THE O_2 DAYGLOW OBSERVATIONS WITH THE SPICAM IR EXPERIMENT ON MARS-EXPRESS.

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Introduction:

Ozone is one of the most chemically reactive species of the Martian 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. The point is that solar UV radiation dissociates CO_2 into CO and O, but their recombination is a very slow process in comparison with O recombination into O_2. So, O_2 and CO concentrations are expected to be higher than those that were measured. A stably high CO_2 concentration maintenance is associated with a chemistry involving "odd hydrogen" species (H, OH, HO_2…), as OH can easily react with CO, thus forming CO_2 [1]. These "odd hydrogen" species, with the exception of H_2O_2, had not been directly observed yet. As is known, O_3 can be destroyed by odd hydrogen thereby it can be a sensitive tracer to HO_x species.

Observations:

The SPICAM IR spectrometer onboard Mars express mission, launched in 2003, is capable to measure ozone concentration in the Martian atmosphere using observations of O_2 molecule emission at 1.27 µm [2].

It covers the spectral range of 1-1.7 µm with spectral resolution of 0.5-1.2nm. The field of view of the spectrometer in the nadir-limb mode is 1° that corresponds to 15-100 km for limb observations depending on the distance to limb and ~5 km near the pericenter in nadir.

In this work we present results of limb and nadir observations of the O_2 emission and vertical retrieval of ozone profile based on SPICAM IR data. In the limb observation mode spacecraft scans a disc of the planet, its orientation remaining in an inertial attitude. From January 2004 to April 2010 there were made about 600 limb observations in IR range, but only 105 of them were analyzed, as most part of observations were made as a full spectrum with a low sampling. In case of nadir all dataset from 2004 to 2010 has been analyzed.

O_3 photolisys:

Ozone can photodissociate in the following reactions:

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

$O_3+h\nu \rightarrow O(^3P)+O_2(X^3\Sigma_g)$ (2).

The effectivity of the first reaction is equal to 90%. Photodissociation rate coefficient depends on the solar flux value, solar zenith angle, temperature [3].

For the radiative lifetime we have used the value τ = 4566s [4].

Excited O_2 molecule can be deactivated through emission:

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

or collision:

and $O_2(a^1\Delta_g)+CO_2 \rightarrow O_2(X^3\Sigma_g)+CO_2$. (4)

Emission (3) occurs at the wavelength 1.27µm and 1.58µm, though the second is 45 weaker while being measured in the laboratory.

For the rate constant of deactivation through collision with CO_2 we have used a value

$k = 10^{-20} cm^3 molecules^{-1} s^{-1}$[5].

The O_2 intensity in MR can be expressed as:

$$4\pi I(MR) = 10^{-12} J \int_0^\infty \frac{[O_3]dz}{1+\tau k[CO_2]}, \quad (5)$$

Vertical distribution of the O_2 emission and O_3

The retrieval of the O2 on limb based on an algorithm presented in [6] but with some key modifications. To receive the intensity of the O_2 emission in the 1.27µm band we should take into account some spectral features in this range such as solar Fraunghofer line at 1262, 1268 and 1268nm, CO_2 ice absorption at 1262-1269nm.

Ozone profile can be retrieved from O_2 emission slant profile (Eq. 5) using Abel inversion scheme. To decrease an amplification of the noise of obtained profiles we have used a Tikhonov regularization algorithm (for more details see [7]).

Some examples of retrieved O_3 profiles are shown on the Figure 1 and 2.

Seasonal distribution of the O_2 emission:

We present also the results of O_2 emission observations by SPICAM IR [6] for 3.5 Martian years (Fig.3) from January 2004 (MY26) to November 2010 (MY30). The year-to-year variations of the O_2 dayglow could relate to the local time variations during the observations as well as true seasonal variations of ozone.

As it was mentioned above (Eq. 5), the O_2 emission can be expressed through O_3 concentration, O_2 radiative lifetime and rate constant k of deactivation through collision with CO_2. The latter is known with great uncertainty. To constrain this constant we have made a theoretical O_2 emission map for the same latitudes, longitudes, local times and solar longitudes base on LMD GCM model (version 4.3) as at those SPICAM observations were made [3,8]. A detailed comparison of these two maps can give us a restriction on the value of the rate constant of deactivation ($k<0.5*10^{-20}cm^3$ molecules^{-1} s^{-1}).

