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A quasi-hemispheric model of the Hermean's magnetic field

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Abstract

We analyse and process magnetic field measurements provided by the MErcury Surface, Space ENvironment, Geochemistry, and Ranging (MESSENGER) mission. The vector magnetic field measurements are modelled with a dedicated regional scheme expanded in space and in time. Compared to the widely used global Spherical Harmonics (SH), the regional approach is particularly well suited because the partial and quasi hemispheric distribution of the MESSENGER data represents no major numerical difficulty. We confirm that the internal magnetic field of Mercury is mostly axisymmetric with a magnetic equator shifted northward. However, we also observe a time dependency in the model that is at present hardly explained only by time variations of the external magnetic fields. We present the major spatial and temporal structures shown by the regional model.

1. Introduction

One of the objectives of the MESSENGER spacecraft was to better describe the magnetic fields surrounding the planet Mercury and to better understand their origin. The magnetic measurements are acquired by MESSENGER along a near polar but very elliptical orbit and are useful for internal magnetic field studies mostly above the northern hemisphere. This orbital configuration challenges our ability to separate the measured magnetic fields into their internal and external contributions and to model them globally to high spatial resolution using classical mathematical techniques such as the spherical harmonics ([1], [2]).

In the recent years, attempts have been made to circumvent this difficulty using dedicated regional or local techniques. Such techniques could rely on an equivalent representation of sources (e.g. [3]) using hypotheses about the location of the magnetic field sources. However, other techniques inherited from Earth's studies based on regional mathematical functions could equally be applied without the need for a priori information about the sources. In this paper, we apply the Revised Spherical Cap Harmonic Analysis ([4]) to derive a magnetic field model from the magnetic field measurements of the MESSENGER spacecraft. Then, we analyse the distribution of the residuals in space and in time. From this analysis, we update the model and incorporate time varying functions to represent the data in space and in time. We finally attempt to separate accurately internal and external fields.

2. Model and Results

We consider three terrestrial years of MESSENGER measurements from March 2011 to April 2014. Measurements recorded after April 2014 cover a too small portion of the Northern hemisphere and are thus discarded. We keep all measurements near the periapsis (down to about 200 km altitude) but reject all measurements taken above 1100 km altitude to reduce the influence of magnetospheric field currents in the data. The measurements cover all local times and colatitudes from 0 to about 85° and are thus available over most of the Northern hemisphere (excluding the polar data gap). We assume that the selected data are measured in source free region and apply the R-SCHA potential field modeling technique to fit the measurements in space. We derive the preliminary model to a horizontal spatial wavelength equal to about 800 km (corresponding to a maximum truncation degree equal to 20 in spherical harmonics). The data misfit is about 30 nT for the static part and the correlation between the vector data and the model is better than 0.97.

The model in space is mostly axisymmetric and the magnetic equator is found around latitude 10°N. From the regional spatial power spectrum we estimate that the CMB is located at about 350-400 km depth below the mean Mercury's radius. The computation of the azimuthal power spectrum (in function of the orders m) shows that the static model is explained at 99% by zonal terms. These results are in agreement with previous studies ([1], [2] and [3]). We then analyze the distribution of the residuals in space and in time. The residuals show clear structures in space and in time. We see a sharp increase in the misfit scatter with the altitude around 300 km that is not linked to a well-defined physical process. The time variations of the residuals are also closely related to the position of the Sun. However, we show that these features cannot be easily explained in terms of external magnetic field only. We then iterate the regional model including time dependencies. This reduces the final data misfit to about 13 nT and increases the correlation between the data and the model up to 0.99.

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