Year 2 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 2 Progress Report 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 1670 (15 November 2010). 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 periapsis. 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 2

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. The titles are presented under publications.

One aspect of the data processing that came to the forefront was the need to correct the image data for temperature effects. A calibration factor for conversion of the data numbers in the Version 2 format is provided in the Image Label and needs to be taken into account explicitly for comparing the data even for the same orbit.

2.1 HIGHLIGHTS

- An international conference, "Venus Atmosphere from Surface to Thermosphere – how does it work?" was organized in Madison, Wisconsin during 30 August – 1 September under the aegis of the Venus Exploration Analysis Group (VEXAG). It was attended by seventy five scientists from the international community. Sixty papers were presented at this conference. A CD-ROM containing extended abstracts of these presentations (220 pp) was produced and provided to the participants.
- A STEM workshop for Wisconsin educators was held in conjunction with this conference and coordinated with the National Girls Collaboration Project (NSF funded), and the Wisconsin Department of Public Instruction with over 110 educators in attendance.

- A public event, "Impacts, Planetary Climates and Venus: What can they teach us about Earth?" featuring Prof. Jan Smit (VU University, Amsterdam, the Netherlands, Chixclub Impact), Dr. David Grinspoon (Planetary Climates) and Bill Nye "the Science Guy" speaking about Earth's climate.
- A special issue of ***Icarus*** on Advances in Venus Science has been arranged through discussions with the Icarus Editor and Venus Express Scientists. It will be ready for publication in late summer/early fall 2011 featuring papers from the workshop held in Madison as well as from the Venus Express Science workshop held in Aussois, France (20-26 June 2010) and other contributions on Venus
- Appointed as one of three Guest Editors of ***Icarus*** for the Special issue

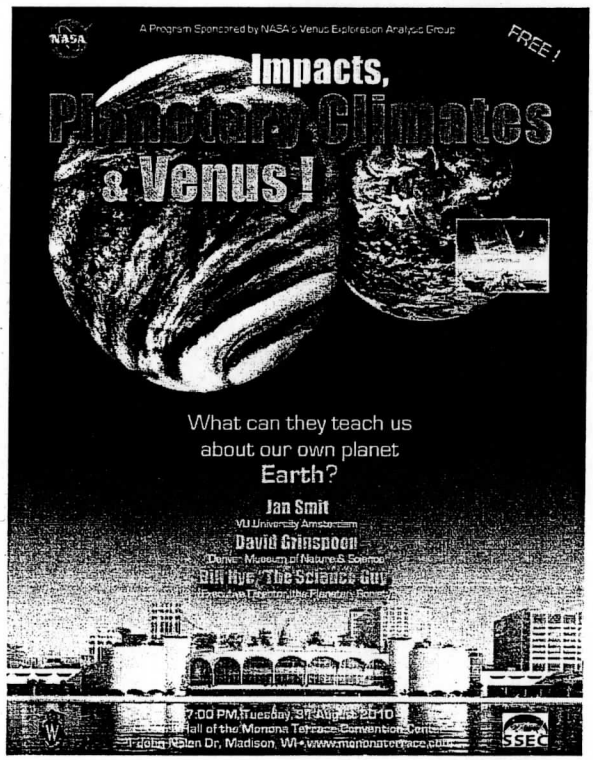


Figure 1. Flyer prepared for the Venus Conference Public Event

Figure 2. CD-ROM volume containing the conference extended abstracts.

