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The Martian crustal magnetic field: a global view as seen from MGS and MAVEN measurements

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Abstract

We present a new model of the Martian crustal magnetic field. This new model supersedes previously published models as it fully exploits the full wealth of available magnetic field measurements. The new model makes advances in four areas. (i) We apply a data selection scheme for MGS MAG Mapping Orbit (M0) measurements in order to reduce external field perturbations. (ii) We make use of MGS Electron Reflectometry (ER) indirect estimates of the total field to better constrain the model. (iii) We further consider MAVEN magnetic field measurements, until the most recent date. (iv) We improve the spatial resolution, down to ~100 km.

1. Introduction

Almost 20 years ago the Mars Global Surveyor revealed the striking magnetic figure of Mars [1]. While devoid of an active magnetic field today, Mars possesses a remanent magnetic field which may reach several thousands of nT locally. The processes which have shaped the crustal magnetization remain largely enigmatic. During almost 7 years MGS made magnetic field measurements, mainly at a constant altitude of 400 km and at only two local times. Low-altitude measurements (below 250 km) and at several local times are very sparse and may hamper the interpretation of magnetic field models in terms of planet history or of magnetic source properties.

The MAVEN mission [2] was inserted in orbit around Mars in Sept. 2014. It flies on a very elliptical orbit, with a periapsis as low as 125 km, and it will cover all local times. In this study we present a new model of the crustal Martian magnetic field built using both MGS and MAVEN measurements, using a technique we developed for MGS [3]. This new model uses MAG measurements by MGS and MAVEN, but also total field estimates at 185 km from MGS electron reflectometry (ER) measurements.

2. MAVEN measurements

MAVEN was inserted in orbit on 21 Sept. 2014. It flies on an elliptical orbit, between 150 and 6200 km, with periodical dip campaigns down to 125 km. The inclination is 74°, and the period is 4.5 hours. We use data up to the most recent available date. Data are night-time selected, and down-sampled to 0.05 Hz below 600 km and between 22:00 and 4:00. The external magnetic field activity is examined using the technique described below.

3. External field proxies and data selection

MGS flew over the same location, altitude and local time once a week during 7 years. This may be seen in a virtual observatory scheme. Every time the spacecraft flew over the same location it measured the same crustal field and a time varying external field. By isolating the time variable constituent it is therefore possible to estimate a temporal proxy which describe the level of external activity [4]. The scheme we follow is:

- night-side, median field measurement for each lat x lon= 0.8° x (0.8° cos(lat)) is found;
- individual differences to median value are computed for each bin and all data;
- Bx residual (mars Sun State system, X pointing towards the Sun) is found;
- L1 (mean) and associated L2 (rms) statistics are computed from differences on a Martian daily basis.

Results are compared to extrapolated magnetometer measurements from ACE spacecraft (close to the Earth). When Mars and the Earth are in adequate location, (anti)correlation is very good, close to -0.7. With this proxy it is easy to identify magnetic events (see Fig. 1), such as the occurrence of the well-documented Halloween 2003 magnetic super storm [5].

MO MGS night side data are selected accordingly, keeping only the 10% quietest Martian days (maximum L2 value of 4.8 nT). Earlier MGS data and recent MAVEN measurements are selected using the remote proxy, when appropriate.

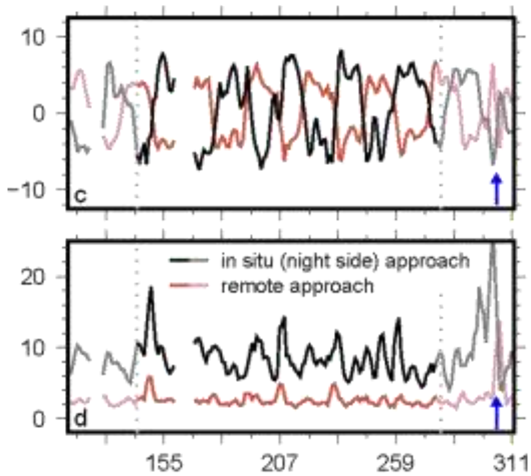

Figure 1: Comparison of in situ MGS proxy and remote (extrapolated) ACE one. Blue arrow indicates Halloween magnetic super storm in 2003. After [4]

4. Improved model resolution

We use Equivalent Source Dipoles: at each point, the magnetic field results from the contributions of sources located homogeneously below the Martian surface. A polar coordinates subdivision is chosen, with a mean distance between sources as low as 110 km. A L2 norm is used with a conjugate gradient approach (iterative scheme). The use of scalar (ER) data requires a priori knowledge of the magnetization vector and associated magnetic field vector at observation location (another iterative scheme).

5. Results

Globally the correlation coefficient between actual and model-predicted measurement exceeds 0.978. We can predict the magnetic field at altitudes as low as 125 km, which is below what was possible previously. The global picture of the magnetic field remains similar to [3], but the model has a better resolution (Fig. 2). The ESD model is converted into spherical harmonics and it converges up to SH degree 140. At a local scale, anomalies are better defined, which should ease the interpretation of the models in terms of magnetization properties.

Ideally actual magnetization and rock susceptibility measurements at the surface of Mars will bring the ultimate constraint on the nature and properties of the crustal Martian magnetic field. This is the main objective of the on-going NEWTON H2020 project, which aims at developing non-invasive in-situ magnetic characterization instrument suite [6].

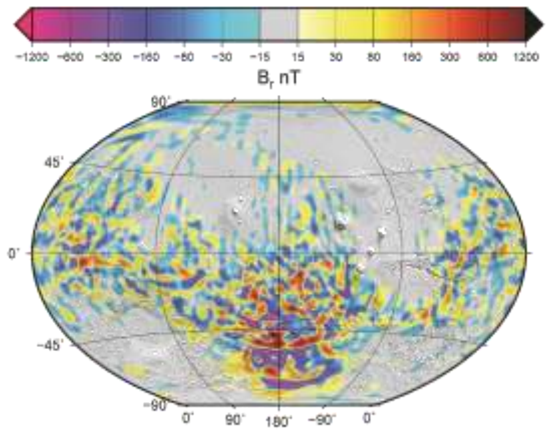

Figure 2: predicted radial field from the new model at 125-km altitude.

6. Acknowledgements

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