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Quasigeostrophic dynamos at low magnetic Prandtl numbers

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Rapidly rotating spherical kinematic dynamos are computed using the combination of a quasigeostrophic (QG) model for the velocity field and a classical spectral 3D code for the magnetic field. On one hand, the QG flow is computed in the equatorial plane of a sphere and corresponds to Rossby wave instabilities of a geostrophic internal shear layer produced by differential rotation (Stewartson layer). On the other hand, the induction equation is computed in the full sphere after a continuation of the QG flow along the rotation axis. We found the threshold of dynamo action for both dipolar and quadrupolar families for relatively high magnetic Reynolds number ($R_m \approx 10^4$). Differential rotation and Rossby-wave propagation are the key ingredients of the dynamo process which can be interpreted in terms of $\alpha\omega$ dynamo. The QG model (with high time and space resolution) enabled us to exhibit numerical dynamos with very low Ekman ($E = 10^{-8}$) and Prandtl numbers ($Pm < 10^{-2}$) which are asymptotically relevant to model planetary core dynamos and experimental models such as the DTS sodium experiment in Grenoble. In some cases, we also observed inversions of the magnetic field at the onset of dynamo action which are interpreted in term of "Parker" oscillation in the dynamo.

In presence of the Lorentz forces, the magnetic field acts back on the velocity field and we can compute the saturation of the quasigeostrophic dynamos. The saturated magnetic fields are very similar to the ones of the kinematic dynamos. To stay valid, the QG approach needs the Elsasser number (measuring the ratio of the Lorentz force to the Coriolis force) to remain small, which is generally the case. Magnetic and kinetic energy spectra are analysed and the action of the magnetic field on the small scales of the velocity field is discussed.