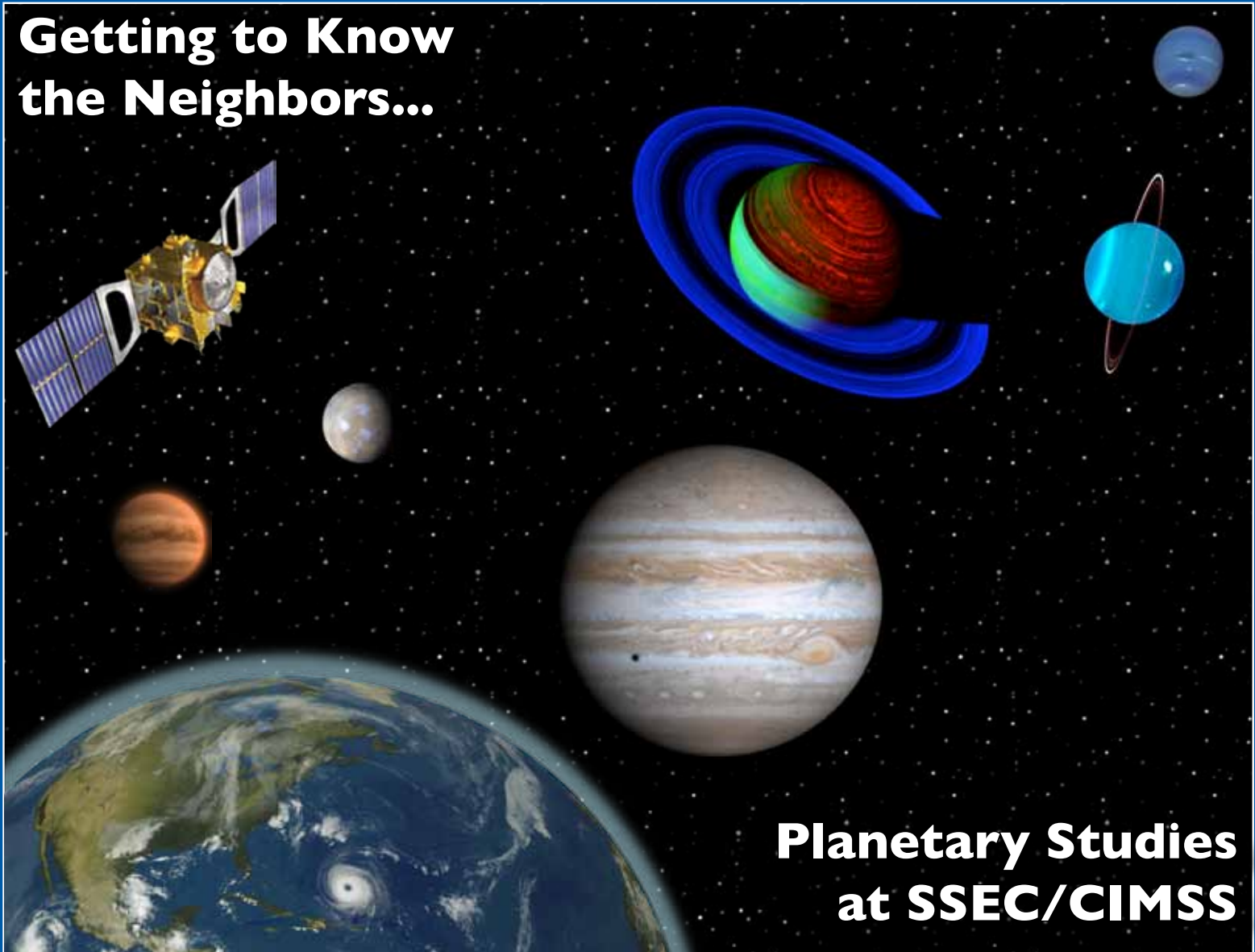


through the atmosphere

Fall 2011

Getting to Know the Neighbors...



Planetary Studies at SSEC/CIMSS



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Director's Note

SSEC scientists have made significant contributions to the study of Earth and our neighboring planets. This edition of *Through the Atmosphere* includes articles that reflect these continued traditions.

The first article summarizes a recent field campaign conducted in a Nevada desert that collected data to calibrate the GOSAT (Greenhouse gases Observing SATellite) sensors. SSEC contributed to this joint Japan/U.S. program by providing observations from the AERIBago, ground-launched balloons and from the Scanning HIS on board the NASA ER-2 aircraft. The field program included the participation of AOS undergraduate students. GOSAT is a young satellite launched in 2009. SSEC's role in new satellites is also demonstrated in the next article which provides a highlight of the new NPP satellite mission launched in 2011. SSEC-produced images from the VIIRS were some of the first to hit the presses!

SSEC's Office of Space Science Education (OSSE) has long provided outstanding education programs about our neighbor Venus. Here we highlight some of OSSE's recent education activities for the

European Space Agency's Venus Express (VEX) Mission. This model education program covers informal and formal education venues.

The next six featured articles summarize some recent research of SSEC scientists about our neighbors:

Venus: Scientists at SSEC are studying vortex structures in Venus' atmosphere, using models to simulate observed vortices. The approach seeks new insights into the physical connections between vortex instabilities and the Venusian global circulation.

Mars: McIDAS is a valuable tool to track clouds and estimate winds from satellite images. It is now being applied to images from the Mars Reconnaissance Orbiter (or MRO) to track the winds over the polar regions of Mars.

Jupiter: Observations of the largest planet in our solar system from Visual and Infrared Mapping Spectrometer (VIMS) are enabling a new evaluation of the chemistry of Jupiter's clouds.

Saturn: Images from the Cassini VIMS are also being used to study recent storms on Saturn. These images

are providing evidence for devising the circulation patterns of our neighbor.

Uranus: The first planet discovered with a telescope, SSEC scientists continue to explore this planet using more modern image sequences. Observed methane anomalies are being used to develop models of the planet's circulation patterns.

Neptune: Named for the Roman god of the sea, this planet was "discovered" by prediction rather than observations. The statistics of our eighth planet are extreme in many ways.

The final article returns to a view of Earth and its tropical storms. As devastating as these storms can be, we still lack a good capability to predict their intensity and in many cases their paths. SSEC and NOAA scientists are collaborating to find a means to improve model forecasts of these storms using hyperspectral infrared observations from satellite sounders, such as AIRS, IASI and the new CrIS (Atmospheric InfraRed Sounder, Infrared Atmospheric Sounding Interferometer and Cross-track Infrared Sounder).

Steven Ackerman
Director, CIMSS

Through the Atmosphere

Fall 2011

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University of Wisconsin-Madison
Space Science and Engineering Center
Cooperative Institute for Meteorological Satellite Studies

Vicarious Calibration of GOSAT TIR in Railroad Valley, NV

In June 2011 the University of Wisconsin-Madison (UW) Space Science and Engineering Center (SSEC) participated in a vicarious calibration campaign of the joint GOSAT/OCO (Greenhouse Gases Observing SATellite/ Orbiting Carbon Observatory) research team on a dry lakebed (playa) in Railroad Valley, Nevada. The calibration campaign is a joint effort between JAXA, the Japanese space agency responsible for the GOSAT satellite launched in 2009, and the Jet Propulsion Laboratory (JPL), the U.S. organization leading the OCO-1 and -2 satellite effort. This campaign was the third in a series of joint Japan/U.S. field measurements to assess the calibration of the GOSAT sensors and validate derived products of carbon dioxide and methane.

SSEC was sponsored by JAXA to provide a quantitative assessment of the calibration accuracy of the thermal infrared (TIR) measurements from GOSAT.

Specifically, the observed emission spectra from the TANSO-FTS (Thermal And Near infrared Sensor for carbon Observations - Fourier Transform Spectrometer) sensor onboard GOSAT were compared to coincident observations from UW-SSEC high altitude aircraft and ground-based spectrometers during

the field campaign between 19-26 June 2011.

The UW Scanning High-resolution Interferometer Sounder (S-HIS) successfully overflew Railroad Valley, Nevada onboard the high-altitude NASA ER-2 along with the Airborne Visible/InfraRed Imaging Spectrometer (AVIRIS) and the MODIS/ASTER Airborne Simulator (MASTER).

The ER-2 overpass on 20 June 2011 was timed to coincide with an overpass of the GOSAT satellite at 21:19 UTC. A joint JPL/UW team also provided coincident upper air observations of pressure, temperature, and water vapor using Vaisala radiosondes released from the center of the Railroad Valley playa for six GOSAT daytime overpasses and three nighttime overpasses between 19-26 June 2011.

The UW also made ground-based measurements from the center of the playa during each GOSAT overpass with an Atmospheric Emitted Radiance Interferometer (AERI).

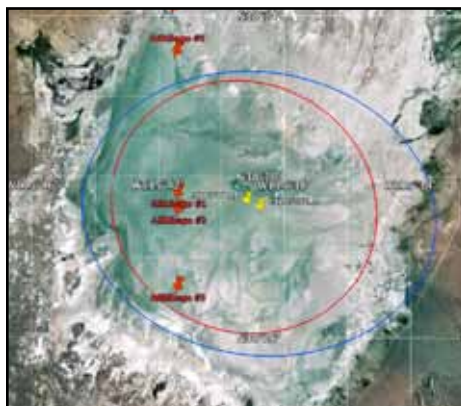
Operated from a research vehicle, the ground-based AERI measured the upwelling surface radiance at three view angles and the downwelling atmospheric emission at two angles. The AERI provided accurate surface emissivity and surface temperature for use in forward model calculations of the satellite observed infrared emission between 6 and 17 microns.

The measurements are still being analyzed but the results show considerable promise toward making significant improvements in the GOSAT TIR band calibration, thereby reducing the uncertainties in the retrieval of CO₂ from the satellite measurements.

Bob Knuteson



UW AOS students Jacola Roman and Elise Garms launching and tracking a Vaisala radiosonde.



Railroad Valley, Nevada, dry lakebed calibration site.

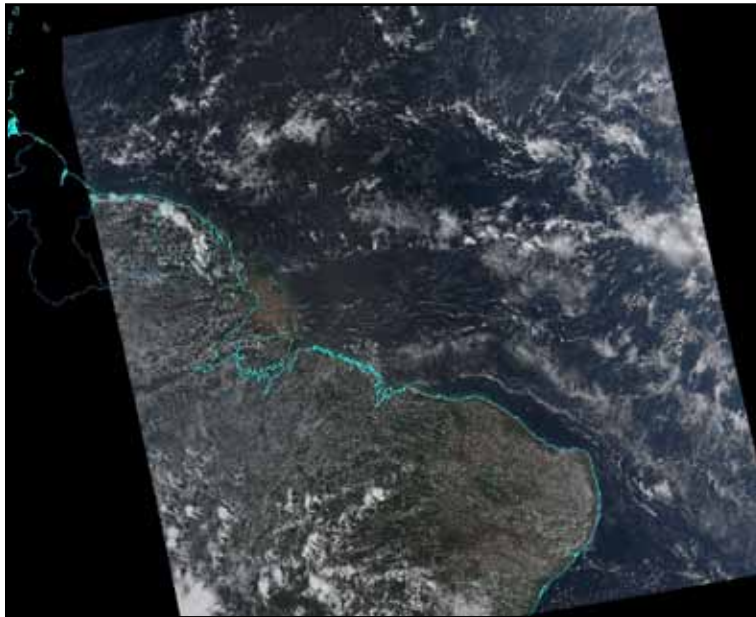


UW-SSEC and JAXA calibration/validation team.

SSEC Captures VIIRS First Light

November 21, 2011... SSEC scientists had long been preparing for that day when the Visible Infrared Imager Radiometer Suite (VIIRS), launched on the National Polar-orbiting Operational Environmental Satellite System Preparatory Project (NPP) a few weeks earlier, first began to acquire measurements. These preparations ranged from characterizing the instrument's spectral performance to creating the very first images made available to the public to ensuring that McIDAS-V (Man Computer Interactive Data Access System-V), SSEC's premier visualization and analysis tool, would be ready for the onslaught of new data.

Characterizing the VIIRS spectral performance prior to launch is key for product accuracy. The relative spectral response (RSR) support the Sensor Data Record (SDR) product (radiance), several Environmental Data Record (EDR) products, and the post-launch validation effort.



McIDAS-V image from VIIRS over South America.

Like its predecessor, MODIS, the only opportunity to ever directly measure the VIIRS RSR was during the prelaunch test program. Once VIIRS was launched, any adjustments to the RSR would be empirical in nature.

VIIRS RSR have been measured at the instrument level for all VIIRS bands during the pre-launch test program at the Raytheon El Segundo facility in the summer of 2009, and again for visible/near-infrared bands during

spacecraft level special testing in spring 2010 at the Ball Aerospace facility in Boulder, CO.

