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The Martian ionosphere: comparison of a global climate model with MARSIS data

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Abstract

We present here the comparison of the electron density profiles predicted by a 3D global climate model (GCM), the Mars GCM developed at the Laboratoire de Météorologie Dynamique (LMD-MGCM) [4], with the measurements from the instrument MARSIS on board Mars Express [5]. The observations were obtained during 5 Martian Years (MY), from MY27 to MY31 (mid 2005-end of 2013). The model was run using the observed day-to-day variability of the UV solar flux and of the dust load during that period. We focus the comparison on two parameters: the electron density at the main peak, and the altitude of the peak. Special attention will be paid to the variability of these two parameters with different geophysical parameters (latitude, SZA, ...), which can provide interesting information about the neutral upper atmosphere of Mars and its interaction with the UV solar radiation.

1. Model-data ionosphere comparison

The structure of the Martian ionosphere is strongly affected by the characteristics of the underlying neutral atmosphere [11]. So, the comparison of the electron density profiles predicted by a GCM with the observations provide an indirect validation of the predicted thermal and density structure in the mesosphere/lower thermosphere region.

The LMD-MGCM is a ground-to-exosphere GCM [2, 3] which self-consistently takes into account the couplings between different atmospheric regions and between different processes. Recently, the photochemical module used to simulate the chemistry of the upper atmosphere of the planet has been improved to simulate the Martian ionosphere [4]. A procedure to take into account the day-to-day variability of the UV solar flux has been included in the modelas well. The model is also able to simulate the dynamics of the ions [1], but we will limit this study to the photochemical region of the ionosphere, below about 180 km from the surface. The version of the model used for this study includes the radiative effects of water ice clouds, which have been shown to produce a significant effect over the mesospheric temperatures [6].

The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) instrument, on board Mars Express, has provided the largest dataset to date about the Martian ionosphere, with more than 140000 electron density profiles obtained during more than 5 Martian Years [12]. The main advantage of the MARSIS data when compared to radio-occultations is the large range of solar zenith angles and latitudes covered by the radar. MARSIS data have been used, among others, to characterise different aspects of the Martian ionosphere, such as the effects of the solar rotation [9], the effects of crustal magnetic fields [10] and the nightside ionosphere [8]

For this comparison, the LMD-MGCM has been run to simulate 5 MYs, from MY27 to MY31, the same period covered by MARSIS observations. The observed day-to-day variability of the UV solar flux is taken into account as described in [4]. The column dust optical depth is taken from [7]. The model results are interpolated to the location (in space and time) of each MARSIS observation, and the electron density at the main peak and the altitude of the peak are extracted, and compared to the observed ones.

Some preliminary conclusions can be already obtained from this comparison. Although the overall agreement is good, there are some differences that can provide interesting information about processes

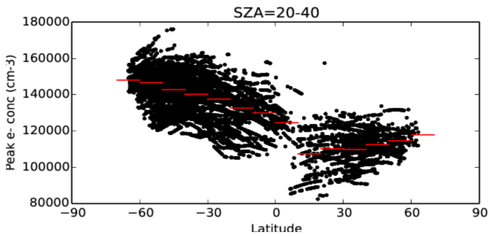

Figure 1: Latitudinal variation of the peak electron density predicted by the model at the location of MARSIS observations with SZA (solar zenith angle) between 20 and 40 degrees. The red lines indicate the median values.

not well represented or even missing in the model. The peak electron density is slightly underestimated by the model, as already found in a previous comparison with MGS radio-occultation data [4]. When the radiative effects of water ice clouds are not included in the LMD-MGCM, the simulated altitude of the peak is significantly underestimated. The peak electron densities predicted by the model show a significant latitudinal variability (Fig. 1), which is not the case in MARSIS observations. We will discuss the possible origin of these data-model discrepancies.

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References

[1] Chaufray, J.-Y., et al.: Three-dimensional Martian ionosphere model: II. Effect of transport processes due to pressure gradients, J. Geophys. Res., Vol. 119, pp. 1614-1636, 2014

[2] Forget, F., et al.: Improved general circulation models of the Martian atmosphere from the surface to above 80 km, J. Geophys. Res., Vol. 104, pp. 24,155–24,176, 1999

[3] González-Galindo, F., et al.: A ground-to-exosphere martian general circulation model: 1. seasonal, diurnal, and solar cycle variation of thermospheric temperatures, J. Geophys. Res., Vol. 114, pp. 4001–+, 2009

[4] González-Galindo, F., et al.: 3D martian ionosphere model: I. the photochemical ionosphere below 180 km, J. Geophys. Res., Vol. 118, pp. 2105–2123, 2013

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

[6] Madeleine, J.-B., et al.: The influence of radiatively active water ice clouds on the Martian climate, Geophys. Res. Lett., 39, pp. 23202-+, 2012

[7] Montabone, L., et al.: Eight-year climatology of dust optical depth on mars, Icarus, Vol. 251, pp. 65–95, 2015

[8] Nemec, F., et al.: Areas of enhanced ionization in the deep nightside ionosphere of Mars, J. Geophys. Res., Vol. 116, pp. E06006-+, 2011

[9] Nielsen, E., et al.: Observations of vertical reflections from the topside martian ionosphere. Space Sci. Rev., Vol. 126, pp. 373–388, 2006

[10] Nielsen, E., et al.: Local plasma processes and enhanced electron densities in the lower ionosphere in magnetic cusp regions on Mars. Planet. Space Sci., Vol. 55, pp. 2164–2172, 2007

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

[12] Withers, P., Morgan, D.D. and Gurnett, D.A.: Variations in peak electron densities in the ionosphere of Mars over a full solar cycle, Icarus, Vol. 251, pp. 5-11, 2015