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Circulation of the lower cloud level on the nightside of Venus from VIRTIS-M (Venus Express) and IR2 (Akatsuki) data in 1.74 µm

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Abstract

This research is aimed to understand circulation of the Venusian atmosphere at the lower cloud level (44-48 km) and its variations with time, latitude, longitude and local time. On the nightside winds at these altitudes can be tracked from the orbit by using infrared imaging instruments. Here we compare results obtained in the same spectral window of 1.74 µm by two instruments flown on two most recent missions to Venus. Comparison of the results shows accordance in the meridional component direction and magnitude, however a significant difference in the values of the zonal component of the wind. Mean zonal speed measured from IR2 data in 2016 exceeds that of VIRTIS-M data in 2006-2008 by a value up to 16 m s^{-1}. Because of recent investigations of the stationary gravity waves and their potential influence on the atmospheric circulation [3], we examined longitude-latitude dependence of the wind velocities and found variations that can be attributed to such mechanisms.

1. Introduction

The thick cloud layer of Venus rotates around the planet in the westward direction with the peak velocity 60 times higher than that of the planet itself, approximately 100 m s^{-1} for the altitudes of 65-70 km (upper cloud level) above the surface [1], the phenomenon known as retrograde superrotation. In the altitude range of 10-90 km the atmospheric motion is predominantly zonal. The velocity decreases for altitude levels farther from the upper cloud level and for latitudes closer to the poles.

On the nightside, the inhomogeneous distribution of the cloud opacity in the infrared spectral range (thermal emission) leads to a complex morphology of small-scale features of various contrasts. By tracking their displacement one can derive horizontal wind speed at the altitude of remote sensing.

In the spectral window of 1.74 µm on the nightside, the thermal radiance comes from beneath the main cloud level, subsequently passing through the lower clouds at the altitudes of 44-48 km [5]. Thus, the motion of the observed features is associated with atmospheric dynamics at these altitudes.

2. Experimental data and approach

The infrared channel of the imaging spectrometer VIRTIS-M onboard Venus Express performed observations of the nightside from April 2006 to October 2008 with a spectral resolution of 16 nm and pixel size of 10-40 km. Most of its observations covered Southern Hemisphere, primarily high and middle latitudes. To calculate wind velocities using manual wind tracking technique [2], 988 image pairs in 1.74 µm were considered, resulting in 45191 vectors in total. Time intervals between pairs were varying from 1 to 3 hours.

The IR2 camera onboard Akatsuki operated in 2016 and one of its channels collected images in a 1.713 – 1.755 µm band [6]. Although there were fewer images compared to VIRTIS-M, they had better spatial resolution, thus resulting in more retrieved vectors per pair, 15275 for 145 pairs.

Due to different orbital parameters, latitudinal coverage is not the same: VIRTIS-M data is found in the Southern Hemisphere, from the pole to the equator (and in rare occasions, in the near-equatorial latitudes of the Northern Hemisphere); meanwhile IR2 data covers both hemispheres equally, though near the poles the amount of retrieved vectors becomes smaller due to the disk edge proximity and low spatial resolution. Local time data coverage of the night side is slightly different for the two instruments, where it is distributed almost equally before and after midnight in VIRTIS' case and it is predominantly distributed before midnight in IR2 case. Longitudinal coverage for VIRTIS-M is biased in such a way that longitudes from 40 to 160° (approximately the longitudes of Aphrodite Terra) have very little data, whereas IR2 covers this longitude range more extensively than other areas.

3. Results

Recent studies indicated significant differences between results from the two instruments [4]. Our findings confirm that the mean zonal speed was significantly higher in the results of IR2. The difference in values was the highest (78 m s^{-1} compared to 62 m s^{-1}) in the equatorial latitudes, in fact, the shape of the IR2 profile displayed an equatorial “jet”, an effect which was not observed by VIRTIS-M (Figure 1). One of the possible explanations could be that the observed cloud details relate to different altitudes; in that case by implying the vertical wind shear of about 2 m s^{-1} km^{-1} we would assume an altitude difference of ~8 km. On the other hand, the meridional component was resting at the same magnitudes for both experiments, reaching 0-2 m s^{-1} (equatorward direction). Unfortunately, results cannot be compared for the northern latitudes.

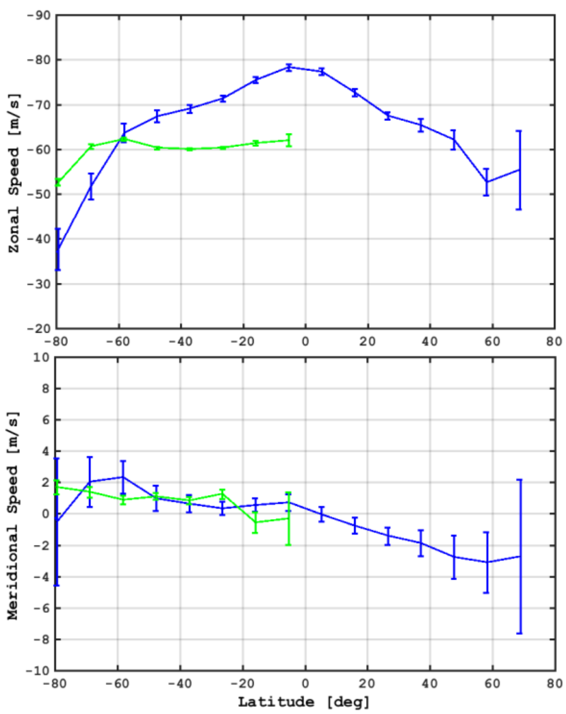

Figure 1: Mean profiles of the zonal and the meridional components of the nightside wind from 1.74 µm images by VIRTIS-M (green) and IR2 (blue). Error bars indicate standard error values in a 99% confidence interval.

Longitudinal profiles of the mean wind speed for both instruments show variability, which can be partially attributed to the influence of the stationary gravity waves. Isolines of zonal and meridional velocities tend to correlate with the shapes of major underlying topographic features.

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