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Turbulence in the Earth's metallic core

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The Earth's magnetic field reflects electric currents in the liquid metallic core that is sustained by a dynamo action of convective motion. The geomagnetic field shows wide spectra in space and time, indicating strong turbulence of the liquid core. Theoretical and computational studies show that (1) in a low-wavenumber range, magnetic energy density is much greater than kinetic energy density and the flow is in a magnetostrophic state in which viscous and advection terms are needless, and that (2) in a higher-wavenumber range, advection becomes important and the energy densities are equipartitioned. The magnetic field inside the core is considered to be so non-uniformly distributed that the dynamics in the strong and weak field regions could be different.

It is impossible to know the core flow and the internal magnetic field by direct observations. Even the spacial structure of the surface magnetic field is observationally restricted. However, we can know relatively long time variations of the geomagnetic field (up to hundred millions years) thanks to paleomagnetic records. We showed that time variations of the axial dipole moment, which is considered to be the most robust information in paleomagnetic records, had relation with the wavenumber spectrum of the core surface electric current density, and possibly with the flow velocity spectrum beneath the core surface (Sakuraba and Hamano, 2007). We explain the logic of estimation of the turbulent spectra in the core by observations.

One of the authors performed geodynamo simulations in which lower (more Earth-like) viscosity parameters were used than ever achieved (Sakuraba and Roberts, 2009). In a low-viscosity regime, the region where the magnetic energy density is much stronger than the kinetic energy and the structure is large-scale sharply contrasted with the region where the magnetic field is weak and the high-wavenumber flow is dominated. As our dynamo is caused by thermal convection, the boundary condition at the core surface temperature has an impact on the solutions. We compare two cases, a uniform surface temperature model and a uniform surface heat-flux model, and explain the differences of the turbulent features.