SSEC participated in both measurement activities: on-site at El Segundo monitoring the test program and providing early review of the test data as part of the Government Team, and on-site at Ball Aerospace contributing to the test planning and early review during the RSR special test program.

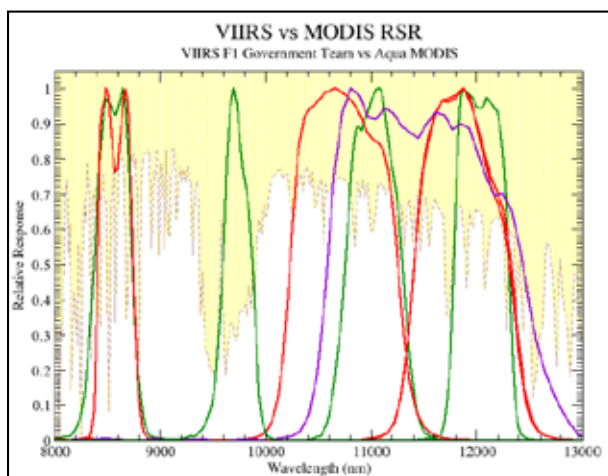
After test data collection, SSEC led an RSR subgroup of the Government Team formed to analyze all VIIRS spectral measurements and provide a Government Team RSR data set independent of industry analysis.

The flow of VIIRS data presented another opportunity and challenge. At SSEC, scientists adding new capabilities to the McIDAS-V visualization and analysis software worked with NASA and NOAA scientists for several months to bring the VIIRS data into the McIDAS

data model to use the full imaging and analysis capabilities of the system software. The complex file structures of VIIRS data were resolved over that period by using simulated VIIRS data provided by NASA and the contractor to understand the data format and rework it for visualization and analysis.

Additionally, there was a need to combine (aggregate) the individual granules (each granule is just under 90 seconds long) to create larger images and to remove some of the image oversampling (the so-called bow tie effect) to provide a high quality product. With these issues resolved using the simulated data, the first images were acquired by McIDAS-V for visualization and analysis. The figure above shows one of the first VIIRS images over the mouth of the Amazon River in South America. The SSEC McIDAS development team continues to work closely with JPSS to support data analysis and visualization of VIIRS, ATMS and CrIS data.

Chris Moeller
Tom Achtor
Leanne Avila



VIIRS spectral response for bands M14, M15, M16 (in red) and 15 (purple) along with MODIS bands 29-32 (green) for comparison.

Venus: Education and Public Outreach

Since May of 2006, SSEC's Office of Space Science Education (OSSE) has undertaken an innovative and active Education and Public Outreach Program for the NASA sponsored participating and interdisciplinary scientists in collaboration with the European Space Agency's Venus Express (VEX) Mission.

The national and international scale effort has focused on the use of authentic Venus Express data as the foundation for its ongoing activities in formal and informal learning as well as public outreach. Over the past five years major programmatic activities and achievements include:

- a dedicated web presence (venus.wisc.edu) that is regularly updated with current Venus events and content
- ongoing public lectures and presentations by the VEX science team members
- design of a baseline Venus Cloud Tracking activity aligned to middle and high school science/mathematics standards with supporting teacher training, and most recently
- an intensive, 10-week summer High School research experience focusing on the encouragement of STEM (Science, Technology, Engineering,

and Mathematics) career opportunities for young women (especially from rural, underserved regions).

The "Unsolved Mysteries of Venus" learning modules were developed by OSSE staff, including an undergraduate student in science education, and continue to be the centerpiece of formal education efforts.

Since 2007 over fifty teachers have been trained for classroom implementation of the activity in coordination with the annual Ali'I Teacher Workshop in Honolulu, HI, which attracts teachers from across the nation.

Additional teacher training workshops have been conducted in Milwaukee, WI, and in Livermore, CA where the cloud tracking activity has been integrated as part of the curriculum.

In February 2012 the Venus Express E/PO team will conduct the first of three annual teacher professional development workshops in Madrid, Spain, in collaboration with the European Space Agency's education staff.

Additional activities include a special emphasis on programming for low-income and underserved students and their communities as well as special events for young women. For the past two years, approximately 100 students and their parents and teachers have participated in the annual career fair conducted at the New Testament School(s) located in Milwaukee, WI.



*Students analyze Venus Express data sets.
Photo by Hsuan-Yun Pi.*

Other Public Outreach highlights and programs targeting young women included hosting of the annual National Girls' Collaborative Annual meeting in Madison, WI, in August, 2010 with Bill Nye "the Science Guy" as the featured guest speaker. Approximately 100 teachers and their students attended the event.

In the summer of 2011, five young women, ages 14-18, from New Glarus High School participated in a 10-week summer research experience, focusing on the analysis of authentic Venus Express data sets. Using actual Venus Express Cloud images, the five students successfully analyzed multiple data sets which validated earlier studies of Venus wind vectors from Pioneer Venus (Limaye, 1982).

Programming for the Venus Express Education and Outreach activities is led by OSSE Director, Rosalyn Pertzborn, with support from Hsuan-Yun Pi (graduate student) and key contributing VEX science team members including Dr. Sanjay Limaye (SSEC) and Dr. Kevin Baines (SSEC/JPL).



Dr. Sanjay Limaye with New Glarus High School student. Photo by Hsuan-Yun Pi.

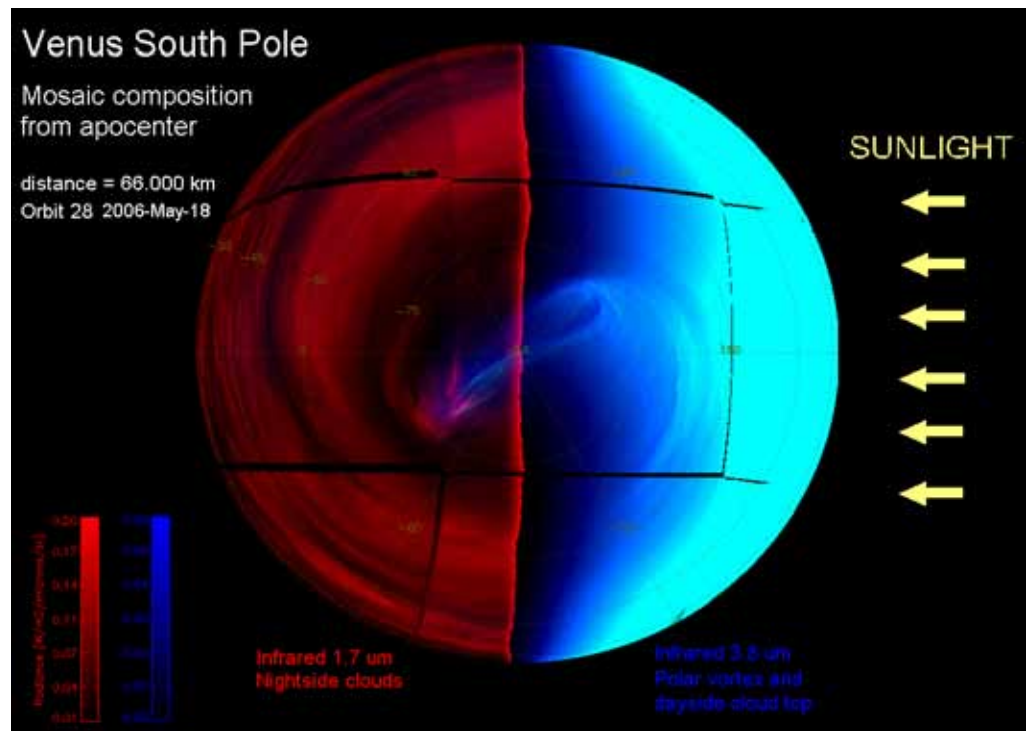
Rosalyn Pertzborn

Venus: Vortex Instabilities

Mariner 10, Pioneer Venus, and the recent Venus Express mission have revealed cloud-level (i.e., 48 to 70 km above ground level) hemispheric vortices centered over each pole of the planet. These vortices often possess visually stunning zonal asymmetries in infrared imagery. Some of the more pronounced vortex features may result from an instability associated with the zonal-mean winds in the Venusian cloud-layer.

In fact, Limaye et al. (2009; *Geophys. Res. Letts.*) studied cloud-tracked zonal winds from Pioneer Venus observations and found the vortex structure was barotropically unstable. This instability could plausibly explain the observed zonal asymmetries. Barotropic instability can result from strong horizontal wind shear in the flow.

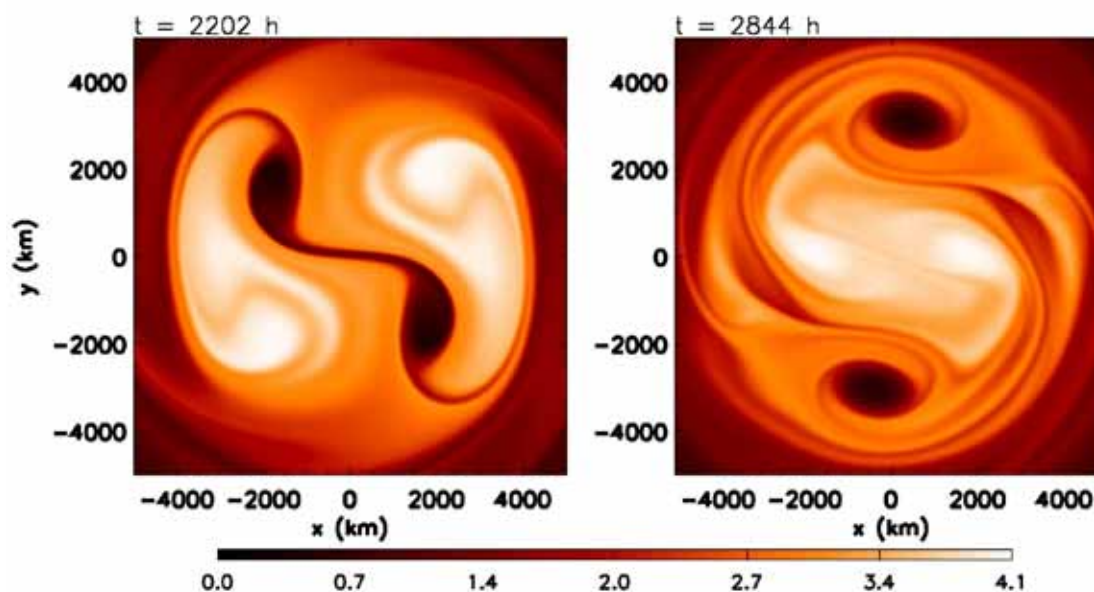
Knowledge of the Venusian vortices and their asymmetries has existed for decades, but fundamental aspects of the planet's atmosphere are still



VIRTIS imagery of a wavenumber-2 feature in the southern hemispheric vortex poleward of 60° latitude at 1.7 μm (night side; left) and 3.8 μm (day side; right).

mysterious. For example, the Venusian atmosphere rotates in the same direction as the planetary surface at more than 100 m s⁻¹ near the cloud tops, yet a theory for superrotation remains incomplete. It is unknown

whether this superrotation is connected to vortex instabilities. Some scientists are currently developing general circulation models (GCMs) to study these connections and general mechanisms for superrotation.



Individual fields of absolute vorticity (in units of 10^{-5} s^{-1}) at two different times in a two-dimensional numerical model initialized with observed cloud-tracked winds (Limaye et al. 2009).

Scientists at SSEC are studying vortex instabilities with idealized models that neglect processes such as cloud microphysics, radiative transfer, and turbulent surface-atmosphere interactions. These simplified models allow for high spatial resolution representation of the vortices that is often not possible in computationally expensive GCMs.

These simplified models complement full-physics GCMs because they help understand key physical processes (such as flow instabilities) that are too difficult to elegantly isolate from the complexities of full-physics GCM atmospheres. The idealized approach may shed new insight into the physical connections between vortex instabilities and the Venusian global circulation.

In addition to idealized models, SSEC continues to take a leading role in observational analysis of cloud structures related to Venusian vortices.

In imagery sequences from the Venus Monitoring Camera aboard Venus Express, large spiral bands can be seen expanding toward the equator from the turbulent vortex core centered near the pole. Scientists are currently examining the temporal and spatial characteristics of these wave structures to determine if these waves are planetary vortex Rossby waves propagating on the meridional vortex structure.

If these waves are in fact Rossby waves, and if they can be related to the zonally asymmetric structures in the core of the Venusian vortices, then it can be stated that vortex instabilities likely influence the global circulation of Venus. With the assistance of GCMs and idealized models, it is hoped that the wave-mean flow interactions between Rossby waves and the general circulation can be quantified.

