also accompanied by a weak stress field layer near the ICB. The thickness of this boundary layer is comparable to the depth of the weak anisotropy region observed near the ICB.
Joule heating may cause interactions of the flow and magnetic fields between the inner and outer cores. Since the inner core flow induced by Joule heating invokes mass exchange with the outer core, this flow would affect flow and magnetic fields in the outer core through absorption and release of latent heat and the light elements at the ICB. When the magnetic field in the outer core varies, the magnetic field penetrates the inner core from the ICB, and, at the same time, the distribution of Joule heating is affected, which causes reflecting effects on the fluid flow in the inner core.

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