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Reconciling westward drift and inner-core super-rotation in very low viscosity models of the geodynamo

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In this presentation we reconcile two well known ideas relating to the dynamics of the deep Earth. The first is the observed westward drift of the non-dipole geomagnetic field, dating originally back to Halley in the 17th Century. This basic property of the geomagnetic field, part of a complex picture of the secular variation, has persisted for at least the last 400 years or so, although archeomagnetic studies show that the main drift was predominantly eastward in the early 2nd millennium AD.

Independent of geomagnetic observations, mounting evidence from seismological studies point to a present-day super-rotation of the inner core. One plausible idea that matches most observational theories is that the rotation rate of the inner core fluctuates in time — at the present time just we happen to observe a relative eastward motion.

Numerical models of the geodynamo typically run far from the regions of parameter space relevant to the Earth's core. However, by looking only for steady solutions that are consistent with an imposed Earth-like magnetic field, we are able to run 3D super-computer models at an unprecedentedly low viscosity. We find that at very low-viscosities of $E = 10^{-7}$ – 10^{-9} (where E is the Ekman number), the negative cylindrically-averaged axial electromagnetic torque drives a strong westward flow in the outer core whilst imparting a positive (eastward-directed) torque on the inner core, reproducing the apparent drift direction and the direction of the relative inner-core rotation of the present day. The signs of these torques are opposite and are the leading order contributors to the net torque, required to be zero due to the assumed electrically insulating overlying mantle.

This model linking the directions of outer-core drift and inner-core rotation suggests an intriguing possibility for the dynamics of the Earth. As we show, should the electromagnetic torque reverse in sign due to a perturbation of the internal geomagnetic field, the predominant drift direction in the outer core would be eastward, with a concomitant westward torque on the inner core. This is precisely the opposite of what is observed today, and suggests that the eastward drift of 1000 years ago may have been associated with a westward relative inner-core rotation.