Mars' Heterogeneous South Polar Magnetic Field Revealed using Altitude Vector Slepian Functions.

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Introduction

The Mars Global Surveyor satellite mission (1997–2006) provided us with the first ever global coverage of magnetic measurements for Mars. Due to the absence of a core field, the magnetic measurements on the day side have a larger noise component than nighttime measurements. Generally, the lower the measurement altitude, the less signal attenuation, in particular for relatively small scale magnetic features.

In its orbit insertion, Mars Global Surveyor flew through the Martian atmosphere at altitudes down to approximately 100 km above the planet's surface. Figure 1 shows the location of the low altitude (below 200 km above mean volumetric radius 3390 km) nighttime data plotted over the Martian topography provided by [1].

In our contribution we present a model for the Martian crustal magnetic field around the South Pole calculated locally from these highest-quality data. Our approach allows us to reliably resolve finer details than would be possible by diluting the highest-quality data with lower-quality data covering the entire planet.

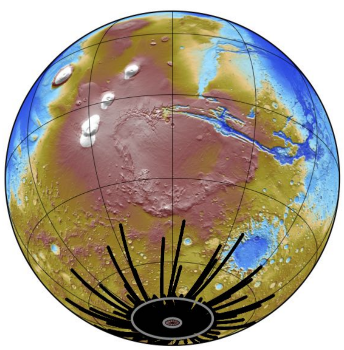

Figure 1: Location of low altitude (less than 200 km above mean volumetric radius) nighttime data from Mars Global Surveyor satellite mission.

Altitude vector Slepian functions

Classical downward continuation of satellite magnetic field data employs spherical-harmonics, which by their very nature are global functions and therefore not well suited for processing our local data.

Here we propose to fit and downward-continue the highest-quality data with our newly designed "altitude vector Slepian functions". These functions, a localized alternative to vector spherical harmonics, are an enhanced version of the vector Slepian functions presented by [2, 3]. Instead of solving a bandlimited concentration problem, we minimize the misfit between a bandlimited upward-continued (to the average satellite altitude) vector function, and a generic data function at satellite altitude within a chosen region. The principal components of this optimization problem are the altitude vector Slepian functions. The generic data function only appears in the problem formulation but does not enter the construction of the altitude vector Slepian functions.

The first few altitude vector Slepian functions have a low noise sensitivity under downward continuation while the subsequent altitude vector Slepian functions are increasingly sensitive to noise under downward continuation but also allow to resolve finer detail. The noise sensitivity versus resolving power of the investigation can be controlled by the number of altitude vector Slepian functions we use to fit and downward-continue the field.

Regional and subregional magnetic field modeling

Figure 2 shows the radial component of our resulting model obtained by fitting the 620 best altitude vector Slepian functions constructed for the annulus between latitudes $-76°$ and $-87°$ and maximum spherical-harmonic degree $L = 130$. We dub this crustal magnetic field model SP130. The field's intensity and structure vary strongly over the region.

Along the antimeridian, the field shows a series of parallel stripes that abruptly end at around longitude $150°$ at the rim of the Prometheus crater. Between longitudes $-120°$ and $-60°$, we observe parallel stripes that seem to be a continuation of the parallel stripes around the antimeridian. From this investigation alone it is unclear if these lines are real or artifacts. Close to the Australe Montes topographical feature at latitude $-80.2°$ and longitude $14°$ we see a feature with a dipolar shape.

In order to investigate the observed features independently of the strong field heterogeneity surrounding them, we selected 5 subregions within the South Polar annulus that are indicated in Figure 3 by the large gray circles. For each of these subregions we solve for the crustal magnetic field from low-altitude nighttime data

