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Can core flows inferred from geomagnetic field models explain the Earth's dynamo?

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Abstract

We test the ability of large-scale velocity fields inferred from geomagnetic secular variation data to produce the global magnetic field of the Earth. Our kinematic dynamo calculations use quasi-geostrophic (QG) flows inverted from geomagnetic field models which, as such, incorporate flow structures that are Earth-like and may be important for the geodynamo. Furthermore, the QG hypothesis allows straightforward prolongation of the flow from the core surface to the bulk. As expected from previous studies, we check that a simple QG flow is not able to sustain the magnetic field against ohmic decay. Additional complexity is then introduced in the flow, inspired by the action of the Lorentz force. Indeed, on centennial timescales, the Lorentz force can balance the Coriolis force and strict quasi-geostrophy may not be the best ansatz. When our columnar flow is modified to account for the action of the Lorentz force, magnetic field is generated for Elsasser numbers larger than 0.25 and magnetic Reynolds numbers larger than 100. This suggests that our large-scale flow captures the relevant features for the generation of the Earth's magnetic field and that the invisible small-scale flow may not be directly involved in this process. Near the threshold, the resulting magnetic field is dominated by an axial dipole, with some reversed flux patches. Time dependence is also considered, derived from principal component analysis applied to the inverted flows. We find that time periods from 120 to 50 yr do not affect the mean growth rate of the kinematic dynamos. Finally, we note that the footprint of the inner core in the magnetic field generated deep in the bulk of the shell, although we did not include one in our computations.

Keywords: Inverse theory, Numerical approximations and analysis, Dynamo: theories and simulations, Magnetic field, Core, outer core and inner core, Planetary interiors

Subject: Geomagnetism, Rock Magnetism and Palaeomagnetism

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