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Ionospheric Current Systems at Mars: Magnetic Perturbations above Crustal Fields Measured by MGS and MAVEN

K. Gwen Hanley (1), David Brain (2), Tristan Weber (2), Jasper Halekas (3), Jared Espley (4), Jack Connerney (4), David Mitchell (1), and Bruce Jakosky (2)
(1) University of California Berkeley, Space Sciences Laboratory (gwen.hanley@berkeley.edu), (2) University of Colorado Boulder, Laboratory for Atmospheric and Space Physics, (3) University of Iowa, Department of Physics and Astronomy, (4) NASA Goddard Space Flight Center

1. Introduction

Currents in the Martian atmosphere are responsible for plasma transport throughout the upper atmosphere of the planet. Observations of auroral emission [1,2,3,4] and accelerated charged particles [2,3] at Mars suggest that electric fields form parallel to vertical crustal magnetic field lines, similar to Earth's auroral regions. Particles accelerated by parallel electric fields form currents that may facilitate charged particle escape from these magnetic cusp regions. Signatures of currents near crustal fields can be detected by analyzing disturbances in the local magnetic field (Figure 1) .

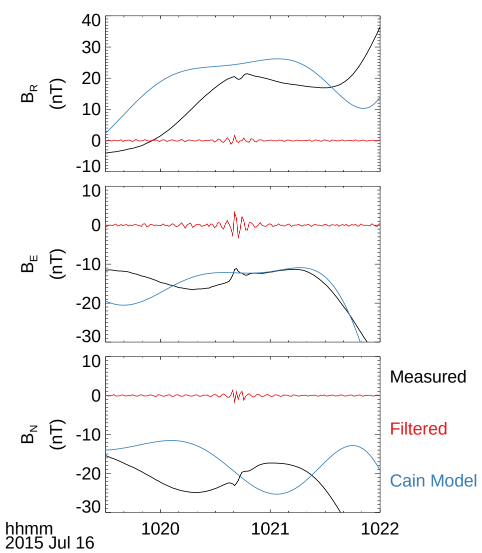

Figure 1: An example of a magnetic perturbation in radial, eastward, and northward magnetic field components in MAVEN data. The red line is the result of passing the black line through a high-pass filter while the blue line is the Cain model of the crustal magnetic field [5].

There have been reports of events consistent with field-aligned current signatures at Mars [1,6,7], but there has been no study of where and how frequently they occur, nor the drivers behind their occurrence or strength. We use magnetic field and electron energy measurements collected by Mars Global Surveyor (MGS) and the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission to investigate the incidence and distribution of low-altitude current systems on the night side of the planet in regions of moderate to strong crustal fields.

2. Magnetic Perturbations

Through systematic study of thousands of events occurring on the planet's night side, we find that magnetic perturbations are particularly numerous in regions of radial magnetic field or in boundaries between regions of differing magnetic topology (Figure 2). These conditions are consistent with magnetic cusp regions.

We find no correlation between crustal magnetic field strength and the occurrence or magnitude of magnetic perturbations (Figure 2). From the MGS data, which

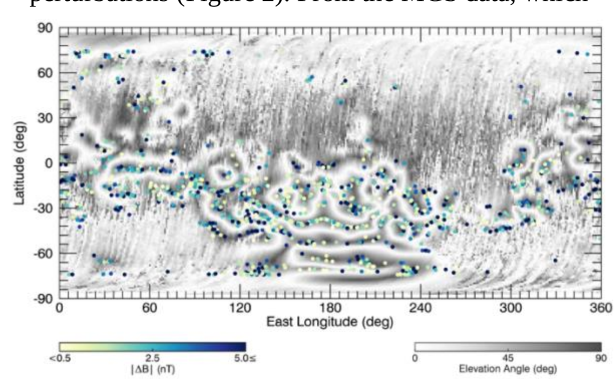

Figure 2: A map of perturbations detected in MAVEN data, colored by perturbation magnitude, overlaid on a map of magnetic elevation angle based on MGS data.

