Magnetic reversals in a geodynamo model with a stably-stratified layer

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Earth's magnetic field arises from the turbulent dynamics of the electrically conductive fluid in the outer core. This process, known as geodynamo, is self-sustained by the convective motion of the flow under the influence of a strong rotation. The geomagnetic field has a large-scale dipolar structure, roughly aligned with Earth's rotation axis. A remarkable feature of the geomagnetic field is the phenomenon of polarity reversals, in which the Earth's magnetic north and south poles switch places. This process occurs at irregular intervals and is recorded in geological and archaeological materials. Recent geomagnetic and seismological measurements suggest the presence of a stably-stratified layer below the core-mantle boundary, possibly formed by thermal and compositional effects. Although its size and stratification strength are still debated, the presence of this layer can influence the dynamics and morphology of the geodynamo.

I investigate the influence of this stably-stratified layer using direct numerical simulations (DNS) of the incompressible magnetohydrodynamics (MHD) equations under the Boussinesq approximation. This model describes the motion of a liquid metal driven by convection in a rotational frame of reference. I solve these equations using a code that uses a pseudo-spectral method for the angular directions and a second-order finite-differences scheme for the radial direction, with a hybrid MPI-OpenMP parallelisation.

This research explores the impact of this layer on the geodynamo process, including how it affects the magnetic field's morphology, and the how it modifies the frequency of polarity reversals. I also study the effects of different boundary conditions on these properties. In particular, I show that imposing heterogeneous boundary conditions for the heat flux (corresponding to a more realistic scenario) can lead to different magnetic morphologies, including hemispheric dynamos (stronger in one hemisphere than the other), and that it can modify the reversals frequency. I compare the results obtained from my DNS with low-dimensional dynamical systems to provide a better interpretation of the observations. This research will enhance our understanding of the Earth's magnetic field dynamics, as well as the mechanisms driving polarity reversals, and contribute to more accurate predictive models.

References

1. T. Gastine, J. Aubert & A. Fournier, Dynamo-based limit to the extent of a stable layer atop Earth's core, *Geophys. J. Int*, (2020) **222**, 1433-1448.