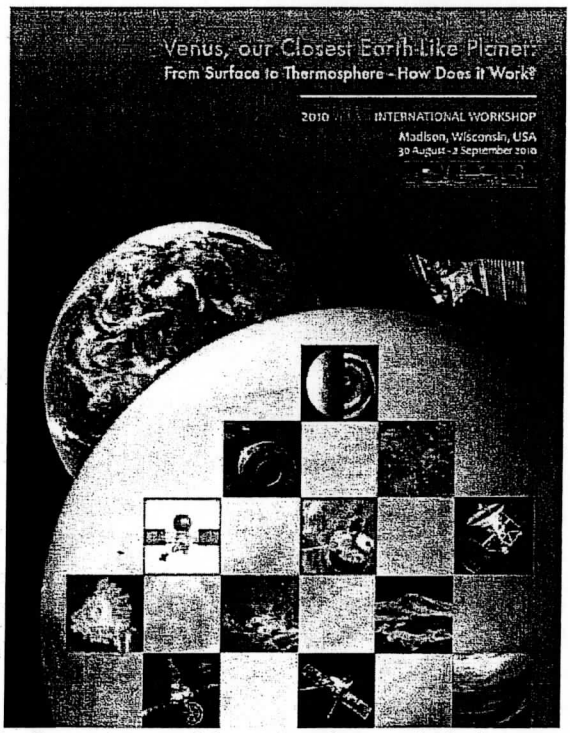
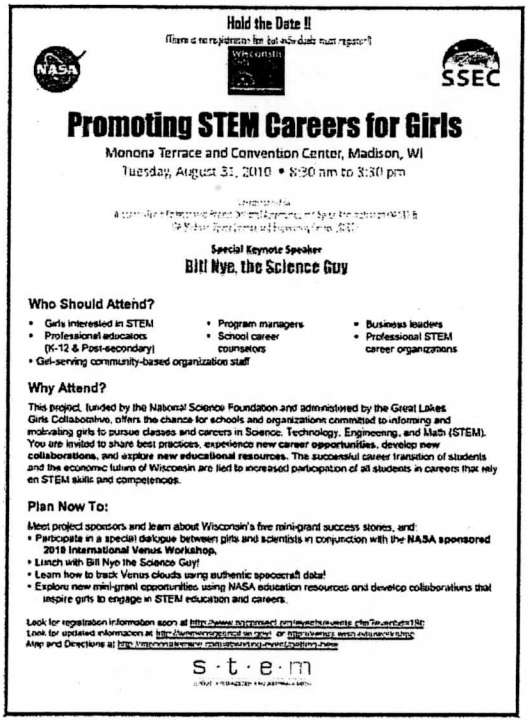


Figure 3. Cover page of the printed extended abstract volume.



Hold the Date !!

SSEC

Promoting STEM Careers for Girls

Monona Terrace and Convention Center, Madison, WI

Tuesday, August 31, 2010 • 8:30 am to 3:30 pm

Special Keynote Speaker

Bill Nye, the Science Guy

Who Should Attend?

- Girls interested in STEM
- Professional educators (K-12 & Post-secondary)
- Program managers
- School career counselors
- Business leaders
- Professional STEM career organizations
- Girl-serving community-based organization staff

Why Attend?

This project, funded by the National Science Foundation and administered by the Great Lakes Girls Collaborative, offers the chance for schools and organizations committed to informing and motivating girls to pursue classes and careers in Science, Technology, Engineering, and Math (STEM). You are invited to share best practices, experience new career opportunities, develop new collaborations, and explore new educational resources. The successful career transition of students and the economic future of Wisconsin are tied to increased participation of all students in careers that rely on STEM skills and competencies.

Plan Now To:

Meet project sponsors and learn about Wisconsin's five mini-grant success stories, and:

- Participate in a special dialogue between girls and scientists in conjunction with the NASA sponsored 2010 International Venus Workshop.
- Lunch with Bill Nye the Science Guy!
- Learn how to track Venus clouds using authentic spacecraft data!
- Explore new mini-grant opportunities using NASA education resources and develop collaborations that inspire girls to engage in STEM education and careers.

Look for registration information soon at

Look for updated information at

Map and Directions at

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Figure 4. Flyer for the Educator workshop.

VMC Observing Sequence Planning

One of the puzzling questions about Venus clouds is their rapid evolution. One of my contributions as a Participating Scientist was to submit a recommendation to acquire a sequence of images acquired very quickly when the spacecraft is close to the planet and can see the same portion of Venus. A few sequences of rapid imaging were acquired to look at the short term changes (~ minute) at a spatial resolution of ~ 1 km. These results are being analyzed.

