Dynamics of Venus cloud observed by Venus Express/VMC

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Introduction

To understand the dynamics of the Venus atmosphere such as superrotation, a number of analyses have been done by tracking cloud motion method from images taken by Venus spacecrafts(ex. Rossow et al., 1990; Markiewicz et al., 2007). It was assumed that the cloud height is about 70 km.

In this study, we tried to estimate both cloud height and wind velocity from Venus Express / VMC data by stereo tracking method without assuming cloud height. We conducted also traditional 2D tracking to derive the local map of wind vector fields from the VMC data.

Data

Venus Express (VEX) [Svedhem et al., 2007]

- VEX operates in a polar elliptical orbit with apocentre distance of 66,000 km.
- Pericentre is located at ~78° N with an altitude of 250-350 km.
- Revolution period is 24 h.

Venus Monitoring Camera (VMC) [Markiewicz et al., 2007]

- Wavelength / band width are 365 / 40 nm (UV), 513 / 50 nm (VIS), 965 / 40 nm (NIR1), 1000 / 40 nm (NIR2).
- Total field of view is ~17.5°

In this study, we use the UV image data obtained by Venus Express/VMC from equator to mid-latitude in the northern hemisphere. We use also SPICE kernels to obtain the spacecraft location and information.

Method 1 (2D tracking)

Analysis Procedure

1. Assuming the cloud height (~70 km), the cloud images are transferred into latitude-longitude coordinates.
2. The area (60x60 pixels) is selected in the first cloud image.
3. The location with maximum correlation between images is found in the second image. (the search area is 120x120 pixels)
4. We estimate wind speed from the displacement between two images.

Data Selection

- When the maximum correlation occurs on the edge of the search region, the data is eliminated.

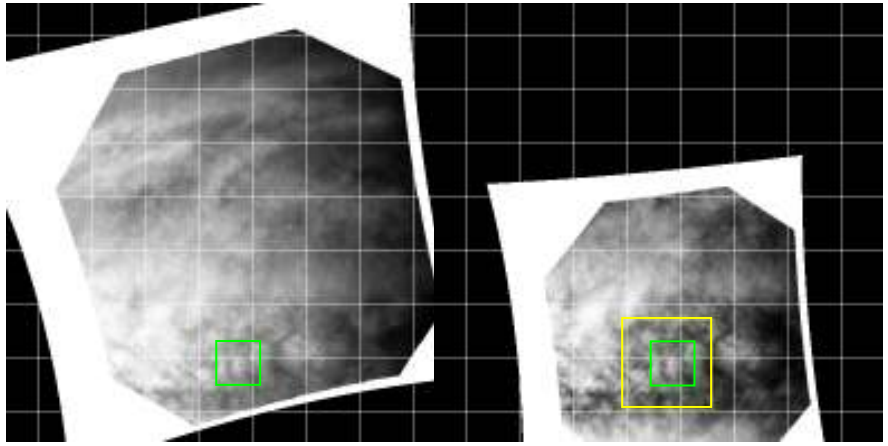


Fig. 1: An example of 2D tracking image.

Method 2(stereo tracking)

We derive both cloud height and wind speed simultanously by the stereo disparity without remapping into latitude-longitude coordinates.

Analysis Procedure

1. The area(60x60 pixels) is selected in the first image.
2. The location with maximum correlation between images is found in the second image. (the search region is 180x180 pixels)

(2.5 We find scale and rotation angle with the best correlation coefficient → only for local map analyses)

