Geophysical Research Abstracts,
Vol. 10, EGU2008-A-03880, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-03880
EGU General Assembly 2008

Towards understanding geomagnetic field reversals

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Magnetic field reversals are particularly spectacular events in the geomagnetic history. The associated weaker magnetic field strength bears potential health risks and an increased liability of electronic devises. Understanding the causes and the dynamics of reversals is therefore of prime interest. We have conducted several numerical dynamo simulations in order to locate the parameter space where Earth-like reversals happen and to pin down the required key flow properties. Earth-like not too frequent reversals occur when the Raylei gh number is high enough, i.e. when the convective driving of the flow is sufficien tly vigorous. In this regime, equatorial as well as azimuthal flow symmetries are significantly broken, and the time behavior is complex. These latter properties are necessary rather than sufficient conditions, since they are assumed before reversals set in. When examining the flow force balance we find that Earth-like reversals require that inertial forces amount to about 10Coriolis force, which indicates that advection plays an important role. When inertial forces become even stronger, promoted by a higher Rayleigh number, the dynamo reverses too frequently and looses its Earth-like time behavior. Unraveli ng the reason for field reversals is complicated by the complex spatial structure a nd irregular time dependence of the dynamo process. The visualization of the interp lay between the fluid flow and the magnetic field is notoriously difficult. A newly developed tool, the Dynamical Magnetic Fieldline Imager (DMFI), enabled us to highlight the key flow features that trigger reversals. These features are connected with convective upwellings, which is why we call them magnetic upwelli ngs. They can create a significant amount of inverse or horizontal magnetic field wit h a strong equatorial dipole component that tilts the global field direction. The statistical variation in appearance, duration, and amplitude of these upwellings translates to similar variations in the magnetic field direction. Reversals can

only occur for particularly strong upwellings or when several upwellings team up to tilt the dipole over, thereby promoting a state of undecided polarity. Both scenarios are highly unlikely, which explains the rareness of magnetic field reversals. That fact that the upwellings are promoted by highly equatorial asymmetric flow features makes the connection to the required symmetry breaking.