EPSC Abstracts
Vol. 6, EPSC-DPS2011-1223, 2011
EPSC-DPS Joint Meeting 2011

Martian O2 dayglow at 1.27 µm and atmospheric waves

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Abstract

Atmospheric waves on the southern polar regions (-80° < LAT < -60°) traced by the O2($a_1\Delta_g$) airglow at 1.27 µm have been detected on the OMEGA nadir maps. During the day O2($a_1\Delta_g$) excited molecules are produced by the photolysis of ozone. They are deactivated by radiating most of the photons at λ = 1.27 µm or through collisions with CO2 molecules (quenching) for altitudes < 20-26 km where this process is dominant. In this paper we investigate the role of the CO2 quenching in the observed airglow intensity fluctuations and the hypothesis that the detected wave patterns trace gravity waves (GWs) activity.

1. Data Set and Method

1.1 Nadir maps

Following detections in isolated OMEGA observations [1, 2, 3], a detailed method has been applied for searching waves in the OMEGA data acquired on the southern polar region in nadir mode during late winter/early spring Martian Year (MY) 28, Ls from 170.7° up to 182.1°, for a total of 16 OMEGA cubes (see Table 1). To search for waves, mean profiles of the O_2 emission along the Y and X directions of OMEGA maps have been computed, binning the data in boxes 5×5 pixel wide. For each profile, we consider a wave to be detected when the following conditions occur: (1) presence of 2 local maxima and 2 local minima; (2) $O_2(a^1\Delta_g)$ emission intensity of the minima ≥ detection limit; (3) difference between the maxima and the minima ≥ $G_0 + 2\sigma$, where G_0 and σ are respectively the center and the standard deviation of the Gaussian fit applied to the standard deviation histogram of the mean profiles. The $G_0 + 2\sigma$ limit ranges between 1 and 2 MR (1 R = 10^6 photons cm^{-2} s^{-1} $(4\pi$ sr$)^{-1}$).
Waves appear preferentially at high incidence angles, show spatial scales ranging from 50 to 150 km and amplitudes from 1 to 4 MR in intensity. In Figure 1 an example is shown.

Table 1: List of the OMEGA cubes used in this study.

Cube Num.	LS Degree	DELTA (MR App.)	Sp. scale (km)
3908_0	170.654	2-4	100
3917_0	172.038	2-4	100
3935_0	174.822	-	-
3939_0	175.444	-	-
3944_0	176.225	1-3	80-100
3947_0	176.693	2-3	80-130
3953_0	177.633	1	50-80
3960_0	178.731	1-2	50-100
3961_0	178.889	1-2	70-100
3962_0	179.046	1-2	70-110
3966_0	179.676	2-4	70-100
3972_0	180.623	2-4	70-150
3974_0	180.940	1-2	60-90
3975_0	181.098	1	50-80
3978_0	181.575	1	50-70
3981_0	182.050	1	50-80

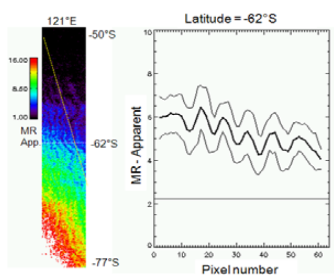

Figure 1: $O_2(a^1\Delta_g)$ map for cube num. 3953_0 (left panel). The yellow dotted line shows the location of the terminator for the considered observation. The white dotted line indicates where the $O_2(a^1\Delta_g)$ emission intensity profile shown on the right panel has been extracted.

