Scale disparity between the velocity and magnetic fields in low Ekman number dynamo models

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It is generally believed that the geomagnetic field is generated by convective motion of an electrically conducting fluid in the Earth's outer core, known as the geodynamo. Recent numerical studies clarified that columnar convection cell plays essential roles in dynamo process. However, it is still unclear whether numerical models represent the dynamics in the Earth's core, properly, since non-dimensional parameters in the present numerical models of the geodynamo are still far from those in the Earth's core. The most serious problem arises from the difference in the Ekman number, E. In numerical models, the Ekman number is larger, by orders of magnitude, than that in the geodynamo. Thus, it is required that the Ekman number is low enough to reach nearly inviscid regime, as is the case with the Earth's core of $E\sim 10^{-9}$. Here, numerical models of the geodynamo at the Ekman number as low as 10^{-6} are provided. In our results, many small-scale convection cells attached to the inner portion of the core appear, while dominantly dipolar magnetic field is generated by such convection cells. What is worth noting here is the large difference in characteristic length scale between the convection and magnetic field. Such scale disparity indicates that small-scale convective motion generates large-scale magnetic field by collecting small scale fields more significantly than in a case at higher Ekman number. This fact suggests that backward energy cascade plays a major role to maintain dipolar magnetic field in low Ekman number dynamos as in the geodynamo.