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Impact of Crustal Magnetic Fields on Day-to-night Plasma Transport in the Martian Ionosphere

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Abstract

This study is aimed at a systematic investigation of the impact of crustal magnetic fields on day-to-night transport in the Martian ionosphere, based on the Mars Express (MEx) data in both the Active Ionospheric Sounding (AIS) mode and the Subsurface (SS) mode. Our analysis reveals noticeable differences in the variations of near-terminator topside plasma scale height and total electron content (TEC) between regions of the Martian ionosphere with and without strong crustal magnetic fields. The observed trends are fully compatible with a scenario in which strong crustal magnetic fields exert a blocking effect on day-to-night transport in the Martian ionosphere across the terminator.

1. Introduction

At the dayside, Mars contains a regular Chapman-like ionosphere mainly produced by solar EUV / X-ray ionization (Withers 2009). In contrast, the nightside ionosphere of Mars is patchy and sporadic (Gurnett et al. 2008), with impact ionization by precipitating electrons from the Solar Wind (SW) and day-to-night transport generally thought to be the two most important sources (Zhang et al. 1990, Duru et al. 2011, Withers et al. 2012, Cui et al. 2015). It has been shown extensively that the crustal magnetic fields exert a profound influence on the morphology of the Martian ionosphere deep in the nightside where electron precipitation dominates (e.g., Safaeinili et al., 2007, Lillis et al. 2009). This study is the first attempt to investigate systematically the impact of crustal magnetic fields on day-to-night transport in the near-terminator Martian ionosphere. Two independent tests have been performed, both based on the data obtained with the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) onboard Mars Express (MEx).

2. Topside plasma scale height

Based on the MARSIS data in the Active Ionospheric Sounding (AIS) mode, we derive the topside plasma scale height in the near-terminator Martian ionosphere well above the peak. We find that over regions free of crustal magnetic fields, this scale height increases progressively with time as Mars rotates into darkness. Such a feature is fully compatible with predictions from photochemical models as the upper regions of the Martian ionosphere are dominated by O^+ with a relatively long chemical timescale and the lower regions dominated by O_2^+ that are lost via dissociative recombination much faster. In contrast, the observed variation of near-terminator topside plasma scale height is inconsistent with predictions from photochemical models over regions of strong crustal magnetic fields. We attribute such a difference to the blocking of day-to-night transport by strong crustal magnetic fields.

3. Total electron content (TEC)

Based on the MARSIS data in the Subsurface (SS) mode, we further examine the time evolution of TEC at any fixed location on Mars as it passes nightward across the terminator. This part of the work is a direct extension of our early analysis of the same dataset (Cui et al. 2015) that focused on the northern hemisphere only and led to an estimated nightward plasma flow velocity of 2 km/s on average. Our analysis here, implemented to the data acquired over the entire region of the near-terminator Martian ionosphere and divided into several categories with varying magnitude of crustal magnetic fields, reveals

a clear tendency of faster decline in TEC over regions with strong crustal magnetic fields, as compared to other regions away from. Such an observation could also be understood as an outcome of blocked day-to-night transport due to strong crustal magnetic fields. Quantitative description of such an effect is then performed using a simplified one-dimensional, time-dependent photochemical model treating the horizontal plasma flow velocity as the only free parameter to be constrained by the data.

4. Summary and Conclusions

Based on the MARSIS data in both the AIS and SS modes, our analysis reveals noticeable differences in the variations of topside plasma scale height and TEC between regions of the near-terminator Martian ionosphere with and without strong crustal magnetic fields. The observed behaviors of these variations are fully compatible with a scenario in which strong crustal magnetic fields exert a blocking effect on day-to-night transport in the Martian ionosphere across the terminator.

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References

[1] Cui, J., et al., Day-to-night transport in the Martian ionosphere: Implications from total electron content measurements, J. Geophys. Res., 120, 2333-2346, 2015.

[2] Duru, F., et al., Nightside ionosphere of Mars studied with local electron densities: A general overview and electron density depressions, J. Geophys. Res., 116, A10316, 2011.

[3] Gurnett, D. A., et al., An overview of radar soundings of the Martian ionosphere from the Mars Express spacecraft, Adv. Space Res., 41, 1335-1346, 2008.

[4] Lillis, R. J., et a., Nightside ionosphere of Mars: Modeling the effects of crustal magnetic fields and electron pitch angle distributions on electron impact ionization, J. Geophys. Res., 114, E11009, 2009.

[5] Safaeinili, A., et al., Estimation of the total electron content of the Martian ionosphere using radar sounder surface echoes, Geophys. Res. Lett., 34, L23204, 2007.

[6] Withers, P., A review of observed variability in the dayside ionosphere of Mars, Adv. Space Res., 44, 277-307, 2009.

[7] Withers, P., et al., Observations of the nightside ionosphere of Mars by the Mars Express Radio Science Experiment (MaRS), J. Geophys. Res., 117, A12307, 2012.

[8] Zhang, M. H. G., et al., An observational study of the nightside ionospheres of Mars and Venus with radio occultation methods, J. Geophys. Res., 95, 17095-17102, 1990.