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Longitudinally hemispheric structures in the geodynamo : from their physical origin to their geomagnetic consequences

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The investigation of geomagnetic variations has revealed the presence in Earth's core of a planetary-scale, axially columnar and eccentric gyre flow. Together with the magnetic anomaly of low intensity presently seen beneath the South Atlantic, these structures show that longitudinal hemisphericity is a common feature of the geodynamo. Here, we propose that these hemispherical features result from the onset properties of spherical shell rotating convection in presence of an imposed axial magnetic field, with spatially homogeneous fixed-flux thermal boundary conditions. For an Earth-like range of background magnetic field amplitudes, we find hemispherical critical convection modes that are largely supported by a magneto-Archimedes-Coriolis (MAC) balance and where viscosity plays a secondary role. The morphology of the critical modes is in agreement with the general circulation of the gyre. Pursuing this analysis with fully developed, turbulent self-sustained dynamo simulations, we find that hemispherical modes inherited from convection onset can be maintained if the MAC balance is not perturbed by inertia, the force coming at the next order in the force balance. The presence of the eccentric gyre is therefore conditioned to the magnetic energy matching or exceeding the kinetic energy in the system, the so-called strong-field dynamo regime. The simulations also feature low magnetic intensity anomalies that rotate westward together with the gyre flow. We highlight a strong correlation between the gyre longitudinal position, the low intensity focus of magnetic intensity, and the eccentricity of the dynamo-generated dipole, showing that these hemispherical structures are indeed linked by the properties of magnetic induction.

Speaker information

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Auteur: GRASSET, Luc (IPGP)**Co-auteur:** M. AUBERT, Julien (IPGP)**Classification de Session:** Poster**Classification de thématique:** Earth and Environment