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地球ダイナモモデルにおける西方移動、ねじれ振動およびジャーク
Westward drift, torsional oscillations and jerks in a numerical geodynamo model

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Recent high-resolution, low-viscosity geodynamo simulations have shed a new light on the origins of geomagnetic secular variations of time scales shorter than the convective turnover time (about 500 years in the Earth's liquid outer core). Here I report some results of my ongoing project to physically explain relatively short time-scale secular variations such as geomagnetic westward drift and jerks. I performed geodynamo simulations using the Ekman number of 5 x 10^{-7} and the magnetic Prandtl number of 0.2 (Sakuraba and Roberts, 2009). These parameters are far away from those of the Earth's core but are hopefully small enough to investigate some basic features of magnetohydrodynamic (MHD) flows of low-viscosity rotating fluids. In this model, there are several strong magnetic flux patches in the low-latitudes on the core-mantle boundary (CMB), moving westward with the angular velocity close to that of the thermal-wind-type westward flow beneath the CMB. The azimuthal wavenumber (m) of the low-latitude flux patches is 5 to 7, which roughly coincides with the recent core-surface field estimated by Finlay and Jackson (2003). However, if scaled by the magnetic diffusion time, the angular velocity is too slow because the magnetic Reynolds number is not so large (about 200). This suggests that it is better to scale the time by the convective turnover time. Fourier analysis indicates that the drift angular velocity depends on both m and the latitude. The higher-wavenumber components ($m>5$) coherently move with the westward flow in the low-latitudes and the amplitude becomes weak in the high-latitudes. The lower-wavenumber components of m=1 and 2 show an intermittent feature in the low-latitude and sometimes move eastward, indicating existence of MHD waves. In the high-latitudes, there is a tendency that the field pattern, dominated by low-wavenumber components, moves eastward because the tangent cylinder rotates eastward in my model. I suggest that the Fourier analysis (not the spherical harmonic analysis) of the geomagnetic secular variation gives insight into the origin of the westward drift and the dynamics of the core convection. The torsional oscillations signify oscillatory motions of axial cylinders inside the fluid core that are propagated along the cylindrically radial (the s-) direction with the Alfven speed, which is considered to be much greater than the flow speed. The numerical model clearly shows the torsional waves traveling both inward and outward. There is a slight asymmetry between the ingoing and outgoing waves, suggesting the locality of the excitation source. The power spectrum of the wave motion at a constant radius indicates a tendency that longer-period waves contain greater power, but the propagation speed of those significant components are slower than the theoretically expected Alfven speed. The Alfven-type torsional waves have periods close to or shorter than the convective turnover time. The model also shows clear jerk-like secular variations if observed at the planet's surface. Small-amplitude jerks occur frequently and large-amplitude ones scarcely. Jerks are largely explained by the changes of the core-surface magnetic field of $1 < m < 7$. Presently, I try to understand the mechanism that creates jerk-like zigzag pattern in secular variations. The small-amplitude frequent jerks seem to be explained by the field disturbance due to torsional waves, as has been indicated by Bloxham (2002).

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