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09:30-09:45

# Effects of thermal boundary conditions for cooling from the CMB on geodynamo with various Rayleigh numbers and inner core radii

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The Earth has been sustaining its intrinsic magnetic field for at least 3.5 billion years as revealed by paleomagnetic studies [e.g., Biggin et al., 2015]. The geomagnetic field is generated and maintained by dynamo action due to convection of liquid iron alloy in the outer core. Studies of the thermochemical evolution of the Earth's core suggest that the solid inner core has been growing up for approximately one billion years [e.g., O'Rourke and Stevenson, 2016]. Consequently, heat flow in the core has also been changing through the Earth's history [e.g., Driscoll and Bercovici, 2014]. Hence it is important to investigate effects of heat flux in relation to various inner core size on dynamo action to understand a physical state of the past Earth. Heimpel et al. (2005) evaluated dynamo onset conditions with various inner core size for a fixed temperature (FT) boundary condition. Hori et al. (2010) found that magnetic field is more dipolar on a fixed heat flux (FF) boundary condition, zero flux at the inner-core boundary (ICB) and outgoing flux at the core-mantle boundary (CMB), rather than on the fixed temperature boundary condition for the range of the inner to outer core radius ratio, $r_i/r_o$ = 0.1 and 0.35. It is suggested that the fixed heat flux boundary condition to sustain a strong dipole field would be preferred to the fixed temperature boundary condition in $0.1 < r_i/r_o < 0.35$. Therefore, we carry out dynamo simulations with the fixed heat flux boundary condition for cooling from the CMB to understand geodynamo in the past Earth.

In the present study, we investigate the effects of cooling from the CMB on numerical dynamos with various inner core size using a numerical dynamo code Calypso [Matsui et al., 2014]. We fix the Ekman, Prandtl, and magnetic Prandtl numbers to be $E = 10^{-3}$, $Pr = 1$, and $Pm = 5$, respectively, and change the Rayleigh number and the radius ratio to be $r_i/r_o$ = 0.15, 0.25, and 0.35. For boundary condition, we perform simulations with (i) FT, (ii) FF with balanced heat flow at ICB and CMB, and (iii) FF with taken into account of the cooling of the core. To compare these three conditions, we perform the simulations with the same flux Rayleigh number ($Ra^F$) at the CMB. First, we compare (i) FT cases and (ii) FF with balanced heat flow cases. The results show that the $Ra^F$ range to sustain the intense dipole field in (ii) FF cases is smaller than that for the (i) FT cases. FF with balanced heat flow boundary is inappropriate to a strong dipolar dynamo for all $r_i/r_o$. We also compare the two FF cases. In $r_i/r_o$ = 0.25, strong dynamo is sustained with balanced heat flow case (ii) with $Ra^F = 1.08*10^6$, while dynamo is failed with zero flux (iii). In the case (iii), kinetic energy density is approximately 1/4 times of that of heat balance case (ii). This result suggested that convection in case (ii) is not intense enough to sustain dynamo. We will discuss how heat flux condition is suitable to sustain the intense dipolar field by further simulations with various thermal boundary conditions.