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Study of Mars' crustal magnetic field displacements due to its interaction with the solar wind

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Abstract

When the solar wind interacts with the planetary obstacles, it defines a magnetosphere. In planets which do not have an active magnetic field, as Mars, they are called induced magnetospheres. Although Mars currently does not have a global magnetic field, its crustal magnetization is quite intense and must be considered in the studies of plasma processes in its magnetosphere. This work has as its main topic of interest the study of the crustal magnetic field displacement in the planet's terminator region as function of the solar zenith. To achieve this, data provided by three space missions to Mars (MGS, MAVEN and MEX) will be used. The observed magnetic field will be compared to a Mars crustal magnetic field model and the variations between them will be studied.

1. Introduction

Mars presents an induced magnetosphere, which is generated by the interaction between the solar wind and the planets' ionosphere [5]. However, regions of intense remnant crustal magnetic fields [1], mainly concentrated in the southern hemisphere, can perturb the global interaction at low altitudes [2]. Above these regions, "mini-magnetospheres" with extensions up to 1000 km are formed [6] and the access of the solar wind to low altitudes can be blocked [2].

It was observed that significant amounts of atmosphere are often removed from Mars by bulk removal processes [3]. The higher portions of the crustal field lines, which carry atmospheric ions, are stretched by the interaction with the solar wind and detach through magnetic reconnection. The process is shown in Figure 1 below, presented by Brain et al. (2010) [3].

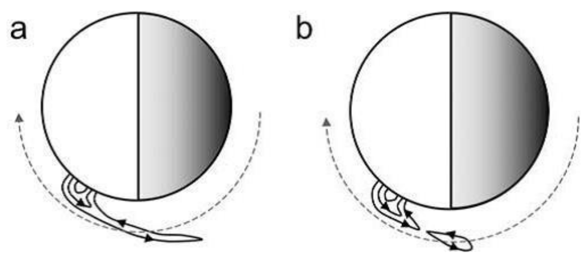

Figure 1: Example of crustal field lines displacement. The Sun is to the left. (a) Crustal field lines are still connected to the planet, being stretched downstream by the solar wind. (b) Upper portions of the field lines are detached.

The displacement of the crustal magnetic field lines occurs frequently and represents up to 10% of the actual ionospheric plasma escape from Mars [3], Knowing that, this work has as its aim to study Martian crustal magnetic field displacements, due to the interaction with the solar wind.

2. Data and Methodology

Magnetic field data were obtained by three space missions to Mars: Mars Global Surveyor (MGS) and Mars Atmosphere and Volatile Evolution (MAVEN), led by National Aeronautics and Space Administration, and Mars Express (MEX), led by the European Space Agency. MGS and MAVEN included two identical triaxial fluxgate magnetometers, responsible for collecting vectorial magnetic field data. MEX does not include a magnetometer, but magnetic field intensity can be derived from the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) data. Time intervals were selected for the years 1997-2006 for MGS, 2014-2018 for MAVEN and 2004-2018 for MEX.

Data processing will be done with the software CCATi, developed by the Max Planck Institute for Solar System Researches. With CCATi, the difference between observed data and a crustal magnetic field model made by Cain et al. (2003) [4] can be calculated. The resulting maps will be analyzed as a function of solar zenith angle (SZA) and altitude. The differences between the observed and the modelled magnetic fields (ΔB) represent the displacement of the crustal field.

3. Preliminary Results

Figure 2 shows ΔB for MARSIS data as a function of SZA (between 0˚ and 180˚) and altitude (200-1500 km) for the years 2006-2013. The plot presents the maximum value in each bin. The large difference observed in the dayside is caused by the compressed magnetic field, but the difference observed beyond 60º in a layer between 300 and 400 km altitude can be associated with crustal field displacement due to its interaction with the solar wind.

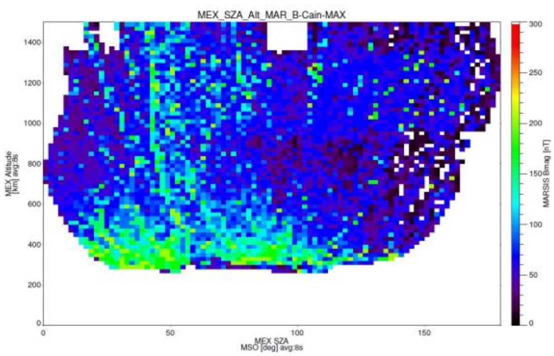

Figure 2: ΔB as a function of SZA and altitude using maximum value.

Furthermore, MGS and MAVEN data will be analyzed in a similar way. Different ranges of SZA and ΔB will be investigated to study where the effect of the magnetic field displacement is more intense.

4. Conclusions

The crustal magnetic field displacements are responsible for a significant amount of ionospheric plasma escape from Mars. For this reason, it is important to have a better knowledge about this process. The results show a substantial difference between observed and modelled crustal magnetic fields, in the region of the planet's terminator, especially at low altitudes. This work is still in its initial phase and we plan to compare data from the three spacecrafts, for varying altitudes and SZA.

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