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Seasonal density variations in the Martian thermosphere from observations of UV dayglow by MAVEN/IUVS

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1. Introduction

Satellite observations of the Martian UV dayglow spectrum started with the UV spectrometer on board Mariner 6 and 7 (flybys) and the Mariner 9 orbiter, followed by SPICAM on Mars Express. Two Martian years of ultraviolet dayglow observations by the Imaging Ultraviolet Spectrograph (IUVS, [1]) on board the Mars Atmosphere and Volatile EvolutioN mission (MAVEN) are now available. The CO Cameron bands range from 170 nm to 270 nm and correspond to the forbidden transitions from the excited a $^3\Pi$ state to the X $^1\Sigma$ ground state of CO. The CO_2^+ ultraviolet doublet (UVD) emission at 298 and 299 nm and corresponds to the (B $^2\Sigma \rightarrow$ X $^2\Sigma$) transition. Therefore, the study of the variations of their vertical distribution is a valuable source of information about the CO_2 distribution at and above 120 km and its variations. Similarly, the sources of the OI dayglow emission at 297.2 nm are directly dependent on CO_2. This emission presents two peaks located near 80 and 120 km [2]. The atomic oxygen multiplets at 130 and 136 nm were shown to also vary depending on the Martian season and dust load [3]. The observations show a strong time, seasonal and latitudinal variability of all four emission vertical distributions. In this talk, we combine the IUVS data and model simulations for these emissions to draw a global picture of the changes that affected the gas distribution during the period 2014-2019.

2. Observations and data analysis

IUVS started collecting data in September 2014 and continues to operate up to now. It observes the day- and nightside emissions from the Martian upper atmosphere in the spectral range 115-340 nm with a spectral resolution of 1.2 nm (Fig. 1). A maximum of 12 successive limb scans is collected during the 22 minutes of the periapsis phase. Limb observations used in this study were collected on the dayside between October 18 2014 and June 2018. They extend over a total period of two Martian years, from the southern summer in year 32 till southern summer of year 34. These data provide an unprecedented dataset, covering a wide range of latitudes and local times. We present analysis of periapsis limb observations with tangent point altitudes between 80 and 200 km using data available on NASA's Planetary Data System (PDS).

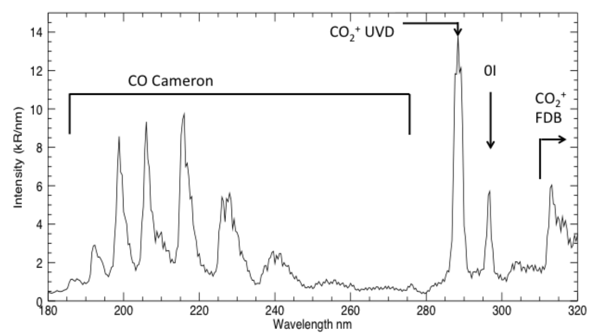

Figure 1: average of 330 ultraviolet spectra based on limb scans collected with IUVS/MUV between 115 and 125 km during October 2015. The positions of the Cameron, CO_2^+ UVD and FDB bands and the OI 297.2 nm emissions are indicated.

Following background subtraction and multiple linear regression of the spectral components, mean limb profiles (example in Fig. 2) of the different emissions have been assembled by grouping the observations into 10° of Ls and 10° of latitude to build seasonal–latitudinal maps of the altitude of each dayglow emission. Model simulations of the observed limb profiles have been performed using a model combining the various sources of CO (a$^3\Pi$), CO_2^+ (B$^2\Sigma$), O(^{1}S), O(^{3}S) and O(^{5}S) excited states. These sources include resonance scattering of solar photons, photoionization and photodissociation, collisions by photoelectrons and chemical reactions.

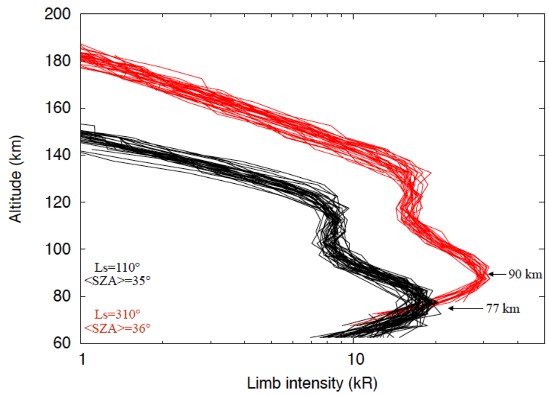

Figure 2: examples of two sub-groups of limb scans for OI 297.2 nm at two different seasons, but nearly equal solar zenith angles [2].

A radiative transfer code is used in the case of the optically thick OI 130 nm emission. The situ solar flux measured by the Extreme UV Monitor (EUVM, [4]) on board MAVEN and the neutral densities from the Mars Climate Database (MCD) are used for these calculations.

3. Results

Our simulations demonstrate that the peak altitudes of the CO_2^+ UVD, the Cameron bands and the OI 297.2 nm emissions are good proxies of the amount of CO_2 above the emission peaks. In particular, the peak altitudes Z_M of the UVD, Cameron and 297.2 nm emissions are directly controlled by the slant CO_2 column density overlying the emission peaks. The characteristics of the OI 130 and 135 nm profiles depend on both the O and the CO_2 distribution [3]. We take advantage of this feature, combined with the unprecedented quality and coverage of the IUVS limb observations, to map the variations of these emissions observed during the 4 years of the MAVEN mission. In particular, we present the parallel seasonal variations of Z_M as a function of latitude and local time of the different emissions. An example for the Cameron and UVD emissions is shown in Fig. 3. We demonstrate that the changes of altitude Z_M of different isobar levels co-vary and result from both seasonal surface-atmosphere exchanges and atmospheric dust load following global dust storms. In general, the MCD CO_2 density requires only minor scaling to match the observations.

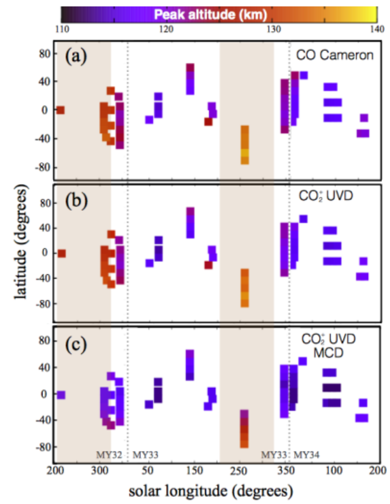

Figure 3: Seasonal-latitudinal map of the peak brightness altitude as a function of Martian season (L_S) for solar zenith angles <40°: (a) observed Cameron bands, (b) CO_2^+ UVD, (c) simulated CO_2^+ UVD with MCD neutral densities. The brown shaded areas indicate the dust seasons (220°<Ls<310°).

Acknowledgements

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