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Exospheric temperatures at Mars measured by SPICAM: seasonal trends

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Abstract

A new analysis of the airglow spectra recorded by the UV spectrometer SPICAM onboard Mars Express is presented, with emphasis on the CO Cameron bands, the CO_2^+(B–X) UV and O I (2972Å) emissions. Exospheric/thermospheric temperatures are retrieved from the individual dayglow altitude profiles using a direct fit of the emission profiles by a set of barometric and Epstein functions and by adjusting the forward kinetic transport model *Aeroplanets* to fit the emission profiles. It is suggested that the CO_2^+ emission is the best candidate for an accurate retrieval of exospheric temperatures. Variations with solar longitude of the exospheric temperatures are investigated by the MTGCM global circulation model and compared with the observations. Reasonable agreement with observations is found for solar longitudes ranging from 140° to 300°, for solar minimum to moderate conditions.

1. Context

Since the 1990s, several missions have successfully reached the orbit of Mars, improving the knowledge of its space environment. One of the important discoveries is the large variability of the Martian thermosphere density with the solar longitude (see [1]). For future missions, a good knowledge of the atmospheric parameters is necessary (e.g., for accurate landing).

As of 2004, the UV spectrometer SPICAM onboard ESA Mars Express has been observing the Martian dayglow and nightglow [2]. The Cameron bands of $CO(a^3\Pi - X^1\Sigma)$, present in the range 1800–2500Å, the most prominent feature of the Martian dayglow spectrum [3], the $CO_2^+(\tilde{B}^2\Sigma - \tilde{X}^2\Pi)$ doublet around 2890Å and $O(^1S - ^3P)$ at 2972Å, are clearly seen in the SPICAM spectrum. All three emissions are candidates for being good tracers of the CO_2 density profiles ([4, 5]). A way to test these assumptions is to derive from altitude profiles of these emissions their characteristic scale height H and thus their associated exospheric temperatures. Above the altitude peak of the emissions (typically 140 km altitude), the scale height retrieved from dayglow emissions should be close to that of their respective parent neutral density [6] if no vertical winds are present.

2. Analysis and discussion

2.1. SPICAM analysis/kinetic modelling

New analyses of SPICAM dayglow profiles (2004–2006) of the three main emissions mentioned above are performed with the removal of the solar spectrum contamination for the CO_2^+ doublet and OI(2972).

The resulting altitude profiles are more accurate, especially at altitudes lower than 100 km where solar contamination may maximise. Adequate discretisation of the altitude profiles versus solar longitude Ls, solar zenith angle and latitude is performed in order to facilitate the comparison with GCM models.

In parallel, the kinetic model *Aeroplanets* (see for instance [4, 7, 5] for full descriptions) is used in combination with inverse techniques to reproduce the observed emissions: the exospheric temperatures are deduced directly from the neutral CO_2 profile deduced from a fit to the observations.

2.2. Global circulation model simulations

MTGCM simulations of exospheric temperatures ([8]) are performed to compare with the observations. MTGCM couples two codes: the NASA Ames MGCM (0–90 km) and the NCAR-Michigan MTGCM (70–300 km), linked across an interface at 1.32-μbar on a regular $5 \times 5°$ grid. The vertical resolution is $\frac{1}{2}H$. Adjustables are the F10.7 (70 to 200), the solar longitude, dust opacities and heating efficiencies (in the range 19–22%) [9]. Solar EUV-UV fluxes are taken from Solar2000 or the FISM model.

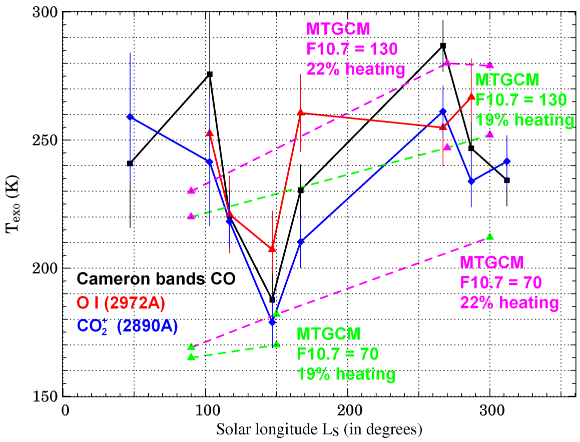

Figure 1: Variation with solar longitude of SPICAM retrieved exospheric temperatures.

2.3. Preliminary results

Figure 1 summarises the preliminary results of this study. SPICAM observations are shown in solid lines, while MTGCM simulations are shown in dashed lines. Reasonable agreement is seen between observations and simulations, showing a similar trend.

The best line to derive realistic exospheric temperatures is found to be CO_2^+ as the main excitation processes are photoionisation and electron impact ionisation of CO_2. In contrast to CO Cameron bands, electron recombination does not play an important role, which explains the discrepancies between Cameron band and CO_2^+ results when reconstructing exospheric temperatures. When comparing SPICAM reconstructed exospheric temperatures to MTGCM results, the seasonal trend is well reproduced overall, except in the Ls range 40–100°. New observations from SPICAM might clarify this issue in order to get a better signal-to-noise ratio and a better orbit sampling with respect to F10.7. At the altitudes considered between 130 and 180 km, the isothermal behaviour of the atmosphere may not always be reached.

3. Summary and Conclusions

Observing exospheric temperatures at Mars has a great impact on the understanding of the planet (evolution of the atmosphere, seasonal and spatial variabilities, etc.). Mars Express SPICAM/UV is reliable in deriving consistent estimates of these temperatures, but faces some problems: the technique used is accurate only between 130 and 180 km, and the current fitting techniques show that the density profile could be non-isothermal in this altitude range. When this is the case, the result is an inaccurate estimate of exospheric temperatures. Simulations including MTGCM and transport kinetic models in combination with inversion techniques are currently performed to study this issue in more detail. It is therefore of great importance that new missions, such as NASA MAVEN, measure these altitudes.

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