

Year 3 Report on NASA Award Number NNX09AE85G

INVESTIGATION OF THE VENUS ATMOSPHERIC DYNAMICS
FROM VMC AND VIRTIS INSTRUMENTS ON VENUS EXPRESS

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1. INTRODUCTION

This is the Year 3 Progress Report (January – December 2011) on NASA Grant NNX09AE85G (Venus Atmospheric Dynamics from VMC and VIRTIS Instruments on Venus Express). The Venus Monitoring Camera (VMC) continues to function well and is collecting images of Venus in all filters. The Visible InfraRed Imaging Spectrometer (VIRTIS) has suffered a cooler failure and is not currently acquiring mapping data in the near infrared.

In November 2010 ESA announced that the Venus Express mission has been extended to continue operations through 2014. Funding beyond 2012 will be forthcoming following a review in 2012.

Processed VMC images have been retrieved from the VMC Team through Orbit 1999 (September 2011). The VMC camera has stabilized and has not shown any additional degradation. The flat-fielding of the images requires that the on-orbit flats be acquired using Venus cloud cover as the target when at close approach when the image contrast is negligible due to the very high spatial resolution. Processing of these “flats” takes several days before the final processed, Level 2 version (.01) becomes available. The quality of the processed (Level 2, Version 1) data using these additional flats is dependent on the ability to acquire sufficient “flats” near periastron. DLR also provides mapped products (Level 3) although these are not used in the data analysis done at University of Wisconsin.

2. PROGRESS MADE DURING YEAR 3

Progress was made in all areas of the proposed investigation and is described below with some highlights. I continued participation in research from Venus Express data with colleagues from VIRTIS, VeRa and SPICAV/SOIR teams in addition to VMC. Four papers are currently being prepared for submission to Science and Icarus on various topics.

One of the significant issues to arise this year was the continuing difficulty in determining the altitude of the haze layers captured in VMC images during close approach. Previously attributed to a variety of possible causes, the discrepancy led to a concern about the pixel size of all four VMC cameras. I devoted a major effort during this year towards exploring this point in great detail.

Since wide angle star field images from VMC are not yet available, the only means of verifying the FoV was to determine the altitude of the cloud top using the limb location in the VMC data. The cloud top altitude has been previously determined from nadir view VIRTIS data and suggests that visible cloud top is about 73 km at low latitudes and as low as ~ 67 km in polar latitudes (Ignatiev et al., 2009).

The cloud top altitude in VMC images was determined by applying a gradient filter to the image data to locate the limb and use a variety of ellipse fitting routines to determine the center of the Venus disk and its major and minor axes accurately. Most data showed eccentricity of only about 0.05. Figure 1 below shows the distribution of a circle fit to limb in nearly 8,000 images in

n2 filter, indicating that the mode cloudtop altitude is considerably higher than the expected value, indicating a need to update the VMC FoV. Similar results are found for other filters also.

