EPSC Abstracts
Vol. 6, EPSC-DPS2011-1160, 2011
EPSC-DPS Joint Meeting 2011

Magnetic Lithosphere of Mars from MGS-MAG data

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1. Introduction

Magnetic field vector data has been collected by Mars Global Surveyor using a Flux-Magnetometer as well as Electron Reflectometry during its aerobraking, science and mapping phases for a total duration of nine years. Although low altitude data is generally more suitable to resolve local magnetic anomalies, we use the mapping phase orbit data as it provides a stable 400 km altitude, sun-synchronous orbit covering the entire Martian surface.

This data set has been investigated using spherical harmonic analysis and equivalent dipole models [1]. One of the critical steps in these analyzes is the careful selection of data points in order to reduce noise as well as the use of a proper regularization technique for data inversion. Therefore, we investigate the effectiveness of different data processing and selection approaches and compare the modeled magnetic field to the data. Furthermore, the application of new field representations and regularization techniques and their application to Mars will be discussed.

2. Data Processing

Mars Global Surveyor provided a huge amount of vector magnetic field measurements covering several times the Martian surface. Therefore, data points can be averaged to improve the signal to noise ratio and computation time can be reduced if a subset of data is carefully selected.

Due to ionospheric currents induced by solar wind day-side data is generally contaminated with external fields which originate in the ionosphere. This is not only a source of temporarily variable noise in the data, but also precludes the representation of the magnetic field in terms of a magnetic potential. Therefore, only night-side data is generally selected in a first step. As a second processing step, we will apply two different methods to reduce the data set and compare the resulting models to the MGS measurements. In the first approach, the Martian surface is divided into triangles with approximately equal surface area and the median of the data in each triangle is calculated. The resulting data set consists of 80000 data points each representing one triangle. In a second approach, we use the raw data and simply select one data point every 40 s.

3. Inversion

We use a spherical harmonic model up to degree and order $l_{max} = 60$ to represent the lithospheric magnetic field of Mars. In such a model, the lithospheric field is represented by the Gauss coefficients g_l^m and h_l^m and the magnetic potential in a source-free region is then given by

$$V(r, \theta, \phi) = a \sum_{l=1}^{l_{max}} \sum_{m=0}^{l} \left(\frac{a}{r}\right)^{(l+1)} \Psi_l^m(\theta, \phi) \quad (1)$$

where

$$\Psi_l^m(\theta, \phi) = [g_l^m \cos m\phi + h_l^m \sin m\phi] \, P_n^m(\cos\theta) \quad (2)$$

and a is the reference radius of the model, P_n^m are the associated Legendre Polynomials of degree n and order m and r, θ, ϕ are the spherical coordinates of the point at which the potential is calculated.

The Gauss coefficients are determined by a linear inversion of the selected magnetic field data and the model is regularized using a L_2-norm. The model is fitted to all three components of the magnetic field vector with equal weights. Alternatively, the fit of the radial component, which contains most of the ionospheric noise, could be dampened.

4. Residuals

The residuals of the model, i.e., the difference between the measured and modeled magnetic field components, were calculated for the entire MGS data set as well as for the reduced data used for building the model. The histogram of the residuals for the magnetic field vector pointing horizontally to the North is shown in Fig. 1. It can be seen that the misfits are quite large with a standard deviation of 29 nT. This may be due to the relatively low degree up to which the model has been calculated. Therefore, we will investigate models with spherical harmonics expanded to higher degrees in the future.

A summary of the mean values and standard deviations of the residuals is shown in Tab.1, where the results for each component of the magnetic field is shown. Residuals have been calculated both for the entire data set and the subset used to build the model.

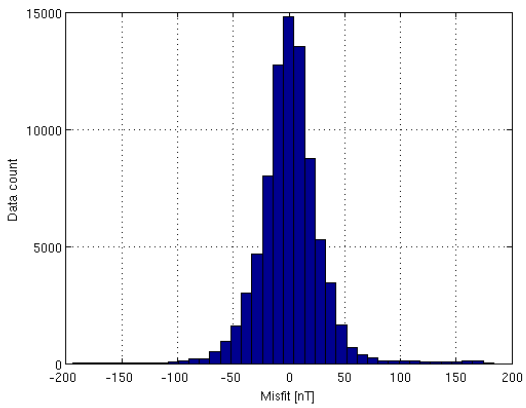

Figure 1: Residuals of the magnetic field component pointing horizontally North. The data was compared to the model built from the data averaged over triangles.

Table 1: Average and standard deviation of the residuals for the model built from the data averaged over triangles and the subset where one point was selected every 40s. The residuals were calculate using the entire MGS data set and the (averaged) data used to build the model, as indicated.

		North	East	Down
Triangles	Mean [nT]	0.88	-0.49	0.34
(Model)	σ [nT]	28.11	19.68	33.39
Triangles	Mean [nT]	0.57	-0.45	-0.19
(Complete)	σ [nT]	29.88	20.33	32.13
Raw (40s)	Mean [nT]	0.90	-0.44	-0.05
(Model)	σ [nT]	27.57	19.78	32.40
Raw (40 s)	Mean [nT]	0.57	-0.43	-0.20
(Complete)	σ [nT]	29.55	20.23	31.77

5. Summary and Conclusion

We used different approaches for data selection and processing of MGS-MAG magnetic field data. From this data, models of the lithospheric magnetic field using a spherical harmonic representation have been calculated. The residuals show that the component of the magnetic field pointing vertically down seems to contain most of the noise.

Furthermore, the model based on data averaged over triangles needs significantly less computational time as the data set is reduced from over 50×10^6 data points to ~ 80000. In addition, no significant information is lost as the signal to noise ratio can be improved by averaging over independent measurements.

In a next step and after having carefully analyzed data selection and processing methods, we will apply alternative representations of the lithospheric field to the case of Mars. These include localized functions and wavelets, which have already been successfully applied to Earth's lithospheric field. The main advantage of localized functions is that they allow for a varying spatial resolution [2], resulting in more reliable models of the lithospheric magnetization. Furthermore, new regularization mechanisms such as the maximum entropy approach [3] will be applied to Mars. This would improve the anomaly resolutions by accepting very strong gradients in the model when necessary. Additionally, L1-norm regularization is also possible with similar effects.

Acknowledgments

This work was supported by the Deutsche Forschungsgemeinschaft (DFG) in the priority program SPP1488 "Planetary Magnetism" under grant GR 3751/1-1.

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