Numerical dynamo model in a sphere: implications for an early dynamo action

Futoshi Takahashi[1]
[1] Tokyo Tech

In the early stage of the geodynamo, convection in the Earth's core should be driven thermally by core cooling, because of absence or smallness, if any, of the solid inner core. In many of the numerical dynamo models so far, thermal convection is driven by temperature difference between the inner and outer boundaries, which is physically unrealistic without the inner core: that is, heat flux goes to infinity at the origin. Therefore, convection must be driven by core cooling. In this paper, we report results of numerical dynamo simulation in a rotating sphere driven by secular core cooling.

The Ekman number, E, employed in the runs is 10^{-5}, the Prandtl number, Pr, is one, and the magnetic Prandtl number, Pm is varied as Pm = 1-1.5, respectively. The range of the Rayleigh number, Ra, is 6-15 x10ˆ7. The inner core radius 0.001 times the outer core radius is nominally adopted for numerical stability. Boundaries are no-slip, electrically insulating for the flow and the magnetic field, while fixed heat flux is assumed at the outer boundary.

Self-sustaining dynamo is relatively difficult to achieve due to absence of the inner core, even when the magnetic Reynolds number exceeds 100. In successful dynamos, the magnetic field shows complicated non-dipolar structure with nearly periodic reversals of the dipole constituent, whereas well-organized columnar flow structure arises. Effects of large-scale heat-flux heterogeneity at the outer boundary on dynamo action are also examined. Heat-flux heterogeneity gives additional power to the dynamo, which is, otherwise, subcritical. The flow structure is strongly affected by the cold downwelling flow continuously induced by the imposed heat-flux heterogeneity. Details and implications for planetary dynamos will be presented.