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Magnetic reversal frequency scaling in dynamos with thermochemical convection

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Scaling relationships are derived for the frequency of magnetic polarity reversals in numerical dynamos powered by thermochemical convection. We show that the average number of reversals per unit of time scales with the local Rossby number Rol of the convection. With uniform core-mantle boundary (CMB) heat flux, polarity reversals are absent below a critical value Rol_crit $\sim$ 0.05, beyond which reversal frequency increases approximately linearly with Rol. The relative standard deviation of the dipole intensity fluctuations increases with reversal frequency and Rol. With heterogeneous CMB heat flux that models the large-scale seismic heterogeneity in Earth's lower mantle, reversal frequency also exhibits linear dependence on Rol, and increases approximately as the square root of the amplitude of the CMB heterogeneity. Applied to the history of the geodynamo, these results imply that outer core convection was relatively weak with low CMB heat flux and Rol<Rol_crit during magnetic superchrons and relatively vigorous with higher, more heterogeneous CMB heat flux and Rol>Rol_crit when geomagnetic reversals were frequent. They also suggest that polarity reversals may have been commonplace in the early history of other terrestrial planets. We find that zonal heterogeneity in CMB heat flux produces special effects. Close to Rol_crit, enhanced equatorial cooling at the CMB increases reversal frequency by concentrating magnetic field at low latitudes, whereas far beyond Rol_crit, enhanced polar cooling at the CMB increases reversal frequency by amplifying outer core convection.