SUMMARY ABSTRACTS

Venus, our Closest Earth-Like Planet:

From Surface to Thermosphere - How Does it Work?

2010 VEXAG INTERNATIONAL WORKSHOP

Madison, Wisconsin, USA

30 August - 2 September 2010

VEXAG
Venus Exploration Analysis Group

An International Workshop on

Venus, Our Closest Earth-like Planet: From Surface to Thermosphere - How does it Work?

Madison, Wisconsin
30 August – 2 September 2010

Organizing Committee

Suhil Atreya
Mark Bullock
Curt Covey
David Grinspoon
Sanjay Limaye
Paul Menzel
Franck Montmessin
Sue Smrekar

Convenors:
Sue Smrekar and Sanjay Limaye (VEXAG Co-Chairs)
Adriana C. Ocampo (NASA HQ)

PROGRAM

Sponsored by the National Aeronautics and Space Administration

VEXAG
Venus Exploration Analysis Group

The need for this workshop was recognized and conceived during the 2008 and 2009 VEXAG meetings and follows the first workshop on Venus Geochemistry held in Houston, Texas in March 2009. It also follows the launch of Akatsuki by JAXA on 21 May 2010 and the Venus Express workshop in June 2010 organized by ESA. The workshop occurs during the open period of NASA's Discovery Program solicitation. It is anticipated that several proposals targeting extensive studies of Venus will be submitted. In addition, SAGE, a New Frontiers mission is under further study. Simultaneously several Venus mission concepts are also being developed in Russia and in Europe for ESA's Cosmic Vision Program. Therefore, I believe it is vital to foster coordinated efforts through an international dialog that will enhance and maximize the scientific returns.

Almost sixty abstracts have been submitted on the atmosphere of Venus and its surface interactions, as well as new ideas for future Venus exploration initiatives to obtain observations that will provide a better understanding of Venus' evolution and climate. The workshop will also promote comparative climate studies of terrestrial planets in our own solar system and beyond.

The workshop attendance demonstrates a very strong international interest in Venus exploration. A number of graduate students are also presenting at the workshop. The workshop has been made possible through the combined efforts of the Venus community and VEXAG Steering Committee, as well as by the past VEXAG Co-Chairs (Janet Luhman, Sushil Atreya, Ellen Stofan and Steve Mackwell). The three day program will culminate with the 8th VEXAG meeting. Our efforts would not have been possible without the support of Adriana C. Ocampo (NASA/SMD) and the strong interest shown by Dr. James Green (NASA/PSD). Tommy Thompson (JPL) has also provided valuable support throughout the planning of this workshop.

To promote the value of Venus science, a workshop for educators is being held at the workshop facility during the same period (August 31st). Organized by Rosalyn Pertzborn (Office of Space Science Education, Space Science and Engineering Center at the University of Wisconsin) in collaboration with the Wisconsin Department of Public Instruction and the National Girls' Collaborative (NSF); more than seventy five educators and area community leaders will participate in a day-long workshop. The program will focus on STEM education issues for young women with Venus as the science content theme. Bill Nye "the Science Guy" will be a featured speaker along with selected Venus scientists. An evening public event, "Impacts, Planetary Climates and Venus!" featuring Prof. Jan Smit, Dr. David Grinspoon and Bill Nye "the Science Guy" has also been arranged during the workshop.

Finally, the workshop and the Education and Public Outreach events, as well as student travel have been made possible through the support and funding from NASA. The VEXAG community will be honoring Dr. Steve Saunders during this meeting for his contribution to the advancement of Venus science and planting the seed that evolved into VEXAG.

Sanjay S. Limaye
Space Science and Engineering Center
University of Wisconsin
Madison, Wisconsin
24 August 2010

The Venus Exploration Analysis Group (VEXAG) was established by NASA in July 2005 to identify scientific priorities and strategy for exploration of Venus. VEXAG is currently composed of two co-chairs and five focus groups. The focus groups will actively solicit input from the scientific community. VEXAG will report its findings and provide input to NASA, but will not make recommendations.

Workshop Program

8th VEXAG Meeting on Thursday, 2 September 2010!

POSTER PRESENTATIONS

P1. VORTEX: A Mission Concept Study to Venus – *J. Adams, A. Ball, C. Runyon, and P.J. Benfield*

The NASA Discovery/New Frontiers/Lunar Quest Program Office is supporting an innovative educational experiment that provides an opportunity to train the next generation of scientists and engineers by permitting them to respond to an official NASA Announcement of Opportunity (AO) [1]. Undergraduate student teams from four Universities in science and engineering are taking part in this ongoing exercise. This Academic AO Project is divided into the traditional New Frontiers roles, with the overall science, project management and engineering functions. Teams include partners at The University of Alabama in Huntsville (UAH), the College of Charleston (CofC), ESTACA (Ecole Supérieure des Techniques Aéronautiques et de Construction Automobile) University in Paris, France, and Southern University in Baton Rouge, LA (SUBR).

P2. Hydrocarbons and Organics on Venus: Where Are They Now? – *M. Baek and S. Atreya*

Hydrocarbons and organics are absent on Venus, based on in situ and ground-based measurements to date. Potential sources of methane and organic compounds on Venus and their possible loss processes are discussed and compared to the cases on Earth and Mars in this work. Venus Orbiter Recon and Tandem Environmental Xploration Benfield, Michael

P3. Observing Venus from Himalayan Chandra Telescope at Hanle – *B. C. Bhatt, T. P. Prabhu, and S. S. Limaye*

The Indian Astronomical Observatory (IAO) was set up with a 2m visible-infrared telescope named Himalayan Chandra Telescope (HCT) at Mt Saraswati, Hanle, at an altitude of 4500 m above sea level following an extensive survey (Bull. Astr. Soc. India, 24, 859-869, 1996) of potential high altitude astronomical sites in India during 1993-1997 by the Indian Institute of Astrophysics (IIA), Bangalore. Hanle, in Ladakh region of Jammu & Kashmir in northern India was chosen as an excellent high altitude site for ground based astronomy. Hanle provides more than 250 usable nights uniformly spread over the year, with low humidity, good transparency and seeing. Equipped with three instruments – a faint object spectrograph, a near infrared imager and a visible CCD camera, HCT (tended by local operators) is remotely utilized via a satellite communication link from the Centre for Research & Education in Science & Technology (CREST), Hosakote, an off site campus of the Indian Institute of Astrophysics (IIA) on the outskirts of Bangalore. HCT has been used to observe the night side of Venus near conjunctions since 2004 and is available to the global community through a regular proposal process for time allocation.

P4. The Case for InSAR at Venus – *R.Ghail, P. Mason, and C. Cochrane*

The Magellan mission to Venus revealed a planet of contradictions, with a wealth of geological features but no obvious evidence for plate tectonics and a crater distribution that seemed to imply a static surface. Recently, Venus Express has provided the most compelling evidence to date for recent activity, reopening the whole question of how Venus behaves as a planet. Is it a dynamic, active planet like Earth or a dormant world, geologically more similar to Mars than our own planet. The clues are in the Magellan data but a new interferometric SAR mission is our only realistic hope for finding the answers by quantifying rates of surface change. This paper examines the evidence observational and theoretical evidence for an active Venus and outlines an M (Discovery) class mission to address these questions

P5. Effects of atmospheric waves on the O2-1.27 um nightglow distribution in Venus – *N. Hoshino, H .Fujiwara, M. Takagi, and Y. Kasaba*

We have investigated the impact of small-scale gravity waves and planetary scale waves (Kelvin wave, Rossby wave and thermal tides) on the O_2-1.27 μm nightglow distribution in Venus. As shown in previous studies [e.g., Bougher et al., 1988], our result shows that small-scale gravity wave transports the westward momentum and drives the retrograde zonal wind (RZW). The nightglow emission region shifts westward because of the RZW. Our result also shows that Kelvin wave is the dominant wave in the planetary-scale waves in the Venusian mesosphere and thermosphere. The Kelvin wave propagates upward up to about 140 km with the zonal wind fluctuation of about 12 m/s and causes the fluctuations of the O_2-1.27μm nightglow distribution between 00:00 LT and 00:20 LT.

P6. Venus Pressure Chamber: A Small Testing Facility for the Community – *N. M. Johnson*

A Venus pressure test chamber has been acquired for the Venus scientific community and is housed at the Goddard Space Flight Center in Greenbelt, Maryland. It is available to the community for testing of small flight components/instruments and/or short-term experiments that require high temperatures and pressures. The chamber is able to maintain Venus surface temperatures and pressures (~740K and ~95 bar, respectively) for up to ~48 hours under a carbon dioxide atmosphere. The dimensions of the chamber are five inches in diameter and twelve inches deep. The actual working space is slightly smaller because of volume taken up by monitoring sensors. Detailed information and availability will be presented at the upcoming meeting in Madison, Wisconsin.

