Kinematic dynamo associated with a drifting columnar convection

Hinami Taniguchi[1]; Futoshi Takahashi[2]
[1] Kyushu Univ.; [2] Kyushu Univ.

The terrestrial bodies that maintain their intrinsic magnetic fields have dynamos in the fluid cores, in which convection is driven in various ways. In case of the Earth, it is believed that compositional convection, which is fed by light element ejection from the ICB upon inner core growth, is dominant and powers the geodynamo: it is so-called 'bottom-up' type convection. In a body, iron ejection due to solidification of iron could occur at the core-mantle boundary under a certain condition, and the solidified iron falls downward like snow drop, that is so-called 'iron snow', which would also power compositional convection. It strongly depends on temperature-pressure conditions and bulk sulfur content in the core which sort of compositional buoyancy contributes to convection. In this study, we focus on the kinematic dynamo associated with a top-down type drifting flow, and solve the kinematic dynamo problem numerically.

Let us consider an electrically conducting fluid contained in a rotating spherical shell, in which the velocity field is prescribed as a drifting columnar flow. The velocity field is obtained by solving a linear stability analysis for top-down type convection as an eigenvalue problem. The imaginary part of the eigenvalue associated with the critical mode gives us the drift rate of columnar convection. The Ekman number and magnetic Prandtl number are $2.0*10^{-4}$ and 0.10 respectively. The control parameter is the magnetic Reynolds number in the kinematic dynamo problem. The induction equation is solved by time-marching with a minute initial dipole field given as a seed. We search for the critical value giving the neutral growth rate of the dipole field to understand a basic feature of the kinematic dynamo driven by top-down type drifting columnar convection. As a result, it is found that the magnetic fields at the onset repeats a periodic change consisting of asymmetric growth and decay phases. In the growing phase, the magnetic energy is dominated by the small-scale components, whereas in the decaying phase the magnetic fields show a large-scale feature dominated by the dipole component. Although numerical convergence is a concern, which should be checked higher resolution calculations, such an asymmetric behavior with respect to time may be associated with geomagnetic excursions and reversals, during which the dipole field is substantially reduced and then, the geodynamo might act in nearly a kinematic manner.