Étude de la nature de la bifurcation dynamo obtenue à l'aide de simulations géodynamos

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We investigate the nature of the dynamo bifurcation in a configuration applicable to the Earth's liquid outer core, i.e. in a rotating spherical shell with thermally driven motions with no-slip boundaries. Unlike in previous studies on dynamo bifurcations, the control parameters have been varied significantly in order to deduce general tendencies. Numerical studies on the stability domain of dipolar magnetic fields found a dichotomy between non-reversing dipole-dominated dynamos and the reversing non-dipole-dominated multipolar solutions. We show that, by considering weak initial fields, the above transition disappears and is replaced by a region of bistability for which dipolar and multipolar dynamos coexist. Such a result was also observed in models with free-slip boundaries in which the geostrophic zonal flow can develop and participate to the dynamo mechanism for non-dipolar fields. We show that a similar process develops in no-slip models when viscous effects are reduced sufficiently.

The following three regimes are distinguished : (i) Close to the onset of convection (Ra_c) with only the most critical convective mode (wave number) being present, dynamos set in supercritically in the Ekman number regime explored here and are dipole-dominated. Larger critical magnetic Reynolds numbers indicate that they are particularly inefficient. (ii) in the range $3 < Ra/Ra_c < Ra_c$, the bifurcations are subcritical and only dipole-dominated dynamos exist. (iii) in the turbulent regime ($Ra/Ra_c > 10$), the relative importance of zonal flows increases with Ra in non-magnetic models. The field topology depends on the magnitude of the initial magnetic field. The dipolar branch has a subcritical behavior whereas the multipolar branch has a supercritical behavior. By approaching more realistic parameters, the extension of this bistable regime increases. A hysteretic behavior questions the common interpretation for geomagnetic reversals.

Far above the dynamo threshold (by increasing the magnetic Prandtl number), Lorentz forces contribute to the first order force balance, as predicted for planetary dynamos. In the turbulent regime ($Ra > 10Ra_c$), dipolar fields affect significantly the flow speed, the flow structure and heat transfer. This physical regime seems to be relevant for studying geomagnetic processes.