3. We estimate wind speed from the displacement between two images.

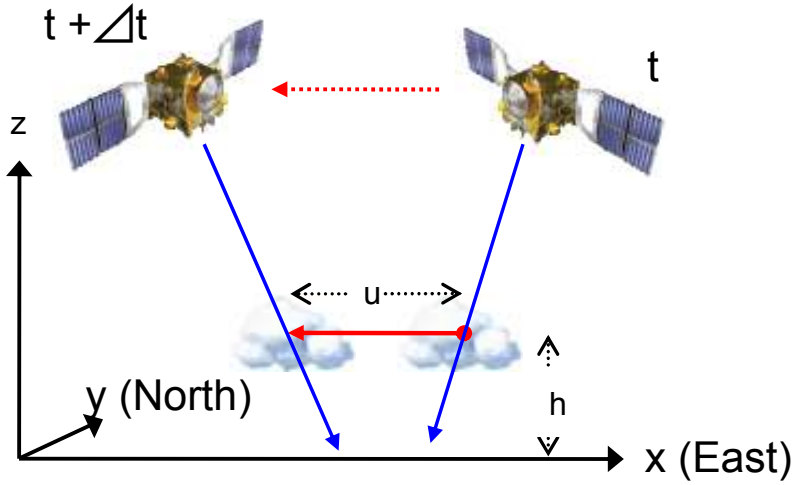


Fig. 2 : Schematic of stereo tracking method.

Method 2(stereo tracking)

Assumptions

- Cloud height is constant during the time difference ⊿t.
- Meriodinal wind velocity is very low relative to zonal wind. (= 0 m/s)

Data Selection

- Maximum correlation Rmax > 0.85
- Distance between Rmax point and Rmax * 0.99 point is less than 10 pixels.
- Rmax point is not the edge of the search area.

Latitudinal distribution of cloud height (Method 2)

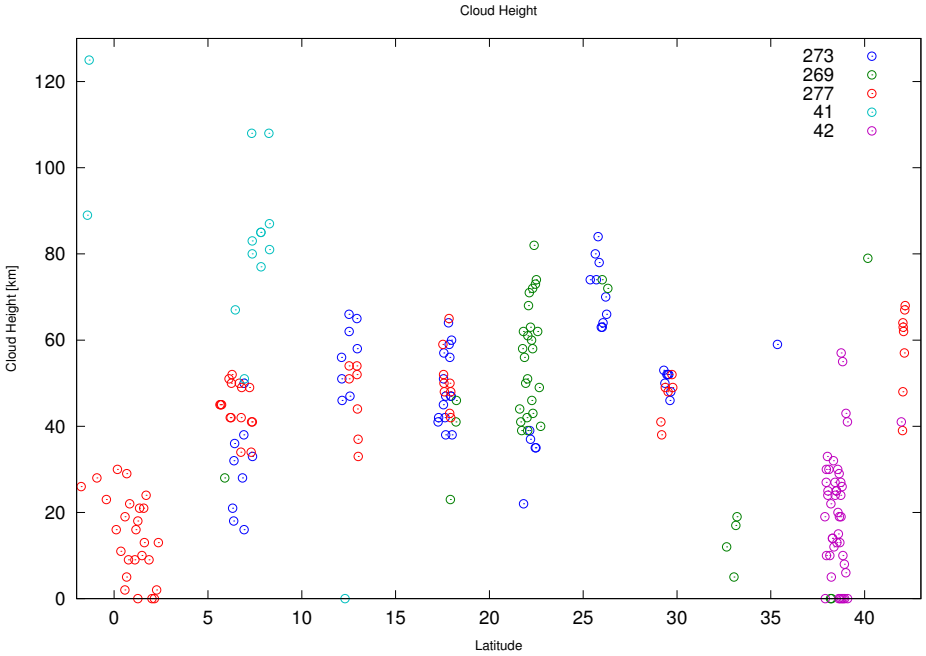


Fig. 3: Latitudinal distribution of cloud height.

- Color shows different orbit.

Results

- Cloud height is mainly distributed in the altitude range of 40-80 km.

- The estimated cloud height shows increase with the increase of latitude.

