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Faint thermal features at the Venusian cloud top found by averaging multiple infrared images taken by Akatsuki

Kiichi Fukuya (1), Takeshi Imamura (1), Makoto Taguchi (2), Tetsuya Fukuhara (2) and Toru Kouyama (3)

(1) The University of Tokyo, Japan (2) Rikkyo University, Japan (3) National Institute of Advanced Industrial Science and Technology, Japan (kiichi-fukuya@g.ecc.u-tokyo.ac.jp)

Abstract

Venus' cloud-top temperature distribution is now continuously mapped by LIR (Long-wave Infrared camera) mounted on the Venus orbiter Akatsuki. The images taken by LIR is relatively featureless except large-scale stationary features [1]. Here we investigate faint thermal features with typical amplitudes of less than 0.3 K by averaging of multiple LIR images to suppress noise. Averaging was done in two types of the coordinate system: the longitude-latitude coordinate system fixed to the surface, and the "atmospheric coordinate system" that moves westward at an angular velocity corresponding to 90 m/s on the equator. The former can emphasize stationary patterns and the latter, drifted patterns embedded in the background zonal flow. By using this method, small-scale, faint thermal features were newly found.

1. Introduction

LIR onboard Akatsuki is providing thermal images of Venusian cloud top regularly at 1-2 hour intervals. One of the findings by LIR is the existence of bow-shaped structures extending over 10,000 km in the north-south direction [1]. The features are fixed in position without flowing with the super-rotation and appear above highlands with altitudes higher than 3 km [2]. It was suggested based on a comparison with numerical simulations that the features are gravity waves generated by near-surface flows impinging on mountains. The features tend to occur in the local afternoon [2]. In the previous studies using LIR data, only planetary-scale features have been investigated. On the other hand, Peralta et al. [3] analyzed the data taken by VIRTIS onboard Venus Express, and reported the existence of many small-scale stationary features; however, VIRTIS can observe the night side only, and the observations were confined to the high latitude of the southern hemisphere because of the geometry of the orbit. Small-scale stationary features like those observed by VIRTIS have not been observed by LIR probably because of the limitation of the random error of the measurement of ~0.3 K.

As for non-stationary features, no notable structures have been found in LIR images. The morphology of Venusian clouds has mostly been observed in UV, and streaky features and mottle features are known to exist. Such UV features were often used for cloud tracking to measure the wind velocity on the dayside. Thermal images can potentially cover all localtime regions; the cloud-level winds on both day and night side in the polar region were measured by cloud tracking using thermal images obtained by VIRTIS [4]. The cloud morphology in thermal infrared and the wind field over the broad latitude and locacltime regions have not been observed.

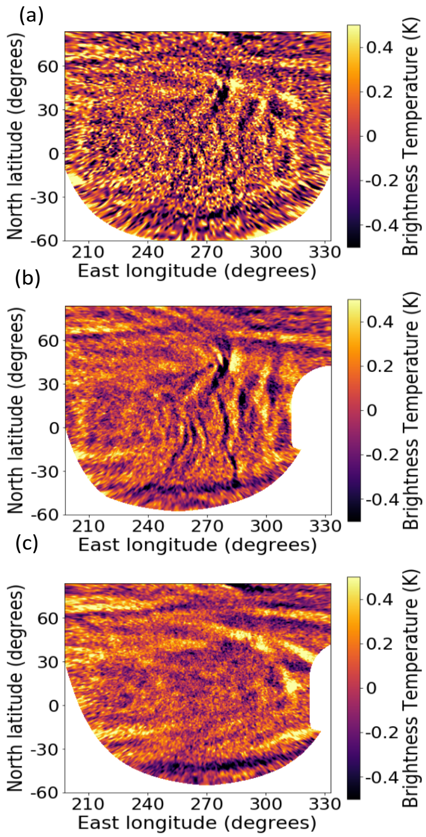

Figure 1: Example of image processing. (a) High-pass filtered brightness temperature map obtained from a LIR image without averaging. (b) Average of 6 high-pass filtered images in the longitude-latitude coordinate system fixed to the surface. (c) Average of 6 high-pass filtered images in the super-rotating coordinate system. The data taken on 25 January 2017 were used.

2. Results

2.1 Stationary features

To investigate the topographical and local time dependency of small-scale, weak stationary features that are unclear in original LIR data, we averaged multiple images taken by LIR in half a day in the longitude-latitude coordinate system. The averaging suppresses noise and moving features, thereby enhancing stationary features. An example of the result is shown in Figure 1b; small-scale, stationary wave trains were newly found even above relatively-low topographic rises with altitudes of 1-3 km in low latitude regions. The detailed distribution of stationary features is under investigation.

2.2 Drifting features

By averaging multiple images in the super-rotating coordinate system that moves westward at an angular velocity corresponding to 90 m/s on the equator, faint drifting features similar to the UV features were extracted as shown in Figure 1c. This averaging suppresses noise and stationary features, thereby enhancing drifting features moving with the superrotational flow. We frequently see similarities in the morphology between LIR and UVI images obtained simultaneously on the dayside. The newly-processed LIR images also revealed nightside cloud features. With this method, it might be possible to measure the wind velocity by cloud tracking also on the night side where cloud tracking in UV does not work.

References

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