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Modelling of VIRTIS/VEX $O_2(a^1\Delta_g)$ nightglow profiles affected by gravity waves action

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Abstract

In this work we report on the modelling of $O_2(a^1\Delta_g)$ nightglow limb profiles perturbed by the gravity waves (GWs) propagation in the Venus atmosphere. Data have been acquired by the VIRTIS (Visible and InfraRed Thermal Imaging Spectrometer) instrument on boards the ESA mission Venus Express (VEX). The high variability observed in the shape of the $O_2(a^1\Delta_g)$ nightglow limb profiles between 80 and 120 km, often characterized by the presence of a double peak, implies GWs occurrence at the considered altitudes. In order to model and derive the GWs properties, we apply to Venus a well-known theory used to study terrestrial airglow fluctuations induced by the GWs propagation.

1. Introduction

On Venus' nightside, $O_2(a^1\Delta_g)$ molecules arise by the three-body reaction O + O +M → $O_2(a^1\Delta_g)$ + M, then they decay at the fundamental state $O_2(X^3\Sigma^-{}_g)$ by emitting most of the photons at 1.27 µm or through quenching $O_2(a^1\Delta_g)$ +M → $O_2(X^3\Sigma^-{}_g)$ + M. In the condition of photochemical equilibrium, a balance occurs between the chemical production and losses [4], and we have (M corresponding to CO_2 predominantly):

$$[O_2(a^1\Delta_g)]/\tau = \varepsilon\times k\_T\times[CO_2]\times[O]^2 - C\times[CO_2]\times[O_2(a^1\Delta_g)] \quad (1)$$

where τ is the $O_2(a^1\Delta_g)$ molecules life time (3880 < τ < 6800 sec), ε and *k_T* are respectively the three-body reaction efficiency (70 < ε < 80%) and reaction rate (1.5 × T^{-2} 10^{-27} cm^6 sec^{-1}), while *C* is the quenching reaction rate (< 2.0 × 10^{-20} cm^3 sec^{-1}).
The 1.27 µm emission falls inside the VIRTIS/VEX spectral range and it has been studied through both nadir and limb data. Volume emission rate profiles reveal usually a peak at 97~ km, but a double peak frequently appears as well, at 103-105 km [1]. The double peak structures originate by the propagation of GWs, common features of planetary atmospheres that play a crucial role in defining circulation and structure of the mesosphere. By inducing vertical fluctuations on both temperature and density profiles, GWs can also affect the airglow intensities. In this study we propose to apply the theory developed by [2] and [3] for studying terrestrial airglows to model the Venus GWs responsible for the fluctuations observed in the VIRTIS $O_2(a^1\Delta_g)$ nightglow data.

2. VIRTIS instrument and Data Set

VIRTIS is an imaging spectrometer covering the 0.27-5.1 µm range [1]. It includes two spectrometers: VIRTIS-M, a mapping spectrometer with medium spectral resolution, and VIRTIS-H, an echelle spectrometer with higher spectral resolution than VIRTIS–M but no imaging capability. VIRTIS-M consists of two channels: a visible channel (spanning the 0.27-1 µm range) and an infrared channel (covering the 1-5.1 µm range). In this study the data of the VIRTIS-M infrared channel (spectral sampling =10 nm, IFOV = 0.250 mrad) that show $O_2(a^1\Delta_g)$ nightglow profiles double-peak shaped are considered. They have been inverted through an onion peeling method.

3. Modelling

Assuming monochromatic GWs propagating in an isothermal and windless atmosphere, the relative density perturbation can be written as [2, 3]:

$$\frac{\rho_p}{\rho_u} = 1+\varepsilon_{GW}\times e^{\beta(z-z_{O2})}\times\cos[\omega t-kx-m(z-z_{O2})] \quad (2)$$

where z is the altitude, z_{O2} is the altitude of the peak of the O_2 layer, ε_{GW} is the GW amplitude at z_{O2}, 1/β is the amplitude growth length, ω is the intrinsic frequency, *k* is the horizontal wave number, *m* is the vertical wave number and γ is the ratio of specific heats. The horizontal and vertical wave numbers are linked to the intrinsic period through the GW dispersion relation. The perturbed (p) and unperturbed (u) temperature, carbon dioxide and atomic oxygen distributions are linked through the following relationships:

$$\frac{T_p}{T_u} = \left(\frac{\rho_p}{\rho_u}\right)^{-1}, \quad \frac{[CO_2]_p}{[CO_2]_u} = \frac{\rho_p}{\rho_u}, \quad \frac{[O]_p}{[O]_u} = \left(\frac{\rho_p}{\rho_u}\right)^{g_0} \qquad (3)$$

where the expression of the g_0 exponent depends on the fit of the considered species density profile and it is function of the altitude as well. As far as the initial (unperturbed) profiles are concerned, we considered a Gaussian profile for the $O_2(a^1\Delta_g)$ density distribution, and CO_2 density and temperature profiles as derived from the SPICAV data [4, 5]. The atomic oxygen density profile has been modelled following the method in [4]. Combining Eq. (1), (2), (3) and playing with the involved free parameters, we can thus model the VIRTIS $O_2(a^1\Delta_g)$ nightglow inverted profiles.