1.2 Limb profiles

OMEGA can also operate in limb mode. Although no limb profiles where acquired during the considered period, the limb was scanned during the northern early spring (orb. 2648, Ls = 6°) at 45° N, when the amount of O_3 detected by SPICAM [4] is comparable to the one observed at Ls = 180° between 60° and 80°S. In orb. 2648 the emitting layer is between 15 and 35 km. We used this normalized vertical profile to retrieve the O3 limb profile corresponding to a nadir integrated $O2(a_1\Delta_g)$ intensity of 3 MR. We apply the formula:

$$\alpha\ [O3] = [O2(a^1\Delta_g)]/\tau + k\ [O2(a^1\Delta_g)]\ [CO2] \quad (1)$$

where the square brackets indicate the number density for the given species; α is the rate constant of the reaction O3 +hν → O + $O2(a^1\Delta_g)$, it varies with the heliocentric distance, being 1.5×10^{-3} sec^{-1} at the aphelion and 2.2×10^{-3} sec^{-1} at the perihelion; τ is the lifetime of the $O2(a^1\Delta_g)$ molecules, in the literature values range from 3880 to 6803 sec; and k is the rate constant of the quenching reaction $O(a^1\Delta_g)$ + CO2 → $O2(X_3\Sigma_g)$ + CO2 , $0.4 \le k \le 2 \times 10^{-20}$ cm^{-3} $molecules^{-1} sec^{-1}$. The retrieved O3 profile, using for α an intermediate value and k= 2×10^{-20} cm^{-3} $molecules^{-1} sec^{-1}$, is shown in Figure 2.

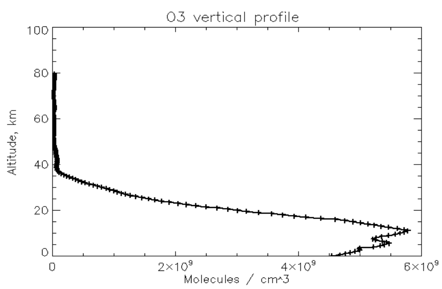

Figure 2 : Ozone density profile.

2. Perturbed CO2 density profiles

To evaluate the impact of density variations in the CO2 profile on the $O2(a_1\Delta_g)$ molecule productions we consider an initial carbon dioxide profile as retrieved from the Mars Express Planetary Fourier Spectrometer (PFS) spectra acquired in similar conditions. Then we introduced in the density profile perturbations with different intensities and at different ranges of altitudes. According to the new profiles, the $O_2(a^1\Delta_g)$ nadir integrated intensities are re-computed and compared with the initial values.

3. Mesoscale model

Since the observed oscillations are correlated to mesoscale fluctuations of atmospheric density (equivalently buoyancy) and/or temperature, they imply significant GW activity in the southern Martian polar regions. To test this hypothesis in the present study we use the Martian mesoscale model described in details in [5] which couples fully compressible non-hydrostatic dynamics and comprehensive Martian physical parameterizations. The model predicts intense GW activity in Martian southern polar regions at any time of day with a moderate diurnal variability caused by fluctuations of atmospheric stability and the impact thereof on GW propagation.

4. Conclusions

In this work the role of the quenching between CO2 and $O_2(a^1\Delta_g)$ molecules in the variation of the intensity observed in the OMEGA $O_2(a^1\Delta_g)$ airglow maps during the southern late winter / early spring on the polar regions is investigated. The mesoscale modeling supports the fact that spatial structures in the O_2 dayglow maps are caused by GW activity.

References

[1] Zasova, L., et al. : Results of measurements with the Planetary Fourier Spectrometer on board Mars Express: Clouds and dust at the end of the Southern summer. A comparison with OMEGA images, Cosmic Res., 44, 305-316, 2006.

[2] Spiga, A., et al. : Remote sensing of surface pressure on Mars with the Mars Express/OMEGA spectrometer: 2. Meteorological maps, J. Geophys. Res.,112, E08S16, 2007.

[3] Altieri, F., et al.: O_2 1.27 µm emission maps as derived from OMEGA/MEx data, Icarus, 204, 499-5111, 2009.

[4] Perrier S., et al. : Global distribution of total ozone on Mars from SPICAM/MEX UV measurements, J. Geophys. Res., 111,. E09S06, 2006.

[5] Spiga, A., and Forget, F.: A new model to simulate the Martian mesoscale and microscale atmospheric circulation: Validation and first results, J. Geophys. Res., 114, E02009, 2009.