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Kinematic dynamo action in rotating and convecting spherical shells

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The ability of flows to generate a magnetic field has long been studied in spherical geometry. The earlier dynamo models (Bullard and Gellmann 1954, Kumar and Roberts 1975, Dudley and James 1989) considered very simplified steady flows. Willis and Gubbins (2004) added time dependence to flows of the Kumar–Roberts class. The timescale of the flow fluctuation, i.e. faster, slower or similar to the magnetic diffusion time, plays a key role in the effect on dynamo action.

Here we study the dynamo properties of time-dependent flows that arise due to thermal instability. These flows have an identifiable simple structure, usually columnar flows, with temporal fluctuations superimposed. Given the importance of relative timescales noted above, particular attention has been payed to the relative magnitudes of thermal, magnetic and viscous timescales in our simulations. It is impossible to calculate at the correct diffusive and rotational timescales of the Earth. We study here, however, how the rapid rotation alters the degree to which relative magnitudes of diffusivities affects the flow regime. We consider first the point where convection is just vigorous enough to produce dynamo action to identify parameter regimes. This will facilitate the identification of how the magnetic field affects the flow leading to saturation in each regime.