Numerical simulations of short-timescale geomagnetic field variations

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Numerical modeling of the convection in the Earth's liquid outer core has succeeded in simulating generation of a dipole-dominated magnetic field and its intermittent polarity reversals. However, previous models have used unrealistically high viscosity for the core fluid because of computational difficulty to resolve small-scale turbulence that would otherwise happen. It is still an open question whether lower-viscosity Earth-type dynamo models can simulate the geomagnetic field and its time variations. Recent models have succeeded in reducing viscosity by about one order of magnitude, compared to previous models. However, such models seem to fail to produce an Earth-like strong magnetic field even though the viscosity is more realistic. I explained that this paradoxical result was caused by geophysically unrealistic boundary condition for the core surface temperature (Sakuraba and Roberts, *Nature Geosci.* **2**, 802, 2009). If the core surface temperature is laterally uniform like recent low-viscosity models, the magnetic field is dipolar but its strength is relatively weak. If the surface heat flux is laterally uniform, which allows a pole-equator temperature difference, westward (retrograde) thermal wind naturally blows beneath the core equator and generates a strong toroidal magnetic field by its omega effect. The resultant dipole moment is relatively strong too. I concluded that the former boundary condition was not only theoretically unrealistic at the Earth's core-mantle boundary, but failed to produce Earth-like magnetic fields.

Small viscosity generally enables the dynamo model to simulate field variations of short timescales. Here I report on attempts to find Earth-like signatures of short-timescale field variations in the low-viscosity geodynamo model. I focus on three characteristic geomagnetic secular variations: westward drift, torsional oscillations, and jerks. The simulated westward drift is confined in the equatorial belt like the geomagnetic field variations for the last 400 years. The drift is primarily caused by advection, but larger-scale (lower-wavenumber) fields tend to be stationary or rather move eastward, which suggests that some planetary-scale MHD waves modulate the field behaviors. The drift velocity is slower than the Earth's probably because the simulated magnetic Reynolds number is too small. The axial angular velocity of a cylinder in the liquid outer core can be defined as a function of the cylinder's radius and the time, and this shows wavelike propagation both toward the rotation axis and toward the core equator. The phase velocity is slightly slower than that predicted by the Braginsky's theory of torsional oscillations. All three magnetic field components in my model sometimes show zigzag variations in time like the geomagnetic jerk. The simulated jerk seems to be a local phenomenon, but the cause is still under investigation.