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Stationary waves and slow cloud features challenge Venus's night side superrotation

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Abstract

We present the first global measurements of the night side circulation of Venus at the upper cloud level from the tracking of individual features in thermal emission images at 3.8 and 5.0 µm during 2006-2008 (Venus Express/VIRTIS) and 2015 (IRTF/SpeX). The zonal motions range from -110 to -60 m/s, consistent with those found for the dayside but with larger dispersion6. Slow motions (-50 to -20 m/s) are also found and may indicate temporal changes in the vertical structure of the superrotation [1]. Abundant stationary wave patterns with zonal speeds from -10 to +10 m/s clearly dominate the night upper clouds.

1. Introduction

The atmosphere of Venus rotates at the cloud tops sixty times faster than the solid globe, a phenomenon called superrotation. Whereas on the dayside cloud top motions are well determined [2], the night side circulation remains poorly studied except at the polar region [3]. Night images at 3.8 and 5.0 µm sense the thermal contrasts of the upper clouds at ~65 km [4] and first images at these wavelengths were obtained during the Galileo flyby [5]. The largest dataset was acquired with the instrument VIRTIS on Venus Express (VEx), and was used to infer the winds at the southern polar region [2]. Middle and low latitudes have so far been ignored because images at these wavelengths display very low contrast.

2. Observations and Methods

We used 3.8 and 5.0 µm images obtained by VIRTIS-M from June 2006 to August 2008, and ground-based observations at 4.7 µm taken with SpeX instrument on the 3-m NASA Infrared Telescope Facility (IRTF) in July 2015 to study the motions of the night clouds of Venus. The spatial resolution of the images range from about 10 km/pix in VIRTIS-M to 400 km/pixel in the case of SpeX. Observational constraints due to the polar orbit of VEx limit the number of available images showing mid-to-low latitudes. Additional constraints (like exposure time and detector temperature) reduced our final dataset to 55 VEx orbits (~55 Earth days) which were deemed useful for cloud tracking.

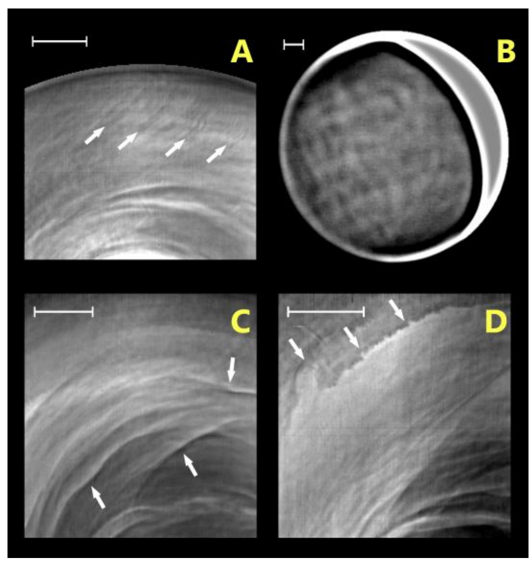

Figure 1: New upper clouds features on Venus night.

Night thermal features from the upper clouds exhibit important day-to-day changes in their appearance, revealing cloudy features unseen in dayside ultraviolet images (Figure 1). Three types of features and motions are found: wavy patterns, patchy/irregular, and filaments or shear-like patterns. Large-scale wavy features are the most abundant (Fig. 1A), frequently seen between the equator and 60ºS and, together with a small number of the irregular structures, exhibit almost stationary motions (Figure 2). The wave trains have wavelengths 100–250 km, are oriented ±45º relative to the parallels and have packet lengths of ~1000 km. Their properties differ from day side gravity waves observed at the same altitude. Big-scale features can be also observed in 5-µm ground-based images obtained by IRTF/SpeX (Fig. 1B). Bright stretched filaments (1C) and sheared-like features (1D) are also observed frequently.

2.1 Radiative-Transfer studies

We re-assessed previous altitude estimations using two Radiative Transfer models [4,6] which adopt a standard description of the Venus cloud particles (sulfuric acid of 75%) distributed vertically with 4 size modes with different number densities and temperature profiles from VIRA. Our calculations show that radiation is sensitive to a range of altitudes between 60 and 72 km. Since thinner clouds occur occasionally in Venus (what may result in larger contributions from lower altitudes), additional descriptions of the thermal opacity were explored reducing by a factor of 10 the number density of a size mode, while leaving the other size modes unmodified. The calculations show that even in conditions of thinner clouds the bulk of radiation at 3.8 and 5.0 µm originates at altitudes above 50 km.

3. Results and Conclusions

Figure 2 displays the latitudinal (left graph) and vertical (right) distribution of the velocities are shown. Wavy and other patterns are displayed with green and red dots, respectively. Fast filaments and shear-like features are shown with cyan dots, while eventual cases of extremely slow tracers are shown with dark yellow dots. Tracers in SpeX images are displayed as blue circles with error bars. Individual errors with VIRTIS range 5–15 m/s. Meridional profiles of zonal winds at dayside levels of the cloud tops (~70 km) and upper clouds' deck (~60 km) during the Galileo flyby [5] and VEx missions [2] are displayed with dashed and continuous black lines with shaded areas showing the dispersion of the measurements. Contrarily to the dayside motions dominated by mean super-rotating winds ranging -120 to -90 m/s, night side motions are far more variable. The abundant wave patterns with zonal speeds from -10 to +10 m/s can be interpreted as stationary gravity waves supported by the positive static stability above 60 km. VEx/VeRa radio-occultation at the geographical locations where they appear reveal vertical wavelengths ranging 4–17 km.

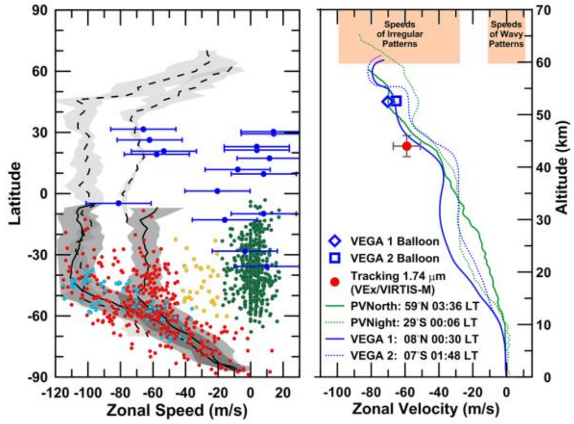

Figure 2: Meridional and vertical profiles for motions.

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