Latitudinal distribution of westward wind speed (Method 2)

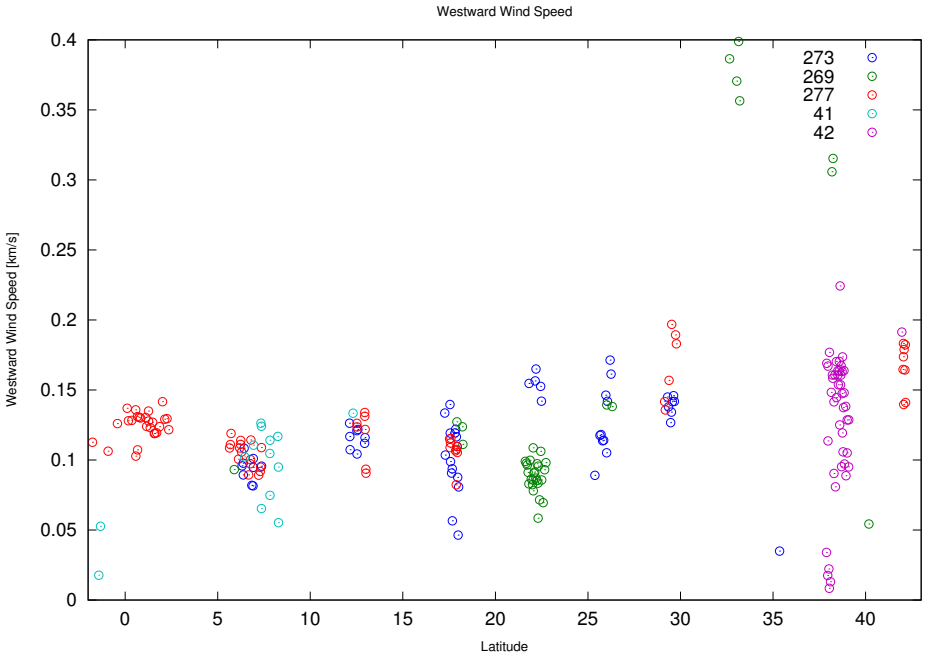


