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3-D simulations of the Martian ionosphere: the post-terminator ionosphere

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Abstract

We present 3-D simulations of the Martian ionosphere performed with the General Circulation Model developed at Laboratoire de Météorologie Dynamique, LMD-MGCM. Special emphasis is put in the behavior of the nighttime ionosphere, much less known than its dayside counterpart.

1. Introduction

While the basic processes at the origin of the Martian dayside ionosphere and its variability are relatively well-known, thanks among others to the measurements of MGS and MarsExpress (see [6]), much less is known about the behavior of the ionosphere during nighttime, due to the scarcity of observations. [4], using measurements by MarsExpress radar MARSIS, have shown that the occurrence rate of nightside ionospheric areas with electronic densities higher than the detection limit of the instrument decreases with increasing Solar Zenith Angle for SZA<125 degrees, for areas of weak crustal magnetic fields. This patchy behavior is attributed to the transport of plasma from the dayside. The measured peak electronic concentrations are usually lower than $2{\cdot}10^4$ cm^{-3}. [5] report the detection of areas of enhanced ionization in the deep nightside (SZA>125 degrees), corresponding to regions with open magnetic field configuration. And [7], using MarsExpress MaRS vertical electron density profiles, found a decrease in the electronic concentrations with increasing SZA up to 115 degrees, again attributed to plasma transport. MaRS results suggest also that electron precipitation in the deep nightside is the main ionospheric source.

In this work we use the a 3-D GCM, recently improved to include ionospheric processes, in order to characterize the processes that populate the Mars nightside ionosphere, and specially near the terminator.

2. The improved ionospheric LMD-MGCM

The model used in this study is an improved version of the LMD-MGCM described in [2]. The improvements include an extension of the thermospheric chemical module to include ionospheric chemistry and the ionization by UV photons and photoelectrons, a new method to take into account the day-to-day variability of the UV solar flux, an improved parameterization of the 15 μm cooling by CO_2 under Non-Local Thermodynamic Equilibrium conditions, and an improved molecular diffusion scheme. These improvements are described in detail by [3]. The model has been further extended to include plasma dynamics processes [1]. The model does not include the effects of precipitating particles. The effects of magnetic fields are neither considered at this stage.

3. Summary of results

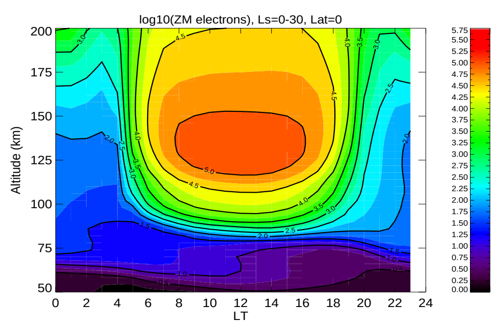

Figure 1: Electronic concentration as a function of altitude and local time for equatorial latitudes. A logarithmic color scale is used, so that 5 means 10^5 cm^{-3}

Even in the absence of plasma transport from the dayside, our model predicts the presence of a nightside ionosphere (see Fig. 1). This nightside ionosphere is mainly formed by NO^+ ions, which have a chemical lifetime long enough to survive during the night, even in the absence of chemical productions. A decrease of the electronic concentration with increasing SZA for SZA<120 degrees, similar to the decrease observed by MARSIS and MaRS, is obtained. When plasma transport is included, the electronic concentration in the lower ionosphere is furter increased. However, the overall picture is not modified by the inclusion of plasma dynamics. These results suggest that photochemistry, and not plasma transport, is at the origin of the decrease of electronic concentrations in the post-terminator ionosphere. This nighttime ionosphere, as a chemical remnant from the daylight hours, fades with time during the night. In the deep nightside the predicted densities are low, and our model can not explain the presence of areas of enhanced ionization, since the effects of precipitating electrons are not yet considered. Our results, combined with the measurements of local nighttime enhancements, indicate that below about 140 km there is a nighttime background ionosphere of photochemical rather than transport origin, on top of which enhanced patches may be created locally by precipitation or other processes.

References

[1] Chaufray, J.-Y., González-Galindo, F., Forget, F., López-Valverde, M.A., Leblanc, F., Modolo, R., Hess, S., Yagi, M., Blelly, P.-L., and Witasse, O.: 3D Martian ionosphere model: II. Effect of transport processes without magnetic field, paper submitted to Journal of Geophysical Research, 2013.

[2] González-Galindo, F., Forget, F., López-Valverde, M. A., Angelats i Coll, M., and Millour, E.: A ground-to-exosphere Martian general circulation model: 1. Seasonal, diurnal, and solar cycle variation of thermospheric temperatures, Journal of Geophysical Research, Volume 114, E04001, 2009.

[3] González-Galindo, F., Chaufray, J.-Y., Gilli, G., López-Valverde, M.A., Forget, F., Leblanc, F., Modolo, R., Hess, S., and Yagi, M.: 3D Martian ionosphere model: I. The photochemical ionosphere below 180 km, paper submitted to Journal of Geophysical Research, 2013.

[4] Nemec, F., Morgan, D. D., Gurnett, D. A., and Duru, F.: Nightside ionosphere of Mars: Radar soundings by the Mars Express spacecraft, Journal of Geophysical Research, Volume 115, E12009, 2010.

[5] Nemec, F., Morgan, D.D., Gurnett, D.A. and Brain, D.A.: Areas of enhanced ionization in the deep nightside ionosphere of Mars, Journal of Geophysical Research, Volume 116, E06006, 2011.

[6] Withers, P.: A review of observed variability in the dayside ionosphere of Mars, Advances in Space Research, Vol. 44, pp. 277-307, 2009.

[7] Withers, P., Fillingim, M. O., Lillis, R. J., HäUsler, B., Hinson, D. P., Tyler, G. L., Patzold, M., Peter, K., Tellmann, S., and Witasse, O.: Observations of the nightside ionosphere of Mars by the Mars Express Radio Science Experiment (MaRS), Journal of Geophysical Research, Volume 117, A12307, 2012.