Oscillatory large-scale dynamo action in rapidly-rotating convection

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It is well known that convection in electrically-conducting fluids can give rise to hydromagnetic dynamo action. In the absence of rotation, such a dynamo tends to produce a small-scale, intermittent magnetic field distribution. However if a convective layer is rotating very rapidly (such that the Coriolis force plays a leading-order role in the dynamics) it becomes possible, under certain circumstances, to excite a large-scale dynamo with a significant mean magnetic field. We investigate a convectively-driven dynamo in a rapidly-rotating compressible fluid, confined to a Cartesian domain. At moderately supercritical Rayleigh numbers, this system is (hydrodynamically) unstable to a large-scale vortex instability, which eventu- ally leads to the rapid amplification of a seed magnetic field. As the magnetic field becomes dynamically significant, the large-scale vortex is suppressed, but the mean magnetic field continues to grow. The final nonlinear state is characterised by a large-scale (near-equipartition) horizontal magnetic field that oscillates with a period comparable to that of the ohmic decay time. This dynamo has been the subject of a benchmarking exercise, with three independent compressible codes producing quantitatively comparable results. We have also verified that a very similar dynamo can be found in the Boussinesq case. Strongly modulated large-scale oscillatory dynamos are found at higher Rayleigh numbers, with periods of reduced activity ("grand minima"-like events) occurring during transient phases in which the large-scale vortex instability temporarily re-establishes itself, before being suppressed again by the magnetic field.
