Lateral core mantle boundary heat flux variations as a model of Martian paleomagnetic field

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Abstract

The presence of a strong crustal magnetization on Mars [1] indicates an ancient magnetic field. The dichotomy in the crustal magnetization between the northern and southern hemisphere supports the idea of a hemispherical magnetic field at the late stage of the dynamo action. The flow in the underlying core is strongly influenced by the mantle convection. A significant feature of the Martian mantle dynamics is the low degree convection [2] leading to a lateral inhomogeneous heat flux at the Core Mantle Boundary (CMB). This affect the dynamics of the liquid iron core. We investigate the possible effect of the cmb heat flux pattern on the core dynamo action using numerical simulations. The Martian core is modelled as a rotating spherical shell of conducting fluid, where the flow is driven only by thermal convection since we assume no solid inner core.

The lateral heat flux variations at the CMB are considered as degree-1 heat flux perturbations. We systematically investigate the influence of the amplitude of the perturbation and its tilt angle with respect to the rotation axis on the magnetic field configuration. In the hemisphere of higher heat flux the vigor of the dynamo action is amplified while in the other hemisphere the convection is weakened.

A degree-1 cmb heat flux pattern oriented along the rotation axis establishes a strong equatorial asymmetric temperature profile. As a consequence an equatorial asymmetric convection mode is established, since the cooling is more efficient in the southern hemisphere. The action of the coriolis force on advection along the latitudinal temperature gradient (meridional circulation) forces strong zonal winds, which are retrograde in the north and prograde in the south. Most of the kinetic energy is then carried by axisymmetric zonal flows. The dipole character of the magnetic field reduces due to weakening the columnar convection. Additionally, shearing in the boundary between the zonal wind cells, produces strong magnetic field which moves southwards, if the relative perturbation increases. The flow is dominated by equatorial asymmetric, axisymmetric motion and hemispherical configuration of magnetic field is preferred (figure 1).

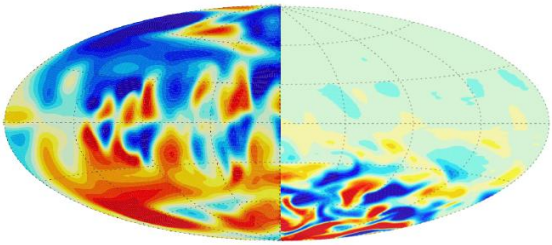

Figure 1: Radial magnetic field at the core mantle boundary for the reference case (constant flux) on the left half, and the strong perturbed system on the right. The dipolar morpholgy is lost, and a hemispherical dynamo is established.

References

[1] Acuna, A. et al.: Global Distribution of Crustal Magnetization Discovered by the Mars Global Surveyor MAG/ER Experiment, Science, Vol. 284, Iss. 5415, p. 790, 1999

[2] Roberts, J.H. and Zhong, S.: Degree-1 Mantle Convection and the Origin of the Martian Hemispheric Dichotomy, 37th Annual Lunar and Planetary Science Conference, March 13-17, 2006, League City, Texas, abstract no.1447, 2000.