回転流体球における磁気不安定と地磁気西方移動

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Magnetic instability in a rotating fluid sphere and geomagnetic westward drift

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A strong toroidal magnetic field confined in a rapidly rotating, electrically conducting fluid sphere is known to be unstable when the Elsasser number, which is the only dimensionless number relating to the field intensity, angular velocity, conductivity and density, exceeds a certain critical value (e.g., Phillips and Ivers, 2005). The unstable mode exhibits an eastward or westward traveling wave of perturbed magnetic and velocity fields. This study is aimed to elucidate the instability of various types of basic fields and to discuss the relation to the geomagnetic westward drift. The eigenvalue calculations for the linear stability show that the toroidal magnetic field alone exhibits an eastward traveling wave. As the toroidal flux tube is located near the equator of the fluid sphere, higher-wavenumber modes tend to be most unstable. The effect of the basic flow field is also examined. When a uniform axial magnetic field is imposed and the toroidal field is assumed to be created by a basic zonal flow (the omega-effect), the system tends to be more stable. As the toroidal field is confined near the equator, the unstable mode exhibits a westward drift. Even when the toroidal field is antisymmetric with respect to the equator, the unstable mode can belong to the quadrupole family (i.e., the perturbed radial magnetic field is symmetric with respect to the equator). There is a wave dispersion in the sense that a lower wavenumber mode tends to move eastward. The numerical results indicate that the magnetic instability itself creates an eastward drift, but the advection caused by the basic flow field modifies the direction of the wave. This study suggests that the geomagnetic westward drift most clearly observed near the equator of the Atlantic hemisphere reflects the existence of strong toroidal magnetic fields near the core surface.