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SPICAM observations of thermospheric airglow during the 2007 dust storm

N. Schneider (1), M. Chaffin (1), D. Everding (1), F. Leblanc (2), J. Y. Chaufray (2), F. Montmessin (2), J.-L. Bertaux (2) and the SPICAM team
(1) Laboratory for Atmospheric and Space Physics, Boulder, Colorado, USA (nick.schneider@lasp.colorado.edu), (2) LATMOS/IPSL, Guyancourt, France

Abstract

In 2007 (Mars Year 28), Mars experienced a global dust storm. Previous studies have reported large changes in the H Lyman alpha coronal airglow during this period, corresponding to a large decrease in H escape fluxes during the declining phase of the dust storm. Here we present airglow measurements of CO Cameron band and CO_2^+ UV Doublet emission in the thermosphere from 2007 data gathered by the SPICAM (SPectroscopy for the Investigation of the Characteristics of the Atmosphere of Mars) instrument on Mars Express. During the dust storm period in late 2007, lower atmospheric temperatures were enhanced, pushing the thermosphere to higher altitudes. At the same time, more intense UV heating resulting from the perihelion passage of Mars resulted in extended upper atmospheric scale heights. We compare our retrievals and techniques to previous studies, which found no enhancement in thermospheric scale heights during this period.

1. SPICAM Observations of the Thermosphere

The SPICAM instrument on Mars Express is an imaging ultraviolet spectrograph that observes in the far and mid UV from $118-320$ nm (Bertaux et. al. 2006). The instrument has a focus on stellar occulations, but also performs thermospheric limb scans and nadir observations. In limb mode, the instrument observes the characteristic airglow spectrum of Mars (Figure 1), whose most conspicuous features in the mid-UV are the CO Cameron bands (180-260 nm), and the CO_2^+ UV doublet (289 nm). These features reveal thermospheric properties, with the UV Doublet diagnosing the neutral CO_2 scale height and the CO Cameron bands reflecting a larger scale height that is a blend of thermal and nonthermal emission sources. Previous studies, including most recently Stiepen et. al. (2015), have examined the time evolution of the scale height and peak altitude of these features. Unfortunately, the need to share observing time with other Mars Express instruments, and difficulties in the instrument data analysis introduced by stray light and detector high voltage spikes often limit the useful dataset, making observations sparse. As a result, these previous studies have extracted limited information about the thermosphere, particularly in the 2007 dust storm year. In addition, these previous studies found no large differences between 2007 and other years, despite the presumably large influence of the dust storm. This motivates our independent study of the dataset.

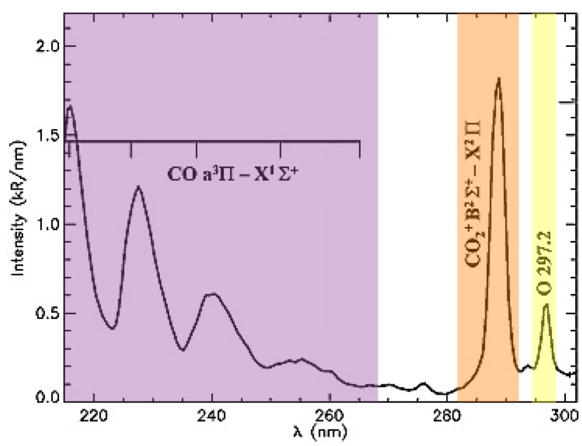

Figure 1: Mid-UV airglow of Mars, adapted from Leblanc et. al. (2006).

2. Retrieving Thermospheric Properties

To extract thermospheric peak altitudes and scale heights from the dataset, we employ a multiple linear regression technique. In this method, individual reduced spectra are fit by scaling input model spectra by linear coefficients, and summing the models together. For model spectra we use a Cameron band model convolved and binned to the instrument resolution (Stevens et. al. 2015), a solar spectrum extracted from nadir observations made by SPICAM, and Gaussians at the location of the UV Doublet and OI 297.2 nm feature. We also include a linear component to account for dark subtraction offsets and large-scale stray light features.

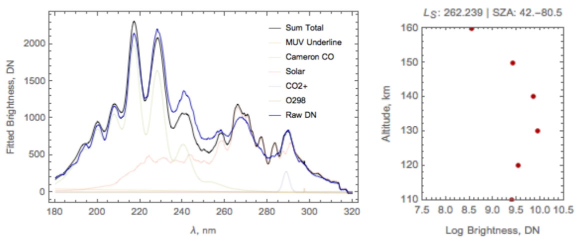

Figure 2: (a) Example SPICAM spectrum and multiple linear regression fit, showing composite fit and fitted components. (b) Retrieved altitude profile of CO Cameron band emission for a single limb scan. Each point represents the Cameron band fit component to the average SPICAM spectrum for surrounding altitudes.

An example fitted spectrum is shown in Figure 2a. Our method does a resonable job of reproducing the data, with offsets in the vicinity of $240 - 260$ nm potentially caused by poor knowledge of the solar stray light at this location. Applying this technique to multiple spectra from a given limb scan produces intensity altitude profiles (Figure 2b), which can then be fit to extract a peak altitude and scale height.

3. Response of the Thermosphere in 2007

By applying our fit procedure across 2007, we produce peak altitudes and scale heights for both the Cameron bands and the CO_2^+ UVD, shown in Figure 3. We see an increase of the peak altitude by over 10 km, centered on Southern summer solstice and declining approximately linearly on either side of the peak. Scale heights are more peaked, with a linear increase from 15 km near L_s 200 to 30 km near L_s 300, and a steep decline following the peak. These observations have implications for the structure and variability of the thermosphere and the upper atmospheric environment underlying the large variability in the H corona, which we will discuss more fully in our presentation.

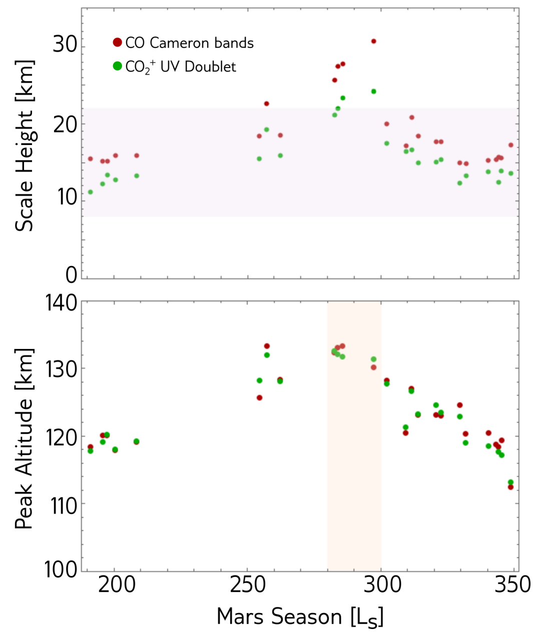

Figure 3: Retrieved peak altitudes and scale heights of thermospheric emissions at Mars in 2007.

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