EPSC Abstracts
Vol. 13, EPSC-DPS2019-499-2, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Study of the hydrogen escape rate at Mars during Martian years 28 and 29 from comparisons between SPICAM/Mars Express observations and GCM-LMD simulations

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Abstract

Several evidences indicate that Mars was not always as dry as it is today. Substantial amount of water could have escaped in the form of atomic hydrogen [1]. Recent observations suggest important seasonal variations of the hydrogen escape rate with a larger rate during southern summer [2,3] due to an increase of the water vapor in the mesosphere during dust storm [4,5,6].

In order to better characterize the hydrogen escape variations, we have simulated the 3D atomic hydrogen density in the Martian upper atmosphere (below the exobase) and the associated Jeans escape rate during Martian years 28 and 29 using the LMD-GCM with the suitable dust and solar activity scenarios [7, 8, 9]. The hydrogen density in the exosphere has been computed using a kinetic approach, neglecting all interactions above the exobase [10]. The coronal Lyman-α brightness has been computed using a 3D radiative transfer model which accounts for the monthly average hydrogen density for these two years and is compared to a large set of observations by Mars Express/SPICAM [11]. The simulated brightness is generally in good agreement with the observations for Ls <230° and Ls > 330° for Martian year 28 and Ls < 270°, Ls > 340° for Martian year 29, but the model strongly underestimated the brightness for 230 < Ls < 330° for Martian year 28 and 270 < Ls < 340° for Martian year 29. In these simulations the transport of water vapor contributes to the production of hydrogen at high altitudes during southern summer. A possible explanation for the model discrepancy is an underestimate of this water transport, associated with an underestimate of the hygropause altitude and/or an underestimate of the supersaturation of the mesosphere. Considering this discrepancy, we estimate the hydrogen escape rate during these two Martian years to vary by almost two orders of magnitude, between ~10^{25} to $6x10^{26}$ s^{-1} (equivalent to a global layer of water ~33 to 1960 mm deep every billion years), in agreement with the seasonal variations estimated directly from the fit of the SPICAM observations during the Martian year 28. Our analysis suggests that episodic dust storms and associated enhancements at high altitude near perihelion are a major factor in the H escape estimates averaged over one martian year or longer periods, but the accumulated water lost at this rate for 4 billions years is much lower than the amount of water needed to form the flow channels observed on Mars.

Acknowledgements

This project was partially funded by the Programme National de Planetologie and Programme National Soleil Terre and by the Centre National d'Etudes Spatiales. This work has been partially funded by the European Union Horizon 2020 Programme (H2020 Compet -08-2014) under grant agreement UPWARDS-633127.

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