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Cloud tracking of the Venus atmosphere with Akatsuki: High-quality wind snapshots, jets, and instabilities

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Abstract

We have conducted cloud tracking using image data from Akatsuki, a Venus orbiting satellite, at multiple wavelengths. Our method provides cloud-motion vectors with unprecedented high quality. Obtained cloud top winds exhibit rich spatial and temporal variability. In the lower cloud layer, it is observed that a jet stream was formed in the equatorial region in 2016, which persisted at least over a few months. Occasionally, batropically unstable vortices are found to develop to erode the shear associated with the jet.

1. Introduction

The Akatsuki spacecraft was inserted into an orbit of Venus on 7 December 2015. Since then, it has been providing images of Venusian clouds at multiple wavelengths. Here, we present the current status and scientific achievement of the dynamical study of the Venus atmosphere based on cloud tracking, which is one of the main objectives of the Akatsuki project.

2. Data and Method

We use data from Akatsuki's ultraviolet imager UVI, which conducts dayside imaging at 283 and 365 nm, and the near-infrared imager IR2, which conducts both dayside and nightside imaging at multiple wavelengths near 2 μm. (We also use data from the other near-infrared imager IR1 at ~1 μm, but it is not treated in this presentation.)

We conduct sophisticated automated cloud tracking [1, 2]. In this method, multiple images are combined to increase the accuracy and reduce erroneous template match. It also uses an error correction-rejection algorithm based on a revised relaxation method [2]. Our study also provides

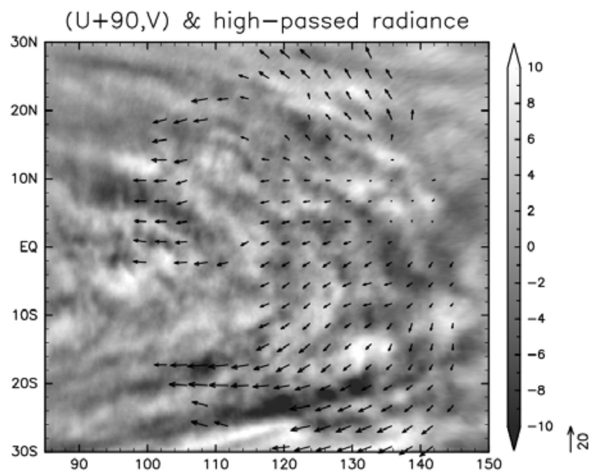

Figure 1: Horizontal winds at the cloud top derived from three UVI 365-nm images obtained on 7 Dec 2015 (arrows: here, a uniform zonal wind of 90 m/s is added to visualize spatial variation) and high-passed radiance at the beginning of tracking (W m^{-2} sr^{-1} μm^{-1}).

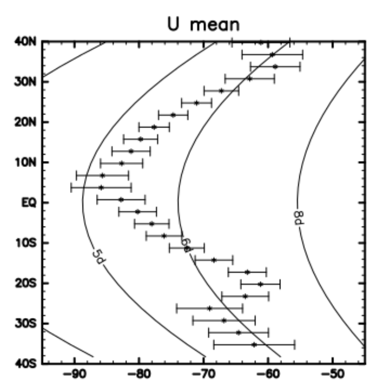

Figure 2: Longitudinally averaged zonal wind in the lower cloud layer derived from four IR2 2.26 μm images obtained on 11 Jul 2016. Error bars indicate the range of uncertainty. Curves show corresponding rotation periods (5, 6, and 8 days).

objective error estimation based on the shape of cross-correlation surfaces [1]. We apply the automated cloud tracking carefully, conducting comparison among various parameter settings and human-eye verification as in the manual tracking

3. Results

Dayside cloud-top (~70 km) motion is derived from UVI images with unprecedented high-quality. Figure 1 shows an example, which is obtained from three UVI images at 365 nm on the day of Akatsuki's orbital insertion (7 December 2015). The motion vectors are shown only where the estimated error measure [1] is smaller than 10 m/s and the difference from the 283-nm results is smaller than 5 m/s. The overall feature is consistent with the known tidal flow with divergence. The figure also indicates smaller-scale motion. The results for multiple days suggest rich temporal variability (not shown).

IR2 provides a unique opportunity to derive winds in the lower cloud layer (45-50 km). Zonal winds obtained in July, 2016 and later at low latitude are much faster than previously reported (Figure 2). Since it exhibits a jet like feature with a maximum rotational speed, we call it as the equatorial jet [3]. The equatorial zonal wind was slightly slower in March, 2016 and did not exhibit a rotational speed maximum. Subsequent observation was focused on the dayside until June, and hence the lower-cloud-layer winds cannot be derived, so we can only guess that the jet was formed in this period.

Previous near-infrared cloud tracking studies have reported mid-latitude jets. Cloud tracking with IR2 provides consistent results.

The nightside cloud images from IR2 suggest a variety of dynamical features. Figure 3 shows the radiance at 2.26 μm exhibiting features like overturning vortices as in the barotropic instability. The cloud tracking reveals that their motion is actually consistent with the unstable eddies. Also, comparison of mean zonal winds on this day and 5 days earlier (at one rotation period before) suggests the erosion of shear associated with equatorial jet, which is consistent with barotropic instability. We argue that there is a mechanism to create the jet, and the instability acts to horizontally diffuse the angular momentum associated with the jet.

4. Conclusions

Cloud tracking with Akatsuki images has been conducted successfully, and some novel features have been found such as sub-planetary-scale cloud-top features, and equatorial jets and instabilities in the lower cloud layer. Further studies are ongoing.

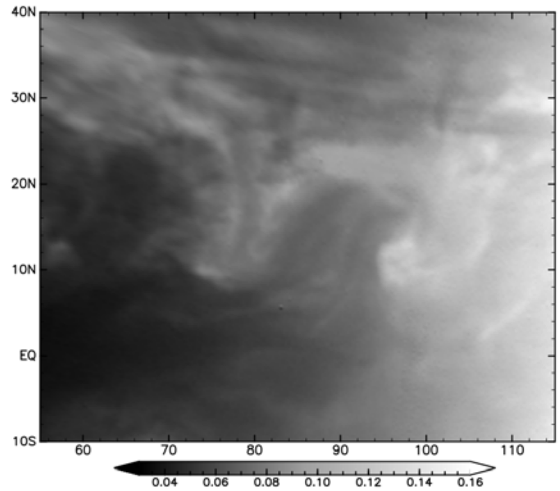

Figure 3: Unstable vortices captured by nightside imaging of IR2: 2.26-μm radiance (W m^{-2} sr^{-1} μm^{-1}) obtained by IR2 on 25 Aug 2016.

Acknowledgements

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