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Gravity waves in the upper mesosphere of Venus

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Abstract

Gravity waves are common features in planetary atmospheres. They can manifest through fluctuations on temperature and density fields, and hence on airglow intensities. In analogy to the Earth's and Mars' cases, we apply a well-known theory to investigate the gravity waves influence in shaping the O_2 nightglow emissions in the infrared in the Venus atmosphere. We use VIRTIS/Venus Express observations at limb, acquired during the mission period from 2006-07-05 to 2008-08-15. We present wave properties, like vertical wavelength λ_z and wave amplitude ϵ_{GW}. Other parameters, like for example horizontal wavelength, are inferred and discussed.

1. Introduction

Gravity waves (GWs) are mesoscale atmospheric oscillations related to the buoyancy force, which play a key role in the circulation of planetary atmospheres. These buoyancy waves can exist whenever an atmosphere is stably stratified, so that the vertical displacement of air particles produces density changes that cause gravity to act as restoring force [1]. Since GWs can induce fluctuations on both temperature and density fields, they can affect the airglow intensities as well. Assuming an isothermal atmosphere, [2, 3] demonstrated that the relative atmospheric density perturbations induced by GWs could be modeled analytically. In particular, the O_2 density perturbed profile can be expressed by the following equations:

$$[O_2(^1\Delta_g)]_p = \left(\frac{\rho_p}{\rho_u}\right)^{3+2g_0(z)} \cdot \frac{(A + C\cdot[CO_2]_u)}{\left(A + C\cdot\left(\frac{\rho_p}{\rho_u}\right)\cdot[CO_2]_u\right)} \cdot [O_2(^1\Delta_g)]_u$$

$$g_0 = \frac{\gamma H - H_1}{(\gamma - 1)H_1} - \frac{\gamma H}{(\gamma - 1)H_2} \times e^{-(z-z_0)/H_2}$$

where A is the Einstein coefficient, C is the CO_2 quenching coefficient, p and u indicate the perturbed and unperturbed profiles, respectively. g_0 is an analitic expression able to fit the O density profile. H, H_1, H_2 are three different scale heights, the latter two required to fit the O density profile.

This theory, developed for the Earth, has been successfully applied to the Martian case [4,5]. In the present work, we apply the same method to Venus, in order to infer GWs properties propagating in the upper mesosphere of the planet.

2. Data selection and analysis

Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) is the imaging spectrometer on board the Venus Express (VEX) mission around Venus. In the period from 2006-07-05 to 2008-08-15, it acquired limb data of the night side of Venus. In particular, we focus on the wavelength region from 1.2 to 1.35μm, where the O_2 IR Atmospheric (0-0) band falls. For the proposed GWs investigation, we used these data at limb, and inverted in order to derive the volume emission rate. The inversion method is based on the onion peeling technique [6], with the Tikhonov normalization. After the inversion method, a double peaked structure often appears, showing the main emission peak at about 97 km height, and a secondary peak 3 to 5 km higher than the primary peak. In a previous work [7], these double-peaked structures were suggested to be linked to GWs. In this study, by applying the theory developed by [2,3], we demonstrate that these double peaked profiles can be explained as vertically propagating GWs.

3. Results

The analyzed VIRTIS/VEX inverted $O_2(a^1\Delta_g)$ nightglow limb profiles can be successfully modeled, assuming GWs propagation. The nightglow O_2 emission distribution as a function of latitude is shown after the inversion technique, in figure 1 for sequence of data acquired on 2007-05-09. A second O_2 layer appears at about 103 km height, for latitudes higher than 45°.

In figure 2, we show one example of fitted vertical profile. The main GW parameters, retrieved in this study are the vertical wavelength λ_z and the wave amplitude ϵ_{GW} at the O_2 peak. The λ_z ranges between 7 and 16 km, while ϵ_{GW} varies in the range 3-14%.

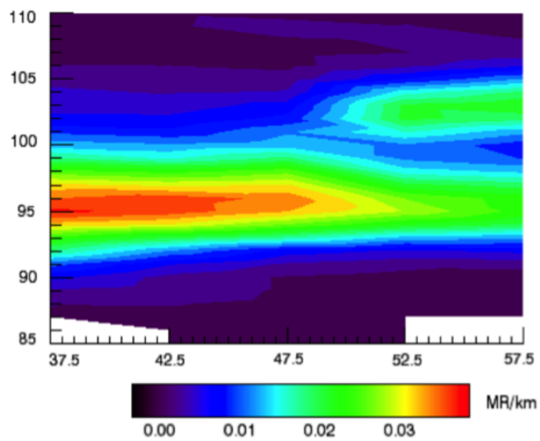

Figure 1: O_2 nightglow emission distribution, after the inversion technique. Two O_2 layers appear for latitudes higher than 45°

The study confirms the high variability induced by GW propagation in the $O_2(a^1\Delta_g)$ profiles, as observed in the VIRTIS data. The results are discussed in [8].

4. Future works

Following the theory developed by [9], we will be able to derive additional parameters to better constraint the waves detected in the upper atmosphere of Venus. This is the first evaluation of parameters of gravity waves in the nightside of Venus, at the nightglow altitudes.

Acknowledgements

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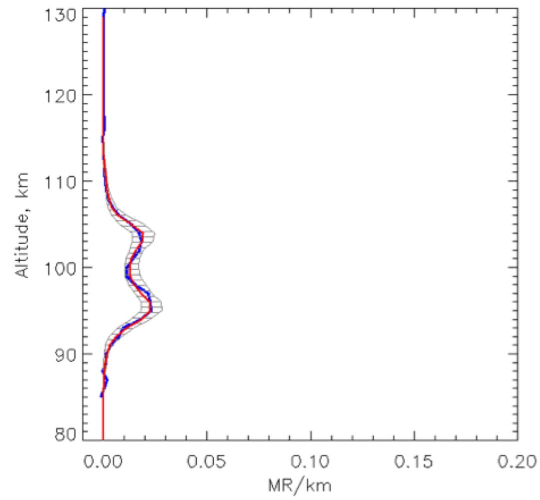

Figure 2: VIRTIS observation fitted with a profile, modified by a GW with vertical wavelength of 9 km and a GW amplitude of 9%. The observation was acquired on 2007-05-09, at 51°N, and a local time of 0.3h.

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