P7. Abundance and Vertical Distribution of the Unknown Absorber from analysis of VMC images – *K. Molaverdikhani, K. McGouldrick, and L. W. Esposito*

The Venus' atmosphere shows strong absorption of solar radiation between 0.2 and 0.5 μm and SO_2 could well explain the absorption of region between 0.2 to 0.32 μm, while absorption in longer wavelengths required another absorber that is not identified yet (Esposito et al., 1997). The center of Venus Monitor Camera's UV filter was chosen to cover the spectral range from 0.345 to 0.385 μm for investigation on the spatial and vertical distribution of the UV-blue absorbers at the cloud tops (Markiewicz et al. 2007).

The concentration and distribution of this absorber is very important not just from the chemistry aspect of Venus upper atmosphere but also for thermal balance of the planet and subsequently global dynamics of clouds. Previously, the variations of ultraviolet absorbers and possible candidates for unknown absorber have been analyzed (Esposito et al. 1988, Pollack et al. 1980) in the upper clouds.

In this paper, we generate a suite of models for the three free parameters in the upper atmosphere of Venus in which we are interested: sulfur dioxide abundance at 40mb, scale height of sulfur dioxide, and the typical radius of the upper haze particles (assumed to be composed of 84.5% sulfuric acid) and two extra free parameters on unknown absorber: pressure level and total optical depth of the absorber. We select a good model based on independency of geographical parameters to the geometrics parameters. We calculate required concentration and distribution to reproduce exact observed reflectivities for images taken with VEX VMC.

P8. Automated Cloud Tracking System for the Akatsuki Venus Climate Orbiter Data – *K. Ogohara, N. Satoh, M. Takagi, and T. Imamura*

A planned procedure of data processing of Akatsuki (Venus Climate Orbiter, VCO) including derivation of horizontal wind vectors by the cloud tracking technique is described. All Venus (cloud) images taken by cameras onboard Akatsuki are attached with geometry information (e.g. longitude, latitude, incident angle, and so on). The images are converted to rectangular latitude-longitude-latitude maps. After some manipulations (solar zenith angle correction, high-pass filtering, etc.), horizontal wind vectors are derived by the cloud tracking scheme from the brightness maps. Applying this procedure to all the cameras (and filters) onboard Akatsuki, we may obtain three dimensional wind distributions.

P9. Global Variations in the Lithospheric Thickness on Venus: Implications for the Evolution of Volcanism – *C. P. Orth and V. S. Solomatov*

We focus on the long-wavelength Venusian topography and geoid and place constraints on the global average lithospheric thickness by assuming that the stagnant lid overlying the convective mantle is in isostatic equilibrium – the isostatic stagnant lid (ISL) approximation. Application of the ISL approximation to Venus suggests that the global lithospheric thickness is around 300 km and that crustal thickening is required only in a few regions to satisfy gravity and topography data. To model the evolution of volcanic activity we first assume that at some point in Venusian history the planet was substantially molten and large amounts of magmatism were present. The convective heat flux at the base of the lid is assumed to be negligible and the decline in volcanism is caused by the growth of a conductively cooling lid. If no mechanism is present to maintain sufficient thinning of the lithosphere, then at some point the lid will grow either to a depth where the temperature profile no longer intersects the solidus or to a depth below the solid/melt density inversion (around 300 km) and melting will cease.

P10. CO2 Absorption in the Far Wings of Ro-vibrational Bands Under Venus Conditions – *A.V. Rodin, A. Fedorova, S. Stefani, N. Ignatiev, M. Snels, G. Piccioni, and P. Drossart*

The results of laboratory measurements of CO2 absorption under high pressures and temperatures are compared with synthetic spectra based on different models of spectral line profile. The model taking into account line mixing in the strong collision approximation shows better agreement with data than widely used empirical profile with exponential cutoff. In the wavelength range shorter than 1.5 micron line mixing model tends to predict too sharp decay of the far wings and excessive absorption near the band cores.

P11. Non-hydrostatic General Circulation Model of Venus Atmosphere – *A.V. Rodin, I.V. Mingalev, K.G. Orlov, and N. Ignatiev, (presented by A. Fedorova)*

First non-hydrostatic general circulation model of the Venus atmosphere is presented. The model is based on the full set of gas dynamics equations and reproduces all major dynamical structure of the atmosphere: zonal superrotation, thermal tide, and polar vortices. Circulation pattern throughout the atmosphere reveals remarkable sensitivity to thermal forcing in the upper cloud level, confirming that superrotation is primarily driven by thermal tide.

P12. Venus III Book – *F. W. Taylor, C. T. Russell, T. Satoh, H. Svedhem, and D.V. Titov*

An overview is given of the new knowledge that has been acquired about the planet Venus since the publication of the books Venus I (Eds. D.M. Hunten, L. Colin, T. Donahue and V. Moroz, University of Arizona Press, 1982.and Venus II (Eds. S.W. Bougher, D.M. Hunten, and R.J. Phillips, University of Arizona Press, 1997). It is proposed that this new knowledge should form the basis for a new volume, Venus III. Although stimulated by the recent successful Venus Express (Vex) mission, and timed to incorporate results from the Japanese Venus Climate Orbiter (VCO, also known as Planet-C and Akatsuki), which is scheduled to arrive at the planet in December this year, new contributions from any source including theory, models, and future mission planning would be included, and authorship open to all subject only to the usual editorial process including independent reviews.

P13. The study of IMF and its implications – *H. O. Vats*

The interplanetary magnetic field (IMF) is a part of the Sun’s magnetic field that is carried into interplanetary space by the solar wind. The interplanetary magnetic field lines are said to be “frozen in” to the solar wind plasma. Because of the Sun’s rotation, the IMF, like the solar wind, travels outward in a spiral pattern that is often compared to the pattern of water sprayed from a rotating lawn sprinkler. The IMF originates in regions on the Sun where the magnetic field is “open” that is, where field lines emerging from one region do not return to a conjugate region but extend virtually indefinitely into space.

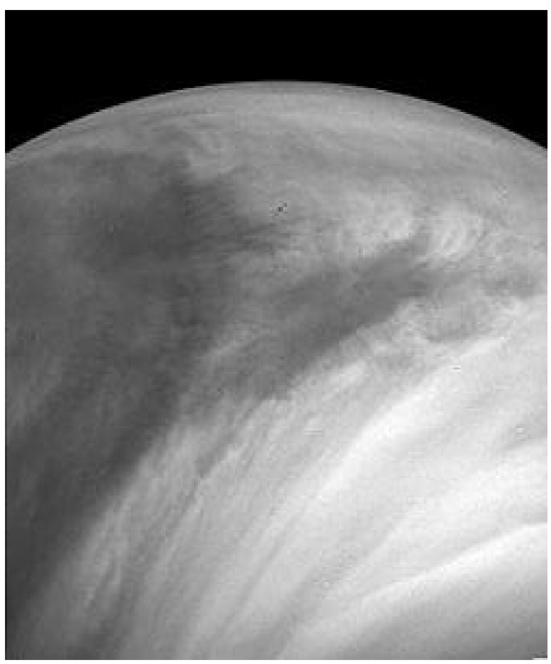
P14. Correlations Between VMC and 2.3 micron Ground-based Cloud Tracking Wind Field Estimates – *E. F. Young, M. A. Bullock, S. S. Limaye and W. Markiewicz*

Over the past six inferior conjunctions of Venus, we have obtained image sequences of Venus' night side in the 2.3 µm CO2 window. In particular, we observed Venus from the IRTF (NASA's Infrared Telescope Facility) for ten nights in July 2007 and ten more in September 2007, nights which correspond to reasonably good VMC (Venus Monitoring Camera) image sequences of Venus' southern hemisphere. The goal of this work is to derive wind fields, based on cloud tracking, for both the infrared ground-based images and the nearly simultaneous UV spacecraft images.

P15. Venera-D Mission of Russia – *L. Zasova (presented by A. Fedorova)*

Venus was actively studied by Soviet and US missions in 60-80th years of the last century. The investigations carried out both from the orbit and *in situ* were highly successful. After a 15-years break in space research of Venus, the ESA Venus Express mission, launched in 2005, successfully continues its work on orbit around Venus. In 2010 the launch of the Japanese Climate Orbiter (Planet-C) mission is planned.

