STUDY OF THE MARTIAN IONOSPHERE WITH A GENERAL CIRCULATION MODEL.

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Introduction

The Martian ionosphere has been studied by space missions since the beginning of the space age. Recently, the orbiters Mars Global Surveyor, Mars Odyssey and Mars Express have included instruments to study this component of the Martian atmosphere, which has triggered a renovated interest in this atmospheric region. The data from these instruments have allowed the study, among others, of the morphology of the ionosphere in the terminators (Fox and Yeager, 2006), of ionospheric structures associated with crustal magnetic fields (Gurnett et al., 2005), of the presence of meteoric layers (Withers et al., 2008), and of the effects of the EUV solar flux on the Total Electron Content (Lillis et al., 2010). From a global perspective, these measurements show that the ionosphere is influenced by external forcings (e.g. the solar flux) and also by the 3-D structure and variability of the underlying neutral atmosphere (Bougher et al., 2004). A General Circulation Model is a very useful tool for to study the ionosphere and its couplings, since predicted variations (spatial and temporal) in the temperature and composition of the neutral atmosphere are calculated and their effects on the ionosphere straightforwardly taken into account, so that no assumptions have to be made regarding these parameters

The ionospheric LMD-MGCM

The LMD-MGCM (Forget et al., 1999; González-Galindo et al., 2009) is a ground-to-exosphere General Circulation Model that self-consistently studies the thermal structure, the dynamics and the composition of the Martian atmosphere from the ground up to the exosphere. Processes included for the study of the Martian upper atmosphere include the UV heating, NLTE CO2 15 μm cooling, thermal conduction, molecular viscosity, molecular diffusion and photochemistry. This photochemical model, optimized for the conditions of the rarified upper atmosphere of Mars, and that originally considered 27 reactions between 15 neutral species of the C, H and O families (González-Galindo et al., 2005), has been recently extended to include the N family and ionospheric species and reactions, up to a total of 26 species (CO_2, CO, O, O_2, O_3, $O(^1D)$, H, OH, HO_2, H_2, H_2O, H_2O_2, N, NO, NO_2, $N(^2D)$, N_2, CO_2^+, O_2^+, CO^+, O^+, C^+, NO^+, N_2^+, H^+ and N^+) and 85 reactions between them, including photodissociations and photoionizations. Photochemical equilibrium is used for the ions, given their short lifetimes, and the atmosphere is kept globally neutral. While the ions are transported by the general circulation, no plasma transport processes (e.g. the effects of magnetic fields, or ambipolar diffusion) are included in the model, which limits its validity to the photochemically dominated region, below about 200 km.

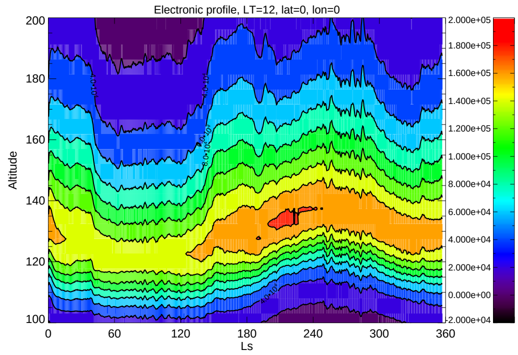

Figure 1: Electron density profile (cm-3) predicted by the LMD-MGCM at the equator and LT=12 during one Martian year

Results

We will present the results of a simulation for a full Martian year performed with the LMD-MGCM. The major characteristics of the Martian ionosphere as obtained by the different Mars missions are well simulated with our model. Also we are able to make predictions about its variations with local time, latitude, season, solar cycle and other geophysical parameters that affect the neutrals at those altitudes, like the dust content of the lower atmosphere.

The variability of the density and altitude of the primary ionospheric peak during this Martian year can be seen in Fig. 1. The variation of the altitude and the density of the peak will be compared with those obtained by the analysis of MGS data (Withers, 2009; Fox and Yeager, 2009). The altitude of the peak changes during the year, with minimum altitude around the aphelion season and maximum altitude close to perihelion. This

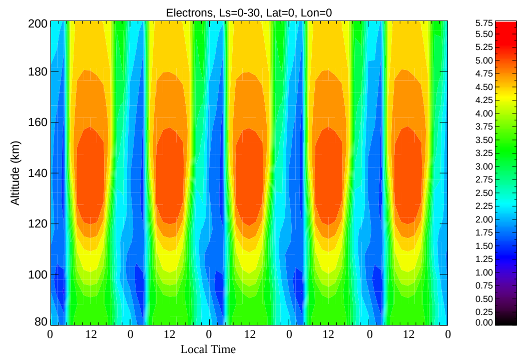

Figure 2: Temporal evolution of the electron density profile (cm-3, logarithmic scale) predicted by the LMD-MGCM at the equator during 5 Martian days. The existence of a remnant ionosphere during nighttime can be observed.

is due to the variation of pressure produced by the inflation/contraction of the background neutral atmosphere with seasons. The density of the peak also changes with season, being maximum at perihelion and minimum at aphelion due to the eccentricity of the Martian orbit, that produces a stronger photoionization rate during the perihelion season. As has been observed, O_2^+ is the dominant ionospheric species at all altitudes below 200 km, with important contributions from NO^+ in the lower ionosphere and, in some cases, O^+ in the upper ionosphere.

Our model is able to track the daily changes in the concentrations of the different ionospheric (and of course neutral) species. While most of the ionospheric species have very short lifetimes and disappear quickly at the beginning of the night, NO^+ is an exception to this behavior, and the existence of a nighttime ionosphere formed mainly by NO^+ is predicted by the model (fig. 2, González-Galindo et al., in preparation). A nighttime ionosphere has been observed, and attributed to the transport of plasma from the dayside and ionization by precipitation electrons (Withers, 2009). The results of our model show that photochemistry has also a small contribution to this nighttime ionosphere.

The spatial distribution of the different ionospheric species, and how they are influenced by the distribution of neutral species, will be also studied.

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