EPSC Abstracts
Vol. 6, EPSC-DPS2011-267, 2011
EPSC-DPS Joint Meeting 2011

Sources of polar plume ion escape on Mars

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Abstract

The Mars pick-up ion transport model has been developed to study the relative role of kinetic processes on ion transport through near-Mars space. Mars does not have a strong, intrinsic dipole magnetic field and consequently the solar wind directly interacts with the dayside upper atmosphere causing particles to be stripped away from the atmosphere. The Mars Pickup Ion Model calculates the detailed ion velocity space distribution (VSD) through a background magnetic and electric field model at specific locations. The main objective of this work is to robustly probe the sources of polar plume ion escape relative to loss down the central tail. Because the VSDs are non-Maxwellian and reveal asymmetric, non-gyrotropic features, our simulation can investigate the role of kinetics in polar plume loss without using the Maxwellian assumptions of current MHD models.

1. Introduction

We have used a parallelized 3-D Monte Carlo model that describes how Mars pickup oxygen ions are transported and accelerated. As a result of Mars' weak magnetic field in comparison with Earth, the direct interaction between the solar wind and the planetary neutral environment triggers the creation of planetary ions which are then accelerated and stripped from the Martian atmosphere. An important loss mechanism for the heavy particles, such as O and O_2, is the creation of pick-up ions above the exobase where neutrals in the exosphere are ionized, and they are instantaneously affected by the solar wind and interplanetary magnetic field (IMF). These newly-created ions are picked up by the solar wind, and rapidly accelerated away from Mars by the solar wind's motional electric field. Three important sources for ion production are (1) photoionization from solar radiation, (2) charge exchange collisions with ions, and (3) impact ionization by solar wind electrons listed below, respectively.

$$O + hv \rightarrow O^+ + e^- \quad (1)$$

$$O + H^+ \rightarrow O^+ + H \quad (2)$$

$$O + e^- \rightarrow O^+ + e^- + e^- \quad (3)$$

2. Approach

Mars Pick-Up Ion Model

[Fang et al., 2010] developed a parallelized 3-D Monte Carlo model that describes how Mars pickup oxygen ions are transported and accelerated once they are generated in the upper atmosphere and exosphere. The pick-up ions are created through photoionization, charge exchange collisions of solar wind protons, as well as impact ionization by solar wind electrons. The magnetic and electric fields are calculated by a separate model and provide the background conditions for our test particle simulation [Fang et al., 2008]. The source term grids are spaced uniformly and are proportional to the natural logarithm of the radial distance between some lower boundary (typically 170-300 km above the Mars surface) up to some outer boundary (typically 3-5 Martian radii). The Mars pick-up ion model can then extract VSDs at designated locations along a specified satellite orbit, and any number of orbits or detectors per orbit can be included in a simulation.

The MHD Model

The MHD model used to calculate the background electric and magnetic fields is the Mars BATS-R-US model which solves for the bulk plasma and field parameters with a lower boundary of 100 km to an outer boundary beyond the bow shock at 8 R_M upstream and 24 R_M downstream. The model is a 3-D multispecies simulation [Ma et al., 2004], which solves the dimensionless conservative form of the MHD equations using multiple continuity equations but single-fluid momentum and energy equations. The crustal magnetic field sources are included by using the spherical harmonic crustal magnetic field model from [Arkani-Hamed, 2004].

3. Polar plume loss

The main objective of this work is to establish the importance of the polar plume for planetary ion escape relative to loss down the central tail. The asymmetries in the loss highlight the role of kinetics when modeling non-thermal loss in the Martian atmosphere. The loss from photoionization is the most dominant mechanism yet ions produced via electron impact have a distinct signature and contribute enormously to the total loss. Further analysis will show the correlation between ion source production and loss, which changes as a function of solar cycle. The authors will also present comparative loss rates with the central tail as a function of ionization mechanism.

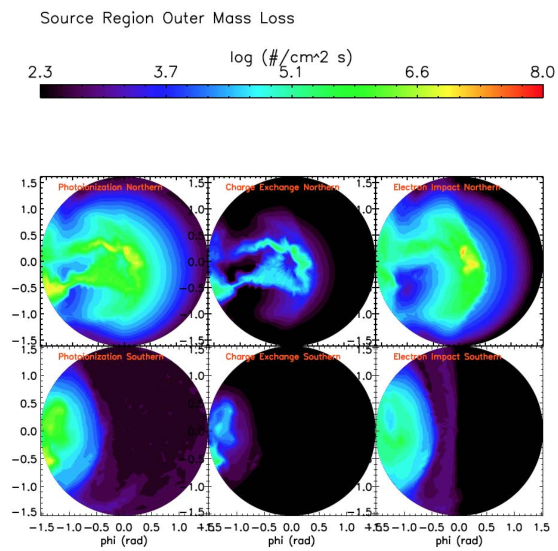

Figure 1: Loss plots of O^+ from the 3 source regions at the outer boundary of 3 R_M in the northern and southern hemisphere. The ions follow the background electric and magnetic fields input from the MHD model.

4. Summary and Conclusions

The Mars pick-up ion transport model provides a kinetic approach for studying the various physical processes controlling ion creation, transport and loss through near-Mars space. The resolution provided by over 1 billion test particles permits the examination of pick-up ion flux distributions in spatial locations and energy ranges that have not been examined before. Sources of ions from photoionization, charge exchange collisions, and impact ionization vary for solar maximum and minimum conditions which previous MHD studies have not observed. Additionally, the polar plume of escaping oxygen ions can be studied as a function of these sources and enrich our understanding of Martian atmospheric evolution with respect to other loss mechanisms.

Acknowledgements

The author would like to acknowledge the valuable assistance of Dr. Michael Liemohn and Dr. Xiaohua Fang.

References

[Arkani-Hamed, 2004] Arkani-Hamed, J. (2004). A Coherent Magnetic Field Model of the Martian Crust. *AGU Spring Meeting Abstracts*, pages A3+.

[Fang et al., 2010] Fang, X., Liemohn, M. W., Nagy, A. F., Luhmann, J. G., and Ma, Y. (2010). On the effect of the martian crustal magnetic field on atmospheric erosion. *Icarus*, 206:130–138.

[Fang et al., 2008] Fang, X., Liemohn, M. W., Nagy, A. F., Ma, Y., De Zeeuw, D. L., Kozyra, J. U., and Zurbuchen, T. H. (2008). Pickup oxygen ion velocity space and spatial distribution around Mars. *Journal of Geophysical Research (Space Physics)*, 113:2210–+.

[Ma et al., 2004] Ma, Y., Nagy, A. F., Sokolov, I. V., and Hansen, K. C. (2004). Three-dimensional, multispecies, high spatial resolution MHD studies of the solar wind interaction with Mars. *Journal of Geophysical Research (Space Physics)*, 109:7211–+.