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Circulation of Venusian atmosphere at 95-100 km apparent motions of 1.27 µm nightglow of O_2 observed by VIRTIS on board Venus Express

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Abstract

The infrared M-channel of the Visible and InfraRed Thermal Imaging Spectrometer (VIRTIS) onboard Venus Express Mission was performing observations of the atmosphere of Venus from 2006 to 2008. At 1.27 µm on the nightside it was able to monitor the $O_2(a^1\Delta)$ airglow, the distribution of which is highly variable in magnitude, location and morphology [6]. Tracking the displacement of bright features allows for measuring the wind velocities at the altitudes of the emission (95-100 km). This altitude range is located above the zonal superrotation-dominated area and below the influence of the SS-AS (subsolar-antisolar) mode of circulation, resulting in a complex behavior, therefore understanding this motion is a key aspect of the Venus atmosphere dynamics. In this work we have analyzed the entire VIRTIS-M-IR dataset of nadir images to obtain maps of the mean zonal and meridional components of the wind speed as well as analyze dependence of the motion on local time, latitude and longitude and orbit-to-orbit variation.

1. Introduction

Planet Venus possesses a thick atmosphere which demonstrates a complex combination of motions. The most distinctive dynamic feature of the atmosphere is the zonal super-rotation, a strong and consistent flow that reaches its peak velocity (~100 m s^{-1}) in the low latitudes at the altitude of 65-70 km above the surface [3] and drops in magnitude in the poleward direction. Present at much higher altitudes (> 110 km) is a subsolar-to-antisolar (SS-AS) circulation cell, which is driven by the solar heating. The two mechanisms interfere with each other in the transition region, 90-110 km, and the resulting complex dynamic pattern is not well understood [1][5].

A good indicator of the atmospheric motion on the nightside is the oxygen airglow $O_2(a^1\Delta)$ at 1.27 µm wavelength. Formed in the dayside thermosphere due to the photolysis of the CO_2 molecules, atomic oxygen travels onto the nightside with the SS-AS circulation, and recombines into molecular oxygen in the excited $(a^1\Delta)$ state [2].

The "cloud-like" morphology of the oxygen nightglow allows for manually tracking the displacement of certain features in them over time, given a set of consecutive images. Previous partial analysis of the dataset revealed the wind velocities to reach 100 m/s and have a large variety of directions and the general coincidence of the apparent nightglow motion with the SS-AS mode of circulation [1].

2. Experimental data and approach

For this work we have selected 90 orbits (Table 1), where VIRTIS-M-IR obtained images, filtered by the following criteria:

- Visually identified presence of the oxygen airglow at 1.27 µm;
- Exposure time of 3 seconds and longer in order to work with an acceptable signal-to-noise ratio and minimize errors [7];
- Series of images which are spread out by 0.5 or 1 or 2 hours, focused at the same area of the disk of Venus, to allow tracking the displacement of features.

Although the lifetime of a $(a^1\Delta)$ excited state is ~70 min, the large bright nightglow structures (1000-4000 km) are persistent for several hours, implying a downward flux of O_2 molecules. The smaller features, up to 100 km, which are used for wind tracking, can disappear over the course of 2 hours and more. Most wind vectors are tracked along the edges of the bright structures where the signal gradient is high, whereas areas of peak brightness are devoid of traceable markings.

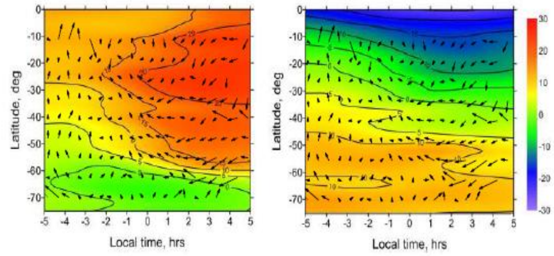

Figure 1.Average zonal (left) and meridional (right) components of $O_2(a^1\Delta)$ nightglow motion as a function of local time and latitude.

3. Results and Conclusions

We analyzed the resulting amount of 6019 vectors across the nightside in the southern hemisphere and equatorial region (no northern hemisphere due to the Venus Express orbit [8]).

The mean zonal component behaves differently before and after midnight. The 0 to +5 h local time range is dominated by the eastward motion (+10 to +70 m/s), whereas in the -5 to 0 h range the behavior is more complex, although the westward (-10 to -40 m/s) is more prevalent. Same dichotomy concerns the meridional component: it is predominantly equatorward before midnight (0 to +40 m/s), and mostly poleward after midnight (-50 to +20 m/s) (Figure 1).

No direct correlation of the wind speed with the surface was found, although the longitude-latitude range which corresponds to Aphrodite Terra, the largest surface structure was scarcely covered by nadir VIRTIS-M measurements.

The dataset of nadir images contains few series of consecutive orbits, however the available series appeared to be extremely helpful to analyze the orbit-to orbit variation. With ~24 hours between each orbit we were able to observe how the directions and the magnitudes of motions change with relation to the changing nightglow itself. Areas of circular motion with a lifetime of less than 24 hours were discovered, ranging from 1500 to 4000 km in diameter.

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