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Martian thermosphere scale height from SPICAM dayglow measurements

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Abstract

We analyze the ultraviolet dayglow in the atmosphere of Mars through CO_2^+ and CO Cameron emissions. These emissions are accumulated on a large dataset of dayside grazing limb performed by the Spectroscopy for Investigation of Characteristics of the Atmosphere of Mars (SPICAM) instrument on board the Mars Express spacecraft. The temperature of the Martian upper atmosphere can be retrieved from these limb emission profiles. We present discussion on the validity domain for such retrieval. We also show evidence for local (spatial and temporal) variability in the scale height of the atmosphere at the altitude of these emissions.

1. Introduction

The Mariner 6 mission, as early as the 1970's, performed the first observations of the CO_2^+ and CO Cameron ultraviolet emissions in the dayside of Mars [1]. The CO_2^+ emission at 289 nm arises from the relaxation of the CO_2^{+*} molecule in the $B^2\Sigma^+$ state to the $X^2\Pi$ state. CO_2^+ ($B^2\Sigma^+$) molecules are produced mainly in the dayside of Mars through photoionisation (1), photoelectron impact (2) and fluorescent scattering (3), as following [2,3,4]:

$$CO_2 + h\nu \rightarrow CO_2^+\left(B^2\Sigma_u^+\right) + e^- \quad (1)$$
$$CO_2 + e^- \rightarrow CO_2^+\left(B^2\Sigma_u^+\right) + 2e^- \quad (2)$$
$$CO_2^+\left(X^2\Pi_g\right) + h\nu \rightarrow CO_2^+\left(B^2\Sigma_u^+\right) \quad (3)$$

The CO Cameron bands range from 170 nm to 270 nm and correspond to the forbidden transitions of CO molecules excited into the $a^3\Pi$ state to the ground state. CO molecules are excited to the $a^3\Pi$ state following electron impact (4), photoelectron dissociative impact (5), photodissociation (6) and dissociative recombination (7) [4,5,6]:

$$CO + e^- \rightarrow CO(a^3\Pi) + e^- \quad (4)$$
$$CO_2 + e^- \rightarrow CO(a^3\Pi) + e^- + O^* \quad (5)$$
$$CO_2 + h\nu \rightarrow CO(a^3\Pi) + O^* \quad (6)$$
$$CO_2^+ + e^- \xrightarrow[8.3\ eV]{} CO(a^3\Pi) + O \quad (7)$$

2. Observations

The Spectroscopy for Investigation of Characteristics of the Atmosphere of Mars (SPICAM) instrument on board the Mars Express spacecraft collected dayside airglow ultraviolet emissions of the CO Cameron bands and the CO_2^+ doublet in the Martian atmosphere. Its ultraviolet domain ranges from 118 nm to 320 nm and therefore fully covers the range of the CO Cameron and CO_2^+ emission bands. Among a very large amount of limb profiles obtained since 2004, a subset makes it possible to derive the temperature of the Martian atmosphere from the emission topside scale height [7].

3. Achievements

Limb profiles scale heights are determined by fitting the topside of the profile with an exponential function. We discuss conditions for the scale height derived from CO_2^+ and CO Cameron limb profiles to represent the neutral atmosphere scale height. These conditions are met above the homopause and for altitudes where processes (3) and (7) and negligible compared to other processes that populate $CO(a^3\Pi)$ and $CO_2^+(B^2\Sigma^+)$. Volume emission rate associated with processes (3) and (7) are calculated [8,9,10] and compared to total CO_2^+ ($B^2\Sigma^+$) and CO Cameron ($a_3\Pi$) volume emission rate calculated by atmospheric model [12]. Comparisons with other studies at different solar activities using different

techniques as well as the latest MTGCM-MGITM modeling [13] are also discussed.

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