**Christopher Rozoff
Sanjay IImaye**

Exploring Venus with High-Altitude Balloons

The balloon-borne Venus Aerostatic-Lift Observatories for in-situ Research (VALOR) aerostat is a proposed mission to circumnavigate the northern skies of our sister world, Venus, multiple times during a 24-day flight.

“Venus is perfect for a balloon mission,” says Principal Investigator Kevin Baines. “It’s CO₂ atmosphere is 50% more dense than the nitrogen that makes up 75% of our atmosphere, so it will support more weight in a helium balloon.”

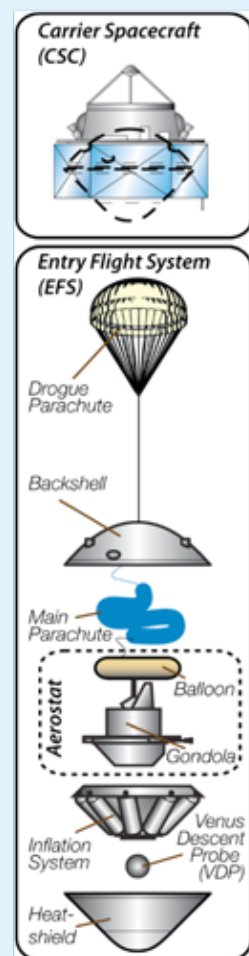
Carried by winds at its 55.5 km high float altitude, the VALOR balloon would sample the chemistry and dynamics of Venus’s sulfur-cloud meteorology. Clouds on Venus are formed chemically, rather than by condensation, so they have different dynamics. Cloud motion is difficult to determine from orbit. Zonal, meridional, and vertical winds would be measured with unprecedented precision, as would trace gases associated with Venus’s active photo- and thermo-chemistry.

“You can’t measure noble gases from orbit,” Baines says. “They are inert and have no spectral signatures. But they don’t change with time, so if you get down into the atmosphere, you get a record from millions of years back. Their isotopes will tell you about the origin of the planet. You just have to be in the atmosphere to measure and sample them. The balloon stays at an altitude where temperature is about room temperature (at half a bar pressure; the wind will be around 100 knots). The jet streams take the balloon around the world in 4 days. It’s a tough balloon.”

In addition, VALOR will sense present-day volcanism, lightning, and thunder. VALOR will measure Venus’ super-rotating winds from temperate to near-polar latitudes (from 25° north to 60° north, or higher). VALOR will also detect convective activity and fly over the tallest plateaus of Venus, searching for topographically-induced gravity waves.

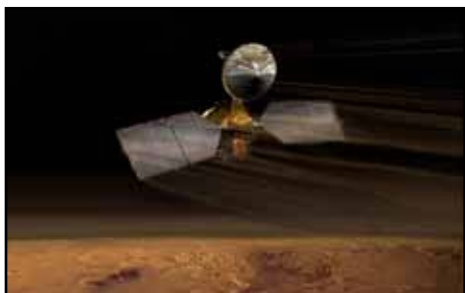
Finally, a deep atmospheric probe supplied by the Russian Space Research Institute will profile pressures, temperatures, and winds down to the ground, examining the stability of the near-surface temperature.

“Why is it that Venus has 100 mph winds – everywhere?” Baines asks. “We don’t know, but it could be important. There is a very good chance that we might get some real information about Earth winds via Venus studies.”



The Winds of Mars

The Mars Reconnaissance Orbiter (MRO) was launched from Cape Canaveral on 12 August 2005, and has been in a 112-minute polar orbit since November of 2006.



Its mission:

- to characterize the present climate of Mars and its physical mechanisms of seasonal and interannual climate change
- to determine the nature of complex layered terrain on Mars and identify water-related landforms
- to search for sites showing evidence of aqueous and/or hydrothermal activity



The MRO's instrument is the Mars Color Imager (MARCI), a charge-coupled device (CCD) camera using seven different filters. MARCI has two all-refractive 180° 'fisheye' lenses, one optimized for the visible and near-IR and one for the UV bands. The beams from these two lenses are brought to the CCD through a prism. A color filter array with seven different bandpasses (five visible/near-IR and two UV) is directly bonded to the CCD.

- to identify and characterize sites with the highest potential for landed science and sample return by future Mars missions
- and to return scientific data from Mars landed craft during a relay phase.

A typical image consists of seven 'framelets', each 1024 pixels wide and 16 pixels high, in each of these bandpasses. The visible resolution from 300 km is about 1 km/pixel at nadir.

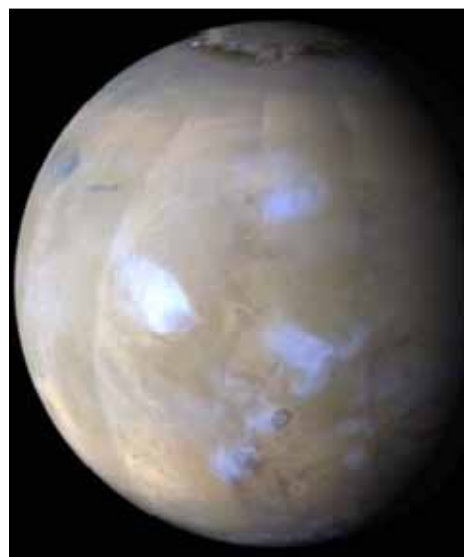
The data, processed by the Malin Space Science Systems (MSSS), produce daily color composites depicting the clouds on Mars.

In May 2009, NASA funded our proposal to track cloud features over the north polar region where clouds form during the Martian summer. The water ice clouds form due to sublimation of the ice from the polar cap.

MSSS provided one summer season of blue and red filter images, reprojected over the north pole. The blue filter is best for water ice clouds; the red filter is sensitive to dust.

In order to track the clouds, time sequences of images are used. These time animations revealed a distortion in the images that prevented us from tracking clouds: not only did the clouds move, so did the surface features!

In order to correct for the geometric distortion landmarks were found, templates were extracted, and offsets were determined using McIDAS software, developed here at SSEC. The landmarks were surface ice features or high-contrast craters.

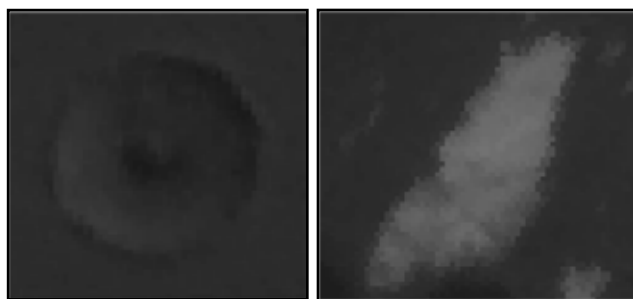


Color composite. Clouds appear as bluish-white features.

Many landmarks were extracted manually from the images, when there was little distortion; that is, when the feature is near nadir (viewed directly below the satellite). Also, good distribution of landmarks over the polar region was required.

Each landmark was then matched (using a cross correlation technique) to all other images in one month of data. Only highly correlated matches are saved. This discards matches of features that are partially obscured (clouds or dust) or too far from nadir.

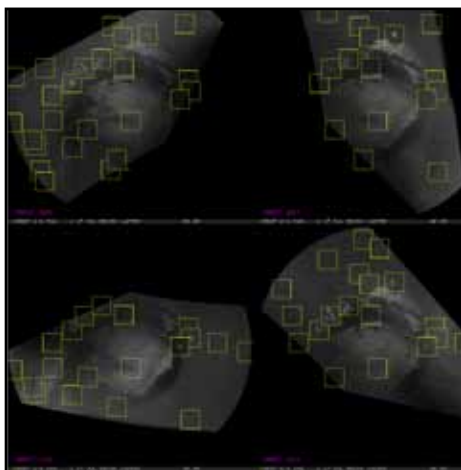
The matching resulted in offsets that could be used by MSSS to reprocess the images. This resulted in corrected



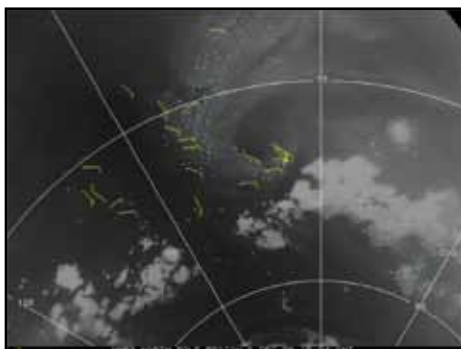
Example landmarks: Crater (left) and a surface ice feature (right).

images where the surface features did not move. Due to the nature of the distortion and camera geometry, this technique worked well for the red filter images; but not for the blue filter images.

Cloud Tracking Methodology is based on code used to derive feature-tracked winds for both geostationary and polar orbiting Earth-based satellite data. This is done by identifying cloud features, or targets, (based on gradients in the image) and then locating (using a cross correlation technique) the feature in images at different times. The speed of the wind can be inferred, based on the displacement of the feature.



Distribution of landmark locations.



Targets are the cyan dots; winds are yellow flags.

Because the clouds are so thin, surface features interfere with the automated cloud tracking. Therefore, we had to manually track clouds and also manually edit the winds to ensure the winds were correct.

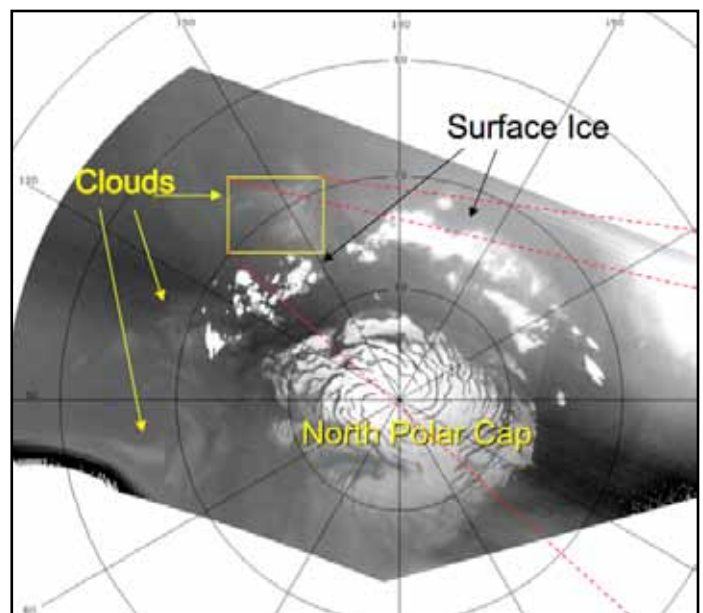
The 'high' density winds dataset retrieved from the north polar region of Mars will be used as input to global models and could lend insight into behavior and life cycle of baroclinic waves and cyclones on the planet.

Current status:

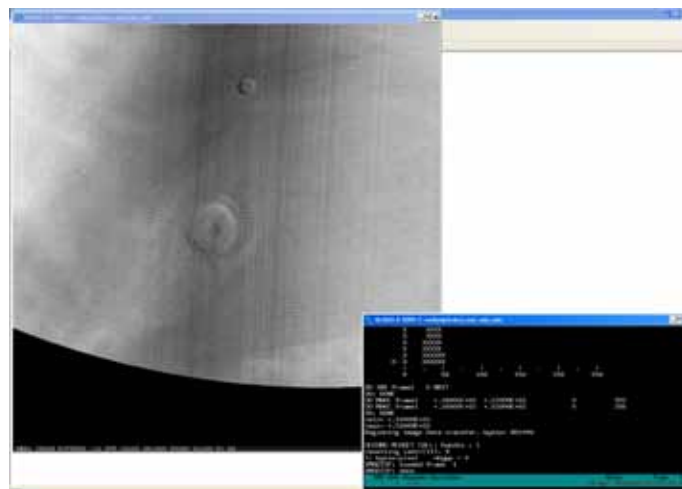
While the manual and automated tracking is complete, as is the quality control of the winds, we are beginning the analysis of the data, along with comparisons to numerical models (from the University of Maryland). Sanjay Limaye and Scott Lindstrom of SSEC are using GPS data to infer the heights of the clouds.

Emily Sorensen, an undergraduate Engineering student who graduated in December 2011, worked on all aspects of the project, from measuring landmarks and determining the distortion, to tracking and quality control of the cloud-tracked motions.

Dave Santek



View from pole to 60° north latitude. The polar ice cap is in the center. The bright white features in the upper left are surface ice. The wispy-like features are clouds.



McIDAS-generated image.

Jupiter: Cloud Chemistry Revealed

The Cassini flyby of Jupiter in 2000 provided spatially resolved spectra of Jupiter's atmosphere using the Visual and Infrared Mapping Spectrometer. A prominent characteristic of these spectra is the presence of a strong absorption at wavelengths from about 2.9 μm to 3.1 μm , previously noticed in a 3- μm spectrum obtained by the Infrared Space Observatory (ISO) in 1996.