Fig. 4: Latitudinal distribution of westward wind speed.

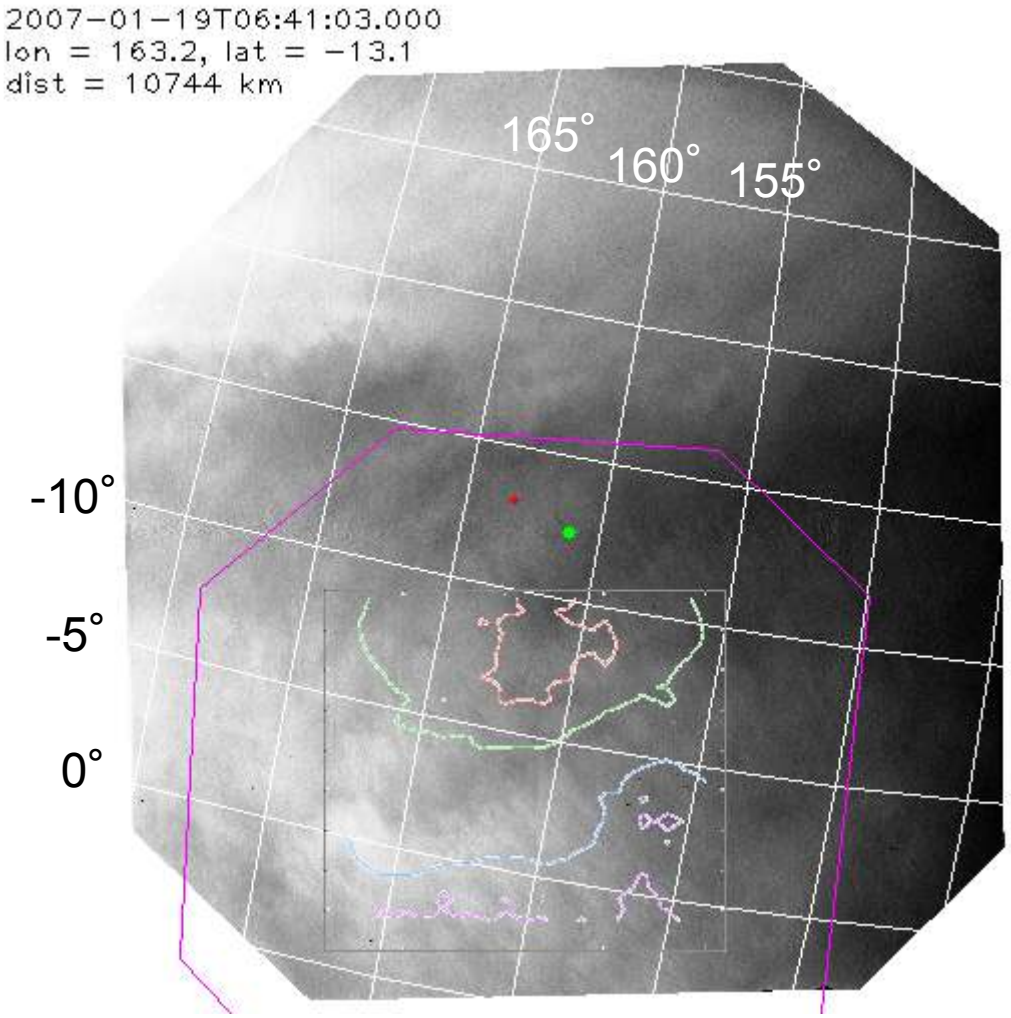
- Color shows different orbit.