However, many questions concerning the structure and evolutions of the planet Venus, which are the key questions of comparative superrotation and very essential for understanding the evolution of the terrestrial climate, cannot be solved by observations only from an orbit. Now in Russia the new investigation phase of Venus begins: the mission Venera-D is included in the Russian Federal Space Program to be launched in 2016-2018.



A recent VMC image of Venus taken in ultraviolet light

Posters will be on display from Monday through Wednesday

MONDAY, 30 AUGUST 2010

1. Dynamics of the Venus Lower Thermosphere – *B. Sandor and R.T. Clancy*

The Venus lower thermosphere is a dynamical transition region, in which both sub-solar-antisolar (SSAS) and retrograde zonal circulation components play critical roles [Lellouch et al., 1997]. The dominant zonal retrograde flow of the lower atmosphere decays above the key solar forcing region of the Venus clouds, reaching a minimum amplitude within the upper mesosphere (80-90 km). Above this level, both zonal wind and SSAS wind components on the nightside are observed to increase rapidly to the 115 km altitude level. Venus nightside sub-mm observations indicate stronger zonal versus SSAS circulation over the 100-115 km region, with extreme temporal variations in both components on timescales as short as one day [Clancy et al., 2010]. In contrast Venus dayside (10 micron emission) measurements indicate stronger SSAS versus zonal circulation, and perhaps less temporal variability, at the 110 km level [Goldstein et al., 1991; Sornig et al., 2008; 2009]. With respect to dynamical predictions, Sub-Solar to Anti-Solar (SSAS) axisymmetric flow strengthens rapidly over 100- 120 km, and then slowly approaches an asymptotic maximum at 130–140 km [Bougher et al., 1986]. Dynamical simulation of thermospheric zonal flow requires stipulation of momentum forcing associated with lower atmospheric wave activity [e.g., Alexander, 1992]. Assuming a gravity wave momentum source, the altitude profiles of zonal to SSAS flows exhibit diurnal dependences, such that SSAS supplants zonal flow at significantly higher altitude on the nightside than on the dayside [Zhang et al., 1996]. The strength of global retrograde zonal and SSAS planetary flow patterns are time-variable, with no observational evidence of correlation between them. Superimposed on the zonal, SSAS bulk flows are strong, localized temporal variabilities. Dynamical models predict such variabilities in terms of wave activity [Takagi and Matsuda, 2005].

2. Investigations of Dynamics and Temperatures in the Venusian Upper Atmosphere by Infrared Heterodyne Spectroscopy – *M. Sornig, G. Sonnabend, D. Stupar, P. Kroetz, T. Livengood and T. Kostiuk*

Dynamics of the Venusian atmospheric transition zone between the sub-solar to anti-solar (SS-AS) flow dominated region above 120km and the superrotation dominated region below 90km is not yet fully understood [1]. Temperatures in the same region are not very well constrained. Measurements are essential to gain a global understanding of the atmosphere and to validate global circulation models. Space based observations can provide temperatures but do not offer direct wind measurements at these altitudes and ground-based results lack in time coverage and spatial resolution [2,3,4,5]. Hence measurements on various time scales and on different locations with sufficient spatial resolution on the planet are important.

3. The VIRTIS Experiment on ESA's Venus Express: Investigations from Surface to Thermosphere – *P. Drossart, G. Piccioni and the VIRTIS/VEX team*

The VIRTIS/Venus Express instrument (Visible and Infrared Thermal Imaging spectrometer) is a versatile instrument consisting in three channels (1) VIRTIS-M-vis, the visible imaging spectrometer (0.4-1µm) (2) VIRTIS-M-ir the infrared imaging spectrometer (1-5□m) and (3) VIRTIS-H the infrared high resolution spectrometer (2-5µm). The respective spectral resolution for VIRTIS-M and VIRTIS-H is ~400 and ~1600 in the middle of their spectral range (Drossart et al, 2007). This combination of channels, observing simultaneously, has allowed VIRTIS to perform powerful investigations in the Venus atmosphere, from the surface, detected in the night side nearinfrared thermal emission windows, to the thermosphere in the non-Local Thermodynamic Equilibrium emission of several molecules. An overview of the main results from VIRTIS since the orbit insertion of Venus Express in April 2006 will be given, with prospect for future investigations in the frame of the extended mission.

4. A Comparison between Venus Observations and the VTGCM to Provide Interpretation of the Varying Temperatures, Winds, and CO Density Distributions – *A. S. Brecht, S. W. Bougher, M. Sornig, and A. C. Vandaele*

The Michigan thermospheric general circulation model for Venus (VTGCM) produces results that are comparable to recently obtained VEX data and ground based observations. The VTGCM is a three dimensional model that can calculate temperatures, zonal winds, meridional winds, vertical winds, and concentration of specific species. The VTGCM also computes the O2 IR, and NO UV nightglow intensity distributions. This study will examine the modeled temperatures, winds, and the CO density distributions. Various maps and profiles are created to specifically be compared to VEX and ground based observations. Sensitivity tests will be conducted to show possible sources of variability. The study will help provide a better understanding of the processes driving the variations of the Venus middle and upper atmosphere.

5. Models of Atmospheric Composition and Chemistry on Venus – *Vladimir A. Krasnopolsky*

The broad range of temperatures and pressures and inclusion of the chlorine and sulfur chemistries to the standard CO-O-H chemistry typical of Mars make chemical modeling of Venus atmosphere a challenging task. Here we will briefly consider the following models: 1) models for the middle atmosphere (58-112 km); 2) model for the nighttime atmosphere and airglow (80-130 km); 3) model of vertical transport and condensation in the H_2O-H_2SO_4 clouds; 4) model for the lower atmosphere (0-47 km).

6. Dynamics, O2 Nightglow, and Ion-Neutral Chemistry of the Venus Upper Atmosphere: Interpretation of Venus Express Datasets Using the VTGCM – *S. W. Bougher, A. Brecht, C. Parkinson, S. Rafkin, and J.-C. Gerard*

The Michigan Thermospheric General Circulation Model for Venus (VTGCM) is being used to interpret recently obtained VEX datasets and ground based measurements in order to constrain the global circulation patterns, and their strong variations, in the upper mesosphere and thermosphere (~80-200 km). The VTGCM is a three dimensional model that can calculate temperatures, 3-component winds, and concentrations of specific species (including O, CO, N2, CO2, O2, N(4S), N(2D), NO, OH) in this altitude region The VTGCM also computes the O2 IR plus visible, and NO UV nightglow intensity distributions. This study investigates simulated O2(1Δ) IR and O2 Herzberg II visible nightglow distributions and their comparisons with available PVO, VEX and ground-based datasets. Implications for the mean (and time variable) circulation patterns over ~90-130 km are presented. In addition, the simulated dayside electron density and peak altitude, and their solar zenith angle (SZA) variations, are compared with corresponding VEX datasets. The SZA variation of the electron density peak height reflects the corresponding changes of the underlying neutral atmosphere. These coordinated data-model comparisons lead to a better understanding of the processes driving the variations of the Venus middle and upper atmosphere structure and dynamics.

7. The Venus oxygen nightglow and density distributions – *L. Soret, J.-C. Gérard, F. Montmessin, G.e Piccioni, P. Drossart and J.-L. Bertaux*

Observing Venus nightglow is a key tool to understand the composition and the dynamics of its atmosphere. Results deduced from observations can be implemented to produce a data model of Venus atmosphere. For instance, the Visible and Infra-Red Thermal Imaging Spectrometer (VIRTIS) instrument on board the Venus Express spacecraft is very useful to analyze the $O_2(a^1\Delta)$ nightglow at 1.27μm in the Venus mesosphere. Nadir observations can be used to create a statistical map of the emission on Venus nightside. It appears that the maximum of the emission is located near the antisolar point. Limb observations also provide information on the altitude and on the shape of the emission layer. Combining nadir observations and vertically integrated limb observations improves the statistics of the emission map on Venus nightside. An associated limb profile can also be deduced for any point of the nightside. Given all these $O_2(a^1\Delta)$ intensity profiles, O_2^* density profiles can be calculated. O density profiles can also be calculated as long as CO_2 density profiles are available. These can be retrieved either from the VTS3 model or from SPICAV stellar occultation measurements. Finally, three-dimensional maps of excited molecular and atomic oxygen densities can be generated. The oxygen density map shows significant differences from the VTS3 model predictions.