2.2 Digital Tracking of Clouds in VMC Images

Both digital and visual tracking techniques continue to be used to measure cloud motions from mapped (rectilinear format, 8 pixels/degree scale in latitude and longitude) ultraviolet images. Experiments with high-pass filters show some improved detail for tracking but overall the cloud motion statistics remain similar.

Figures 5 and 6 show the zonal and meridional components of cloud motions determined from a sequence of images acquired on Orbit 1108 using automated digital tracking method and with the use of a quality control check for valid vectors based on their magnitude and direction as many false positives are present, consistent with previous results. Profiles obtained for a series of orbits are being analyzed, presented at team meetings and conferences and being included in a number of papers being developed for publication in refereed journals (e.g. the special issue of ***Icarus*** on Advances in Venus Science).

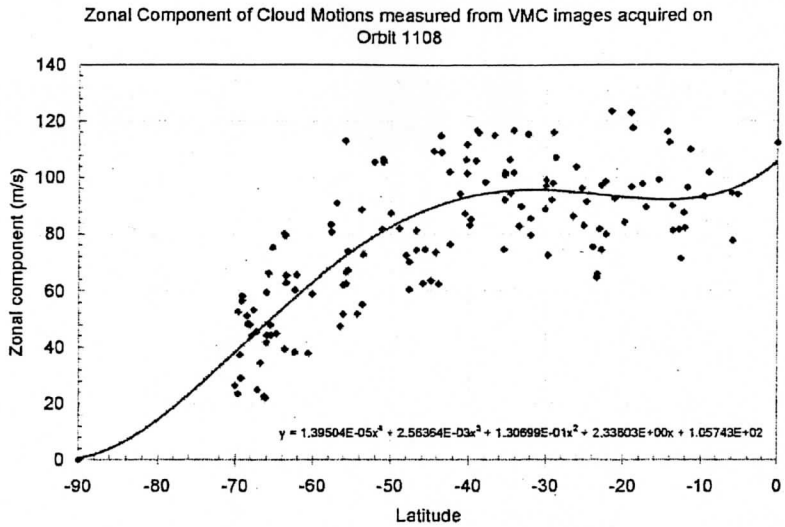

Figure 5. Example of the zonal component cloud motion measurements for images obtained on orbit 1108.

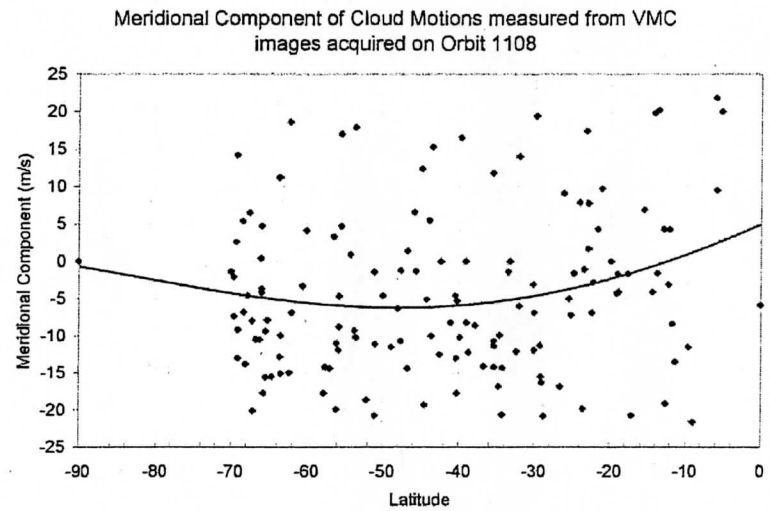

Figure 6. Example of the meridional component of cloud motion measurements for images obtained on orbit 1108.

2.3 Global Structure of the Atmospheric Circulation

The UV filter images acquired by VMC on successive orbits can be used to create a space-time composite view of the southern hemisphere to reveal the global structure of the cloud cover and the inferred circulation as was first done with the Mariner 10 images (Suomi and Limaye, 1978).

