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Oxygen dayglow observations on Mars by SPICAM IR on Mars-Express

S. Guslyakova (1,2), A. A. Fedorova (1,2), Lefevre F. (3), O. I. Korablev (1,2) , F. Montmessin (3), J.-L. Bertaux (3).
(1) Space Research Institute RAS, Russia, Moscow ; (2) Moscow Institute of Physics and Technology (MIPT), Russia, Dolgoprudniy; (3) LATMOS – UVSQ/UPMC/CNRS, France, Guyancourt; (guslyakova@iki.rssi.ru)

Abstract

$O_2(^1\Delta_g)$ dayglow at 1.27 µm reflects the ozone distribution in the Martian atmosphere as a result of ozone photolysis by solar UV radiation. SPICAM IR on Mars-Express performed continuous observations of the O_2 dayglow at limb and nadir from 2004 to 2012 with resolving power of 2200. The results of $O_2(^1\Delta_g)$ observations have been compared with LMD GCM simulation [1-3] to study its seasonal variations and sensitivity to kinetic parameters.

1. Introduction

The ozone is one of the most reactive species of the Martian atmosphere [2-3]. As is known, O_3 is destroyed by odd hydrogen thereby it can be a sensitive tracer to HO_x species. Ozone concentration has been considered to anticorrelate with water vapor abundance that was observed in the Earth atmosphere. Study of temporal and space ozone variability along with water vapor variability is necessary to improve photochemical models which have to explain the CO_2 atmosphere stability phenomenon.

2. The $O_2(^1\Delta_g)$ dayglow on Mars

Oxygen dayglow at 1.27 µm is produced during the following reactions:

$$O_3 + h\nu \rightarrow O(^1D) + O_2(a^1\Delta_g) \qquad (1)$$

The excited oxygen then can be deactivated through an emission at wavelength of 1.27 µm :

$$O_2(a^1\Delta_g) \rightarrow O_2(X^3\Sigma_g) + h\nu$$

or collision:

$$O_2(a^1\Delta_g) + CO_2 \rightarrow O_2(X^3\Sigma_g) + CO_2 \qquad (2)$$

3. The instrument

SPICAM IR spectrometer works on the principle of acousto-optic tunable filter and covers the spectral range of 1-1.7 µm with relatively high resolving power of 1800-2400 [4]. The instrument operates in several modes – nadir and limb observations and solar occultations. Field of view of the SPICAM IR spectrometer is 1°. The FOV projection on limb corresponds to 25-100 km depending on the distance to limb. The spectral power at 1.27 µm is 2200.

4. Observations

4.1 O_2 limb observations

From January 2004 to June 2012 about 600 limb observations in IR range have been performed but only 102 observations were useful for subsequent analysis. To compare observed slant emission rate with modeling results, the O_2 dayglow vertical profiles from GCM [2-3] have been integrated for limb geometry using the Abel transform and convolved with SPICAM vertical resolution for each observation.

Figure 1 presents a seasonal variation of the height mean relation of the observed and modelled O_2 dayglow vertical distribution at limb $\sum_z(N_{mod}(z)/N_{obs}(z))/n$, where n is a number of target altitudes for a vertical profiles. The relation shows a seasonal trend from northern vernal (L_s=0°) to autumnal equinox (L_s=180°) in the high northern latitudes with underestimation of the emission by the model from L_s=0° to L_s=50° and an overestimation from L_s=60° to L_s=150°.

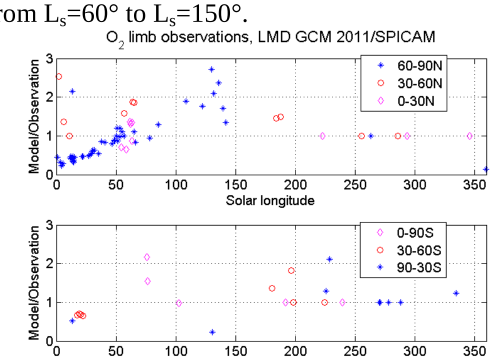

Figure 1: Mean relation of modeled and observed O_2 slant emission rate profiles for different latitudes.