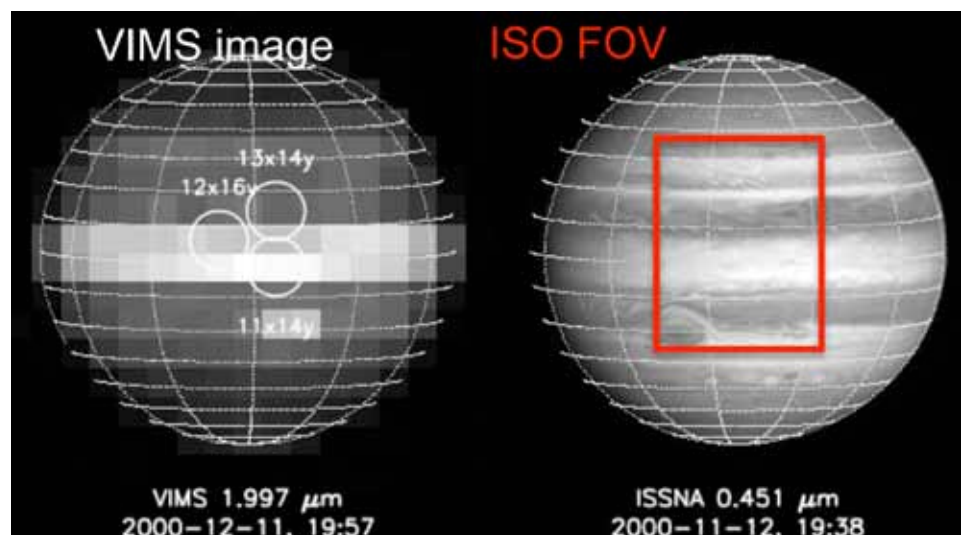
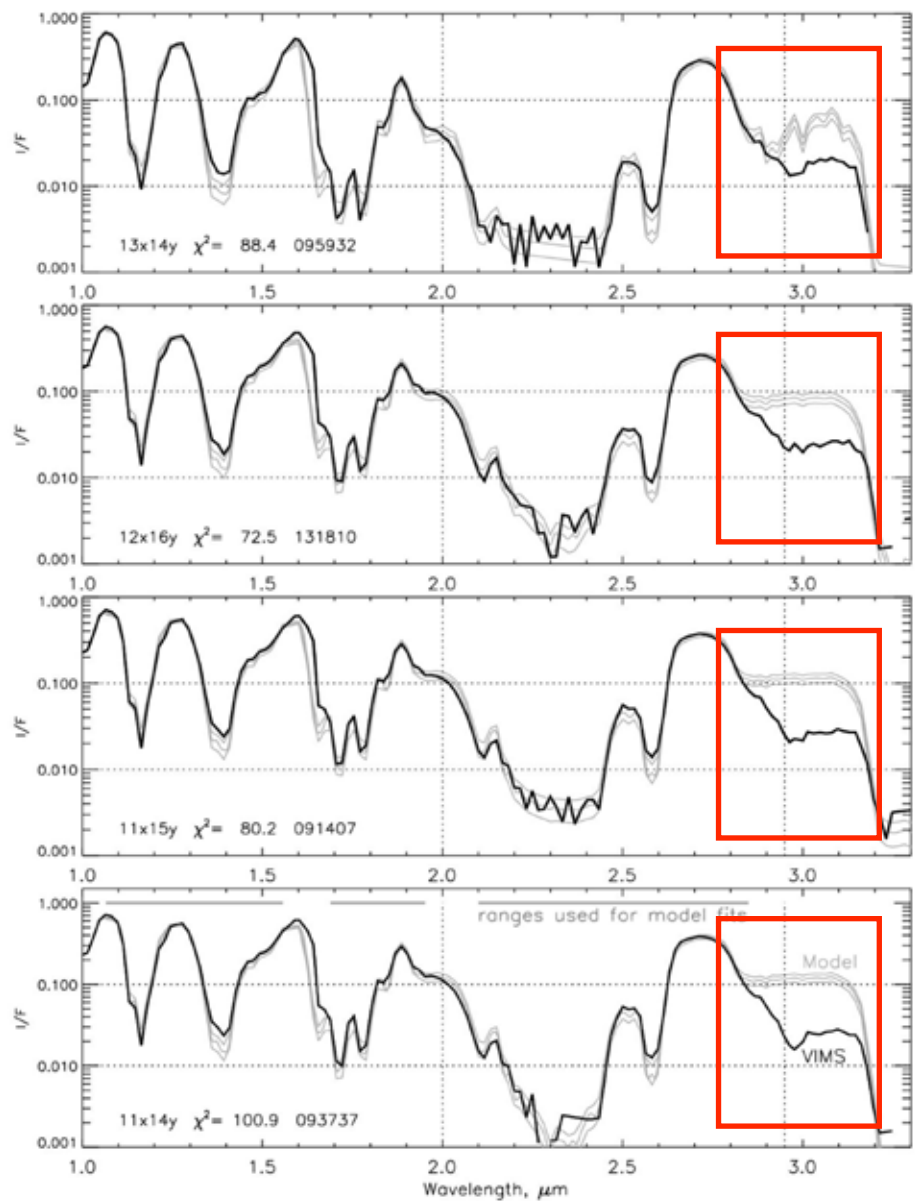
Ammonia ice was a prime candidate as the sole source of particulate absorption. But Irwin et al. 2001 identified a flaw in this explanation: if the absorption is provided by 10- μm NH_3 ice particles, there should also be absorption evident at 2- μm where NH_3 has a sharp feature.

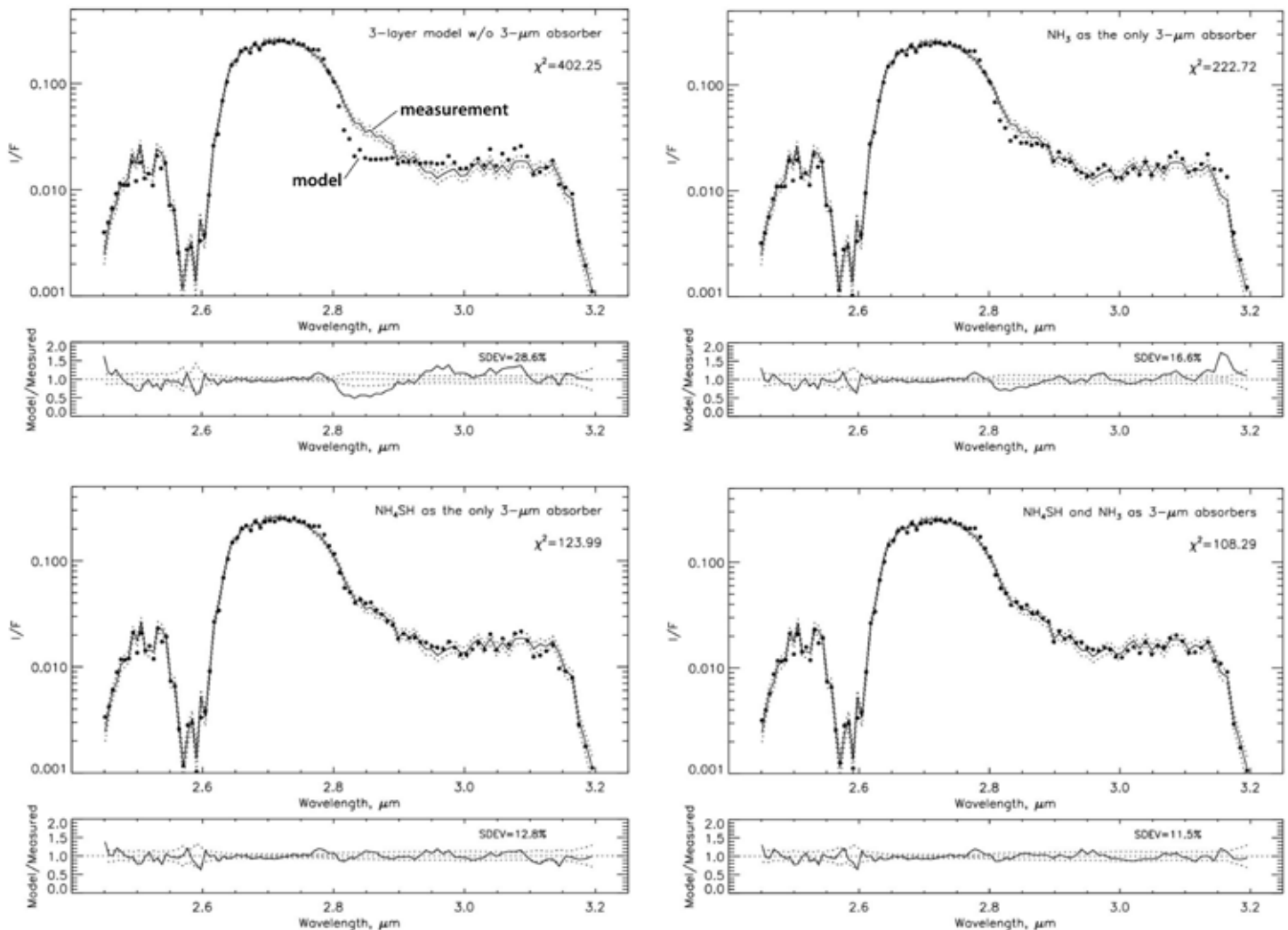
Calculations for a cloud model (as described in Brooke et al. 1998) show the 2- μm feature, but the Near Infrared Mapping Spectrometer spectral measurements do not show it.

SSEC planetary scientists Larry Sromovsky and Pat Fry, using significantly revised NH_3 gas absorption models, showed that ammonium hydrosulfide (NH_4SH) provided a better fit to the ISO spectrum than NH_3 , and that the best fit was obtained when both NH_3 and NH_4SH were present in the clouds.

The 3-micron absorber is present throughout the observable atmosphere of Jupiter, unlike the spectrally identifiable ammonia clouds (SIAC)

The need for a 3- μm absorber is most obvious when trying to fit VIMS spectra (black curves) with grey cloud particles. Such models (grey curves) result in excessive model absolute reflectivity values near 3 μm (the defect is worse for the brightest clouds). The need for absorption is evident in spatially resolved NIMS and VIMS spectra as well as large-FOV ISO spectra and seems to be present everywhere on Jupiter.





For a single 3- μ absorber, the best fit to the ISO spectrum is provided by NH_4SH , in the form of large particles ($r = 15\text{--}20\ \mu$) near a pressure of 450 mb.

previously studied, which are present over less than 1% of Jupiter. These clouds seem to be made of pure NH_3 and do show a 2- μm absorption feature (as identified by Kevin Baines of SSEC in 2002).

Sromovsky and Fry evaluated seven candidate materials for the 3-micron absorbing layer using improved models for methane and ammonia gas absorption that were not available at the time of previously published work on this issue.

For a single 3-micron absorber, the best fit to the ISO spectrum is provided by ammonium hydrosulfide, in the form of large particles ($r = 15\text{--}20$

microns) near a pressure of 450 millibars. Ammonia is a 7-sigma second best fit among substances thought to be present in Jupiter's atmosphere, with water ice an 11-sigma third place.

Better fits can be obtained by two-absorber models with ammonia contributing a minor fraction either as a population of particles just above or mixed with the ammonia hydrosulfide particles, or as a coating on the small particle layer near 320 millibars.

Strong vertical convection would seem to be needed to transport ammonium hydrosulfide particles to the level that is implied by these results. Such

transport would likely result in composite particle composition with NH_3 condensed on top of NH_4SH cores.

Saturn's spectra do not exhibit the broad 3- μm absorption feature characteristic of Jovian spectra, perhaps because the cloud layer containing that absorber is obscured by the moderately thick tropospheric haze that overlies it. However, Saturn spectra do exhibit a small absorption feature near 2.965 μm , which is qualitatively consistent with NH_3 absorption when diluted by combining NH_3 with a substantial conservative core or shell.

Mark Hobson

Saturn - From Pole to Pole

Saturn, the second-largest planet in our Solar System, is easily the most visually spectacular. The gas giant puts on a magnificent display with its immense rings, but, unlike its larger sibling Jupiter, hides the details of its complex atmospheric structures with layers of haze.

Sometimes intriguing glimpses of Saturn's inner dynamism erupt to the outer layers of its atmosphere and can be captured by the Cassini-Huygens Orbiter, which has been observing the planet and its moons for years.

Principal Investigator Kevin Baines (joint appointment at UW-Madison Space Science and Engineering Center and the Jet Propulsion Laboratory in Pasadena, CA) has been studying several recent storm systems on the planet.

"Saturn's year is the equivalent of nearly 30 Earth years," Baines says. "We have previous records of storm activity breaking through the haze, but usually these eruptions happen toward the end of Saturn's summer. We're only two years into the planet's spring season and the features that are appearing are fascinating."

