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# Numerical simulation of MHD dynamos in a rotating spherical shell

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We have performed some numerical simulations for three-dimensional self-consistent magnetohydrodynamic dynamo to examine the generation process of the Earth's magnetic field. We consider the rotating spherical shell filled with electrically conducting fluid under the Boussinesq approximation. In this study, the inner core is considered to be an electric conductor of the same electrical conductivity as the outer core. It is assumed that thermal buoyancy is the driving force of convection and dynamo is driven by secular cooling of the core. To perform numerical computation, the velocity and the magnetic fields are decomposed into the toroidal and the poloidal components, then, all the scalar functions are expanded in terms of spherical harmonics in angular direction. Finite difference method is used in radial direction. Calculating non-linear terms is done using pseudo-spectral method, in which non-linear terms are calculated in physical space and then back into spectral space through Gauss-Legendre-Fourier transform. Spherical harmonic expansion is up to 52 or 62. Distribution of the radial grid points is determined in accordance with the Chebyshev collocation points; 100 grid points within the outer core and 35 within the inner core.

There are some non-dimensional parameters appearing in equations, called the Prandtl number (Pr), the magnetic Prandtl number (Pm), the Ekman number (Ek), the Rayleigh

number (Ra) and the ratio between the outer and the inner core radii (ri/ro). The Prantdl number and the radius ratio are set at 1 and 0.35. The Ekman number is between 5 x 10^{-4} and 10^{-4}. The Rayleigh number is between 5 and 9 times the critical value for non-magnetic convection. The magnetic Prandtl number is O(1). No-slip boundary condition is applied to the velocity field and the inner core can freely rotate along the same rotation axis as reference frame with angular velocity determined by the balance between the viscous and the magnetic torques.

While convection pattern is characterized by its columnar shape outside the tangent cylinder (an imaginary cylinder touching the inner core at the equator), convection is

relatively moderate inside it because of the moderately supercritical Rayleigh number.

The magnetic field shows complex spatial structure, however, its time variation is not so. Such behavior might be attributed

to the small magnetic Prandtl number. The influence of the columnar convection on the magnetic field is strong. At the CMB, magnetic flux lobes appear where downwelling flow exists at middle or high latitude and there are pairs of flux across the equator with opposite polarity at low latitude, which is generated by the columnar convection (alpha-effect). We can see westward flow near the ICB and eastward flow near the CMB inside the tangent cylinder, while westward flow prevails outside. Toroidal magnetic field in a merridional plane concentrates in two bundles near the equator in each hemisphere; one is near the tangent cylinder and the other is near the CMB. Toroidal field generation near the CMB is attributed to the columnar convection. At relatively high Rayleigh number active convection inside the tangent cylinder occurs. We obtain highly dipolar magnetic field with persistent equatorial symmetry from all the simulations performed.

However, there is still a possibility that time integration is not enough to reach equilibrium state. Hence we consider further time integration is necessary.