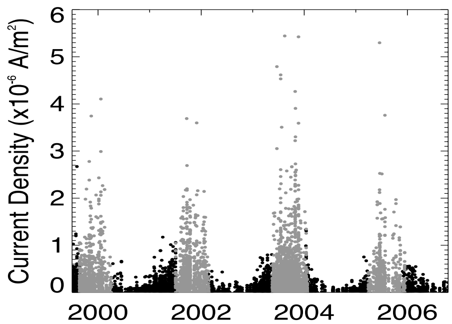

Figure 3: Current densities estimated from MGS data. Gray events are sunlit and black are night side.

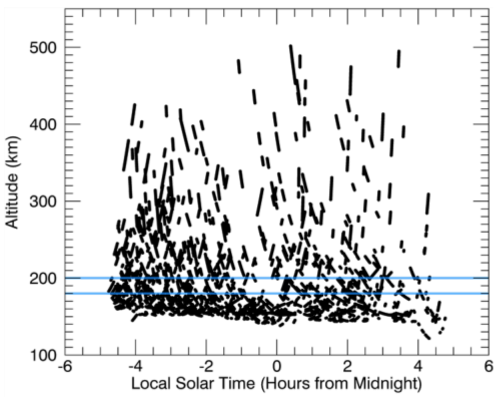

Figure 4: A map of the same perturbations as in Figure 2 with respect to altitude and local solar time. Typical boundaries of the exobase region are shown in blue.

were collected over a longer period of time than the MAVEN data, we find that the occurrence of current systems appears to be affected by Martian season as the magnetic cusps rock back and forth with respect to the Sun (Figure 3). It is likely that seasonal escape rates are affected by the presence or absence of current systems. The MAVEN data, collected over a wider range of local times and altitudes than the MGS data, show that current signatures are most numerous at altitudes below the 400 km circular orbit of MGS, near the exobase region at 180-200 km (Figure 4).

3. Current Densities

The different orbits of MAVEN and MGS necessitated the development of independent methods of estimating current densities from the magnetic field data collected by each spacecraft. We find that each method yields current densities of consistent magnitude, ranging from ~0.1-1 μA/m^2 (Figures 5 and 6). The occurrence of current systems does not appear to be influenced by solar wind pressure, interplanetary magnetic field (IMF) direction, or extreme ultraviolet photon (EUV) flux, suggesting that the variability in their occurrence is driven by variation within the Mars system rather than external sources. Further study of these magnetic perturbations is needed to determine how important of a role they play in the escape of charged particles to space, as well as how the presence of neutral species affect the occurrence and characteristics of current systems.

4. Next Steps

The prevalence of current signatures near the exobase region implies a connection between the formation of currents and the local density of neutral species above crustal fields. The coupling between neutral species and charged particles in cusp regions should be investigated. Additionally, an estimate of current density magnitudes and directions based on electron and ion measurements would also provide insight on the error in the 0.1-1 μA/m^2 current densities calculated from the magnetic field data. By combining these estimates, it is possible to analyze the importance of ionospheric currents in influencing rates of escape to space and how they affect the Martian climate.

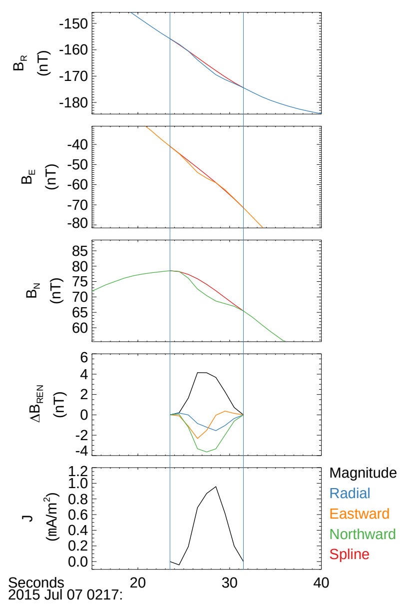

Figure 5: A case study from MAVEN data showing radial, eastward, and northward components of the magnetic perturbation, the spline used to interpolate the background field, and the calculated current density.

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