CRUSTAL MAGNETIC FIELDS ON MARS FROM MAVEN DATA.

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Introduction: A lithospheric magnetic field of ancient origin on Mars was first discovered during the Mars Global Surveyor (MGS) mission [1]. MGS data allowed modeling of crustal magnetic fields and resulted in several different models of regional and global extent (e.g. [2],[3],[4]). The most recent global crustal field model, hereafter M14, is based on the entire MGS data set. M14 used a regularized spherical harmonic inversion to degree and order 110 (spatial wavelength ~ 195 km) to obtain a model of the crustal magnetic field that can be downward continued to Mars' surface [5].

The Mars Atmosphere and Volatile EvolutioN orbiter (MAVEN) has been collecting MAG data since Fall 2014. In this study, we focus on crustal field signals in the new data set. We first assess improvements in geographical and altitude coverage compared with MGS data. A comparison of MAVEN and MGS data with M14 highlights areas where residual signals can provide new information on crustal and external fields. We then use both datasets to produce new regional crustal field models, and an updated global picture of the field. These models show crustal fields in regions with previously unresolvable signals.

Method: We use all publicly available MAVEN and MGS vector magnetic field measurements and bin the data in altitude (10 km), longitude (0.5°) and latitude (0.5°/sin(θ)) bins for all altitudes less than 440 km. To reduce the influence of external fields, we use only night-time data and retain only bins that contain at least 5 data points. The coverages provided by the MGS and MAVEN data sets are shown in Figure 1. To examine any remaining unmodeled signal, we calculate the magnetic field predicted by M14 in each bin. The residual is defined as the average data value in each bin minus the M14-predicted value ($\boldsymbol{d}$-G$\boldsymbol{m}$).

Data assessment: MAVEN night-time magnetic field data show more uniform spatial coverage at altitudes less than the ~400 km MGS mapping orbit (MO) altitude (Figure 1).

Residual signals in the MAVEN data after subtraction of the M14 model prediction are shown in Figure 2. For all components, we observe residuals that are typically less than ~50 nT. For the radial, B_r, component, the increase in the maximum amplitude of the residuals with decreasing altitude is suggestive of unmodeled signal of lithospheric origin. However, for the horizontal components, B_θ and B_φ, we observe a less pronounced increase in residual amplitude at lower altitudes. These unmodeled signals likely reflect some influence of external fields, despite the use of only night-time data. We also examined the spatial distributions of the residuals and the corresponding misfits (residuals normalized by the standard deviation of the data in each bin) in the Mars Body Fixed Frame (not shown here). We identified regions of high residual signal and misfit, in particular regions where the residual signal clearly increased with decreasing altitude, suggesting unmodelled crustal fields. We also observe differences in the statistical distribution of the MGS and MAVEN data sets, specifically in the variability of the data within each bin. These result from differences in the MGS and MAVEN orbits, as well as the time interval spanned by data in each bin (years for MGS versus days for MAVEN), and need to be accounted for in crustal field models that combine both data sets.

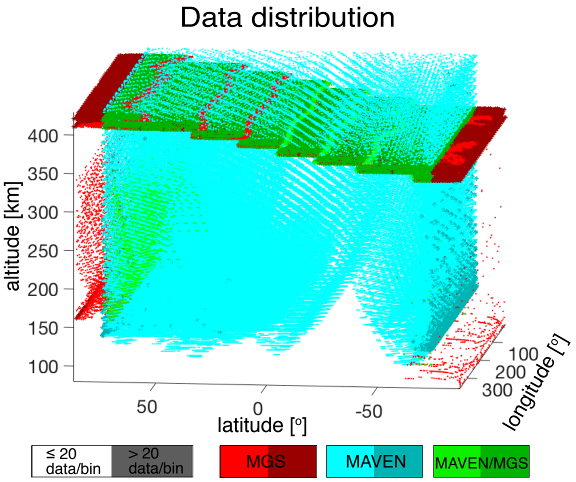

Figure 1. Binned data distribution showing the spatial distributions of the MGS and MAVEN magnetic field data. Only bins with at least 5 data points are shown.