The explanation of such disagreement could relate to the vertical distribution of water vapor. The recent observations of the vertical distribution of H_2O by SPICAM have shown an presence of unexpected amount of water above 30 km at high altitudes at Ls=60-100° in the middle and high northern latitudes [5] that have to decrease the ozone abundance. The GCM modelling of water cycle with supersaturation shows a good agreement with SPICAM data (Fig.2).

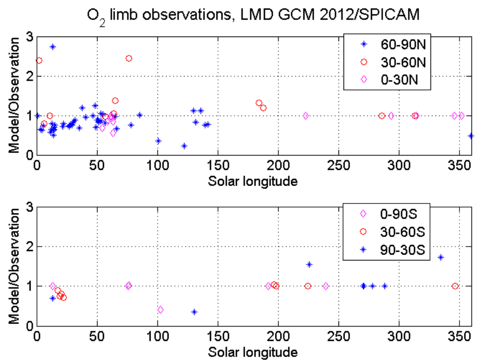

Figure 2: The same as for Figure 1 but for the modified water cycle with the H_2O supersaturation.

4.2 O_2 nadir observations

The nadir observations of O_2 dayglow by SPICAM have been first presented in [6]. Currently a seasonal distribution of the O_2 dayglow has been obtained for 4 Martian years based on SPICAM IR nadir measurements (Fig. 3).

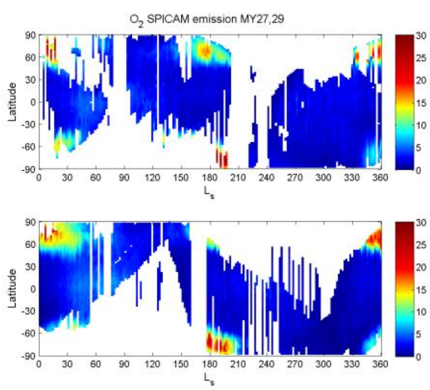

Figure 3: Seasonal distribution of the O_2 emission [MR] observed by SPICAM (MY27, MY29).

Using LMD GCM simulations of O_3 and the geometry of SPICAM observations we can retrieve model O_2 dayglow maps through the following expression:

$$4\pi I(MR) = 10^{-12} J \int_0^\infty \frac{[O_3]dz}{1+\tau k[CO_2]},$$

where 1R = 10^6/photon cm^{-2} s^{-1}(4π ster)$^{-1}$, k is a rate constant for the reaction of collisional deactivation; τ is a radiative lifetime of the $O_2(^1\Delta_g)$.

A quenching rate k of $O_2(a^1\Delta_g)$ by CO_2 (Eq.2) is known with a large uncertainty. Varying this parameter we can choose a value for k in case of which a model map will provide a good agreement with the most part of the SPICAM observations in a rms sense (Fig.4).

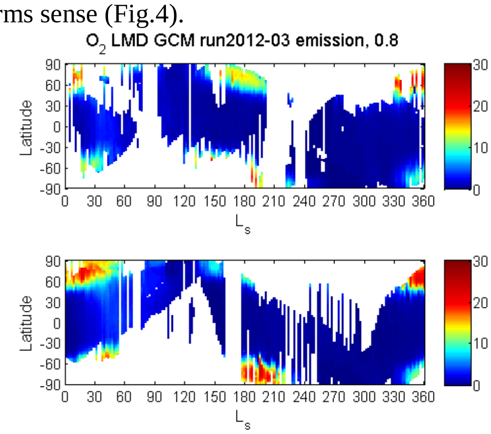

Figure 4: Seasonal distribution of the O_2 emission based on LMD GCM, quenching rate of $O_2(a^1\Delta_g)$ by CO_2 k = 0.8*10^{-20}cm^{3}molec^{-1}sec^{-1}.

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