Hydrogen escape at Mars : Comparisons from MGCM-LMD simulations and observations from Mars-Express/SPICAM

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1) Introduction:

The recent observations of an unexpected large seasonal variation of the Martian hydrogen exosphere is important to characterize the water escape along the Martian history. The Martian Global Circulation Model from Laboratoire de Météorologie Dynamique (MGCM-LMD) is a 3D model able to simulate the full hydrogen cycle from the water at the surface to the hydrogen density at the exobase. The hydrogen density is extended to the exosphere using the Liouville's equation. In this presentation, we will present recent simulations of the Martian hydrogen density, taking into account: (1) the observed day-to-day solar and dust load variability during the recent Martian years, and (2) the 3D hydrogen corona at Lyman-alpha performed with a 3D radiative transfer model. These simulations will be compared to observations performed by several instruments (Mars Express/SPICAM

2) Model:

The LMD-MGCM model is a model of the martian atmosphere from the surface to the exobase, including major species in the Martian atmosphere [1,2]. The seasonal variations at different solar activity have been studied by Chaufray et al. [3,4]. The scenario corresponding to the solar activity and dust during the Martian years 28, 29) [5] are considered in this presentation. No mission measured directly the hydrogen density. The hydrgeon density is derived from UV hydrogen lines, mainly the optically thick Lyman-alpha emission. To directly compare our simulations to the observations performed by SPICAM on Mars Express, we use a 3D Radiative transfer model and derive the brightness profile corresponing to the different geometry of observations. Because the 3D radiative transfer model is time expensive, we consider only monthly average hydrogen distribution and focus on the study of the large time-scale (season and year to year) (Fig. 1).

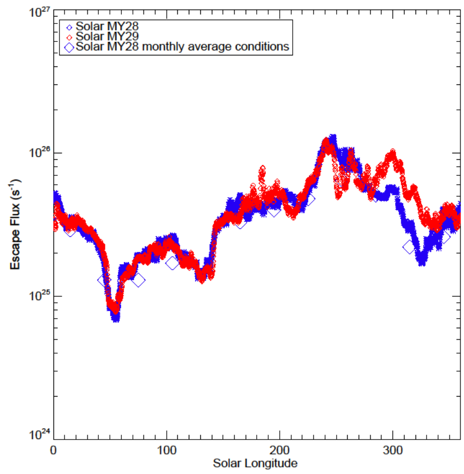

Fig. 1 Simulated escape flux for the Martian years 28 and 29 by the MGCM-LMD model. The escape flux computed with the monthly average hydrogen density and temperature at the exobase are also indicated.

3) Observations

SPICAM on Mars Express has observed the Martian H corona during several years.[6,7]. We here focus on two martian years (28, 29) At this time, there was an anomalous behavior of the image intensifier characterized by sporadic and spurious changes in the gain during one observation [8] responsible of the spodaric increase of the Lyman-alpha brightness in the vertical profiles presented below.

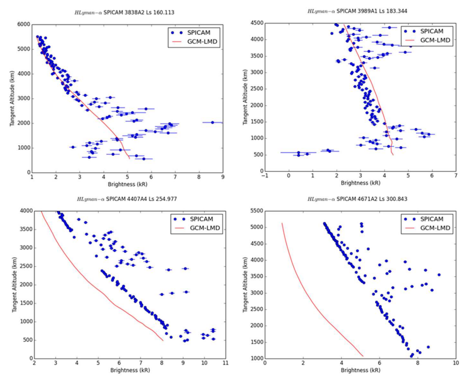

Fig. 2 Examples of comparison between the model and the SPICAM observations during the Martian year 28.

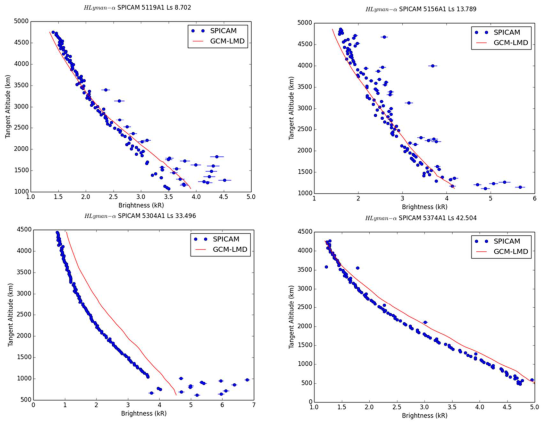

Fig. 3 Examples of comparison between the model and the SPICAM observations during the Martian year 29.

4) Results

During the Martian year 28, the model is in reasonable agreement with the observations for 160° < Ls < 180° (a,b) but underestimate the brightness for 180 < Ls < 330°, especially near southern summer at Ls = 250°-300°. The agreement becomes better after Ls = 330°. An arbitrary background of 500 R was used for all the observations. Small disagreeemnt could be improved with a better estimate of it, but not the difference near Ls=250°-300°, more likely due to a missing source of hydrogen in the model at this season. For the early Martian year 29 (Ls < 60°), the agreement with the observations is reasonable near equinox though the model slightly overestimates the brightness near Ls = 30-50°.

5) Conclusion

We simulate the monthly average Martian hydrogen corona for Martian years 28, 29. We compare the simulated Lyman-alpha brightness to the observed brightness. The model gives reasonable agreement near equinox : Ls ~ 0° for MY 29 and Ls ~ 180° for MY 28.

The model fails to reproduce the large observed brightness between Ls = 210 to 330°, due to a large increase of the hydrogen density confirmed by plasma observations [9]. A possible explanation of this large difference is due to the presence of a larger source of atomic hydrogen at this season not included in the model. The detection of water vapour at higher altitudes (~80 km) than expected at Ls ~ 250° by MEX [10], followed by its photodissociation could increase the abundance of hydrogen in the Martian exosphere and the hydrogen escape flux [11]. Therefore the measurement of the extension of the water vapor in the mesosphere/thermosphere of Mars and its seasonal variation should be needed to confirm this assumption.

References:

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