Simulating geomagnetic field variations: From jerks to superchrons

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The ultimate goal of geomagnetism is to describe and understand all possible spatiotemporal variations of the geomagnetic field. Obviously, forward modeling of the geodynamo is one of the primary approaches for understanding the physical state and the field-generation mechanism inside the Earth's convecting core. First, I point out that the present numerical method is not enough to simulate long-term field behaviors of core convection such as sequence of polarity reversals and superchrons. Recent high-resolution geodynamo simulations have shown that the convective regime seems to be drastically changed when the Ekman number (E) is reduced to the order of 10^{-7} [e.g., Kageyama et al. 2008; Sakuraba & Roberts 2009]. This means that it is necessary for us to use Ekman numbers at least as small as 10^{-7} in geodynamo simulations, as the actual core Ekman number is definitely much smaller. The problem is that such low-E simulations are still too expensive to see time variations longer than few magnetic diffusion times or so. It is probably impossible or very difficult to simulate million-year-scale sequence of polarity reversals in the coming decade. Second, I propose a magnetostrophic approach in geodynamo modeling. This method assumes zero viscosity and infinitely high Alfven velocity, by which the convection can be numerically described with a longer timestep size and a coarser spatial grid because tiny Ekman-layer lengthscales and Alfven-wave timescales disappear. I will report current status of magnetostrophic dynamo simulations. Third, I discuss recent results of low-E geodynamo simulations. I have continued systematic numerical simulations using Ekman numbers less than 10^{-6} and discuss mechanisms for torsional oscillations and geomagnetic jerks.