Results

- Westward wind speed is mainly distributed in the velocity of 0.1 km/s (100 m/s)

- The speed increases with the increase of latitude.

Map of cloud height and wind velocity (orbit 273-25) [Method 2 with target rotation]



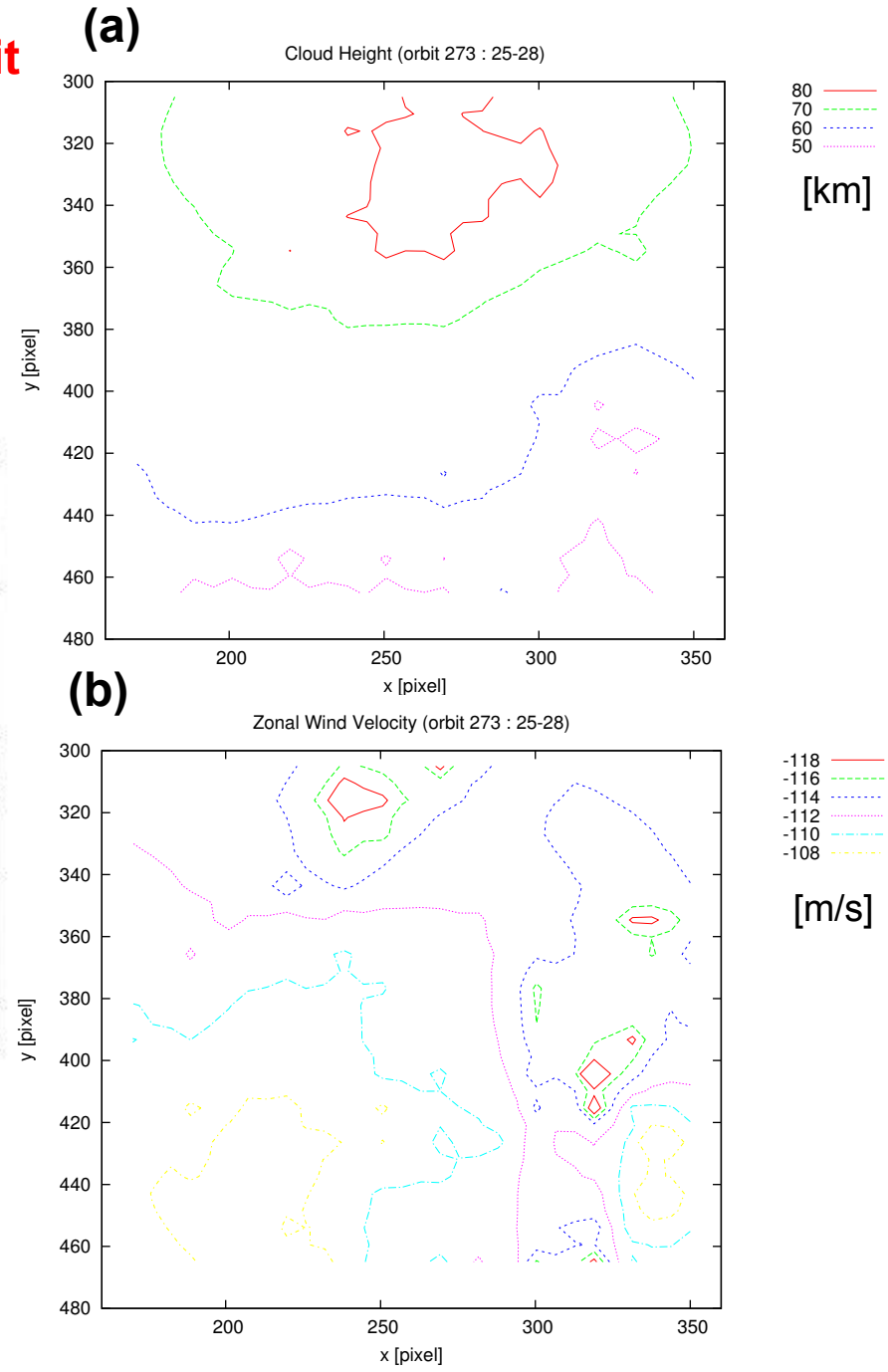


Fig. 5: Map of cloud height on an image (orbit 273-25). The contour shows (a) cloud height and (b) wind velocity.

Map of cloud height and wind velocity (orbit 273-28) [Method 2 with target rotation]