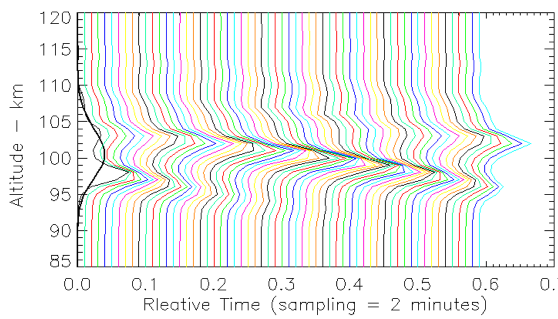

Figure 1: $O_2(a^1\Delta_g)$ volume emission rates perturbed by GWs (thin lines). Black thick line: initial profile.

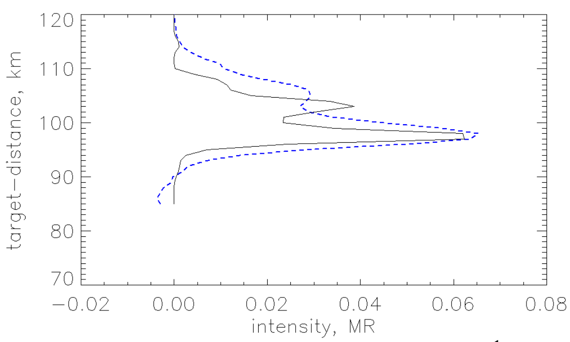

Figure 2: Blue dashed curve: VIRTIS $O_2(a^1\Delta_g)$ nightglow inverted profile. Black curve: model.

4. Results

Figure 1 shows the fluctuation introduced to the initial O_2(a1Δg) nightglow volume emission rate profile by the GWs propagation, confirming the high variability observed in the VIRTIS data. In Figure 2, a VIRTIS $O_2(a^1\Delta_g)$ nightglow inverted profile is compared with a modelled one, with GW vertical wavelength = 7 km, and GW intensity at 100 km = 20%.

5. Summary and Conclusions

The inverted VIRTIS/VEX limb profiles of the $O_2(a^1\Delta_g)$ nightglow intensity at 1.27 µm perturbed by the GWs action have been modelled through a method applied to the terrestrial atmosphere [2, 3]. The initial $O_2(a^1\Delta_g)$ molecules density profile have been assumed to be Gaussian shaped. Unperturbed temperatures and density profiles have been taken from SPICAV data [4, 5], while the initial atomic oxygen density profile has been derived with the same approach of [4]. This study confirms the high variability induced by wave propagation in the $O_2(a^1\Delta_g)$ profiles, as observed in the VIRTIS data.

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References

[1] Piccioni, G., L. Zasova, A. Migliorini, P. Drossart, A. Shakun, A. Garcı´a Mun˜oz, F. P. Mills, and A. Cardesin-Moinelo, Near-IR oxygen nightglow observed by VIRTIS in the Venus upper atmosphere, J. Geophys. Res., 114, E00B38, 2009

[2] Gardner and Shelton, Density response of neutral atmospheric layers to gravity wave perturbations, J. Geophys. Res., 90, A2, 1745-1754, 1995

[3] Swenson, G. R., C. S. Gardner, Analytical models for the responses of the mesospheric OH* and Na layers to atmospheric gravity waves, J. Geophys. Res., 103, D6, 6271-6294, 1998

[4] Gerard, A. S., G. Piccioni, P. Drossart, F. Montmessin, J-L. Bertaux, Atomic oxygen distribution in the Venus mesosphere from observations of O2 infrared airglow by VIRTIS-Venus Express, Icarus, 199, 264–272l. 2009

[5] Bertaux, J-L., Vandaele, A.C., Korablev, O., Villard, E., Fedorova, A., Fussen, D., Quemerais, E., Belyaev, D., A warm layer in Venus' cryosphere and high altitude measurements of HF, HCl, H2O and HDO, Nature 450, 646 – 649, 2007