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Venus's middle & low clouds during the Akatsuki mission

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Abstract

We present a summary of the wind measurements and new cloud patterns discovered on the dayside middle and nightside lower clouds of Venus during the years 2016-2019 using near-infrared (NIR) images from the cameras IR1 and IR2 on Akatsuki, SpeX and iSHELL at NASA's IRTF, and amateur observations. The unexpected high contrasts found on the dayside NIR albedo suggests drastic changes in clouds' optical thickness and/or the presence of NIR absorbers [1]. The nightside clouds exhibit frequent wave packets, billows caused by shear instabilities, equatorial throughs, and new features like dark spots, sharp dark streaks and fully-developed vortices [2]. Nightside zonal wind results at low latitudes confirm the recurrence of the equatorial jet, first evidence of solar tide effect and a decadal variability [3].

1. Introduction

Observations of Venus during the 1920s unveiled the presence of an unknown absorber in ultraviolet images that has permitted, for about 90 years, an extensive study of the dayside upper clouds of Venus at ~70 km above the surface using images taken at ultraviolet images. As a result, we have a good knowledge of the clouds' morphology and winds at this level of the Venus atmosphere [4,5], but we are yet far away from a deep understanding on the role that the atmospheric dynamics play in the variety of shapes and contrasts observed, the mechanisms behind the atmospheric superrotation, or the importance of atmospheric waves and eddies. The exploration of the clouds and dynamics of the dayside middle clouds (50-57 km) and the nightside lower clouds of Venus (48-60 km) delayed about half-a-century and they have been poorly studied compared to the cloud tops on the dayside [4,5]. We provide a summary of the main findings on these cloud levels as revealed from images by Akatsuki (JAXA), Venus Express (ESA) and IRTF (NASA).

2. The dayside middle clouds

The dayside middle clouds can be observed at near-infrared wavelengths (800–950 nm) although, as reported by previous missions, with very low contrast (~4%) that makes harder the measurement of winds with cloud tracking. We inspected the full set of 984 dayside 900-nm images from IR1 covering from 7 December 2015 to 9 December 2016. This dataset was complemented with ground-based observations with small telescopes at Australia and Greece covering a period from October 2016 to January 2017, when Venus in IR1 images exhibited a larger phase angle.

Figure 1 exhibits, showing unseen morphologies with noticeable changes along time. NIR images also display a slightly darker band though normally invaded by bright clouds, which sometimes have swirl-shape and mottled aspect (Fig. 1A–C and G) suggestive of convection. Other times, the previous turbulent regime seems to evolve to a laminar one, with clouds becoming homogeneously bright and/or featureless, conforming multiple stripes with quasi-zonal orientation (Fig. 1D-F). From April to May, the north hemisphere became periodically darkened every 4–5 days (Fig. 1E-F). The sharp albedo changes displayed in 1C have never been observed before Akatsuki, and they were recurrent during the first half of 2016 and absent on UV images of the upper clouds. The 900-nm albedo in IR1 images exhibits contrasts ranging 3–21%. Most of them have values <10%, implying either changes of up to ~40% in the cloud thickness or presence of absorbers [1].

A total of 511 wind measurements were obtained with manual cloud tracking using NIR images from Akatsuki/IR1 and, for the first time, using amateur ground-based observations with NIR filters [1]. Mean zonal winds are found to weakly peak at the equator, while combined data from Venus Express and Akatsuki missions along 10 years reveals long-term variations of the zonal winds of up to 20 m/s [1].

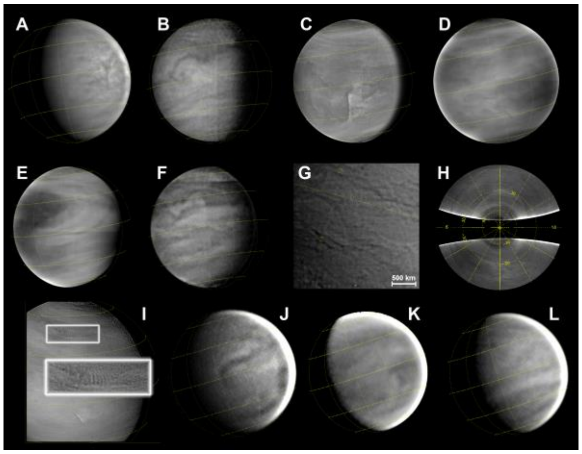

Figure 1: NIR albedo of Venus's clouds during 2016.

3. The nightside lower clouds

A total of 1671 IR2 images at 2.26 µm taken between March–November 2016 were examined to study the night lower clouds' morphology of Venus with spatial resolution ranging from 74−12 km/pixel (off-pericenter) to 1.6−0.2 km (pericentric) [2]. The study was complemented with 2.3-µm images taken along January-February 2017 and November-December 2018 with the instrument SpeX at NASA's IRTF telescope in Hawaii. We performed a detailed characterization and classification of the morphology of the lower clouds. While some patterns are new like sharp dark streaks encircling the planet (Fig. 2A-D), others had been observed only on the dayside, providing information about how a phenomenon affects both clouds' opacity and albedo [2]. Low-latitude clouds are rich in mesoscale waves and black spots [2], while frequent billows and developed vortices (Fig. 2E-F) could be key to explain the generation of waves and constrain the eddies' momentum flux.

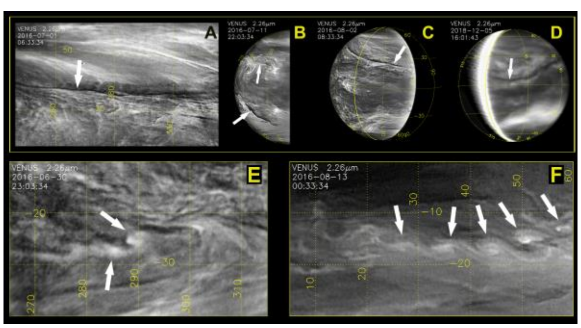

Figure 2: Sharp dark streaks (A-D) and mesoscale vortices (E-F) on the night lower clouds' opacity.

3.1 Lower clouds' wind variability

The zonal and meridional winds (2947 vectors) were measured with manual cloud tracking using Akatsuki/IR2 2.26-µm images with spatial resolution ranging 10-80 km per pixel and covering March-October 2016. Additional winds were measured with ground-based observations at TNG telescope in 2012 and IRTF in 2015 and 2017. The meridional profiles for both components of the winds are found to be consistent with results from the Venus Express mission during 2006–2008 [3], although stronger wind variability is found for the zonal component at equatorial latitudes where Akatsuki observations have better viewing geometry than Venus Express, surely caused by the intermittent jet [6]. The zonal winds at low latitudes also suggest a zonal variability that could be associated with solar tides or vertically propagating orographic waves. Finally, the combination of our wind measurements from TNG, IRTF, and Akatsuki images with wind measurements from previously published data from 1978 to 2017 suggests decadal variations of up to 30 m/s in the winds at the nightside lower clouds of Venus [3].

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