8. 1500 Earth days around Venus imaging with Venus Monitoring Camera on Venus Express – *W. J. Markiewicz, D. Titov, E. Petrova, N. Ignatiev, I. Khatuntsev, R. Moissl, S. S. Limaye, O. Shalygina, and M. Almeida*

The Venus Monitoring Camera (VMC) on Venus Express (VEX) spacecraft has been observing the upper cloud layer since April 2006. To date nearly two hundred thousand images have been acquired. VEX has a highly elliptical orbit allowing for global as well as close up views with resolution down to 200 meter per pixel. We show examples of obtained images emphasizing spatial and temporal variability.

9. Venus Monitoring Camera Observations and Atmospheric Circulation Results from Venus Express – *S.S. Limaye, W. Markiewicz, D.V. Titov, I. Khatuntsev and M. Patsaeva*

The Venus Monitoring Camera (VMC) on European Space Agency's Venus Express mission has been collecting images in four filters almost continuously since it was injected into orbit in April 2006. These images from the 24-hour eccentric, polar orbit have shown the dynamic behavior of the Venus cloud cover with rapid changes in relative brightness on global, regional and small scales. The images have enabled estimates of the large scale circulation of the cloud level flow by multiple, independent efforts. The results are generally consistent and appear to show presence of planetary waves and solar thermal tides. The precise vertical level of the measured cloud motions is not known but has been estimated from near infrared observations from the VIRTIS instrument on Venus Express to be between ~ 70 km at low latitudes and ~ 65 km in polar regions with a rise near the mid-latitudes to about 73 km. Temporal or local solar time changes in the cloud top level appear possible but have not been investigated. Thus some of the apparent temporal variability can be due to cloud level changes. The short term average zonal or East-West flow is observed to fluctuate between ~ 80 m/s – 100 m/s at low latitudes while the latitudinal dependence of the zonal speed shows either a weak increase with latitude or is near constant to mid-latitudes. The mean meridional flow is poleward at most latitudes, peaking in mid-latitudes The relatively low spatial resolution of the images used for tracking clouds dictated by the combination of the VMC field of view and the orbit precludes reliable estimates of the eddy components of motion. Higher resolution images with shorter time interval tend to show slightly faster motions of clouds and thus the VMC large scale tracking results should be interpreted with caution.

10. Volcanism and its role in Climate on Venus – *F. W. Taylor*

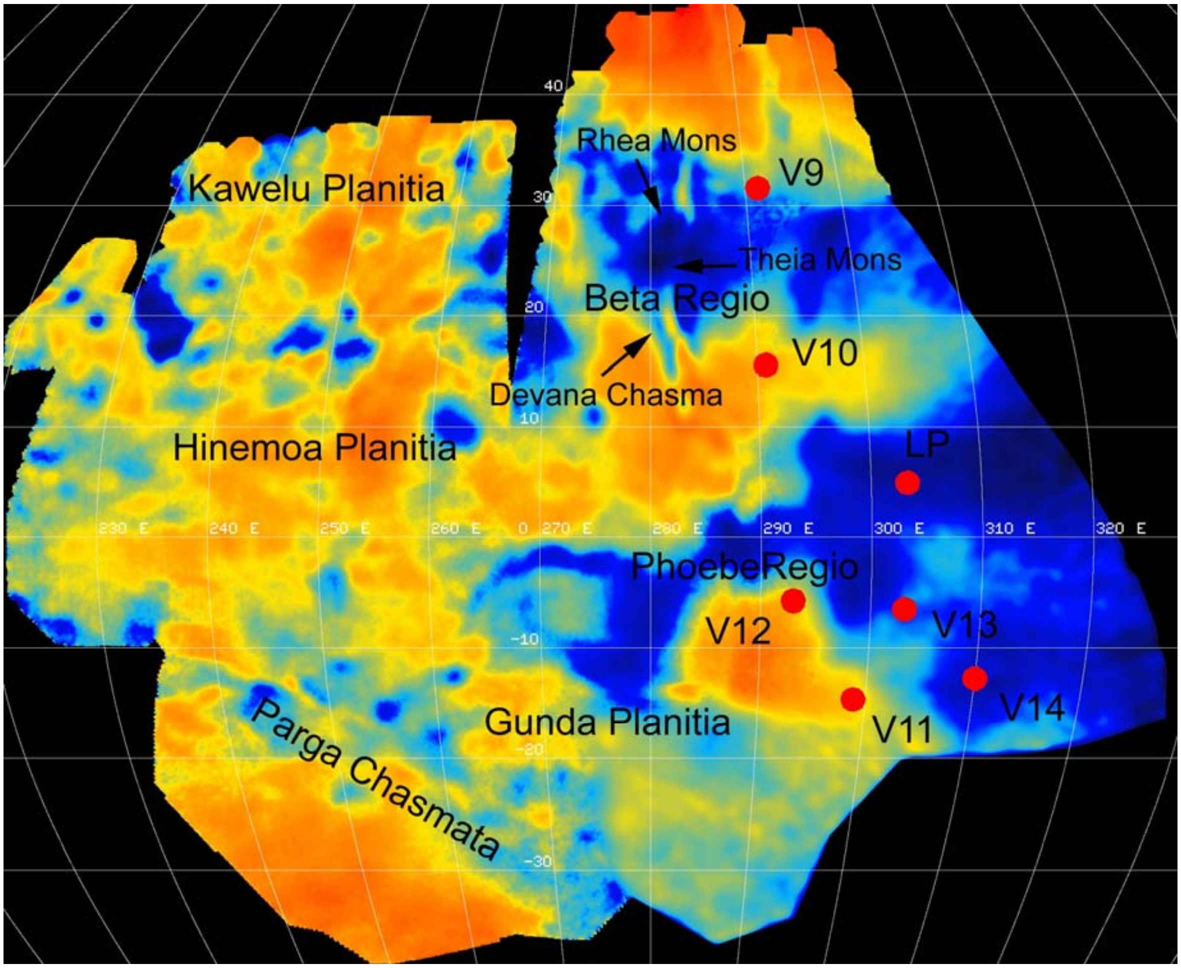
There has clearly been significant volcanic activity on the surface of Venus in recent geological epochs and there is a great deal of indirect evidence that this may continue at the present time. However, the current level of activity is unknown and remains controversial, with estimates for the rate of emission of volcanic gases into the atmosphere ranging from essentially quiescent to very high levels, possibly orders of magnitude greater than those currently found on Earth. This large uncertainty makes it difficult to evaluate the importance of volcanism to the present-day climate on Venus, or to estimate how conditions at the surface might change in the distant future when volcanism subsides. This paper reconsiders some earlier ideas about this conundrum in the light of the most recent evidence from Venus Express and other research, and proposes new model scenarios to tie the data and relevant theory together and suggest an interpretation.

11. Chicxulub Impact Atmospheric Disturbances: Lessons for Venus – *Jan Smit*

The Chicxulub impact has caused one of the largest mass-extinctions in Earth history. The extinction mechanism must be a climate change, induced by the interaction of the impact event with the atmosphere. Interaction includes: entry of the bolide in the atmosphere, ejection of coarse ejecta (tektites, ejecta blanket), re-entry of ejecta, ejection of the fireball plume, and reentry of fireball gases, aerosols and condensates. Types of ejecta seem dependent on the impact size and target properties. Large craters

(>100km) produced crystalline spherules condensed in the fireball –microkrystites- that have a global distribution. Very large terrestrial craters (>180km) produce additionally remarkably similar proximal-distal shock-melt ejecta: bubbly impact melt spherules, accretionary spherules and a global distribution of shocked quartz.

6:00 – 9:00 PM Informal Reception – Memorial Union, Inn Wisconsin Room (second Floor), 800 Langdon Street, Madison



Surface of Venus from the VMC Camera NIR Images

TUESDAY, 31 AUGUST 2010

12. Venus Express Mission – *H. Svedhem*

ESA's Venus Express orbiter mission continues to investigate Venus from its 24-hour, polar elliptic orbit since April 2006. Among its many discoveries include evidence for recent volcanism, electromagnetic activity suggestive of "lightning" (no optical detection yet), presence of OH in the atmosphere, enhanced D/H ratio over the clouds, new meteorological phenomena (sudden local and large scale brightenings of the cloud cover in UV, small scale gravity waves at high polar latitudes), possible evidence of past presence of water on the surface. The data from the Venus Express instruments (VMC, SPICAV/SOIR, VIRTIS, ASPERA) is being made available through ESA's Planetary Science Archive as well as NASA's Planetary Data System. In December 2010 Venus Express will be joined by JAXA's Akatsuki/Venus Climate Orbiter and they will make coordinated observations. VEX is also investigating aerobraking to lower the orbital period to begin a new phase of Venus exploration from a lower orbit.