The Southern Hemisphere Storm

The first storm was observed near 30° south latitude in February 2008. Two new types of clouds were discovered, each with its own distinctive composition: ammonia condensate clouds (likely formed from upwelling ammonia gas) and exceptionally dark clouds from carbon-soot-impregnated condensates.

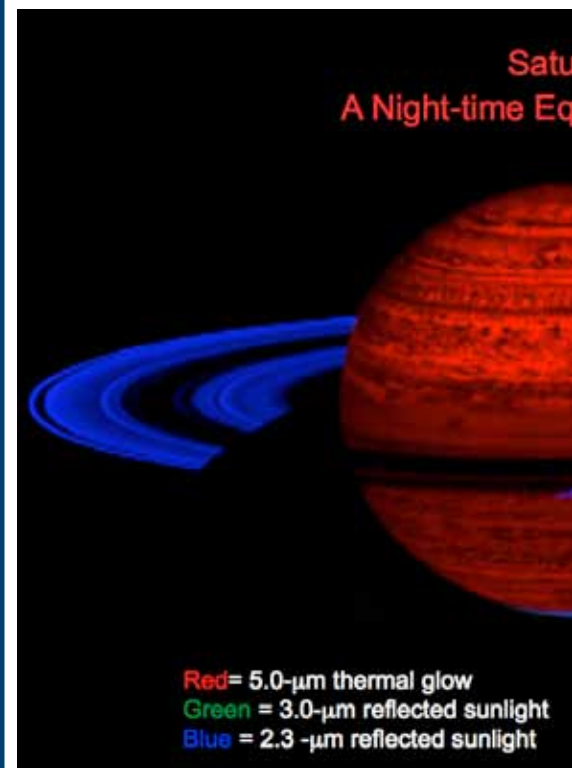
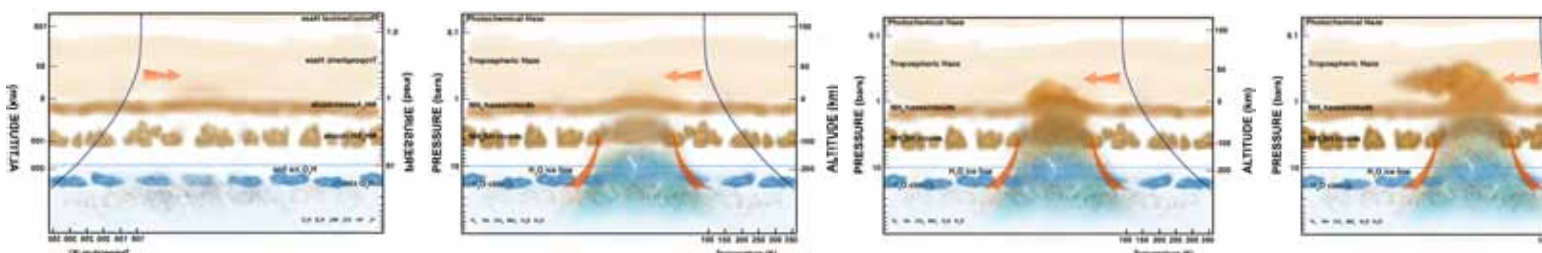
The carbon was likely created by lightning flashes – averaging 2 per minute but more than 10 per second at times – blasting through atmospheric methane near the 10-bar level, some 100 km underneath the cloudtops observed from Earth. Water vapor and water clouds can exist this deep in the atmosphere and can form

thunderstorms. We do not see these water clouds themselves, but instead detect other thunderstorm-related clouds created by convective upwelling.

These clouds give rise to the "Double Bubble Model." Ammonia gas lying just under the upper clouds (themselves likely ammonia) is pushed up in convective upwellings, forming fresh ammonia clouds comprised of exceptionally large particles that are readily identifiable spectroscopically.

Within a few days, dark clouds containing an optically-significant component of lightning-produced carbon soot, reach higher altitudes and become visible.

The "Double Bubble Model"



String of Pearls Near

Kevin Baines is also examining a bizarre train of clouds along a longitude discovered by VIMS in 2005.

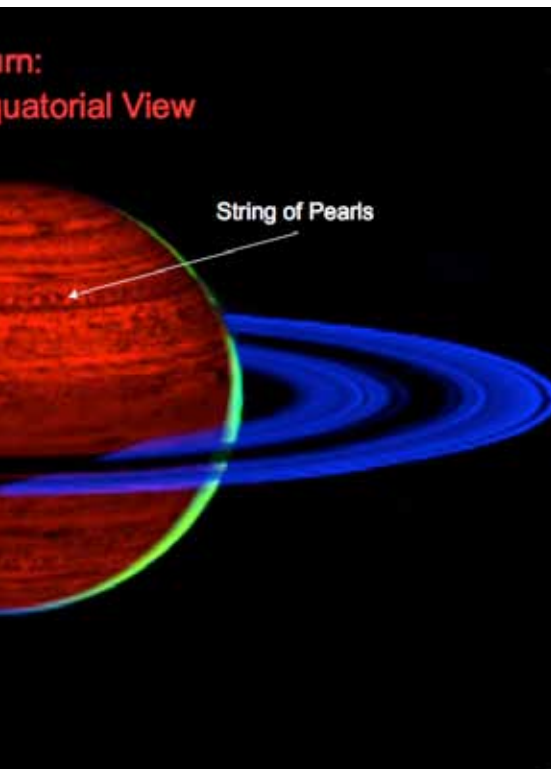
"They appear as a bright string of lights," he says. The level that allows 5-mm thermal light from the deep atmosphere, about 100 km across, and they are separated from each other by about 100 km.

The "necklace," stretching a quarter of the way around the planet, was observed for five years and was remarkable for its persistence.

The necklace disappeared when the Northern Storm arrived in the past year and obliterated it.

"We wonder if there may be a common dynamical mechanism between the storm and the pearls," Baines said. "Both may be manifestations of a process prevalent near 35° north latitude. This is the latitude of the retrograde speed at non-polar latitudes."

It seems possible that the pearls are clearings in the storm clouds or vortex streets. Such features are typically formed by an obstacle such as convectively-forced updrafts or by anvil-type storm clouds covered the pearl region.



er 35° North Latitude

f cloud clearings spanning about 90° of

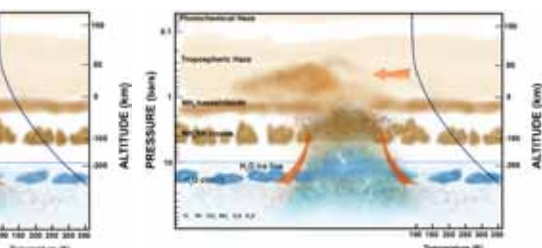
s. “Each ‘light’ is a cloud clearing near the 3-bar depths to shine through. Each clearing is about h other about 4000 kilometers.”

across a Saturn’s northern hemisphere, was its uniform spacing.

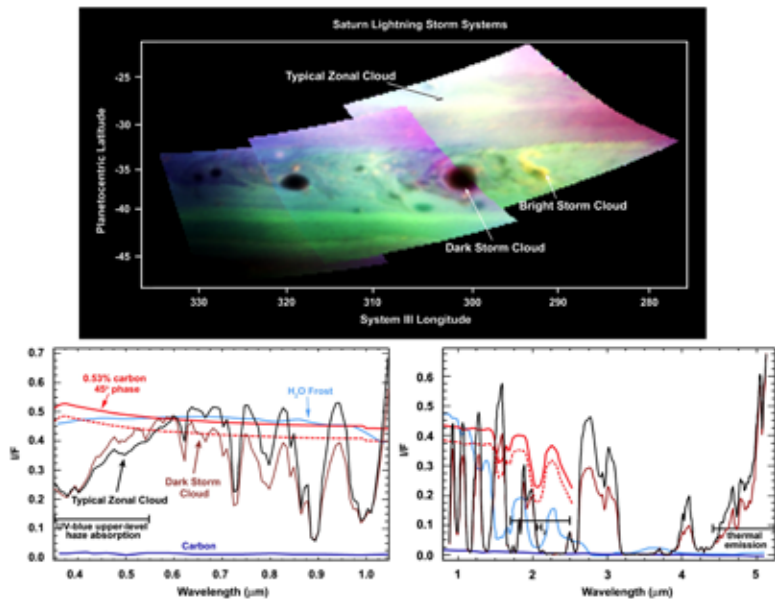
storm expanded into the midst of the “pearls” in

cal mechanism responsible for both the pearls festations of the exceptional vertical dynamics titude where zonal motions have the maximum

clouds, likely vortices found in von Kármán d by winds disrupted by an obstacle, in this case s. The storm appeared as convection increased egion.



Images and Spectra of Clouds on Saturn Associated with Thunderstorm Activity



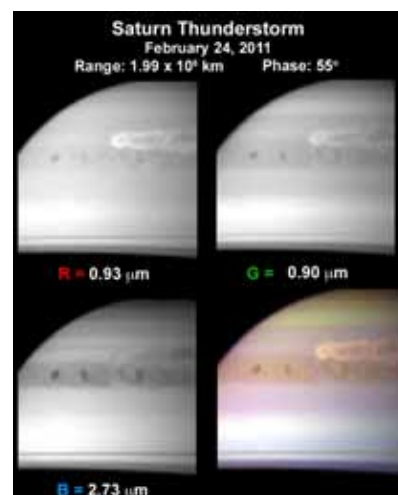
Upper panel: False color image depicts the 0.93 μm atmospheric continuum (red), the 0.90 μm atmospheric methane absorption (green), and the 2.73 μm atmospheric continuum (blue). Dark storm clouds (e.g., arrow pointing to dark region) are unusually dark at both continuum wavelengths.

Lower panels: VIMS spectra of a dark storm cloud (brown) and a more typical cloud (black) are shown in I/F units, as acquired by the instrument's visual channel (left panel) and near-infrared channel (right panel).

Northern Storm near 35° North Latitude

First detected by Cassini's Visual and Infrared Mapping Spectrometer (VIMS) on 5 December 2010, the immense (500 times larger than any other storm detected by Cassini) storm has been studied in detail since February 2011.

“Storms of this magnitude seem to occur at about the same time every



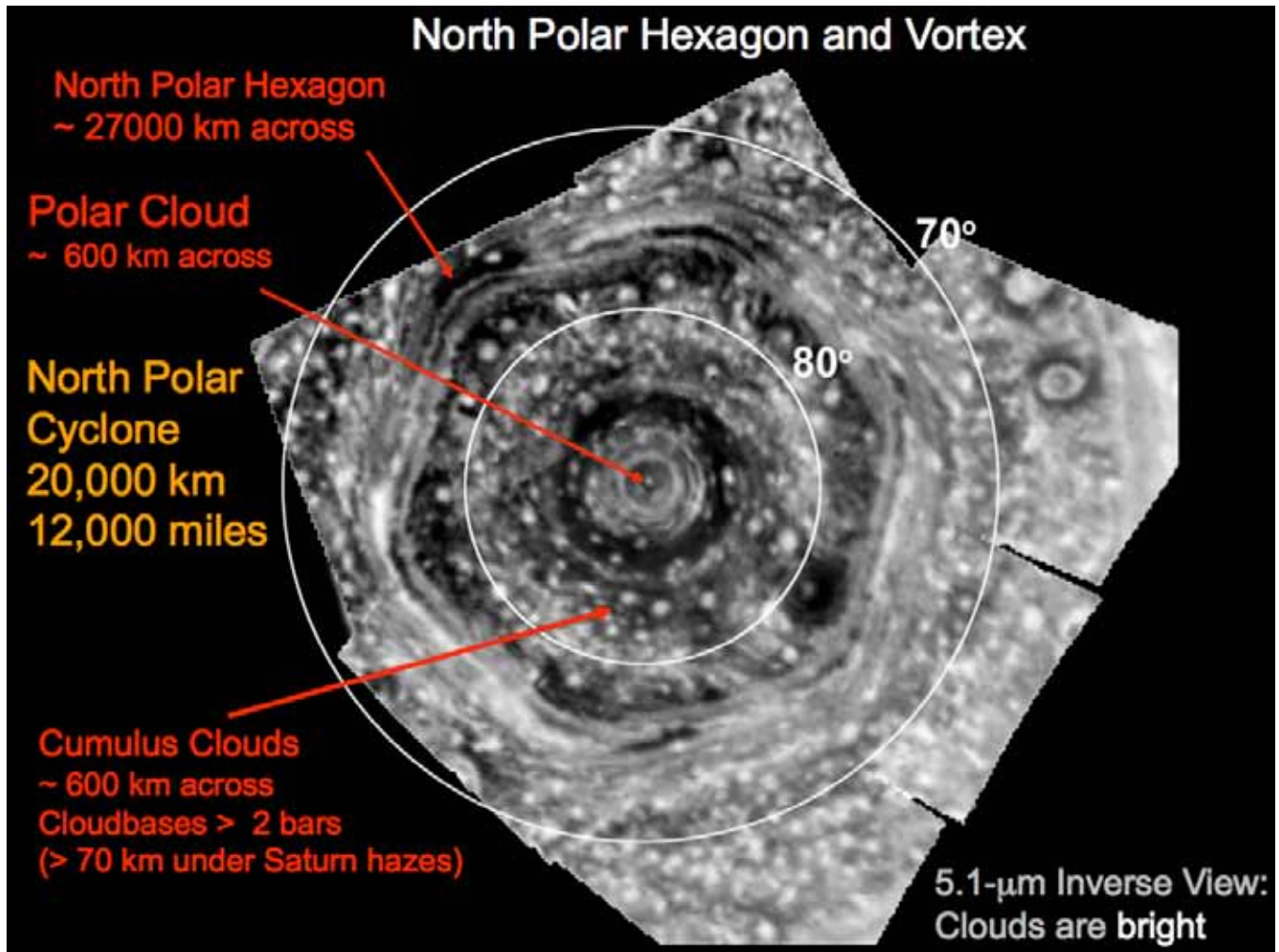
Saturnian year,” Baines said, “and only six have been detected since 1876. This is the first one to be examined by infrared imagery.”

