TURBUENCE IN GEODYNAMO SIMULATIONS

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Abstract We aim at producing geodynamo simulations in a regime more representative of the Earth's core. A major concern is to obtain a dynamical regime where the magnetic energy E_m is much larger than the kinetic energy E_k, as in the Earth's core where $E_m/E_k \sim 10^4$. By using scaling laws, we are able to restart numerical dynamo simulations from different parameters. This allows us to run high resolution spherical simulations with only little transients, which considerably reduces the computing time required to obtain statistical equilibrium. Starting from a well converged simulation at Ekman number $E = 10^{-5}$, we are able to compute at $E = 10^{-6}$ and $E = 10^{-7}$, with a constant magnetic Reynolds number $Rm = 680$. At $E = 10^{-7}$, we have a magnetic Prandtl number $Pm = 0.1$, a Rayleigh number $Ra = 2.4 \times 10^{13}$ and $E_m/E_k \sim 10$. We report energy spectra, correlations and observed feature in physical space.

MOTIVATION

The measurements of the magnetic field of the Earth, from satelites and ground observatories allow us to infer the flow at the core surface using the induction equation. The magnetic field hidden inside the Earth's core can then be evaluated using the observed speed of Torsional Alfvén waves[1]. Its minimal magnetic energy is then evaluated at about 10^4 times larger than the kinetic energy. However, although current dynamo simulations are able to reproduce an Earth-like magnetic field, they mostly lead to equipartition between kinetic and magnetic energy. By increasing the importance of rotation in the force balance, we go toward a regime closer to the Earth's core, with a stronger magnetic field, possibly allowing Alfvén wave.

METHOD

In order to reach more realistic dynamics for the Earth core, we look for a strategy to start a new dynamo simulation from an existing state with different parameters. We use the scaling laws of Christensen and Aubert[2] to rescale quantities while moving in the parameter space. First of all, the rescaled initial guesses are good, and after a short transient where the small scales of the flow are populated, statistical equilibrium of global quantities is obtained, at values close to the prediction of the scaling law. This means the scaling law is still valid at $E = 10^{-7}$. Our procedure allows us to compute dynamo simulation at extreme parameters without the need to compute lengthy transients.
Our numerical method is based on a finite difference scheme in the radial direction, and a spherical harmonic decomposition. The non-linear terms are computed in spatial space, and we use the *SHTns* library[3] for its high performance spherical harmonic transform.

RESULTS

We performed several runs at $E = 10^{-5}$, $E = 10^{-6}$ and $E = 10^{-7}$. In the latter case, the magnetic energy is significantly larger than the kinetic one, as can be seen on figure 1. The spectra are showing equal power densities only at the smallest scales. Meanwhile the flow is becoming more and more correlated in the direction of the rotation axis (figure 2), and the convective plumes originating from the inner-core have a large radial extent.

References

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[2] U. R. Christensen and J. Aubert. Scaling properties of convectionâĂŘdriven dynamos in rotating spherical shells and application to planetary magnetic fields. *Geophysical Journal International* **166**: (1), 97–114, 2006.
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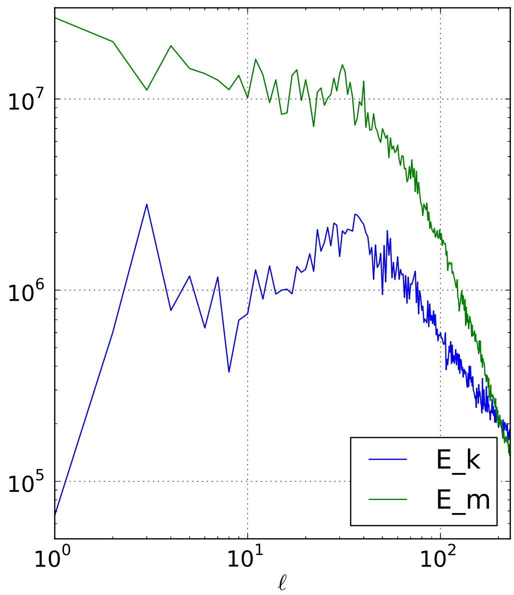

Figure 1. Energy spectra at $r = 0.82$ as a function of the spherical harmonic degree ℓ. $E = 10^{-7}$, $Pm = 0.1$, $Ra = 2.4 \times 10^{13}$.

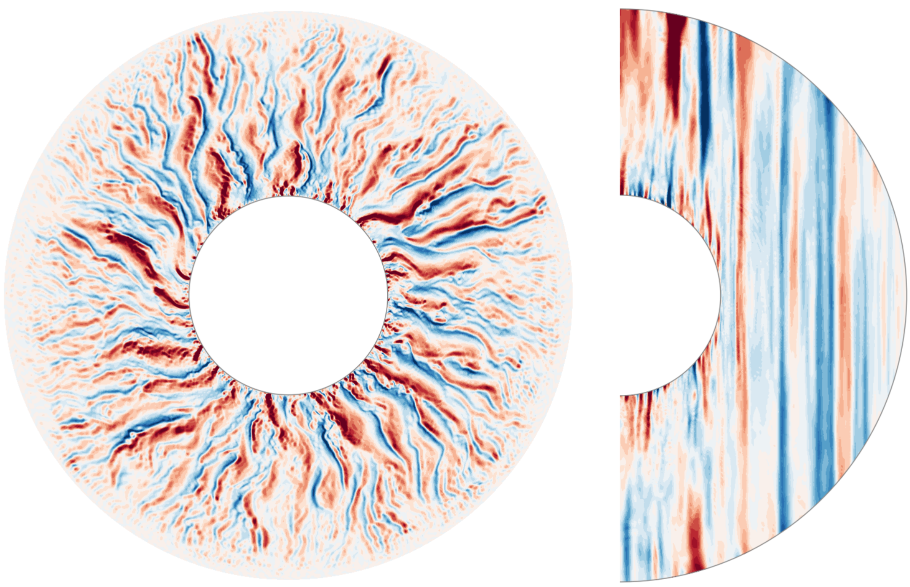

Figure 2. cylindrical radial velocity component in the equatorial plane (left) and a meridional plane (right). $E = 10^{-7}$, $Pm = 0.1$, $Ra = 2.4 \times 10^{13}$.