Flip-flop between strong and weak field states in a numerical geodynamo model

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It is very likely that the geodynamo operates in a strong field state, where the Lorentz force plays an important role in force balance. In numerical dynamos, polarity reversals of the magnetic field occur when the strength of the dipole field decreases, as suggested by paleomagnetic studies, that is, when the dynamo is in the weak field regime, where the effect of the Lorentz force on core dynamics is minor or negligible. The Elsasser number ($¥Lambda$) is a useful measure of the strength of the magnetic field; a strong field state is represented by $¥Lambda ¥sim 1$, while a weak field state by $¥Lambda$ smaller than unity.

We have obtained a numerical solution of three-dimensional magnetohydrodynamic (MHD) dynamo showing a flip-flop between weak and strong field states. The Elsasser number ranges between 0.1 and 1. A large fluctuation of kinetic energy leads to such a transition. However, difference between variations in the structure of the velocity field during transitions, from strong to weak field regime and vice versa, are not so obvious. A transition from weak to strong field regime takes a longer time to be completed than the reverse. We have found that T_1^0-type differential rotation (a toroidal motion of degree 1 and order 0 in spherical harmonics) outside the tangent cylinder grows up before the onset of both types of transitions. Accordingly, the strong magnetic field is drastically and suddenly diminished, whereas the magnetic field gradually increases, during a transition from weak to strong field regime, with the growth of convection columns. This result suggests that the strong differential rotation of T_1^0-type plays some roles in making the existing magnetic field unstable.

The location of the magnetic pole is stable, within 10 degrees from the geographic pole, for a whole period of the numerical simulation. This implies that polarity reversals of the dipole field might not occur whenever the dipole component is significant, even if the dynamo operates in a weak field state.