Thermal imaging showed that the rising gases generated by the storm cooled a 5,000 km wide swath of the atmosphere by 7° to 9° Kelvin.

Above figure: **Red:** 0.93 mm Continuum -- **Green:** 0.90 mm High Alt. Clouds -- **Blue:** 2.73 mm Ammonia absorption -- **Yellow clouds:** NH_3 ice (yellow is the lack of blue. Blue is gone because the material is absorbing the ammonia ice) Absorption at 2.73 mm indicates ammonia ice. A combination of ammonia ice comprised of large particles indicates extremely powerful convective storm.

Mark Hobson

Saturn: North Polar Clouds - The Polar Hexagon and Discovery of the Saturn's North Polar Vortex



Saturn's north polar region is especially mysterious due to an unusual hexagonal feature centered near 76° north latitude, originally revealed in Voyager imagery in 1988.

Images taken by VIMS Cassini some 28 years later reveal that this feature still exists, essentially unchanged. The mechanism maintaining the hexagon is poorly understood. High-speed winds, exceeding 125 m/s, were measured for cloud features at depth within the polar hexagon. This may suggest that the hexagon itself, which remains nearly stationary, is a

westward (retrograde) propagating Rossby wave, a wave created by variations in the Coriolis effect with latitude.

The polar cyclone is similar in size and shape to its counterpart at the south pole; a primary difference is the presence of a small (<600 km in diameter) nearly pole-centered cloud, perhaps indicative of localized upwelling. Many dozens of discrete, circular cloud features dot the polar region, with typical diameters of 300–700 km. Equatorward of 87.8°N, their compact nature in the high-wind polar

environment suggests that vertical shear in horizontal winds may be modest on 1000 km scales. The existence of cyclones at both poles of Saturn indicates that cyclonic circulation may be an important dynamical style in planets with significant atmospheres.

The mysteries of Saturn's atmosphere are slowing coming to light. And this may be a good time to keep one's eye on the giant, ringed beauty.

Stay tuned. The sun is rising!

Kevin Baines

Highlights of Recent Publications

Long-term trends in downwelling spectral infrared radiance over the US Southern Great Plains.

Journal of Climate, Volume 24, Issue 18, 2011.

Gero, P. Jonathan and Turner, David D.

A trend analysis was applied to a 14-year time series of downwelling spectral infrared radiance observations from the Atmospheric Emitted Radiance Interferometer (AERI) located at the Atmospheric Radiation Measurement Program (ARM) site in the U.S. Southern Great Plains.

The possibilities of polar meteorology, environmental remote sensing, communications and space weather applications from Artificial Lagrange Orbit.

Advances in Space Research, Volume 48, Issue 11, 2011.

Lazzara, Matthew A.; Coletti, Alex and Diedrich, Benjamin L.

After 50 years, polar orbiting satellites are still the best view of the polar regions of the Earth. The prospect of a solar sailing satellite system in an Artificial Lagrange Orbit (ALO, also known as “pole sitters”) offers the opportunity for polar environmental remote sensing, communications, forecasting and space weather monitoring.

Improvements in shortwave bulk scattering and absorption models for the remote sensing of ice clouds.

Journal of Applied Meteorology and Climatology, Volume 50, Issue 5, 2011.

Baum, Bryan A.; Yang, Ping; Heymsfield, Andrew J.; Schmitt, Carl G.; Xie, Yu; Bansemer, Aaron; Hu, Yong-Xiang and Zhang, Zhibo.

This study summarizes recent improvements in the development of bulk scattering/absorption models at solar wavelengths. The approach combines microphysical measurements from various field campaigns with single-scattering properties for nine habits including droxtals, plates, solid/hollow columns, solid/hollow bullet rosettes, and several types of aggregates.

Scale-aware integral constraints on autoconversion and accretion in regional and global climate models.

Geophysical Research Letters, Volume 38, 2011.

Bennartz, Ralf; Lauer, Axel and Brenguier, Jean-Louis.

This paper describes a novel method to constrain autoconversion and accretion rates in climate models. The method offers two desirable features that might ultimately help to effectively eliminate autoconversion efficiency

as a free tuning parameter in climate models. Firstly, it can be constrained based on concurrent observations of column integrated cloud properties, namely cloud droplet number concentration, liquid water path, and precipitation rate. Secondly, the scale-dependency of autoconversion can be incorporated and resolved explicitly.

Methane on Uranus: The case for a compact CH₄ cloud layer at low latitudes and a severe CH₄ depletion at high-latitudes based on re-analysis of Voyager occultation measurements and STIS spectroscopy.

Icarus, Volume 215, Issue 1, 2011.

Sromovsky, L. A.; Fry, P. M. and Kim, J. H.

Lindal et al. presented a range of temperature and methane profiles for Uranus that were consistent with 1986 Voyager radio occultation measurements of refractivity versus altitude. A localized refractivity slope variation near 1.2 bars was interpreted to be the result of a condensed methane cloud layer. However, models fit to near-IR spectra found particle concentrations much deeper in the atmosphere, in the 1.5–3 bar range, and a recent analysis of STIS spectra argued for a model in which aerosol particles formed diffusely distributed hazes, with no compact condensation layer.

Honors and Awards

James Kossin

Received the Gold Medal from the Office of Oceanic and Atmospheric Research for excellence in research.

Steven Ackerman

Honored by Wisconsin Academy for his “extraordinary career as an atmospheric scientist.”

Jean Phillips

Appointed next chair for the AMS History Committee.

Tim Schmit

Received a Department of Commerce Silver Medal. Received the T. Theodore Fujita Research Achievement Award from the National Weather Association.

The Advanced Satellite Products Branch, CIMSS, and SSEC

Recognized by the Spaceflight Meteorology Group for support over the years to the Space Shuttle Program.

Uranus: A Puzzling Cloud Distribution

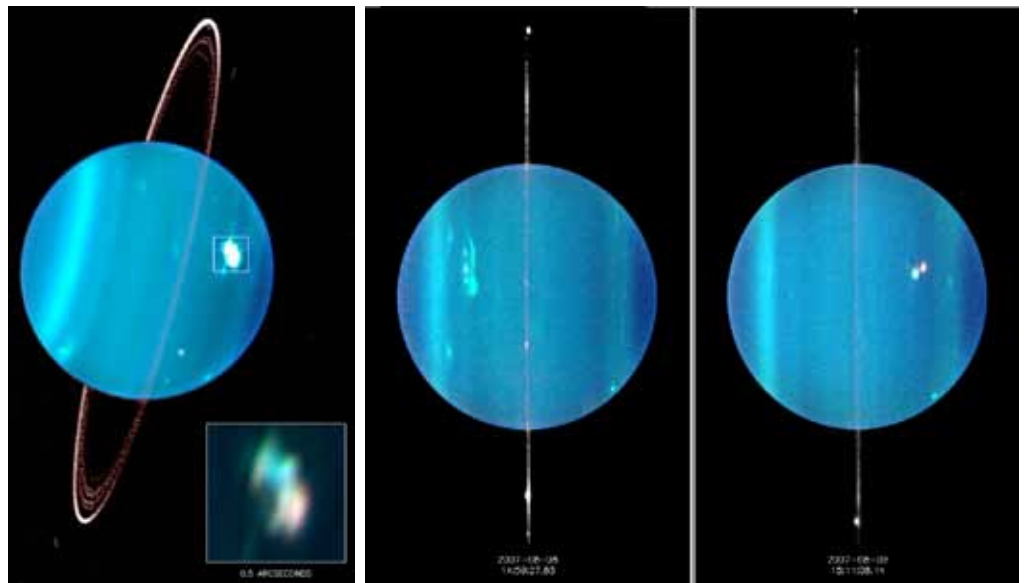
When Voyager 2 flew by Uranus in 1986, its radio-based images showed a rather featureless planet. It was a surprise when, a decade later, the Hubble Space Telescope's (HST) near infrared detectors revealed many previously unseen cloud features. The brightest features were in the northern hemisphere, a latitude range on the planet that had just come into sunlight after having been in darkness for over 40 years. Since the late 1990s HST has observed the planet regularly, joined in 2000 by the 10-meter Keck telescope on Mauna Kea in Hawaii.

Uranus has an 84-year orbital period and a spin-axis tilt of 97° from its orbit normal, so that its poles alternate between 42 years of sunlight and 42 years of darkness, providing the largest fractional seasonal forcing of any planet in our solar system. On average its poles receive more sunlight than its equator. For comparison, the Earth's spin axis tilt is only 23.5° .

Discrete cloud features in the southern hemisphere of Uranus are generally much deeper than those in the northern hemisphere and likely of a different composition.



2006 HST observations captured the first image of a solar eclipse on Uranus, this one by the moon Ariel. Earth and Moon shown for size comparison.



Far left image shows the brightest feature yet seen on Uranus. Later images show Uranus at the 2007 equinox, with its rings viewed directly edge-on.

From analysis of reflected spectra, the main cloud layer on Uranus appeared to be centered much deeper than expected from Voyager 2 radio occultation results (collected in its fly-by in 1986), strongly suggesting that the main cloud could not be composed of methane, in spite of the fact that methane is by far the most abundant condensable gas on the planet.

In observations from 1994 through its 2007 equinox, Principal Investigator Larry Sromovsky at SSEC saw asymmetry in Uranus's cloud structure, with the southern hemisphere, recently coming out of a long summer, being generally brighter than the northern hemisphere. This would not be surprising if it was a long-delayed response to seasonal forcing, but changes were occurring faster than expected.

The bright band at 45°S was beginning to fade, while a new bright band was beginning to form at 45°N .

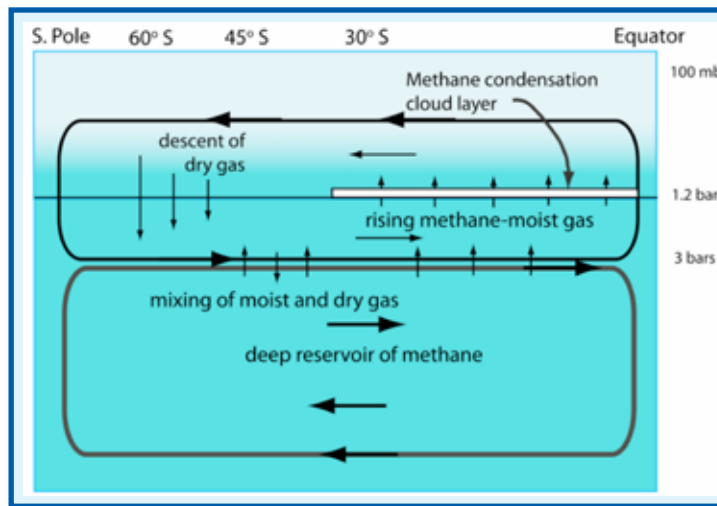
Another interesting asymmetry was the continued complete absence of discrete cloud features south of 45°S , while discrete cloud features were observed north of 45°N (which were only visible in high-pass filtered near-IR images taken by the Keck Observatory telescope). Some mechanism seemed to be inhibiting convection at high southern latitudes but not at high northern latitudes.

In 2009, complex calibration issues were finally resolved allowing observations made in 2002 by the Hubble Space Telescope (HST) Space Telescope Imaging Spectrograph (STIS) to be thoroughly analyzed by Erik Kartoschka of the University of Arizona. They revealed a puzzling lack of methane concentrations in the southern hemisphere of Uranus.