Modeling approach: We conduct local equivalent source dipole inversions, using conjugate gradient least squares with dipoles placed at a depth of 40 km, spaced ~30 km apart. We develop a 2-step approach to accomodate the different statistics of the MGS and MAVEN data sets. In the first step we use only bins with more than 20 data/bin, which are mostly at MGS MO altitudes (Figure 1). We invert for a preliminary model with data weights based on the standard deviation in each bin. In the second step we use all data and data weights based on the residuals calculated from the preliminary model. We then iterate the second step until the distributions of the residuals no longer change. The first step uses data taken over several years (1997-2006 and since 2014) and the data weights reflect a reliable estimate of variability within each bin. Subsequent iterations allow the inclusion of low altitude data that are consistent with the preliminary model. This is important because the lower altitude data are taken over short time intervals, often only one day, in any given bin. Thus large residuals can reflect bias due to external field conditions rather than signals of internal origin. We perform this procedure for areas of 30°x30°, centered every 10°, and build a mosaic of regional models.

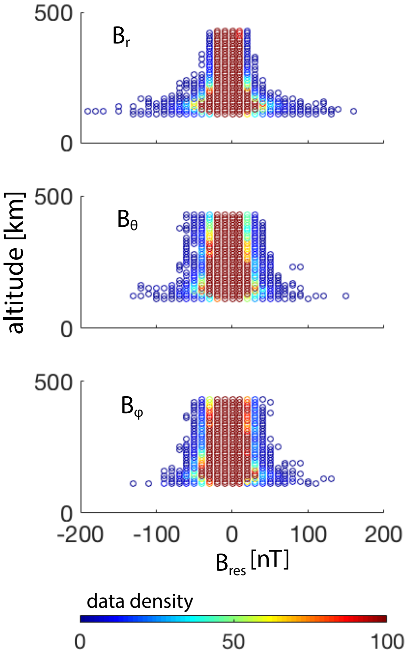

Figure 2. Distributions of the MAVEN magnetic field residuals (data minus M14 model prediction) for the radial (B_r), colatitudinal (B_θ) and longitudinal (B_φ) field components. Color coding describes the number of geographical bins at each altitude (as shown in Figure 1) with residuals of a given magnitude.

Modeling results: We compare the regional models with M14 by plotting the regional variance reduction for each 30°x30° region (Figure 3). We achieve improved fits over many regions, especially at low altitudes and over regions with low-amplitude crustal magnetizations. We discuss some regions as case studies including the area around the North Pole. This area shows high misfits and residuals when modelled with M14 as well as substantial improvements in the models derived using the approach described here.

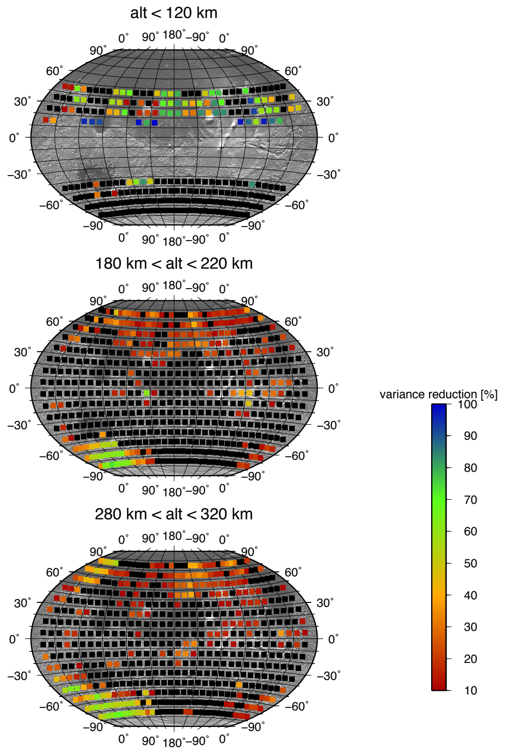

Figure 3. Variance reduction achieved by the new regional models compared with M14. Regions with no substantial variance reduction (less than 10%) relative to to M14, are denoted by the black dots and the color bar denotes improvements in the variance of at least 10%.

Discussion and Conclusion: New data and resulting models capture crustal signals which are not described by earlier field models. These signals contain information on the lithospheric field at shorter wavelengths than previously and over regions of weak magnetization. We also observe different statistical distributions in the MGS and MAVEN data sets arising from different temporal sampling and orbit geometries and the influence of external fields. Future modeling efforts must account for such differences to obtain lithospheric field structure while reliably accounting for external field signals.

References:

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