13. Science Plan of Japanese Venus Orbiter, Akatsuki – *T. Imamura*

Japan's first Venus explorer 'Akatsuki' was launched from the Tanegashima Space Center of Japan in the morning of May 21, 2010 using the H-IIA launch vehicle No. 17. Since the initial tracking progressed quite smoothly, the cameras onboard Akatsuki were oriented to the earth half a day after launch. The 'first light' images, which were taken from the distance of 250,000 km, clearly showed the basic characteristics of the Earth's climate; solar radiation (365 nm and 0.9 μm) is partially reflected by clouds and partially absorbed by the surface, the deposited energy is distributed over the globe by winds and ocean currents, and finally the energy is radiated to space from the whole globe at infrared wavelengths (10 μm). This 'observation' is considered symbolic of Akatsuki, whose another name is Venus Climate Orbiter. The main goal of the mission is to understand the Venusian atmospheric dynamics and cloud physics, with the exploration of the ground surface and the interplanetary dust also being the themes. Akatsuki will arrive at Venus on December 7.

14. SAGE: A proposed New Frontiers mission to land on Venus – *L. Esposito*

SAGE, the Venus Surface and Atmosphere Geochemical Explorer, is proposed to launch to Venus in December 2016, and land on the flanks of a Venus volcano in May 2017, where it survives the hellish Venus environment for 3 hours or more. The SAGE lander will photograph the surface during descent and after landing, excavate the surface and irradiate it with lasers and neutrons to measure the composition and surface texture. The minerals that make up Venus upper crust are still unknown. This new information will allow the scientific team to compare Venus to other terrestrial planets (including the Earth), and planets circling other stars. This will clarify the history of Venus surface, atmosphere and climate. We plan to model the history of Venus and predict its future, comparing Venus to Earth and to extra-solar planets. Other partners are the Jet Propulsion Laboratory which provides the SAGE project management, Lockheed Martin of Denver which builds the carrier spacecraft, and the NASA Ames, Goddard and Langley Research centers. Scientific instruments are contributed by Russia's Institute for Space Research (IKI) with contributions from the Swiss University of Bern, and the French National Center for Space Research (CNES). The lander's robotic arm is contributed by the Canadian Space

15. The European Venus Explorer (EVE) Proposal 2010: Current Status – *C.F. Wilson, E.C. Chassefière, and the EVE Steering committee*

The European Venus Explorer (EVE) is a proposed in situ mission to Venus based on a balloon platform. It will be proposed to ESA in December 2010, for consideration under ESA's Cosmic Vision programme for launch in 2020- 2023. In 2007, the EVE team proposed to ESA a large Venus mission including an orbiter, a cloud-level balloon, and a lander [Chassefiere et al., 2008a, 2008b]. This would have been a complex mission, with significant Russian contributions: the launcher, EDLS and lander, as well as much of the science payload, was to have been provided by Russia.

In 2010, the EVE team plan to propose a smaller, more □uperro mission which could be achieved by ESA alone. The envisaged mission will thus consist of a single cloud-level balloon, with neither an orbiter nor a lander. The details of the mission proposal are still under development, but we take this opportunity to reiterate the science rationale for a cloud-level in-situ mission, and to summarise the baseline mission proposal as is currently envisaged (at time of writing, late July 2010).

16. Venus Aerial Mobility Concepts: In the Clouds & Near the Surface – *T. Balint, L. Glaze, D. Grinspoon, J. Hall, V. Kerzhanovich, M. Adams, M. Amato, C. Baker, and M. A. Bullock*

Over the past two years NASA Headquarters commissioned a number of mission concept studies in support of the National Research Council's 2010 Planetary Decadal Survey (DS) Inner Planets Panel and for its own strategic planning efforts. The DS studies have been performed jointly between the Goddard Space Flight Center (GSFC), the Jet Propulsion Laboratory (JPL), and the Ames Research Center (ARC). Specifically, the science benefits and technology requirements were studied for NASA's Venus Flagship Mission (VFM) [Hall et al., 2009], the Venus Climate Mission (VCM) [Grinspoon et al., 2010], and the Venus Mobile Explorer (VME) [Adams et a., 2009] mission concepts.

17. Venus Science from Earth-Based Observations: Present and Future – *T. Widemann, P. Machado, Y. Liao, E. Young*

The operations of Venus Express and Akatsuki after Dec. 7, 2010 are supported by a new campaign of coordinated ground-based observations, which will (1) provide direct measurements not feasible from the orbiters – e. g. direct absolute wind measurements ; (2) provide simultaneous investigations over several altitude ranges in Venus' dayside and nightside atmosphere ; (3) allow cross-validation of different measurement techniques, (4) allow extended spatial, vertical and temporal scales for time-varying phenomena.

18. Airborne observations of Venus: Past, Present and Future – *C. Tsang, E. F. Young, M. A. Bullock, . Encrenaz*

The role of airborne observatories and their study of the most basic parameters concerning Solar System bodies usually reside as footnotes in the annals of planetary science exploration. This is due in part to the high profile and obvious advantages of spacecraft observations over terrestrial platforms. However, airborne observations of the planets have a long and vibrant history. In this paper, we review the past airborne observations of Venus starting in the mid 1960's, what was achieved and its context within the planetary missions of its time. We will then discuss the current regeneration and investment by NASA for airborne observations and its potential to provide concurrent, cheap and effective science.

19. Doppler Lidar for Wind Measurements on Venus – *U. N. Singh, G. D. Emmitt, J. Yu, and M. J. Kavaya*

NASA Langley Research Center has a long history of developing 2-micron laser transmitter for wind sensing. With support from NASA Laser Risk Reduction Pro-gram (LRRP) and Instrument Incubator Program (IIP), NASA Langley Research Center has developed a state-of-the-art compact lidar transceiver for a pulsed coherent Doppler lidar system for wind measurement. The transmitter portion of the transceiver employs the high-pulse-energy, Ho:Tm:LuLiF, partially conductively cooled laser technology developed at NASA Langley. The transceiver is capable of 250 mJ pulses at 10 Hz. It is very similar to the technology envisioned for co-herent Doppler lidar wind measurements from Earth and Mars orbit. The transceiver is coupled to the large optics and data acquisition system in the NASA Langley VALIDAR mobile trailer. The large optics consists of a 15-cm off-axis beam expanding telescope, and a full-hemispheric scanner. Vertical and horizontal vector winds are measured, as well as relative backscatter. The data acquisition system employs frequency domain velocity estimation and pulse accumulation. It permits real-time display of the processed winds and archival of all data. This lidar system was recently deployed at Howard University facility in Beltsville, Maryland, along with other wind lidar systems.

Coherent Doppler wind lidar ground-based wind measurements and comparisons with other sensors will be presented. A simulation and data product for wind measurement at Venus will be presented.

20. Spatially-Resolved High-Resolution Spectroscopy of Venus: Variations of CO2, CO, HF, HCl, HDO, OCS, and SO2 at the cloud tops, OH and O2, Nightglow – *V. A. Krasnopolsky*

Here we will report basic results of three sessions of observations of Venus in 2007-2009 at NASA IRTF (Hawaii, elevation 4.2 km, the telescope diameter 3 m). The observations were made using a long-slit (30 arcs) spectrograph CSHELL that covers the spectral range of 1.1-5.5 μm with resolving power of 40,000. Venus was observed at maximum elongations with almost equal day and night sides on the Venus disk and maximal geocentric velocities (±13 km/s). Venus' diameter is ~25 arcs at these conditions. The slit was placed parallel to the central meridian near the middle of the day or night side. This makes it possible to study variations of species in the latitude range of ±60° at local times of 4:00, 8:00, 16:00, and 20:00.