Reanalysis of the Voyager occultation and of the CCD spectra measured by the STIS, which uses two compact cloud layers instead of one diffuse layer for the main layer, produced more consistent results between occultation and spectral results for the upper compact layer.

Sromovsky confirmed that at high southern latitudes methane must be strongly decreased in the upper troposphere, suggesting a downwelling at high latitudes and slow rising motions at low latitudes.

A current question is whether the circulation pattern extends to the northern hemisphere. Is methane depleted in the north as it is in the south? Or does the northern convective activity enhance methane? The methane depletion anomalies suggest a meridional circulation pattern on Uranus.



Schematic of methane depletion through condensation that dries ascending air at low latitudes, leading to depleted methane in descending regions at high latitudes.

An upwelling at low latitudes brings about condensation, depleting the methane gas. Gas above the condensation layer flows toward the pole. At mid- to high-latitudes the dry gas descends and pushes the upper tropospheric methane deeper into the atmosphere, which then mixes with methane rich gases at lower altitudes and flows back toward the lower latitudes, restoring the mixing ratio.

Sromovsky surmises that a lower cloud was not seen by radio measurements because it does not produce a significant change in atmospheric refractivity. The methane cloud layer was missed by spectral analysis because the vertical resolution of near

IR spectra is too low to distinguish two compact layers from one diffuse layer.

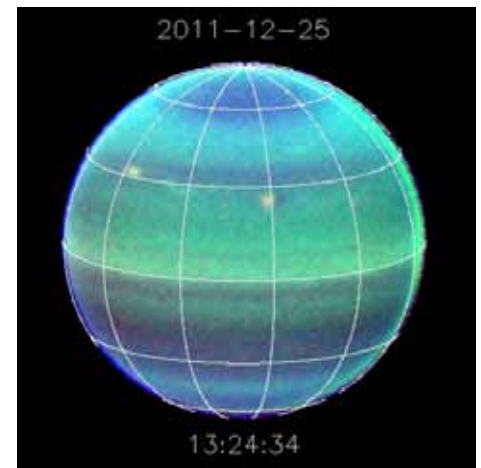
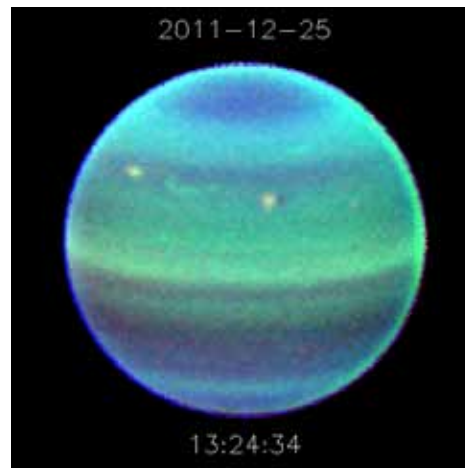
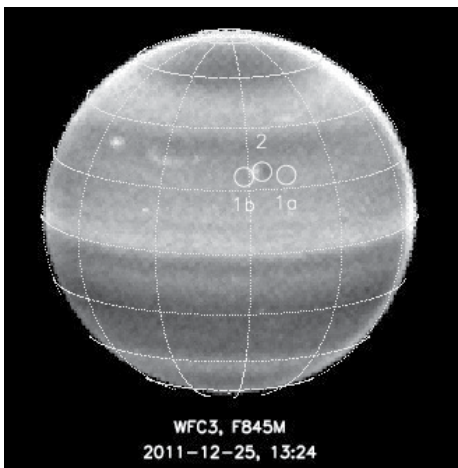
When radio and reflected spectra were combined, it was possible to reach consistent results.

Mark Hobson

Holiday Treat from the 7th Planet

Holiday season observations in 2011 revealed a new dark spot (and a bright companion spot) at the predicted position of the close approach of two previously observed bright spots. Given that only one other dark spot was ever seen on

Uranus, this is an important result. It appears from images taken on 20 December 2011 that the first bright spot, the one that was seen to be increasing in brightness during October, may have dissipated sometime after 16 December.



The black and white image above shows predicted spot positions on the image made with the HST F845M filter. Two predictions are given for the first spot to illustrate the range of uncertainty in its drift rate. The color images show an ungridded image on the left and a gridded image as observed by the HST on Christmas Day.

Neptune: Planet of Extremes



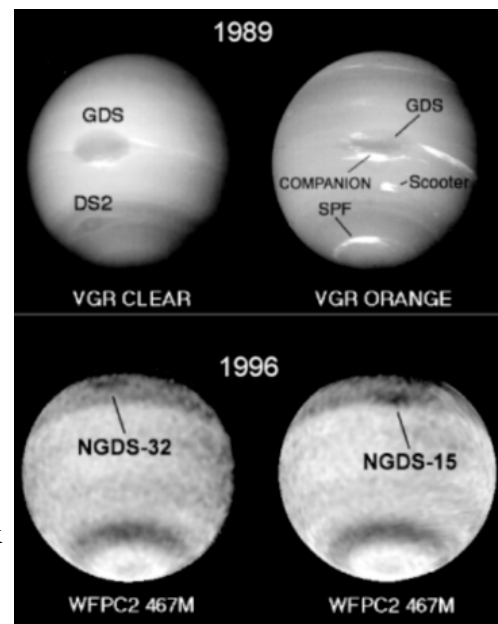
Starting on 23 January 1989, twelve years after its launch, Voyager 2 cameras recorded discrete cloud features in Neptune's atmosphere for approximately 8 months. It discovered a bright cloud associated with Neptune's Great Dark Spot (GDS) and captured the last view of Neptune's Second Dark Spot (DS2) on 24 September 1989 (about 1 month after its close approach to Neptune).

Later measurements of a multitude of smaller features by the Voyager Imaging Team, which included Verner Suomi, co-author of the Voyager science paper and founder of SSEC, revealed high-speed retrograde winds of up to 450 m/sec westward near 70°S,

giving Neptune the widest range of atmospheric angular momentum of any planet in the Solar System. SSEC planetary scientists Sanjay Limaye and Larry Sromovsky found dramatic evolution of small and large bright cloud features on time scales shorter than one hour.

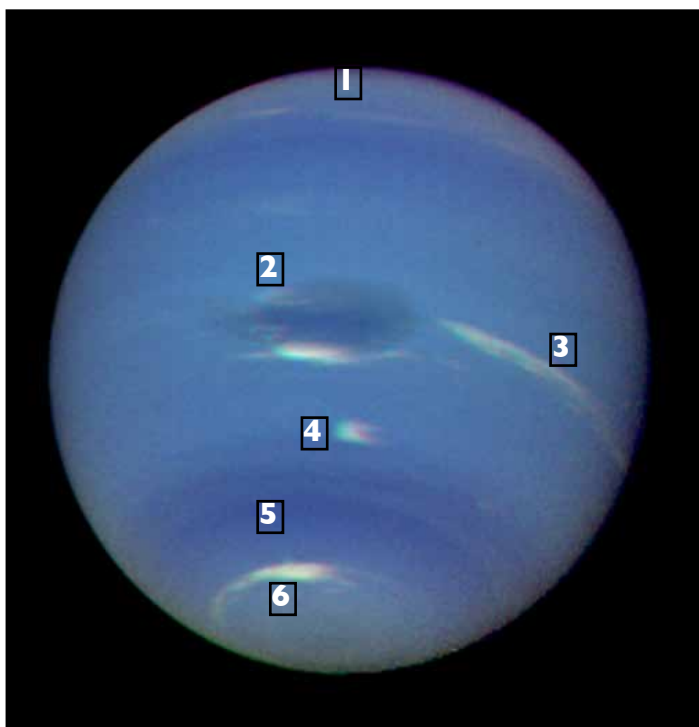
SSEC researchers used Voyager 2 images of Neptune to investigate the dynamics of the Great Dark Spot (GDS), the Scooter, the Second Dark Spot (DS2), and the South Polar Features (SPF). Their studies covered a longer time base than previous work and achieved more complete sampling of the available data.

They found a surprisingly large increase in the mean latitudinal size of the GDS – from 8° in January 1989 to 17° in August. They measured GDS northern motion from 26°S to 17°S and found no evidence of latitudinal limits. They confirmed that the varying longitudinal drift rates of the GDS and DS2 were simple functions of latitude that approximately match the zonal wind profile.



Comparison between 1989 Voyager 2 and 1996 Hubble Space Telescope images of Neptune. (from Sromovsky et al. Icarus 156, 16-36, 2002).

- Voyager observed Great Dark Spot (GDS) disappeared
- Voyager DS2 (second Dark Spot) disappeared
- New GDS found at 32 N
- New GDS found at 15 N
- Both new dark spots disappeared without drifting towards the equator.
- Narrowing of circumpolar dark band.
- Polar band is off center.



In 1989, Voyager observed:

1. Northern Streaks (NS)
2. The Great Dark Spot (GDS) and Bright Companion
3. Near Equatorial Feature (NEF)
4. The Scooter
5. The 2nd Dark Spot (DS2)
6. South Polar Features (SPF)

Characteristics of the Great Dark Spot

- Earth-sized storm 38° in long., 14° in lat.
- Shape & orientation oscillates: period=193 hr., ampl.=7.4° long.
- Expected anticyclonic circulation

GDS companion clouds are thought to be orographic in nature, producing condensation when an obstacle to the mean flow generates vertical waves. These clouds are like lenticular clouds seen in downwind of mountains or cap clouds at mountain summits.

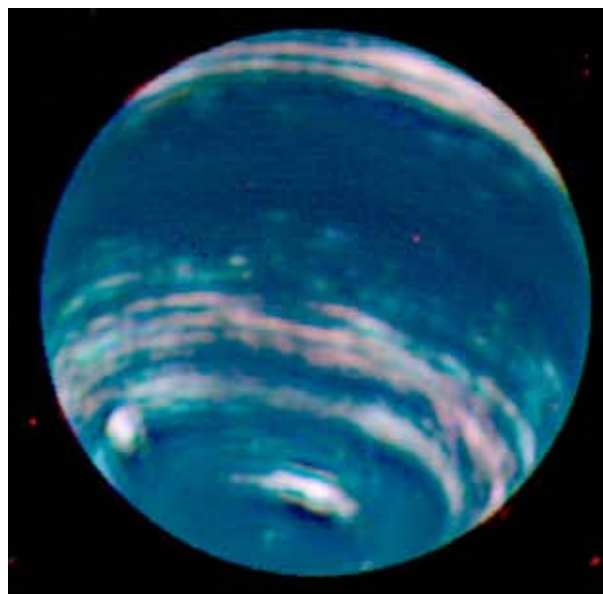
Later SSEC research included the first coordinated contemporaneous imaging of Neptune using the Hubble Space Telescope (HST) Wide Field Planetary Camera 2 and the NASA Infrared Telescope Facility (a 3-meter IR telescope located at 14,000 feet atop Mauna Kea in Hawaii) to obtain high spatial resolution absolutely calibrated imagery.

The HST camera provides high spatial resolution of horizontal and vertical cloud structure while the ground-based IR telescopes provides access to strong methane and hydrogen absorption bands to allow greater discrimination of high altitude vertical cloud structure.

Keck II image (August 2003) of Neptune. The white features are optically thicker high altitude clouds. The pink areas are optically thin clouds at high altitudes.

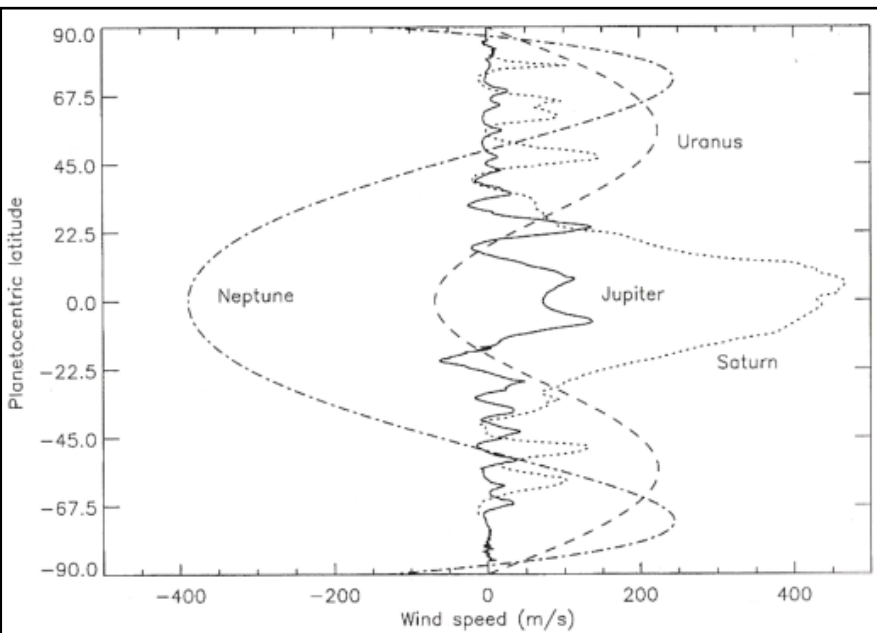
The best Earth-based imagery was obtained from the Keck II telescope, which has a 10-meter mirror and a superb adaptive optics system that can undo the blurring effects of atmospheric turbulence.