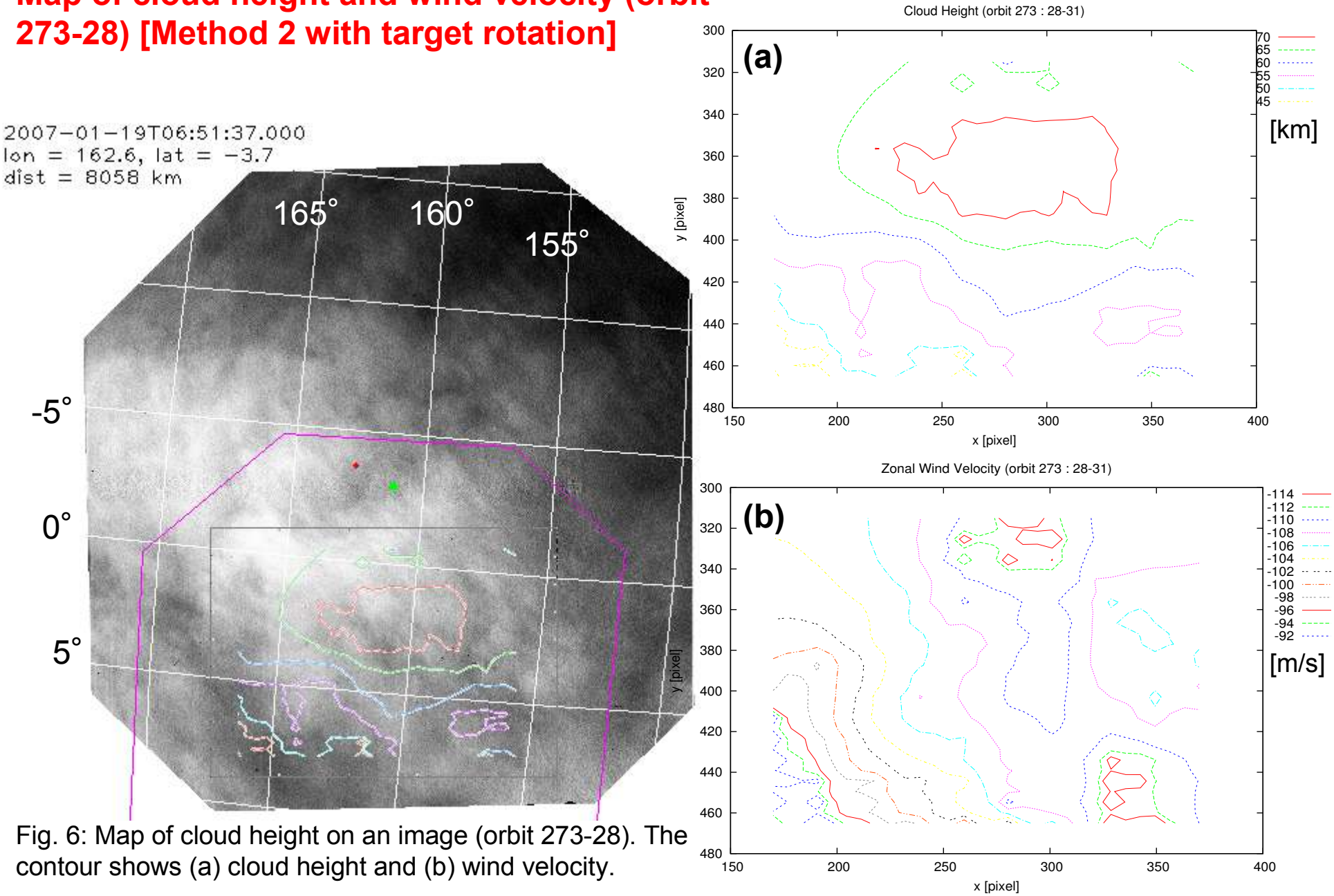


Fig. 6: Map of cloud height on an image (orbit 273-28). The contour shows (a) cloud height and (b) wind velocity.

Map of cloud height and wind velocity

Cloud Height

- The height is distributed in altitude of 40-80 km.

- The height has a peak near the center of the second image and decreases towards the limb.

- The peak seems to depend on the spacecraft height and varies ~10 km for ~2500 km(10744 km – 8058 km).

Wind Velocity

- The velocity is distributed near -100 m/s. (minus means “westward”)

- The velocity seems to be lower in the “left-bottom” dark region(Fig. 6).

Map of wind vectors (orbit 273-28) [Method 1]