21. SO2 Observations above Venus' Clouds by SPICAV/SOIR from the VEX Orbiter – *D. Belyaev, E. Marcq, F. Montmessin, J.-L. Bertaux, A. Mahieux, O. Korablev, and A. Fedorova*

New measurements of sulfur dioxide' (SO_2) content by SPICAV / SOIR instrument onboard Venus Express orbiter provide powerful statistics to study behavior of the gas above Venus' clouds. The instrument (set of spectrometers) is capable to sound atmospheric structure above the clouds at several regimes of observations (nadir, solar and stellar occultations) either in UV or in near IR spectral ranges. From solar occultations we registered two layers of SO_2 above the clouds: 70-80 km with mixing ratio 0.05-0.5 ppmv (absorption at 4 μm), and 90-100 km with 0.1-2 ppmv (at 190-230 nm). With nadir sounding in the UV range we are sensitive to horizontal variations of SO_2 content at the cloud top. Up to now we have processed observations of 2006-2007 in the northern hemisphere. Typical column densities at low latitudes were found between 5 and 50 μm-atm, whereas in the northern polar region SO_2 content was mainly below than 5 μm-atm.

22. Water Vapour in the Venusian Atmosphere with SPICAV IR/VEX – *A. Fedorova, O. Korablev, J.- L. Bertaux, F. Montmessin, and D. Belyaev*

SPICAV VIS-IR is a part of SPICAV/SOIR experiment on Venus-Express. It is a single pixel spectrometer for the spectral range of 0.65-1.7 μm based on AOTF (acousto-optical tunable filter) technology with resulting resolution power is ~1400 at 1.4 μm. Based on 1.38 μm band, H_2O abundance above the clouds has been routinely retrieved for the dataset from the middle 2006 to the end of 2008 (VEX orbits 23-1000) taking into account multiple-scattering in the cloudy atmosphere. Altitude of cloud top level (65-73 km) corresponding □=1 has been obtained from CO_2 bands in the range of 1.4-1.65 μm. Obtained H_2O content varies inside 3-10 ppm and shows weak variations from orbit to orbit and with the latitude. In this report the local time and latitude distribution of H_2O and long-term variability will be analyzed and main uncertainties will be discussed.

23. Photochemical Distribution of Venusian Sulfur and Halogen Species – *C. D. Parkinson, F. Mills, A. Brecht, S. W. Bougher, M. Allen, and Y. L. Yung*

Recent observations of enhanced amounts of SO2 at 100 km by Venus Express (Bertaux et al, 2009) suggest that there is a hitherto unknown source of gaseous sulfur species in the upper atmosphere of Venus. This is contrary to the observations of Sandor and Clancy (2010). Zhang et al (2010) argue that the photolysis of H2SO4 vapor derived from evaporation of H2SO4 aerosols provides a source of SO3, which upon photolysis yields SO2. In this study, the photochemistry of Venus' atmosphere from the cloud tops to 100 km has been modeled using an updated/expanded chemical scheme, with the view to improving our understanding of the vertical distributions of sulfur and halogen species. We mainly follow Yung and DeMore (1982), Mills (1998), Pernice et al. (2004), Krasnopolsky (2009) in our choice of chemical reactions, chemical rate constants, and boundary conditions for 38 species. We will examine two models with HCl mixing ratios of 10-7 and 4 x 10-7, respectively. The former corresponds to Venus Express observations made at high northern latitudes and the latter to the mid- to low-latitude value Young (1972) determined based on infrared measurements by Connes et al (1967). Both models agree satisfactorily with stratospheric observations of key species such as CO, O2 and SO2, but we hope to better quantify the implications of the different HCl mixing ratios observed. Additionally, we perform sensitivity tests where water is set to ~31 ppm at 40 km, but vary the SO2 mixing ratio at the lower boundary about a nominal value of ~25 ppm. We also consider a range of eddy diffusion profiles that vary by a factor of 10 and other sensitivity studies. For our cases, *K* = *K*o *(n(z)/nref)-a*, where *K*o is the eddy diffusion coefficient at some reference altitude, *n* is the number density, *z* is altitude, and *a* is the variable parameter (<1). Our modeling suggests lower HCl abundances result in greater abundances of SO2, SO, and SO3 generally lower O2 abundances, and greater ClO abundances. Also, the effects on sulfur compounds seems more pronounced for lower mixing ratios of SO2 at the lower boundary as well as higher up in the atmosphere i.e. above ~58 km. We consider both SO2 observations of Bertaux et al (2009) and Sandor and Clancy (2010) in our analysis of results. We will use some of this 1-D chemistry in the Venus Thermospheric General Circulation Model (VTGCM) (Bougher et al, 1997) for comparison to VEX datasets.

24. A Search for Lightning signatures in Pioneer Venus Gamma Ray Data – *R. D. Lorenz and D. J. Lawrence*

Observational evidence for lightning on Venus remains sparse and much remains to be learned about the phenomenon. We may hope that future missions will further our understanding of the issue. However, it may be that data acquired by the Pioneer Venus Orbiter (PVO), which some 14 years in orbit 1978-1992, contains some useful information. Gamma Ray emissions are a surprising feature of lightning discharges on Earth. We consider the generation of such emissions by Venusian lightning, and are examining Pioneer Venus gamma ray data.

25. Observing the Clouds of Venus from the Ultraviolet to the Infrared – *K. McGouldrick, T. W. Momary, K. H. Baines, D. H. Grinspoon, K. Molaverdikhani, and L. W. Esposito*

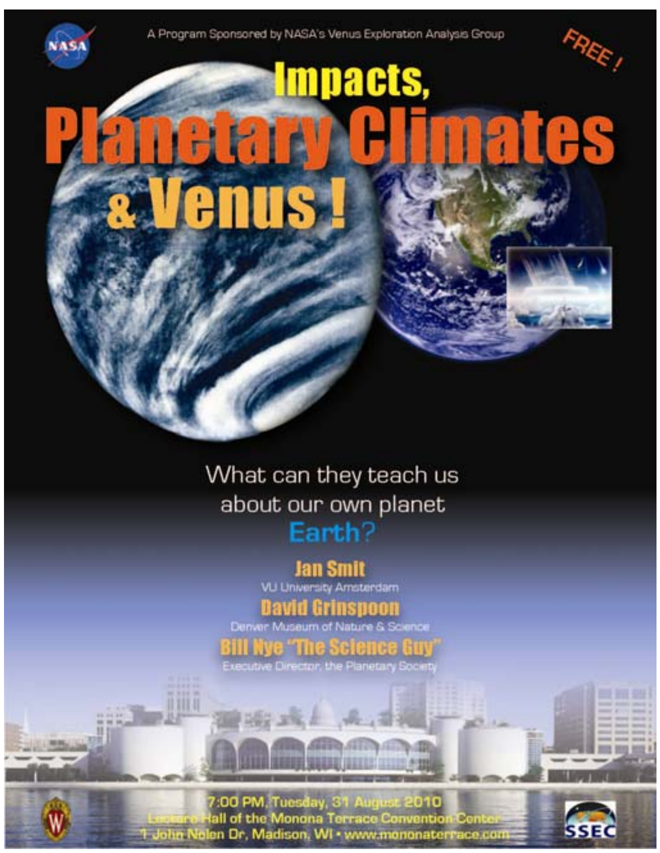
At visible wavelengths, as a consequence of the global coverage of highly scattering cloud particles of sulfuric acid, the face of Venus appears to be spatially and temporally homogeneous. However, observations in the ultraviolet and the infrared indicate a dynamic lower atmosphere that exhibits significant interactions between chemistry, dynamics, cloud microphysics, and radiative balance. Variations in the ultraviolet on the dayside of the planet have been analyzed to measure changes in the concentration and distribution of sulfur dioxide (Esposito et al. 1988), and of the unknown ultraviolet absorber (Pollack et al. 1980) in the upper cloud deck. Spatial inhomogeneities in infrared wavelengths, or 'holes' in the middle and lower cloud decks of Venus, discovered by Allen and Crawford (1984) on the night side of the planet, have been utilized to study the constituents of the lower atmosphere of Venus (e.g., Tsang et al., 2010), the nature and distribution of the cloud particles (e.g., Wilson et al., 2009), and the dynamics (e.g., Sánchez-Lavega et al., 2008) of the lower and middle cloud decks. By observing Venus frequently in the UV and IR over long time baselines, we can assemble a complete and consistent picture of the characteristics and distribution of the cloud particles within each of the three cloud decks, as well as their primary chemical precursors, sulfur dioxide (SO_2) and water vapor (H_2O). Here, we discuss our efforts to characterize the nature of the evolution of the clouds of Venus from analysis of Venus Express / VIRTIS data.

