LARGE-SCALE FLOW AND MAGNETIC FIELD STRUCTURES IN LOW-VISCOSITY GEODYNAMO MODELS: THE EFFECT OF THE THERMAL BOUNDARY CONDITION

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The viscosity of the Earth's fluid core is thought to be too small to affect the dynamo mechanism by which the geomagnetic field is generated. Recent numerical studies on the geodynamo have attempted to decrease the magnetic Prandtl number (*Pm*) and the Ekman number (*E*), which are the nondimensional parameters relevant to viscosity in the numerical models, and have reached Ekman numbers that are $O(10^{-7})$ and magnetic Prandtl numbers that are O(0.1). Surprisingly, the resulting fields have not always simulated the actual geomagnetic field better. For example, Kageyama et al. (2008) reached $E = 2.3 \times 10^{-7}$ and $Pm = 1$ but their simulated magnetic field was not nearly as dipole-dominated as the geomagnetic field. Takahashi et al. (2008) reached $E = 4 \times 10^{-7}$ and $Pm = 0.2$ and obtained a dipolar magnetic field but one whose intensity is weak compared with those generated by simulations at larger *E* and larger *Pm*. We present numerical results for an Earth-type dynamo that also uses small parameter values: $E = 5 \times 10^{-7}$ and $Pm = 0.2$. Our emphasis is laid on the thermal boundary condition at the core surface. The recent low-*E* and low-*Pm* simulations have held the temperature of the core surface constant and uniform. We argue that this isothermal condition is not only geophysically unrealistic but also suppresses the generation of large-scale, strongly dipolar magnetic fields. To demonstrate this, we have replaced the isothermal condition by one in which the outward heat flux at the core surface is laterally uniform. We have compared the results with those obtained from an otherwise identical model having an isothermal surface. The difference in behavior is striking. The isothermal model produces fine-scale, sheet-like convective structures and a weak magnetic field, basically in agreement with the other recent low-*E* models; the uniform-flux model creates a strongly dipolar magnetic field, accompanied by large-scale convective flows and wavy zonal internal magnetic fields, both of wavenumber around 6. This model simulates well the geomagnetic westward drift, which dominates in an equatorial band at the core surface. We conclude that the isothermal boundary condition suppresses meridional circulation and leads to geophysically unrealistic results.

Geodynamo, Core convection, Geomagnetic field

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