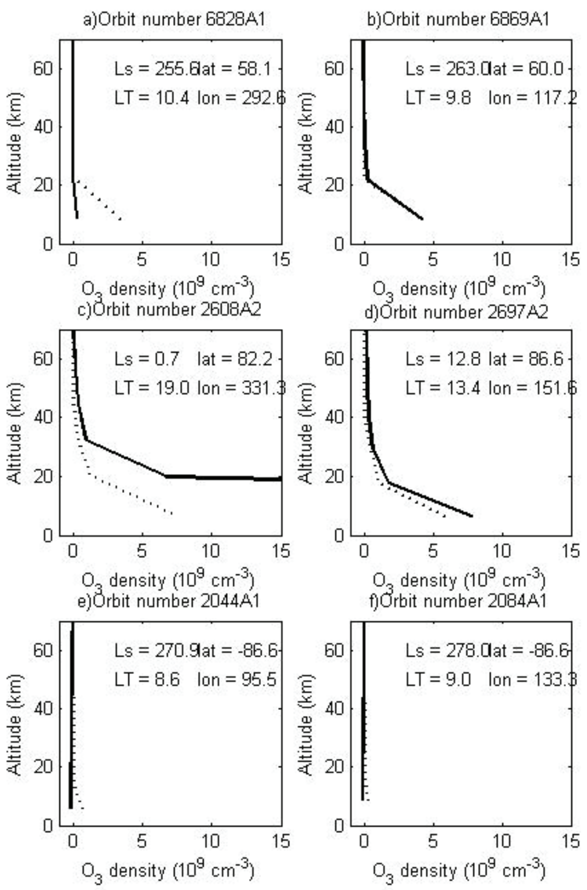

Figure 1. Comparison of observed (solid line) and modeled(dashed line) ozone vertical profiles for perihelion period(a,b), for high northern latitudes during vernal equinox(c,d), for high southern latitudes during winter solstice(e,f).

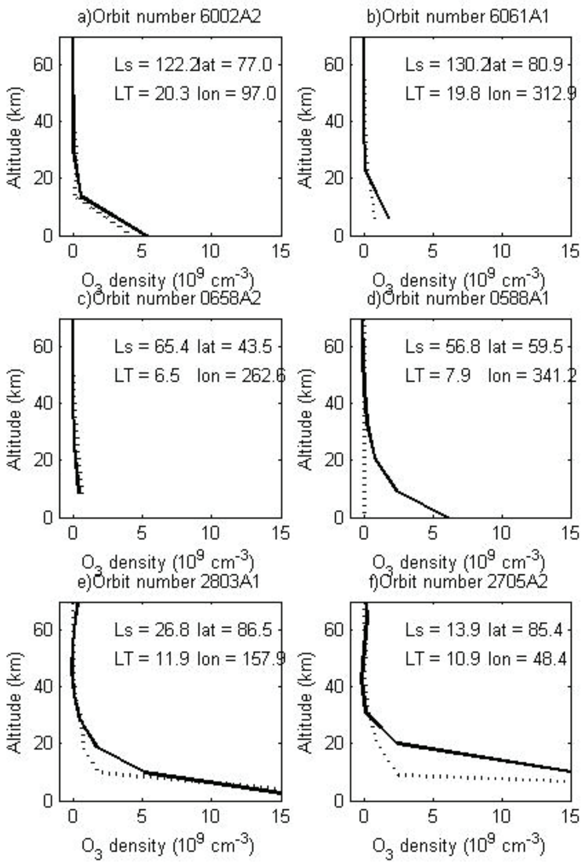

Figure 2. Comparison of observed(solid line) and modeled(dashed line) ozone vertical profiles for high northern latitudes in summer(a,b), for mid northern latitudes in spring(c,d), for high northern latitudes in spring(e,f).