26. Venus Cloud Properties from Venus Express VIRTIS Observations – *J. Barstow, F. Taylor, C. Tsang, C. Wilson, P. Irwin, P. Drossart and G. Piccioni*

Near-infrared spectra from the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) on Venus Express have been used to investigate the vertical structure and global distribution of cloud properties on Venus. The spectral range covered by VIRTIS is sensitive on the nightside to absorption by the lower and middle cloud layers, which are back-lit by radiation from the lower atmosphere and surface. The cloud model used to interpret the spectra is based on previous work by Pollack et al. (1993) and others, and assumes a composition for the cloud particles of sulfuric acid and water, with acid concentration as a free parameter to be determined. Other retrieved parameters are the average size of the particles and the altitude of the cloud base in the model. The sensitivity to these variables across the measured spectral range (1.5 to 2.6 μm) is investigated, and radiances at suitable pairs of wavelengths are used in model branch plots to recover each variable independently. Model spectra are generated using the NEMESIS radiative transfer and retrieval code (Irwin et al. 2008). Spatial variation of sulfuric acid concentration in the cloud particles has been estimated for the first time. This is then used in the determination of other cloud properties and gaseous abundances. Key findings include increased acid concentration and decreased cloud base altitude in regions of optically thick cloud, a peak in cloud base altitude at -50km, and an increased average particle size near the pole. These results are being used to develop better models of the structure and variability of the clouds, which are needed to understand the chemistry, meteorology and radiative energy balance on Venus.

27. Clouds of Venus: Comparison with other Terrestrial Planets – *Franck Montmessin*

Clouds are one of the most eloquent and most fascinating expressions of atmospheric activity. They are a ubiquitous feature of all terrestrial planets of the solar system and thus appear as a baseline component of terrestrial climates. Their presence tells about their forcing conditions, giving meaningful information about dynamics, radiative budget and chemistry of their hosting planet. In turn, they often perturb climate equilibrium through a variety of processes, such that they participate to defining the planet habitability conditions. In this presentation, I will essentially focus on the clouds of Venus and provide some contextual elements through comparison with their Earth and Mars counterparts, pointing towards the commonalities and the peculiarities of the various forms of clouds encountered on each of these planets. Comparing one with each other is thus relevant and may reveal basic and universal mechanisms that may remain hidden when studied separately.



WEDNESDAY, 1 SEPTEMBER 2010

28. Visualizing the surface of Venus – *M. Bullock*

An exciting prospect for major scientific advances in the geological history of Venus is surface imaging on descent through the atmosphere. The dense atmosphere provides a leisurely descent speed, valuable for allowing downlinking of images before arrival at the surface. Images of the surface on a descent probe to Venus would provide crucial information at a scale not yet explored – the 10 m to 10's of km range. Equally important, these images would be taken at visible and near-infrared wavelengths. Comparison with Magellan radar data in making new, detailed geologic interpretations based on optical wavelengths could be extrapolated to similar regions across the planet.

Here I discuss the unique optical and spacecraft dynamics issues in imaging the surface of Venus from a descent probe. Cameras must have a large dynamic range, high quantum efficiency at 1 μm, and be capable of millisecond exposure times. Nighttime images would have the highest surface contrast, but independent altimetry would be needed to account for variations in flux due to altitude-dependant surface temperature. At night, near-IR images with about the resolution of Magellan SAR images can be obtained from just beneath the clouds. Images on descent during the day would see a very bright sky but their interpretation would be less dependent upon altimetry. Images with enough contrast for scientific investigations could be obtained below approximately 15 km.

29. Equilibrium resurfacing of Venus is possible: Results from new Monte Carlo modeling and implications for Venus surface histories – *V. L. Hansen, E. E. Bjonnes, B. James, J. B. Swenson*

Venus' impact crater population imposes two observational constraints that must be met by viable surface histories. (1) Near random spatial distribution of ~975 craters, and (2) few (~170) modified craters (Schaber *et al.* 1992; Herrick *et al.* 1997). Catastrophic resurfacing meets these constraints; equilibrium-resurfacing histories require a balance between crater distribution and modification. Monte Carlo modeling (Strom *et al.* 1994) is widely cited as proof that equilibrium resurfacing is invalid. Small areas of resurfacing met constraint 1 but not 2, large resurfacing areas met constraint 2 but not 1. However, Strom *et al.* did not explore intermediate resurfacing areas, or histories in which impact crater formation outlasts equilibrium resurfacing. We construct three suites of Monte Carlo experiments that vary the duration of resurfacing relative to impact crater formation time (1:1 [suite A], 5:6 [suite B], and 2:3 [suite C]), and vary resurfacing area in the parameter space not previously considered (5, 1, 0.7, and 0.1%). Results are tested against constraints 1 and 2; several experiments met both constraints. Equilibrium resurfacing is statistically viable for suite A at 0.1%, suite B at 0.1%, and suite C for 1, 0.7, and 0.1% resurfacing. The results are consistent with the SPITTER hypothesis, which calls for near-steady-state crater formation and destruction during a time of a globally thin lithosphere (Hansen and Young 2007). Craters are destroyed by formation of individual crustal plateaus, punctuated in time and space. The hypothesis does not depend on a particular mechanism of plateau formation, focusing instead on elements common to all hypotheses. As Venus evolves a thick lithosphere, plateau formation ceases, and with it, crater destruction; the surface accumulates craters.

30. Topographic Comparisons of Uplift Features on Venus and Earth: Implications for Venus Tectonics – *P. R. Stoddard and D. M. Jurdy*

Venus and Earth display different hypsography. We use topographic profiles to search for well-understood terrestrial analogs to Venusian features. Specifically, by using cross-correlation, we correlate average profiles for terrestrial rifts (slow and fast, incipient and inactive) and also hotspots (oceanic and continental) with those for Venusian chasmata and □uperro, to draw inferences as to the processes responsible for shaping Venus' surface.

31. Venus Hotspot Activity and Constraints on Convection – *S. Smrekar, C. Sotin, E. Stofan, A. Bonaccoso, H. Taylor, I. Bollinger*

Venus is estimated to have about 9 nine hotspots, regions where hot, rising mantle plumes produce surface volcanism and a broad topographic rise. Recent studies of the southern hemisphere hotspots observed by VIRTIS imply they are currently active. We attempt to model interior convection in a sphere that produces ~9 plumes arising at the core-mantle boundary, examining the effects of amount of internal heating, core temperature, and Rayleigh number.

32. Themis Regio, Venus: Emissivity Signatures in VIRTIS-Venus Express *Data* – *E.R. Stofan, S.E. Smrekar, J. Helbert, and N. Mueller*

Themis Regio is a highland region, approximately 2000 km across, located in the southern hemisphere of Venus at the terminus of Parga Chasma. It has an average height of about 0.5 km, and is characterized by numerous coronae (Stofan *et al*. 1995). Stofan *et al*. (1995) classified it as a corona-dominated hotspot rise, and Smrekar and Stofan (1999) interpreted the differences between Themis and other volcanic rises to indicate that buoyancy flux and plume duration are the key factors that control the difference between corona-dominated rises and volcano dominated rises. They found that long duration, non-simultaneous, small-scale upwellings are required to form coronae at corona-dominated rises like Themis Regio. Elastic and thermal lithospheric thicknesses estimates at Themis are consistent with terrestrial values, and the corona morphology, evidence for delamination in the gravity data, and the topographic swell suggest Themis is likely underlain by an active plume with on-going surface deformation due to delamination (Smrekar and Stofan 1999).

33. The near-infrared emissivity of the Venus surface: Observations by Venus Express and MESSENGER and a new program of high-temperature laboratory measurements – *J. Helbert, N. Müller, N. Izenberg, J.W. Head, S. C. Solomon, G. Piccioni and P. Drossart*

The Visible and Infrared Thermal Imaging Spec-trometer (VIRTIS) instrument on the ESA Venus Express (VEX) mission has produced the first maps of the surface of Venus from orbit using observations through the atmospheric windows near 1 μm. From the data returned by VIRTIS, maps of surface brightness can be converted to estimates of variations in surface emissivity [1,2]. The mapping indicates three surface types characterized by average, higher than average, and lower than average emissivity. These surface types show a good correlation with geological units identified from radar images. In general, comparatively fresh lava flows are areas of high emissivity, whereas tessera terrain is typically associated with low emissivity.

34. Coupled Surface-Atmosphere Evolution of Venus – *D. Grinspoon*

Recent announcements about the potential discovery of “Earthlike planets” have highlighted the question of what we mean by that phrase. If a planet is similar in mass to Earth, and in an orbit that provides for stellar radiation within a factor of two of that received by Earth, does it qualify? Venus is remarkable for the ways in which “Earth’s twin planet” lacks some of the essential features evoked by the notion of an Earthlike planet. Key among these is a habitable surface environment where liquid water is stable and a global system of plate tectonics.