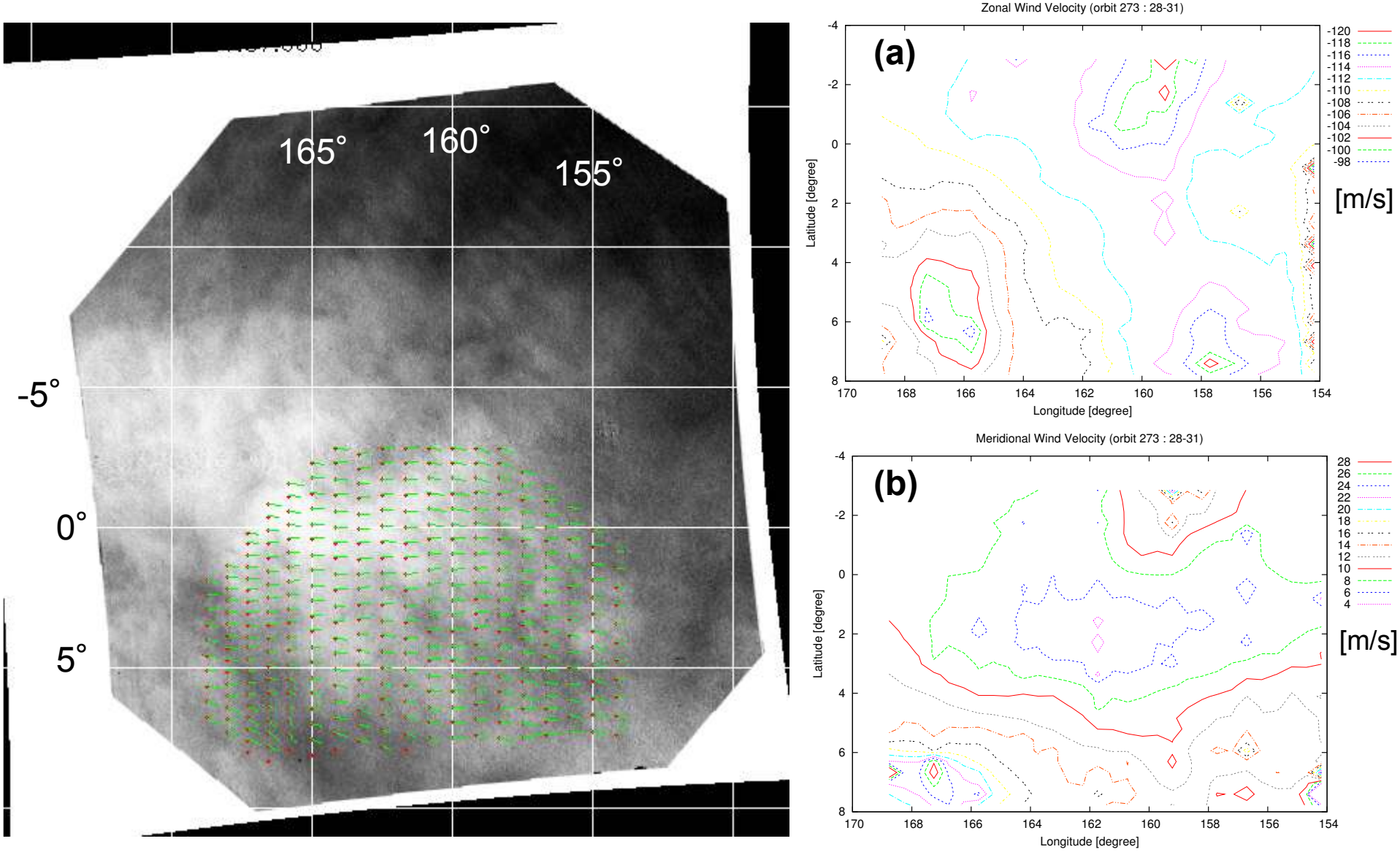


Fig. 7: Map of wind vectors on an image (orbit 273-28). The contour shows (a) zonal and (b) meridional components. Red circles in the left image represent the beginning of vectors.

Map of wind vectors (orbit 269-25) [Method 1]

