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Effect of the 2018 Martian global dust storm on the CO2 density in the lower nightside thermosphere observed from MAVEN/IUVS Lyman-α absorption

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Abstract

The Imaging Ultraviolet Spectrograph (IUVS) on the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission measures Lyman-α emissions from interplanetary and martian hydrogen at the limb and through the extended corona of the planet. In June 2018, an intense global dust storm surrounded Mars for a few months, heating the lower atmosphere and leading to an expansion of the Martian atmosphere of few kilometers in the thermosphere. Nightside IUVS observations before and throughout this Planet Encircling Dust Event (PEDE) showed the altitude of CO_2 absorption of Lyman-α photons in the lower thermosphere to increase by 4.5±1.0 km on 8 June 2018. This altitude shift is attributed to an increase of the CO_2 density by a factor 1.9±0.2 at 110 km due to the heating of the lower atmosphere during the large dust storm occurring at the surface of Mars. These nightside observations, not previously used to study dust storms, in an altitude range not sampled by other instruments, are consistent with dayside MAVEN observations and allow for more comprehensive determination of the global changes produced by the PEDE event on the Martian thermosphere.

1. Introduction

MAVEN/IUVS observes the hydrogen emissions from the Martian corona and the interplanetary medium scanning the limb with tangent altitude ranging from below the surface to the upper exosphere [1]. Below ~ 110 km, interplanetary emissions and part of the planetary emissions is “occulted” by the CO_2 in the Martian atmosphere and the detected signal is weaker than above 110 km. Such absorption was detected in the past by Mars Express [2] and used to study the seasonal variations of the CO2 density [3]. In this study, we use the MAVEN/IUVS observations from 25 May 2018 to 22 June 2018 to study the effect of the PEDE on the Martian nightside lower thermosphere.

2. Method

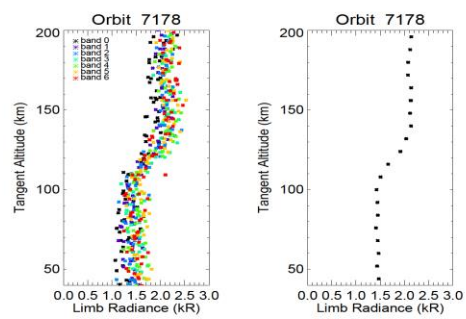

Figure. 1 : Left : Vertical profiles of the H Lyman-α brightness measured at limb between 40 and 200 km for each of 7spatial bins. Right average profile with a vertical resolution of 8 km.

For each orbit, Six inbound limb scans are done in each orbit with a sampling of approximatively 10 km. 7 spatial bins are transmitted per limb scan, leading to 42 individual limb profiles per orbit (Figure 1).

By analogy with stellar occultations, we can calculate the average vertical profile of a transmission function (Figure 2), independent on the absolute calibration of the instrument. Each average transmission profile is fitted with a simple analytical function assuming an isothermal layer between 110 and 160 km, and a spherically symmetric atmosphere near the limb.

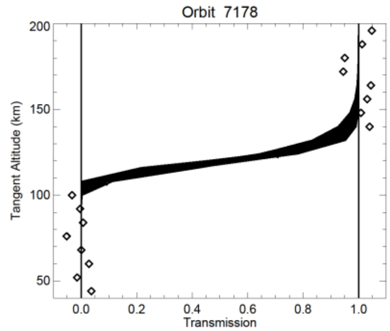

Figure 2. Transmission function for orbit 7178 (diamonds) and The enveloppe of 1000 fits obtained using gaussian random changes in the measured value of the transmission function

3. Effect of the global dust storm and systematic source of errors

The altitude where the slant CO_2 optical thickness is equal to 1 is shown in Figure 3a for the full set of observations. The two free parameters of the fit (Temperature and CO_2 density at 110 km) are compared to the values from the Mars Climate Database (red) (Figure 3b, 3c). The temperature uncertainty is large and the variations could be due to the noise. If we assume a constant average temperature during all the periods, the CO2 density at 110 km (Figure 3d) follows the altitude of the absorption.

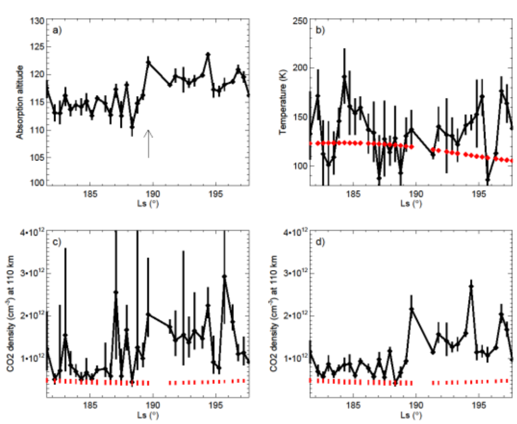

Figure 3 Variations of the CO_2 absorption altitude (km), defined as the altitude where the slant CO_2 absorption optical thickness at Lyman-α is equal to 1 with the orbit number of MAVEN. b) derived temperature for each orbit from the CO_2 scale height. c) variations of the CO_2 density with the orbit number of MAVEN considering the temperature derived from the fit. d) Same as c) but using a same temperature of 133 K for all orbits. Values at the same latitude/local time from the MCD are shown in red.

An increase of the altitude of the absorption layer from 114.5±0.5 km (before Ls = 189°) to 119.0±0.5 km (after Ls = 189°). No temperature variations is detected while an increase of the CO_2 density of 1.9±0.2 is derived. This increase is probably due to an expansion of the Martian atmosphere driven by the heating of the lower atmosphere by the global dust storm. Several assumptions can lead to systematic errors in the derived values. The uncertainty from the isothermal assumption has been estimated using profiles from stellar occultation or MCD, and its effect on the altitude of absorption is estimated to less than 2 km. The uncertainty on the pointing could shift the absorption altitude by few km but if this error is systematic it should not change the shift in altitude observed near 8 June 2018.

4. Summary and Conclusions

A increase by 4.5±1 km of the altitude of the Lyman-α absorption layer is observed on 8 June 2018. At this time an increase of the dayglow peak altitude was also observed at the dayside near MAVEN periapsis and the CO_2 density increase is also detected by the NAVCAM instrument. This increase is due to the heating of the lower atmosphere during the global dust storm. This analysis confirms the global effect of the PEDE on the nightside thermosphere of Mars at altitudes not sampled by other instruments and will provide additional constraints to better understand the dynamics and heating distribution associated with such events. It also confirms the possibility to derive quantitative information on the CO_2 density from Lyman-α absorption at the nightside.

Acknowledgements

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