35. The Calcite-Quartz-Wollastonite-CO2 “Buffer” of Venus’ Atmosphere, with Implications for Other Planets – *Allan H. Treiman*

The surface of Venus is hot enough, ~740K, to support significant and rapid chemical reactions with atmospheric gases. One such reaction Calcite + Quartz = Wollastonite + CO_2, $CaCO_3 + SiO_2 = CaSiO_3 + CO_2$, has been suggested as a buffer of CO_2 pressure. In a Venus-like atmosphere with an adiabatic temperature profile, this reaction cannot buffer atmospheric CO_2 – it is unstable with respect to small perturbations in T and P. The general criteria for a buffering reaction in a Venus-like atmosphere can also be applied to Venus-like exoplanets, and suggest that CO_2 buffering there is unlikely.

36. Coupling the Atmosphere with the Interior Dynamics: Implications for the Resurfacing of Venus – *L. Noack and D. Breuer*

In the present work, we have coupled a 2D convection model with a 1D gray atmosphere model to study the interaction between the interior dynamics and the atmosphere evolution. The coupling of the two models is via outgassing of the interior, which increases the density of the atmosphere, and the associated increase of the surface temperature as a consequence of the greenhouse effect. The increase of the surface temperature then influences the thermal evolution of the interior and thus the subsequent outgassing rate.

We have applied this model to Venus and identified a self-consistent mechanism for a temporal surface mobility. During the thermal evolution of Venus, the surface temperature exceeds a critical temperature at approximately 800-900 K. At this temperature a local mobilization and resurfacing of the surface occurs. The resurfacing takes places at different places and times, leading to a globally renewed surface after some time but due to local effects. As a consequence of the local surface mobilization also the isolating effect of the lid decreases, and the mantle starts to cool very fast. This leads together with the depletion of the mantle in volatiles to a decrease in partial melt and outgassing rates. Therefore, a decrease in the surface temperatures can be observed in contrast to an uncoupled model, for which we assume a constant surface temperature as boundary condition for the mantle convection model. Although the volcanic activity decreases with time, it may be still active in the recent past consistent to the new Venus Express results [Smrekar et al. 2010].

37. Pace of tectonic modes on Venus and Earth and atmospheric Argon – *T. Höink, C. O’Neill, and A. Lenardic*

Differences in tectonic histories of Venus and Earth are controlled by different convective stresses to which their planetary surfaces are exposed. Convective stresses are in turn controlled by the internal viscosity structure of a planet. The tectonic history of Venus and Earth can be understood using melting and degassing models constrained by atmospheric abundances of radiogenic Argon.

38. Venus III: The Atmosphere, Climate, Surface, Interior and Near-Space Environment of an Earth-like Planet – *F. W. Taylor, C. T. Russell, T. Satoh, H. Svedhem, D. V. Titov*

An overview is given of the new knowledge that has been acquired about the planet Venus since the publication of the books Venus I (Eds. D.M. Hunten, L. Colin, T. Donahue and V. Moroz, University of Arizona Press, 1982.and Venus II (Eds. S.W. Bougher, D.M. Hunten, and R.J. Phillips, University of Arizona Press, 1997). It is proposed that this new knowledge should form the basis for a new volume, Venus III. Although stimulated by the recent successful Venus Express (Vex) mission, and timed to incorporate results from the Japanese Venus Climate Orbiter (VCO, also known as Planet-C and *Akatsuki*), which is scheduled to arrive at the planet in December this year, new contributions from any source including theory, models, and future mission planning would be included, and authorship open to all subject only to the usual editorial process including independent reviews.

39. Venus Rotation – *Gerald Schubert*

Observations of Venus’ rotation have the potential of providing paradigm-changing information about the planet’s interior and atmosphere. The solid planet and the atmosphere exchange angular momentum through the torque each exerts on the other at the planet’s surface. The angular momentum exchanges would be readily apparent in length of day (LOD) variations in Venus’ rotation. Schubert (1983) estimated that changes in the length of day on Venus would be about 4.5 $\sum$ hours, where $\sum$ is the fractional change in atmospheric angular momentum. A 20% change in the atmosphere’s angular momentum would lead to an LOD change of an hour. Earth’s atmospheric angular momentum is known to change by several tens of percent on short time scales, so comparable changes in Venus’ atmospheric angular momentum might be possible. Parish et al. (2010) have found atmospheric angular momentum oscillations of this magnitude on a decadal time scale in the behavior of their Venus general circulation model (GCM).

40. The super-rotation mechanism based on Global Circulation Model simulations – *S. Lebonnois, F. Hourdin, F. Forget, V. Eymet, R. Fournier*

The Global Circulation Model developed at the Laboratoire de Meteorologie Dynamique (LMD) has made significant improvements since the radiative transfer module was initiated at LAPLACE 7 years ago. The super-rotation obtained now in some simulations may be compared to observations of cloud-tracking winds from Venus-Express. The analysis of these simulations demonstrates the role played by thermal tides in the distribution of angular momentum within the cloud region. The amplitude and shape of the zonal winds appear to be dependent on the initial state, though the exchange of angular momentum budget at the surface always reaches the same equilibrium. The vertical gradient for the zonal wind between below and above the clouds is also systematically to strong. These discrepancies and questions point to further research on possibly missing processes, such as the interaction between subgrid-scale gravity waves and the mean circulation.

41. Superrotation and Mean Meridional Circulation in the Venus Atmosphere – *M. Takagi and Y. Matsuda*

An exact radiative transfer model applicable to the Venus atmosphere has been incorporated into a three-dimensional general circulation model. Using the solar heating without diurnal variation, numerical simulations have been performed. Preliminary results show that the mean zonal flow (superrotation) is generated above 50 km, but it remains very weak below. The meridional circulation splits into several cells in the vertical direction. The results are not inconsistent with Hollingsworth *et al.* (2007) and Lebonnois *et al.* (2010). It is inferred that the Gierasch mechanism may not work in the Venus lower atmosphere.

42. Angular Momentum in Terrestrial Planetary Atmospheres – *Curt Covey*

The three fundamental conserved quantities of classical non-relativistic physics are mass, energy, and momentum. Modern Earth-atmosphere observations and models are routinely evaluated in terms of their “balance” or “budget” of mass and energy. Investigating sources, sinks, and transport of conserved atmospheric quantities is a fruitful route to understanding the four known terrestrial-type planets that possess substantial atmospheres: Venus, Earth, Mars, and Titan.

43. Dynamical Instabilities in the Polar Vortices of Venus – *C. M. Rozoff and S. S. Limaye*

In the history of studies addressing the general circulation of Venus, atmospheric superrotation and its connection to the polar vortices of Venus have long remained an area of substantial interest. There has been no shortage of theoretical analyses and general circulation model (GCM) studies dedicated to the issue. The paucity of observational data has undoubtedly been a key obstacle to further progress.

A significant number of Venus GCM simulations have captured superrotation, although many contain parameterizations that suffer certain shortcomings and/or have many aspects that are difficult to verify with the lack of data. Progress will continue to occur with ongoing GCM studies, but complex modeling systems in all of geosciences have almost always benefited from accompanying theory based on simpler models that help isolate crucial phenomena found in the GCMs.

44. Development of Venus GCM toward the AKATSUKI mission – *M. Yamamoto, M. Takagi, K. Ikeda, M. Takahashi, and Y. Matsuda*

GCM is a useful tool for investigating dynamics in the Venus atmosphere. We have two strategies for the AKATSUKI mission; one is the use of full-physics GCM (covering the surface to 100 km level), and the second is the use of Venus middle atmosphere GCM in the same manner as terrestrial thermosphere GCM. In this presentation, we review the Venus GCMs developed for the AKATSUKI mission, and discuss the simulated superrotation and wave patterns (such as polar dipole, cold collar, and Y-shaped cloud).

45. Simulations of Multi-year Periodicities with a Venus Atmosphere GCM – *H. F. Parish, G. Schubert, C. Covey, R. L. Walterscheid, A. Grossman, and S. Lebonnois*

We describe simulations of Venus' atmospheric dynamics using a general circulation model (GCM). Our model generates superrotating winds at cloud top heights with magnitudes comparable to those measured by Venus probes. We find an approximate 10 year oscillation within our simulated winds. We calculate the transport of angular momentum in the model and suggest a possible source for the oscillation. There is evidence from observations that multi-year periodic variations may also occur in the real Venus atmosphere.

8th VEXAG Meeting on Thursday, 2 September 2010 !