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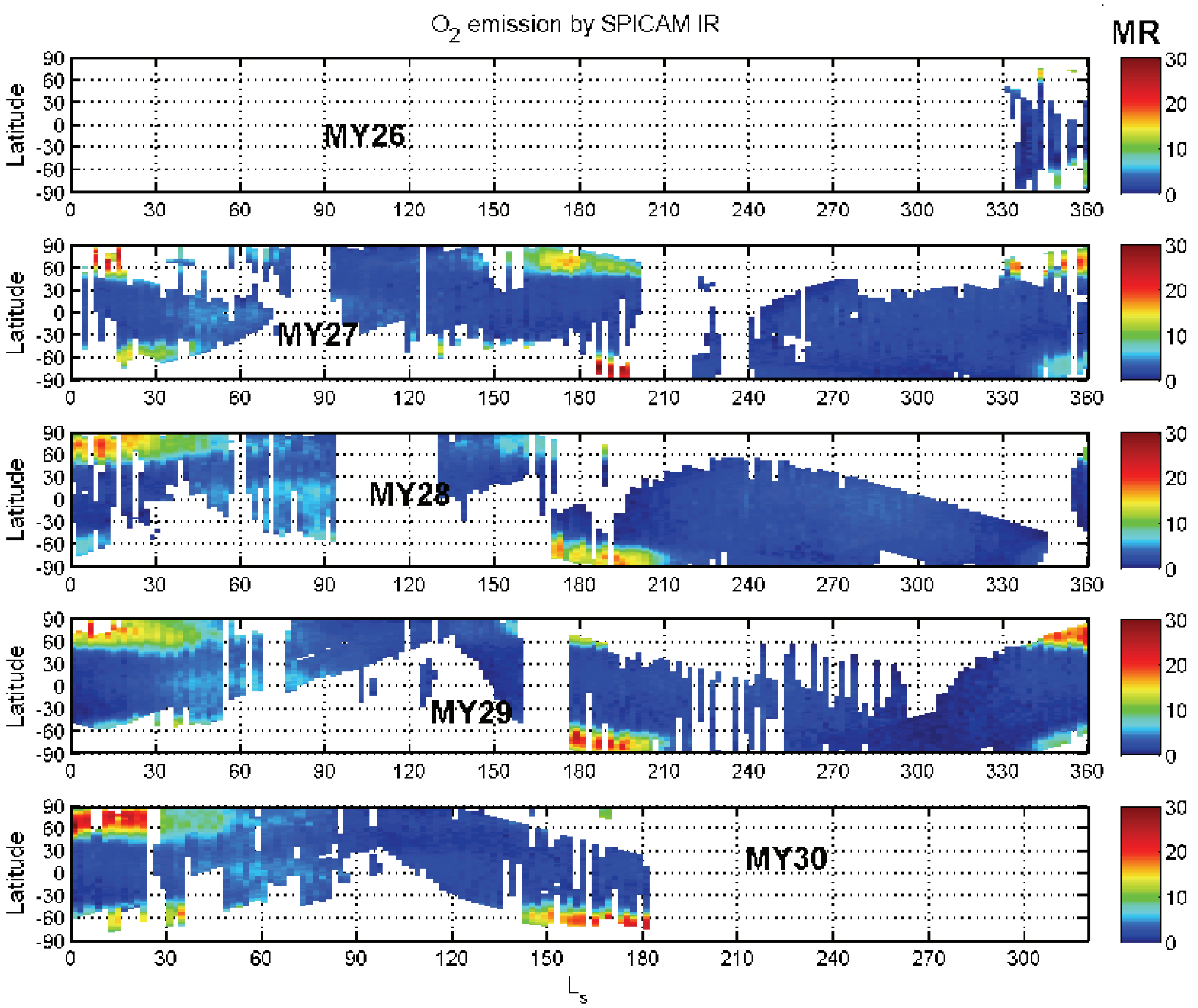

Figure 3. Seasonal distribution of the O_2 emission observed by SPICAM from L_s 330° MY26 (January 2004) to L_s 120° MY30 (November 2010).