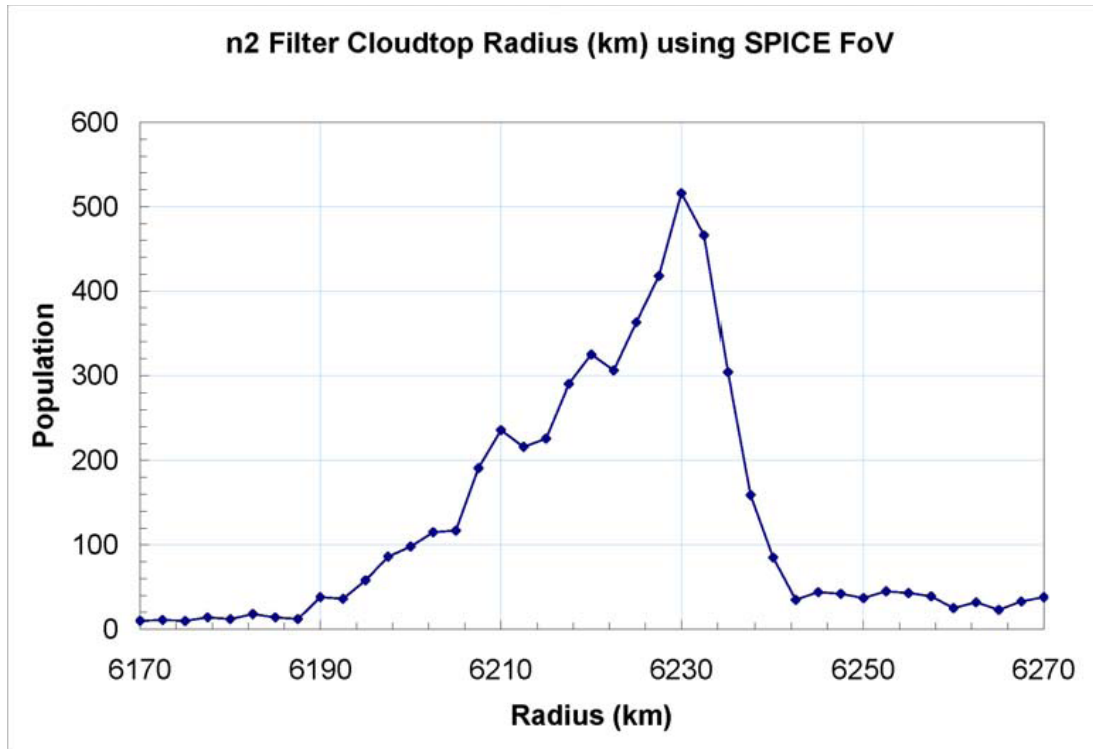


Figure 1. Distribution of cloud top altitude from circle fits to limb location in VMC n2 filter images using the SPICE value for the FoV. The implied altitude of ~ 179 km is much higher than the expected value (~ 6120 km radius), indicating a need to update the FoV.

2.1 HIGHLIGHTS

- Five co-authored papers have been published or accepted for publication based on my contributions
- Conference presentations at European Geophysical Union General Assembly (May 2011), Low Cost Planetary Observations (June 2011) and at the Joint Division for Planetary Sciences and Europlanets Meeting in October 2011
- Supported Venus Education and Public Outreach efforts
- Acted as one of the Guest Editors for the “Advances in Venus Science” special issue of *Icarus*, due to be published in January 2012.
- Discovery of corrective steps needed in flat-fielding of VMC images
- Discovery of need for corrections to the pixel size of VMC cameras

Of these the last two items have some impacts on the accuracy of some of the VMC results and hence corrective steps are being devised.

2.2 GLOBAL STRUCTURE OF THE ATMOSPHERIC CIRCULATION

Venus continues to show evolving morphology in its global cloud level circulation as revealed from Venus Express VMC images. One of the new results is that for the first time we can see not only the asymmetry of the vortex (Figure 2) but also a change in the rotation rate of the inner core from animations of polar projections of composite images.

These results are being compiled and written up for publication in a peer reviewed journal.

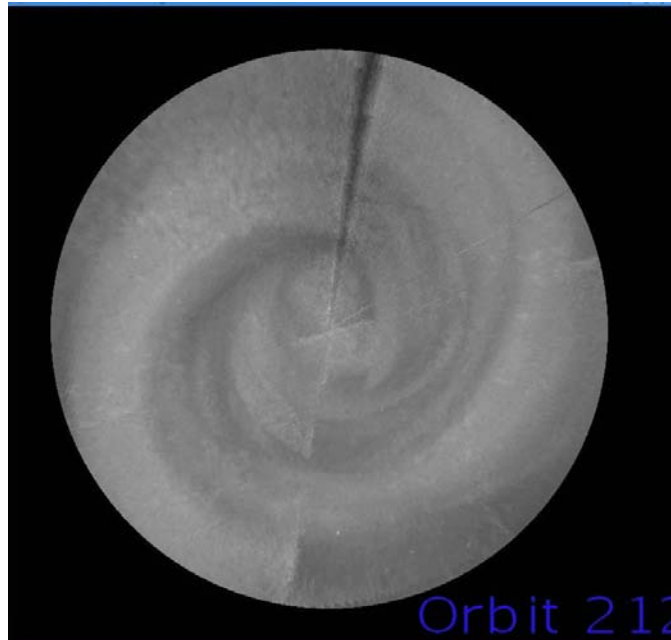


Figure 2. Space time composite of selected ultraviolet images from Venus Express orbits 212-214 providing a view of the southern hemisphere. Each image was rotated about the pole at a nominal rotation rate of the atmosphere at the cloud level to match at high latitudes only.

