IMAGINING CORE DYNAMICS THROUGH THE PRISM OF SATELLITE AND MAGNETIC OBSERVATORY RECORDS

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The large scale part of the flow, averaged over the past 10 years, can be calculated at the Earth's core surface up to harmonic degree about 8. During that time interval, the Earth's main magnetic field has been continuously monitored from low Earth orbiting satellites equipped with vectorial magnetometers. The flow, of the order of a fraction of $mm.s^{-1}$, deduced from the observed time variations of the geomagnetic field, is largely symmetric about the equatorial plane. This result is consistent with the quasi-geostrophic hypothesis for Earth's core motions. Under that hypothesis, the velocity field $\mathbf{u}$ is entirely described from a stream function ψ that does not depend on the z-coordinate parallel to the rotation axis. Neglecting forces such as buoyancy possibly responsible for thermal winds, coupled equations for ψ and some representation of the interior magnetic field $\mathbf{B_i}$ can be written. Then, knowing the time variations of $\psi(t)$ constrains $\mathbf{B_i}$. From the first studies along these lines, it has been concluded that the strength of $\mathbf{B_i}$ exceeds several milliTeslas. Accordingly, the Earth's magnetic field is much stronger in the core interior than at its surface, where its peak value is about 1 mT.

Unfortunately, the time variations of ψ are less well known than its average value. This is a consequence of the modeling of the magnetic field at the core surface, which inevitably penalizes high frequency terms as well as small length scales. Efforts are under way to characterize the uncertainties on $\psi(t)$ that are entailed by this situation. One approach consists in adapting to observatory data an ensemble method that has been devised to account for the small scales of the magnetic field at the core surface that are invisible from satellites. The spatial spectrum of the magnetic field extrapolated to high harmonic degree provides the necessary a priori information.

For the largest length scales, the density of kinetic energy is much smaller than the density of magnetic energy. This is in good agreement with recent numerical simulations of the geodynamo which show, in addition, an intermediate scale where kinetic and magnetic energy are comparable. We thus expect first a better convergence of $\mathbf{B_i}$ than $\mathbf{u}$ with increasing harmonic degree and second time stability of $\mathbf{B_i}$.

The next step will be to obtain an approximate description of $\mathbf{B_i}$ that yields, through the magnetic forces, the time variations of the velocity in the core interior. If that goal can be achieved, data assimilation methods will be transferred to geomagnetism. That would enable to use data from more ancient epochs, obtained e.g. from archeomagnetic techniques, to improve models of core dynamics. Data assimilation requires indeed the knowledge of a reference state, that is not yet available for the Earth's core.