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Cloud top circulation of Venus obtained from denoised thermal infrared images

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This study derives and analyzes the wind field at the Venusian cloud top using the thermal infrared images from the Longwave Infrared Camera (LIR) onboard Japan's Akatsuki orbiter. LIR detects thermal emission in a waveband 8-12 μ m from the cloud deck of Venus on dayside and nightside with equal quality[1]. The data used spans from December 2015 to March 2024, providing substantial observations to ensure the reliability of our results.

However, the noise in the infrared images prevents further investigation of the fine-scale cloud features. To improve data quality, we first applied the Block-Matching and 3D Filtering (BM3D) algorithm to denoise the LIR images. This method suppresses noise based on the inherent non-local self-similarity within an image. The algorithm operates in two stages: grouping structurally similar 2D image patches into 3D arrays, and then collaboratively filtering these arrays in a transform domain to effectively reduce noise. This denoising process significantly enhanced fine-scale cloud structures, which is essential for the subsequent retrieval of wind fields.

With denoised LIR images, we implemented an automated cloud tracking method to estimate cloud motion vectors[2]. This approach identifies and tracks patchy cloud features between consecutive images to derive the wind velocity. We examined the cloud motion vectors with strict screening criteria to ensure the reliability of the wind field. Wind estimation errors were statistically evaluated by dividing images into odd- and even-numbered subsets, deriving wind fields independently from each, and comparing the results.

Comparing with previous studies based on the ultraviolet or near infrared imagery, this work retrieves a long-term dataset of the Venusian wind field on both dayside and nightside, offering a more complete view of the global circulation. Besides, our processing method does not rely on averaging, thereby preserving a higher temporal resolution that allows for the identification of transient features or those not moving at the speed of the background superrotation. Using this dataset, we observed and compared the wind field structures and the circulation. We further evaluated the momentum transport on the dayside and nightside, promoting our understanding of the dynamics in the Venusian atmosphere.

[1] Taguchi, M., Fukuhara, T., Imamura, T., Nakamura, M., Iwagami, N., Ueno, M., Suzuki, M., Hashimoto, G. L., and Mitsuyama, K. (2007). Longwave Infrared Camera onboard the Venus Climate Orbiter. Advances in Space Research, 40(6), 861-868.
[2] Ikegawa, S., & Horinouchi, T. (2016). Improved automatic estimation of winds at the cloud top of Venus using superposition of cross-correlation surfaces. Icarus, 271, 98-119. https://doi.org/10.1016/j.icarus.2016.01.018