2.3 Bright Clouds on Venus and Processing of VMC Images

A very bright cloud was noticed in ultraviolet images of Venus taken by amateurs on 19 July 2009. Subsequent analysis of VMC images also showed such a bright spot. Its brightness seemed to be much brighter than usual, even after temperature correction (described in the Year 2 report), so an effort was undertaken to look for similar bright spots in prior VMC images. Many occurrences were found, many with even higher intensities, leading to an examination of the flat-fielding of the VMC images using on-orbit flats. Further, there appeared to be a small trend to the peak intensities observed, and yet no other anomalies were noticed. This led to an examination of the processing steps that VMC images are subjected to. It was found that a small brightness gradient was present in the flat-fields generated for all orbits until Orbit 976, leading to some bias in the processed images.

3. SCIENTIFIC MEETING AND CONFERENCE PRESENTATIONS

I participated in several scientific conferences as well as VMC and Venus Express Team meetings either in person or by telephone and made presentations on my work. The table below lists the presentations made

Table 1. VMC/Venus Express Team Meetings and Conference presentations

Date	Meeting	Topic/Presentation	Presenter / Authors
23-25 March 2011	26 th Venus Express Science Working Team Meeting, Paris, France	VMC Observations of the Vortex circulation	S.S. Limaye and W.J. Markiewicz
3-7 May 2011	European Geophysical Union General Assembly	Venus Atmosphere: Observations from VMC on Venus Express	S.S. Limaye, R.J. Krauss, W. J. Markiewicz and D. Titov
3-8 October, 2011, Nantes, FRANCE	43 rd Annual Meeting of the Division for Planetary Sciences & Europlanets Joint Meeting	Venus Atmospheric Circulation	S.S. Limaye
13 October 2011	Geological Society of America	Venus: Still the Natural Laboratory	S.S. Limaye and R.S. Saunders
November 16-18, Graz, Austria	27 th Science Working Team Meeting, Venus Express	Cloudtop altitude on Venus and its latitudinal variation	Limaye, S.S.
31 August - 1 September 2011	9 th VEXAG Meeting Chantilly, Virginia	Clouds, Circulation and Organization from VMC Observations of Venus	S.S. Limaye, R.J. Krauss, W.J. Markiewicz

4. EDUCATION AND PUBLIC OUTREACH EFFORTS

I participated in several activities for Venus Express and supported the Venus (see table below) Express Education and Public Outreach efforts (venus.wisc.edu) led by Ms. Rosalyn Pertzborn. One of the key efforts was an innovative program for high school interns for during the summer months (June – July).

Other events that I participated in are given in Table 2 below.

Table 2. Support of and participation in Education and Public Outreach Events in support of Venus Express Mission (venus.wisc.edu).

Date	Location	Topic	Remarks
13 September 2011	UW Space Place, Madison, Wisconsin	Exploring Venus with Venus Express	Public talk

1 June – 4 August 2011	Madison, Wisconsin	Cloud level circulation on Venus by tracking clouds in Venus Express images	High School Summer Interns from New Glarus High School, New Glarus, Wisconsin
3-6 June 2011	University of Hawaii, Honolulu, Hawaii	HISTARS Astronomy Workshop for high school students	Worked with three students on Venus cloud tracking activity

5. PUBLICATIONS AND CONFERENCE PRESENTATIONS

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Leitner, S.S. Limaye, B. Marty, E. Palomba, S.V. Pogrebenko, S.C.R. Rafkin, D.L. Talboys, R.Wieler, L.V. Zasova, C. Szopa and the EVE Team, 2011, The 2010 European Venus Explorer (EVE) mission proposal, *Exp. Astron.*, DOI 10.1007/s10686-011-9259-9.

Young, E.F., M. Bullock, C. Tsang, D.N.B. Hall, S. Limaye, J. Fox, and S.A. Smrekar, 2011. The Case for Venus Observations from the Earth's Stratosphere. A poster presentation at the Low Cost Planetary Missions Conference, Internal Academy of Astronautics, Laurel, MD, 2123 June, 2011.