EPSC Abstracts
Vol. 7 EPSC2012-664 2012
European Planetary Science Congress 2012

Limb Radius from Images taken by Venus Monitoring Camera on Venus Express

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Abstract

Given the large number of images acquired from the VMC since the insertion of Venus Express in orbit in April 2006, it is now possible to measure the altitude of the visible cloud top (slant optical depth, $\tau_{slant} = 1$) from the images. Preliminary results were presented by Limaye et al. (2011) by determination of the τ_{slant} location in the VMC images and using the observing geometry information to determine the altitude by first determining the image center very precisely.

1. Introduction

A good knowledge of the effective cloud top altitude is essential for interpretation of cloud motions measured from Venus images taken in reflected sunlight at different wavelengths. Since the first estimates of the size of Venus by Jeremiah Horrocks during his observations during the transit of Venus in 1639, more than three centuries before much improved optical estimates were made.

Ignatiev et al. (2009) reported the first inferences of the cloud top altitude from nadir observations acquired by the Visible Infrared Thermal Imaging Spectrometer (VIRTIS) on Venus Express using the depth of the 1.6µ CO_2 continuum. Their results indicate that the cloud tops are 74 ± 1 km above the mean surface in low and mid-latitudes and at only 63-69 km in polar latitudes. The nominal cloud top altitude used in most previous analyses of imaging data are generally either 6115 and 6120 km radius, or 62.8 and 67.8 km respectively above the mean surface. The Level 3 map products generated from the VMC data use a cloud altitude of 65 km for all filters.

Information about average zonal winds in the Venus atmosphere has been obtained from the inferred thermal structure from Pioneer Venus and Venus Express radio occultation technique and the assumption of cyclostrophic balance (Limaye, 1995; Piccialli et al., 2012). However, comparing the measured cloud motions from Venus Express observations reveals some significant discrepancies if the cloud motions indeed refer to the cloud top levels derived by Ignatiev et al. (2009). Piccialli et al. showed that near the cloud tops the vertical shear of the zonal flow can be as large as 10 $ms^{-1}.km^{-1}$.

The large number of images acquired from the VMC since the insertion of Venus Express in orbit in April 2006, enable estimating the altitude of the visible cloud top (slant optical depth, $\tau_{slant} = 1$) from the location of the bright (dayside) limb. Preliminary results were presented by Limaye et al. (2011, 2012) by determination of the τ_{slant} location in the VMC images and using the observing geometry information to determine the altitude by first determining the image center very precisely. Results from the four filters of VMC (365, 513, 965 and 1010 nm central wavelengths) provide an estimate of the limb altitude from the slant view that can be compared with the available results.

2. VMC Images

VMC is composed of four independent wide angle optics that share a 1024 x 1024 array detector of 9 micron sized pixels divided into four quadrants (Markiewicz et al., 2006), using one quadrant each. Each quadrant is coated with a narrow band filter (Table 1). The control electronics enables each optical unit to be used as an independent camera, allowing simultaneous or selected image acquisitions with independent exposure times.

Table 1. Characteristics of the VMC instrument.

Filter	Band Center (nm)	Band width (nm)	Focal Length (mm)	iFoV (µradian)	FoV (Deg)
NIR-1	935	70	12.8212	701.960	20.4
NIR-2	1010	20	12.7893	703.916	20.4
UV	365	40	12.9945	692.601	20.1
VIS	513	50	12.7439	706.221	20.5

The relatively wide angle field of view of the four optics makes the iFoV vary from the center of each 512x512 frame towards the edges but can be accounted for explicitly:

Angle = atan(distance on the CCD/focal length)

The values in Table 1 correspond to the VMC I-kernel (SPICE), but the results of this work suggest some small revisions for the iFoV (center of the frame) and thus the focal length for each camera. Venus Monitoring Camera (VMC) has been acquiring images of Venus in four filters since the Venus Express orbiter entered into orbit on 15 April 2006. The ultraviolet filter images have been used to measure motions of cloud features as proxy for ambient wind, so it is important to know the cloud top altitude and its variation with latitude, longitude and whether it varies over time. VMC acquires disk-view images when sub-Venus Express latitude ranges from near the south pole to approximately 25°S, with the distance to Venus (center) varying from ~ 72,500 to 20,000 km, with majority of the images being acquired near apocenter (Figure 1).

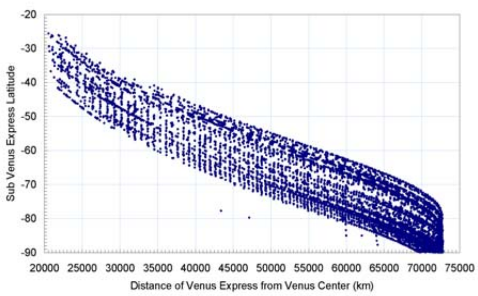

Figure 1. Relationship between the sub-Venus Express latitude and its distance to Venus center when the VMC images were acquired. The spread of the points is due to the gradual changes in the Venus Express orbit's periapsis latitude over the duration of the mission to date.

6. Summary and Conclusions

Results from the limb fits for image center and radius determination for all four VMC fitlers/cameras suggests a small offset between the derived image centers and the center location derived from SPICE kernels of about 1 – 2 pixels. A slight revision in the iFoV (~ 1 to 2 %) is also indicated as the limb altitude values derived are somewhat larger than the expected limb altitude even after allowing for the slant viewing geometry. The derived cloud top altitude variation with latitude shows similar trend at all four wavelengths, but the magnitude is somewhat greater than the results presented by Ignatiev et al. (2009).

Acknowledgements

This work was supported by NASA Grant **NNX09AE85G**. We acknowledge the support of the VMC Team

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