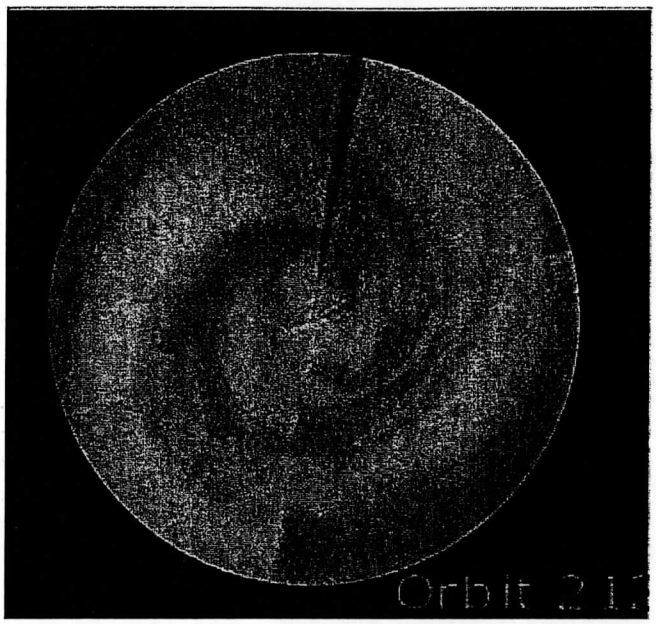

Figure 7. Space time composite of selected ultraviolet images from Venus Express orbits 212-214 providing a view of the southern hemisphere. Each image was rotated about the pole at a nominal rotation rate of the atmosphere at the cloud level to match at high latitudes only.

3. TEAM/SCIENTIFIC MEETINGS 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
April	VMC Team Meeting, Lindau-Katlenburg	Observation Planning, Data Analysis Status	Limaye
May 3-8, 2010	European Geophysical Union Meeting	A Bright Cloud on Venus	Limaye et al.
20-26 June 2010	Venus Express Science Workshop	Atmospheric Circulation on Venus: An update	Limaye and Read
4-8 July, 2010	Asia Oceania Geosciences Society Annual Meeting, Hyderabad, India	Venus Exploration	Limaye
12-13 July, 2010	Workshop on Planetary Atmospheres, Physical Research Laboratory, Ahmedabad, India	Venus: So near yet so different	Limaye
3-8 October, 2010	42nd Annual Meeting of the Division for Planetary Sciences	Venus Atmospheric Circulation	Limaye
November	25th Science Working	Icarus Venus Special Issue	Limaye, S.S.,

8-10	Team Meeting, Venus Express	Update	Markiewicz, W. J., Titov, D., Moissl, R., and the VMC Team

4. EDUCATION AND PUBLIC OUTREACH EFFORTS

I participated in several activities for Venus Express and supported the Venus (see table below) Express/NASA URL for Education and Public Outreach Program (venus.wisc.edu) led by Ms. Rosalyn Pertzborn. One of the key events was the STEM workshop for Educators held in conjunction with the VEXAG sponsored International Conference on Venus Atmosphere in Madison, Wisconsin, with the collaboration of the National Girls Collaborative and the Wisconsin Department of Public Instruction. Selected scientists were invited to speak to the teachers and students attending and a panel of women scientists working on Venus presented their career experiences to the attendees.

Figure 8. Bill Nye speaking to the educators and school students in audince at the STEM workshop (left). Figure 9 (right). The STEM workshop featured women scientists working on Venus - Vicki Hansen, Joanna Barstow, Sue Smrekar, Ellen Stofan, Natasha Johnson and Eve Marie Gagne. Bill Nye the Science Guy's participation was made possible by the Planetary Society.

Figure 10. Bill Nye speaking at the evening public event.

