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

1 January 2010 – 31 December 2010

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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, Chixclum 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

![Flyer](image)

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.
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 profiles 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

<table>
<thead>
<tr>
<th>Date</th>
<th>Meeting</th>
<th>Topic/Presentation</th>
<th>Presenter / Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>VMC Team Meeting, Lindau-Katlenburg</td>
<td>Observation Planning, Data Analysis Status</td>
<td>Limaye</td>
</tr>
<tr>
<td>May 3-8, 2010</td>
<td>European Geophysical Union Meeting</td>
<td>A Bright Cloud on Venus</td>
<td>Limaye et al.</td>
</tr>
<tr>
<td>20-26 June 2010</td>
<td>Venus Express Science Workshop</td>
<td>Atmospheric Circulation on Venus: An update</td>
<td>Limaye and Read</td>
</tr>
<tr>
<td>4-8 July, 2010</td>
<td>Asia Oceania Geosciences Society Annual Meeting, Hyderabad, India</td>
<td>Venus Exploration</td>
<td>Limaye</td>
</tr>
<tr>
<td>12-13 July, 2010</td>
<td>Workshop on Planetary Atmospheres, Physical Research Laboratory, Ahmedabad, India</td>
<td>Venus: So near yet so different</td>
<td>Limaye</td>
</tr>
<tr>
<td>3-8 October, 2010</td>
<td>42nd Annual Meeting of the Division for Planetary Sciences</td>
<td>Venus Atmospheric Circulation</td>
<td>Limaye</td>
</tr>
<tr>
<td>November</td>
<td>25th Science Working</td>
<td>Icarus Venus Special Issue</td>
<td>Limaye, S.S.</td>
</tr>
</tbody>
</table>
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 Pertzhorn. One of the key events was the STEM workshop for Educators held in conjunction with the VEXAM 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 audience 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.](image)

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](http://venus.wisc.edu/multimedia_video.html)

![Figure 10. Bill Nye speaking at the evening public event.](image)
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).

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Name</th>
<th>Activities Title</th>
<th>Format</th>
<th>Presenter(s)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 Aug 2010</td>
<td>Public Lecture</td>
<td>VEXAG Sponsored Public Event: Impacts, Planetary Climates and Venus</td>
<td>Lecture / Audience Q/A</td>
<td>David Grinspoon</td>
<td>Madison, Wisconsin USA</td>
</tr>
<tr>
<td>31 Aug 2010</td>
<td>VEXAG Public Event in conjunction with the International Conference on Venus</td>
<td>VEXAG Sponsored Public Event: Impacts, Planetary Climates and Venus</td>
<td>Lecture</td>
<td>Dr. Jen Smith</td>
<td>Madison, Wisconsin USA</td>
</tr>
<tr>
<td>31 Aug 2010</td>
<td>Impacts, Planetary Climates and Venus: What can they teach us about Earth</td>
<td>VEXAG Sponsored Public Event: Impacts, Planetary Climates and Venus</td>
<td>Lecture</td>
<td>Mr. Bill Nye</td>
<td>Madison, Wisconsin USA</td>
</tr>
<tr>
<td>16 Jun 2010</td>
<td>Aviation and Space Exploration Workshop - PEOPLE Program, UW-Madison</td>
<td>Aviation and Space Exploration Workshop, PEOPLE Program</td>
<td>Video / Group Discussion / Audience Q/A</td>
<td>Dr. Sanjay Limaye</td>
<td>Madison, Wisconsin USA</td>
</tr>
<tr>
<td>15 Jun 2010</td>
<td>University of Wisconsin-Madison PEOPLE Program</td>
<td>Weather and Climate in the Solar System</td>
<td>Lecture / Group Discussion / Audience Q/A</td>
<td>Rosalyn Pertzborn</td>
<td>Madison, WI USA</td>
</tr>
<tr>
<td>22 May 2010</td>
<td>New Testament School Career Workshop</td>
<td>Weather and Climate on Earth and Venus</td>
<td>Lecture / Demonstration / Group Discussion / Audience Q/A / Hand-On</td>
<td>Rosalyn Pertzborn, Hsuan-Yun Pi</td>
<td>Milwaukee, WI USA</td>
</tr>
<tr>
<td>22 Apr 2010</td>
<td>Weather and Climate on Earth and Venus</td>
<td>Weather and Climate on Earth and Venus</td>
<td>Lecture / Group Discussion / Audience Q/A</td>
<td>Sanjay Limaye</td>
<td>Keshena, WI USA</td>
</tr>
</tbody>
</table>

5. **Publications and Conference Presentations**

The following papers are being developed for submission:


**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.

