EPSC Abstracts
Vol. 7 EPSC2012-645 2012
European Planetary Science Congress 2012

Nocturnal variations of the Venus upper cloud scale height

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Abstract

In this work we have developed a procedure to infer the scale height of the upper layer of Venus clouds at different latitudes and different local times. The analysis has been performed on hyperspectral images provided by the VIRTIS instrument, on board Venus Express-ESA. In particular, we considered observations at 3-5 μm, i.e. the spectral region characterised by upper cloud thermal emission.
Preliminary results show no temporal variations equatorward of 50°S and poleward of 60°S, whereas between 60°S and 50°S scale height approaches the near-polar value in the late night.

1. Introduction

The infrared spectrum of the Venus nightside is opacity-dominated at wavelengths lower than 3 μm and only some narrow transmission windows are detectable [1]. From 3 μm to 5 μm, the Venus spectrum is instead characterised by a continuum thermal emission, originated between 62 and 73 km, i.e. the upper cloud region [2]. Therefore studies of the 3-5 μm spectral region would help to infer some properties of the upper layer of the Venusian clouds.
In particular, the limb darkening effect observed at these wavelengths, i.e. the brightness temperature decrease at increasing emission angle, is related to cloud scale height and mesospheric lapse rate. According to the radiative transfer model developed in [3], the following relation occurs:

$$T = T_0 + C \ln \cos \theta , \qquad (1)$$

where T and the T_0 are the observed and the brightness temperature respectively, θ is the emission angle and C is the product between the lapse rate Γ of the upper cloud region and the cloud scale height H.
The Eq. (1) has been applied to NIMS-Galileo data by [4], who obtained H=4.1±0.6 km at equatorial latitudes. This result has been confirmed by [5], who applied the Eq. (1) to VIRTIS-Venus Express data in order to study latitudinal variations of the scale height. [5] found that no limb darkening is observed poleward of 60°S, due either to a very low scale height (i.e. <1 km), a very low lapse rate or both. Moreover, the average H value retrieved between 60°S and 50°S is affected by a large uncertainty, because of the strong lapse rate variations in this region, not only with latitude, but also with local time [6,7].
This work aims to take into account these variations and to monitor the upper cloud scale height during the night-time. Furthermore, Eq. (1) is applied to VIRTIS observations of the Venus nightside at different latitudes and local times.

2. Data selection and reduction

1725 VIRTIS hyperspectral images [8] at high exposure time (i.e. 3.3 and 8 seconds) were considered for this work. In particular, we focused on observations at two wavelengths in the thermal continuum spectral range, i.e. 3.72 μm and 4.00 μm.
Prior to analysis, spectra were reduced, by obtaining a more refined spectral calibration and by removing the contribution of scattered Solar light [5].

3. Data analysis

For each wavelength, the analysis has been performed at different latitude and local time intervals. The three considered latitude ranges are: near-equatorial latitudes (50°S to 0°), where a constant scale height is expected, middle latitudes (60°S to 50°S), within which scale height could vary, and near-polar latitudes (70°S to 60°S), where it is not expected to observe limb darkening. The three considered local times intervals are: early night (19:30-22:30), middle night (22:30-1:30) and late night (1:30-4:30).
Since the parameters of Eq. (1) can change with the atmospheric height (i.e. with brightness temperature), ten brightness temperature intervals were empirically defined [5] for each wavelength, latitude and local time. By means of least squares technique, we obtained twenty estimates of the C parameter (ten for every considered wavelength) at every latitude and local time interval considered.

Scale height can be obtained dividing C for the lapse rate Γ of the upper cloud region. To infer Γ, a grid of atmospheric thermal profiles at different latitudes and local times has been developed, basing on procedure described in [6] and [7].

4. Preliminary results and discussion

The scale height retrieval is currently in progress. Linear fits of observed temperature T as function of $\ln \cos\theta$ are very good at near-equatorial latitudes (Fig. 1) and no trend of C with local time is observed. At near-polar latitudes Eq. (1) does not work whatever the local time interval considered (Fig. 2) Conversely, at middle latitudes, the C value and the goodness of fit decrease from early to late night. In other words, at later local times the upper cloud region at middle latitudes tends to become similar to near-polar latitudes. Since latitudes between 70°S and 60°S are characterised by the presence of a cold collar [9], these results would suggest a cold collar extension toward middle latitudes in the late night, according to [6]'s observations.

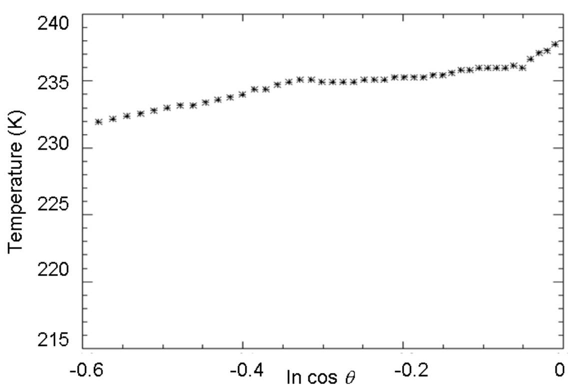

Figure 1. Observed temperature at near-equatorial latitudes, in the early night and at 3.72 µm, as function of $\ln\cos\theta$.

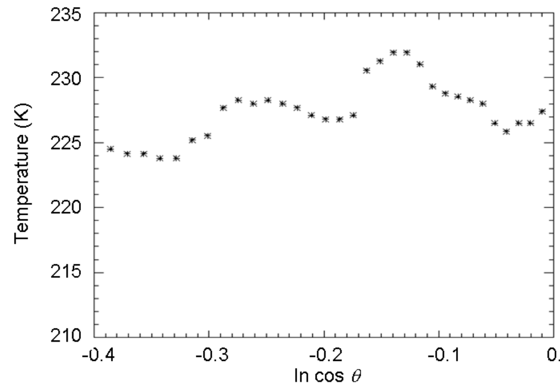

Figure 2. Observed temperature at near-polar latitudes, in the early night and at 3.72 µm, as function of $\ln\cos\theta$.

Acknowledgements

ASI supports VIRTIS and the Venus Express mission through the contract ASI-INAF I/050/10/0. ESA and CNES are also thanked for their support.

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