Mark Hobson



Basic Facts About the Planet Neptune

- Big (4x earth size, 17x earth mass)
- Rock and ice core with thick H₂, He atmosphere
- Most distant planet from sun (30 AU, 4-light hours)
- Long seasons (in 2011 it finally completed one orbit since its discovery in 1846)
- Rapidly rotating (16.11 hour day)
- Highly variable on a variety of time scales
- Weakly supplied with energy ($T_{\text{eff}}=59.3\text{K}$; incident solar irradiance only 1.6 w/m^2)



Some Neptune Extremes

- Longest orbital period (164.8 years)
- Most distant planet (4 light-hours from the sun).
- Coldest planetary atmosphere at cloud level.
- Darkest planet (the sun appears like a star 30 times brighter than our moon.)
- Largest ratio of emitted heat to absorbed solar (2.7)
- Maybe highest wind speeds (900 mph; Saturn's may be higher)
- Certainly widest range of wind speeds(from -400 m/s to +250 m/s).
- First outer planet display of cloud shadows.
- Largest range of angular rotation rates (periods from 11 to 19 hours)
- Greatest variability of reflectivity due to large variations in cloud activity.
- Largest vortex (GDS) relative to size of planet.

Zonal wind structure of the giant planets. Solid line - Jupiter; dotted line - Saturn; dashed line - Uranus; dot-dashed line - Neptune. Note the retrograde winds on Neptune, and the fact that it has the widest range of wind speeds. (from: Jupiter - Vasavada (2002), Porco et al. (2003); Saturn - Sanchez-Laveg et al. (2000); Uranus - Hammel et al. (2001); Neptune - Sromovsky et al. (1993)).

Tracking and Predicting Hurricanes with Advanced Infrared Atmospheric Soundings

Every year hurricanes, typhoons, and tropical cyclones roar across Earth's oceans and crash into land, often causing property damage and loss of life in disastrous proportions. We cannot control these storms, but the ability to accurately predict their paths and their intensities is of utmost importance.

Tropical cyclones form in an environment of moist air, thermodynamic instability, warm ocean water, and other needed conditions. Atmospheric water vapor information is one of the key parameters required for the regional numerical weather prediction (NWP) model to provide accurate hurricane forecasts.

"The amount of water vapor in the atmosphere can be difficult to quantify," says Jun Li, a senior scientist at the UW-Madison Space Science and Engineering Center. "It varies greatly over short distances and over short periods of time. Water vapor travels rapidly and provides energy for storm development."

Today's hyperspectral infrared (IR) sounders from satellites, such as the Atmospheric InfraRed Sounder (AIRS) onboard the National Aeronautic and Space Administration's Earth Observing System Aqua platform, and the Infrared Atmospheric Sounding

Interferometer (IASI) onboard Europe's Metop-A and the Cross-track Infrared Sounder (CrIS) onboard the National Polar-orbiting Environmental Satellite System Preparatory Project (NPP) provide unprecedented global atmospheric temperature and moisture vertical distributions with high accuracy.

Through an advanced retrieval technique, critical water vapor information can be extracted from AIRS/IASI/CrIS radiance measurements. By assimilating the spatially and vertically distributed water vapor information around a tropical cyclone into a regional NWP model, the path and intensity forecast for hurricanes can be improved.

"We explored assimilation by using the high spatial resolution moisture profiles retrieved from AIRS to initialize/analyze the development of a hurricane," says Dr. Li. "We used a recently developed advanced ensemble data assimilation system together with the Weather Research and Forecast (WRF) model developed by the National Center for Atmospheric Research (NCAR) to study the impact of atmospheric temperature and moisture information extracted from AIRS on the hurricane forecasts."

The ensemble assimilation technique has unique advantages in applying the

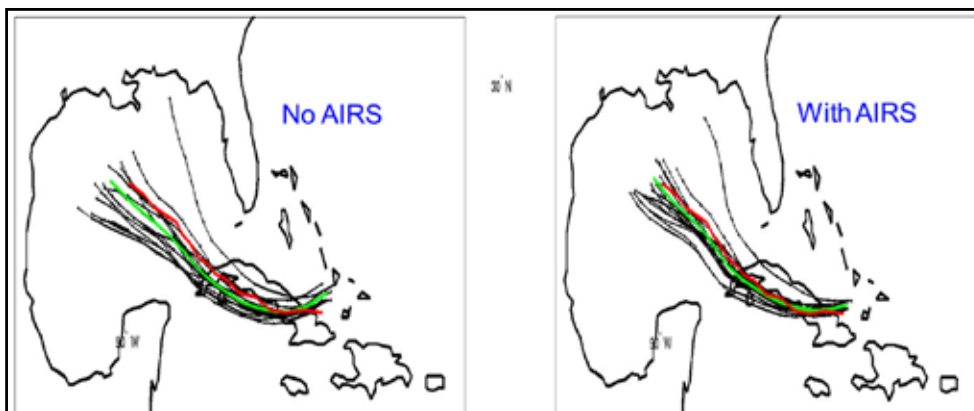
water vapor observations to examine the environment of tropical cyclones, including using weather dependent multivariate forecast error estimates to correct "unobserved variables" of the analysis.

"We then examined the hurricane path and intensity forecast with and without the AIRS water vapor profiles," Dr. Li says. "We found that using the water vapor profiles significantly improves the hurricane path forecast and also substantially improves the hurricane intensity forecast."

Additional hurricane cases are being examined to better document the improvements. A study of Typhoon Sinlaku (2008) showed that assimilation of the environmental advanced IR sounding observations can significantly improve the definition of the initial vortex structure in the analysis and forecasting of rapid intensification.

IR data from other sensors such as IASI and CrIS will also be studied. With an advanced IR sounder like AIRS, IASI or CrIS in the geostationary orbit, the large spatial and temporal variability of water vapor would be captured, an advance critical to further improving the forecasting of hurricane genesis, rapid intensification, path, and intensity.

Jun Li
Tim Schmit



The 96-hour ensemble forecasts (black curves) starting at 00 UTC on 08 September 2008 for hurricane paths compared with observed (red). The left panel shows the forecast without high spectral resolution AIRS water vapor profiles while the right panel shows the improved forecast with AIRS water vapor profiles. Note that the mean forecast (green) is closer to the observed track with the AIRS satellite data. (In collaboration with Hui Liu, NCAR/UCAR)

Photo Contest Winners: Weather as Art (and Science)

Dramatic thunderstorm formations, intricate geometric patterns created by ice and snow, serene views of the sun as it rises and sets...moments captured through a camera lens. Simple, yet striking scenes that speak to more than just the beauty of nature and its weather.

These photos taken by scientists, faculty, staff and students from the Atmospheric Oceanic and Space Sciences Building showcase the way they view the natural world...through the lens of both art and science. Appreciating not only the beauty but also the forces that created the picturesque scene, the photographers have recorded weather throughout the year.

Photographs were judged blindly on three criteria: *Weather*- accurate and clear representation of a weather phenomenon; *Technical*- focus, composition, lighting, etc.; and *Artistry*- beauty, creativity, and drama.

To view the second annual exhibit, administered by the Schwerdtfeger Library, visit the library on the third floor of the AOSS building or the online slideshow: http://library.ssec.wisc.edu/photo_contest/



1st Place: Grant Petty for *Thunderstorm Cell*



2nd Place: Dina Smirnov for *Dryline Thunderstorm*



3rd Place: Matthew Sitkowski for *Lake Mendota Snow*



**Honorable Mention:
Grant Petty for
*Frozen Lake Mendota***

CIMSS Education and Outreach

Engaging the public concerning weather and climate is a lot like, well, weather and climate! Events for all seasons with something for everyone.

2011 Education and Outreach activities kicked off at CIMSS in January with two educator workshops on climate change, one during the workweek for pre-service teachers and naturalists from the Aldo Leopold Nature Center (ALNC) in nearby Monona, WI, and a second for school teachers held on a Saturday.



11 January 2011 Workshop

ALNC was gearing up for the opening of their new Climate Change Center. Participants from both workshops wanting to go deeper could take a web-based Global and Regional Climate Change course offered during the University of Wisconsin-Madison (UW-Madison) spring semester.

These workshops were followed by the American Meteorological Society (AMS) 10th Annual WeatherFest event in Seattle, a science fair for families. CIMSS featured the ever-popular weather applets on two touch-screen monitors and, for the second year in a row, the crowd-pleasing 3D globe with imagery and animations developed at SSEC.

Rick Kohrs demonstrating the 3-D globe, displaying the Earth's climate and weather systems as they appear from space.

The next event was a collaboration with the Federation for Earth Science Information Partners (ESIP) and a Sally Ride Science Educator Institute which involved presenting at NASA's Jet Propulsion Laboratory in February followed by a webinar conducted from CIMSS in March.

The main event in April was an open house in conjunction with the campus-wide Science Expeditions where the UW-Madison welcomes learners and explorers of all ages to experience science as discovery. Visitors to our

building (Atmospheric, Oceanic and Space Sciences) got to do it all: view the globe, visit the Antarctic Meteorological Research Center, interact with the applets, tour the roof, you name it!

Next up was a web seminar specifically for National Weather Service (NWS) storm spotters on the topics of climate change, climate mitigation and emerging applications to access weather and climate data with mobile devices.

Nineteen storm spotters participated in this May event and eleven provided feedback via a follow-up survey. One attendee commented, "Thank-you for putting together this web seminar. As a



Weather balloon launch facilitated by SSEC researcher Erik Olson.



Dave Jones answering questions on the roof.

weather spotter, I found the information helpful, even humbling, to know climate change is already happening. Great job!!!"

From something brand new to a time-tested favorite: June featured the 19th annual CIMSS student workshop.

Ten future scientists from Wisconsin, Minnesota, Illinois, and as far away as Connecticut, visited the UW-Madison

Photos by Margaret Mooney, Patrick Rowley, and Mark Hobson.



Students, chaperones, and WKOW's Brian Olson pose in front of the green screen at WKOW-TV 27.

campus for this popular “weather camp.”

Most events took place at the AOSS building with presentations and activities led by grad students, academic staff, senior scientists, faculty and NOAA researchers.

In addition, participating students also enjoyed field trips to Washburn Observatory, the UW-Madison Planetarium, WKOW-TV 27, Weather Central broadcast and media communications company, the National Weather Service, the UW-Madison Geology Museum, Devil's Lake, and a boat ride on Lake Mendota for a limnology dredging expedition.

Workshop graduates left significantly smarter about Earth System Science and infinitely wiser about future

college and career choices, especially the educational opportunities at the UW-Madison.

With support from NOAA, CIMSS organized a teacher workshop at the ESIP summer meeting in Santa Fe in July. The workshop's overall theme was Earth science education with an integral strand dedicated to climate literacy. Breakout sessions were led by ESIP members from NOAA, NASA, CIMSS, EPA and several Universities around the country.

Also in July was Grandparents University, where over a dozen UW-Madison alums and their grandchildren enrolled in the meteorology major held at AOSS. This is a fun and educational event with building-wide involvement.

Activities took place in the Atmospheric and Oceanic Sciences Department's 14th floor computer lab, the CAVE (CIMSS Analysis and Visualization Environment), the 3D globe room and the roof.

August was UW-Madison Day at the Wisconsin State Fair. CIMSS/SSEC was there too!

In September, students on field trips from local schools learned about CIMSS/SSEC data via the 3D Globe and the weather applets during the first annual Wisconsin Science Festival's “Street Fair” at the Wisconsin Institutes for Discovery.

And while the calendar year was winding down, outreach was still going strong with participation at the NOAA NPOESS Preparatory Project (NPP) Educator's Launch in October. The conference was held in conjunction with the NPP satellite launch at Vandenberg Air



Margaret Mooney at Grandparents University.



Patrick Rowley uses the 3D Globe and Applets to explain weather and climate processes and remote sensing data visualization at the Wisconsin Science Festival.



3D Globe displayed at the Wisconsin State Fair.

Force Base in Lompoc, California. With approximately 100 teachers from across the country at the workshop, CIMSS staff led sessions showcasing CIMSS Online Satellite Applications, including Satellite Applications in Geoscience Education for grades 7-12, and Satellite Observations in Science Education.

Margaret Mooney
Patrick Rowley

If you would like to be added to our mailing list for *Through the Atmosphere*, please contact Maria Vasys at maria.vasys@ssec.wisc.edu.

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