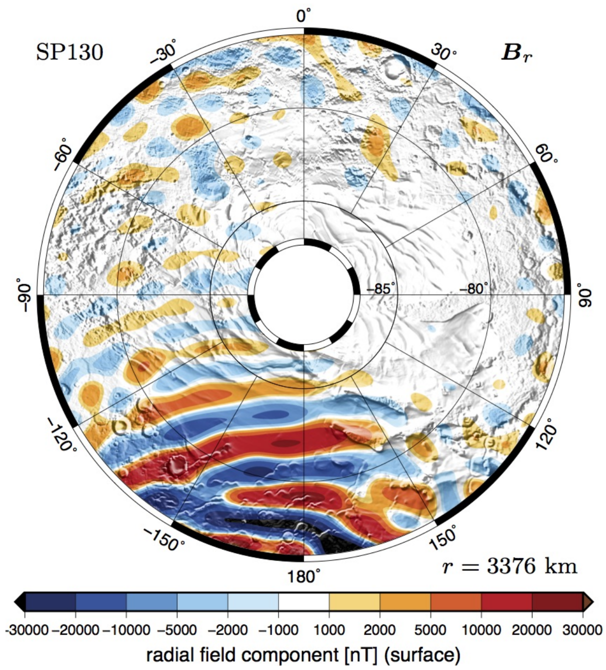

Figure 2: Radial component of the regional altitude-vector-Slepian solution for the crustal magnetic field over the Martian South Pole downward-continued onto the polar radius 3376 km, plotted over topography.

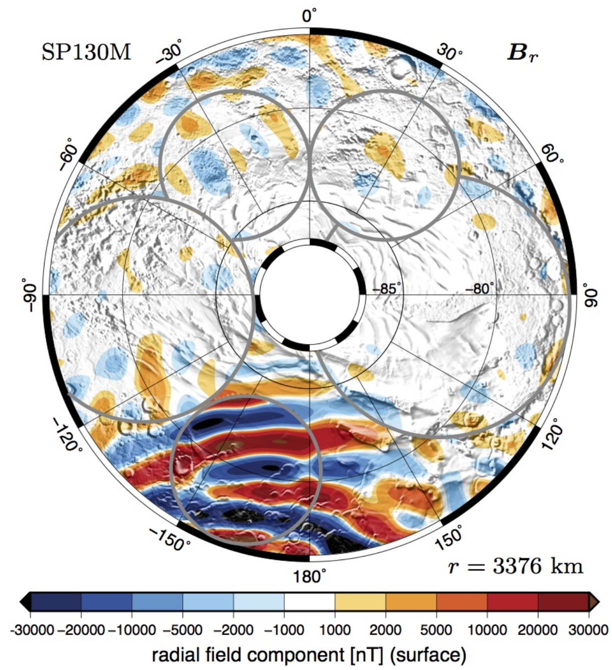

Figure 3: Radial component of the subregional altitude-vector-Slepian solutions (inside the circles) plotted over the regional solution SP130 downward-continued onto the polar radius 3376 km, plotted over topography.

(less than 200 km above mean volumetric radius) located only within each selected region using altitude vector Slepian functions generated specifically for each of these regions for spherical-harmonic bandlimit $L = 130$.

Figure 3 shows the subregional solutions plotted over the South Polar field in a mosaic style (named SP130M). These subregional solutions confirm the weak field over the Prometheus crater and the dipolar feature close to Australe Montes. They do, however, expose the stripes between longitudes $-120°$ and $-60°$ as artifacts. Detailed model and data analysis shows that this is due to fitting strong fields adjacent to weak fields.

The strong magnetic features close to the antimeridian abruptly diminish at the crater rim of the Prometheus basin. We interpret this as a sign of impact demagnetization. Even though the feature strength downward-continued onto the geoid is very high (in this model up to 63000 nT), the resulting magnetization estimation under a model of homogeneous magnetization results in magnetization values lower than previously estimated maximum values [e.g. 4]. This is not surprising considering that a crude estimation for the demagnetization depth by the impactor of between 0.04 and 0.15 times the crater diameter [4] is below the estimated Curie depth on Mars for both magnetite and hematite [4].

Conclusions

We present a high-resolution model of the Martian South Polar magnetic field. Our technique takes advantage of locally available high-quality data and bypasses the need for global inversions based on average-quality data.

Acknowledgements

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