In addition, a hugely successful public program, "Impacts, Planetary Climates and Venus" filled three meeting halls to capacity with standing room only in the Monona Terrace Convention Center. Video was piped in from the main lecture hall for the overflow audience. The program featured Prof. Jan Smit, Dr. David Grinspoon and Bill Nye the Science Guy can be viewed on the web at: *venus.wisc.edu/multimedia_video.html*

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	Event Name	Activities Title	Format	Presenter(s)	Location
31 Aug 2010	Promoting STEM Careers to Girls	Tracking Clouds on Venus	Lecture / Demonstration / Hand-On	Ms. Rosalyn Pertzborn Sanjay Limaye Kevin Baines Hsuan-Yub Pi	Madison, WI USA
31 Aug 2010	Public Lecture	VEXAG Sponsored Public Event: Impacts, Planetary Climates and Venus	Lecture / Audience Q/A	David Grinspoon	Madison, Wisconsin USA
31 Aug 2010	VEXAG Public Event in conjuction with the International Conference on Venus	VEXAG Sponsored Public Event: Impacts, Planetary Climates and Venus	Lecture	Dr. Jan Smit	Madison, Wisconsin USA
31 Aug 2010	Impacts, Planetary Climates and Venus: What can they teach us about Earth	VEXAG Sponsored Public Event: Impacts, Planetary Climates and Venus	Lecture	Mr. Bill Nye	Madison, Wisconsin USA
16 Jun 2010	Aviation and Space Exploration Workshop - PEOPLE Program, UW-Madison	Aviation and Space Exploration Workshop, PEOPLE Program	Video / Group Discussion / Audience Q/A	Dr. Sanjay Limaye	Madison, Wisconsin USA
15 Jun 2010	University of Wisconsin-Madison PEOPLE Program	Weather and Climate in the Solar System	Lecture / Group Discussion / Audience Q/A	Rosalyn Pertzborn	Madison, WI USA
22 May 2010	New Testament School Career Workshop	Weather and Climate on Earth and Venus	Lecture / Demonstration / Group Discussion / Audience Q/A / Hand-On	Rosalyn Pertzborn Hsuan-Yun Pi	Milwaukee, WI USA
22 Apr 2010	Weather and Climate on Earth and Venus	Weather and Climate on Earth and Venus	Lecture / Group Discussion / Audience Q/A	Sanjay Limaye	Keshena, WI USA

5. PUBLICATIONS AND CONFERENCE PRESENTATIONS

The following papers are being developed for submission:

An Unusually Bright Spot on Venus: Possible signature of a volcanic eruption, S. S. Limaye, R.J. Krauss, M. Bullock, D. Grinspoon, W. J. Markiewicz, D.M. Titov, S. E. Smrekar, Lori S. Glaze, H. Svedhem and K. Baines – for submission to *Science,* November 2010.

Zonal thermal winds on Venus derived from the radio-occultation temperature sounding on board Venus Express, A. Piccialli, S. Tellmann, D. V. Titov, S. S. Limaye, I. V. Khatuntsev,

M. Pätzold and B. Häusler. *To be submitted to the Special issue of Icarus on Advances in Venus Science, November 2010.*

Morphology of the cloud tops as observed by the Venus Express Monitoring Camera, D.V. Titov, W.J. Markiewicz, N.I. Ignatiev, S. Li, S.S. Limaye, M. Almeida, Th. Roatsch[6], D. Crisp, L. W. Esposito, S.F. Hviid, R. Jaumann, H.U. Keller, K.-D. Matz, R. Moissl, A. Sanchez-Lavega, F. Scholten, M. Yamada. *To be submitted to the Special issue of Icarus on Advances in Venus Science, November 2010.*

An Assessment of the circulation of Venus atmosphere from Venus Monitoring Camera Observations, by S.S. Limaye, D. M. Titov, W.J. Markiewicz, I. Khatuntsev, and M. Patsaeva. *To be submitted to the Special issue of Icarus on Advances in Venus Science, November 2010*

Atmospheric circulation and dynamics – Observations and knowledge gaps by S.S. Limaye, D.M. Titov and C. Covey. *Draft chapter submitted for the International Space Science Institute Publication on Venus Climate and Comparison of General Circulation Models (L. Bengtsson and R. Bonnet).*