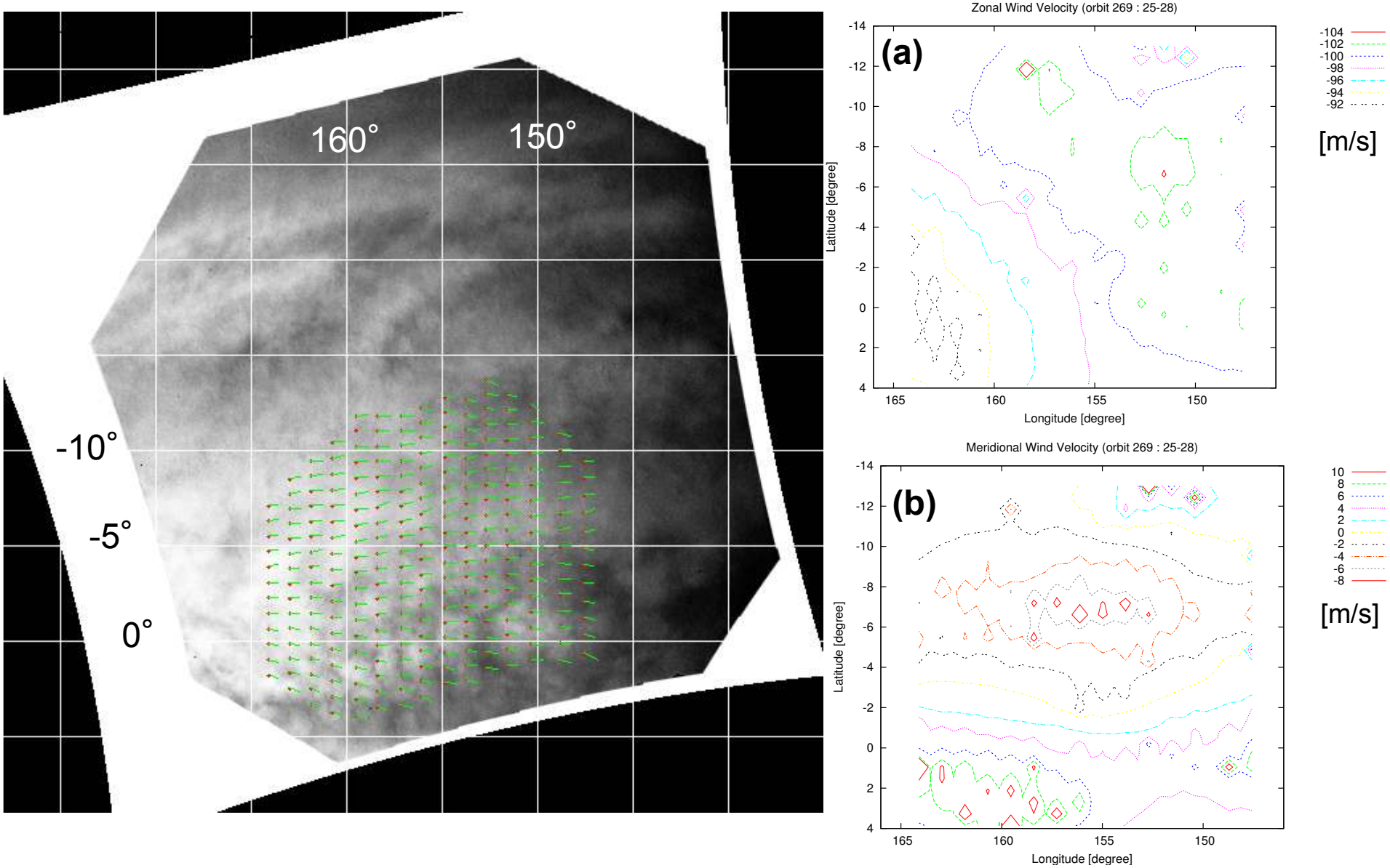


Fig. 8: Map of wind vectors on an image (orbit 269-25). The contour shows (a) zonal and (b) meridional components. Red circles in the left image represent the beginning of vectors.

Map of wind vectors

Zonal Component

- is distributed near -100 m/s.
- is low in the “left-bottom” region.

Meridional Component

- is high in the “left-bottom” region.
- shows the change of wind direction near the equator (Fig. 8).

Conclusions

We estimated the cloud height and zonal wind velocity by stereo tracking, and obtained the distributions of 40-80 km cloud height and ~-100 m/s zonal wind velosity.

- Mean cloud height and zonal wind velocity increase with latitude.

We derived the local map of cloud height and wind speed by stereo tracking.

- The local map of cloud height seems to depend on the spacecraft height and the position in each image.

We derived the local map of wind vectors by 2D tracking.

- The wind direction and velocity show mesoscale structure.

The accuracy of location in the SPICE kernels is very important for the estimations of wind and cloud height from Venus Express / VMC data.

Acknowledgments

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- SPICE toolkit is provided by NASA / NAIF.

References

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