Geophysical Research Abstracts
Vol. 14, EGU2012-8640, 2012
EGU General Assembly 2012

Time variability of hemispherical dynamos: An application to Mars

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The hemispherical magnetization of the martian crust could be the product of large scale demagnetization processes in the northern hemisphere. Alternative, the ancient martian dynamo, that ceased more than four billion years ago, may have produced an already hemispherical magnetic field. Using numerical simulations we explore the second scenario imposing a sinusoidal core-mantle boundary (CMB) heat flux pattern, putting the minimum at the north pole and the maximum at the south pole. Since Mars likely has never developed an inner core our dynamo model is exclusively driven by secular cooling.

The special combination of thermal boundary conditions and driving promotes a flow that is dominated by equatorially anti-symmetric strong thermal winds. These are the consequence of the large temperature differences developing between the norther hemisphere of the core, which remains hot, and the southern hemisphere, which is still cooled by plume like convection. The thermal winds result in a strong ω-effect so that the dynamo is of the $\alpha\omega$-type rather than of the α^2-type more typical for our columnar convection cases.

Already rather mild perturbations of the CMB heat flux pattern lead to strong magnetic oscillations that include fast field reversals. Up to moderate perturbation amplitudes the oscillations seems to be the expression of Parker waves. Larger amplitudes, however, lead to more complex behavior.

One result of these oscillation is that the magnetic field averages out over relatively short periods in the order of tens of thousand years. We can therefore exclude magnetization scenarios assuming that the crustal magnetization was acquired in several overlying layers over a longer time frame. It seems more likely that the magnetization results from a patchwork of localized lava flows sampling typical magnetic field strengths. This scenario leads to magnetic field amplitudes similar to those deduced from martian meteorites and hemisphericity measures like those estimated for the crustal magnetization.