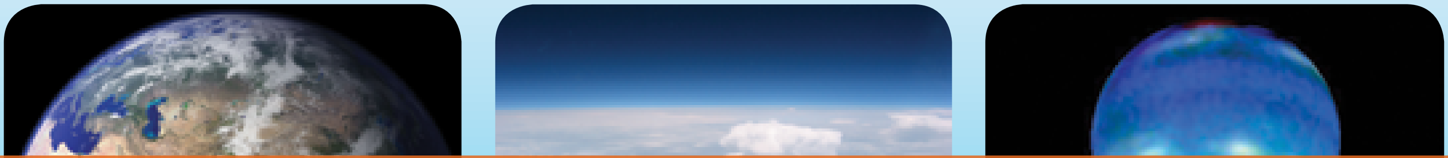
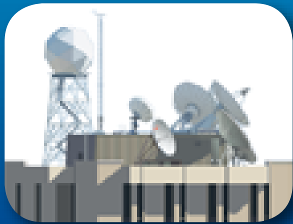
University of Wisconsin-Madison
Space Science and Engineering Center
Cooperative Institute for Meteorological Satellite Studies



through the atmosphere

Summer 2012

Suomi NPP
The Future is Here ...



Issue Highlights...

Director's Note

Suomi NPP is the first Earth science or weather satellite named for an individual. Professor Verner E. Suomi was a true pioneer, an enthusiastic scientist and educator, and a champion for international cooperation in atmospheric exploration. This edition of *Through the Atmosphere* examines the wide-ranging efforts that SSEC, the institution that he co-founded, is making to insure Suomi NPP's success, along with a bit of historical context.

The Suomi NPP spacecraft introduces the first truly new NOAA operational satellite series since the 3-axis stabilized GOES series began in 1994. The first U.S. element of the Joint Polar Satellite System (JPSS), Suomi NPP/JPSS offers many advances compared to the current NOAA series that debuted in 1978 on TIROS-N.

The connection between NPP capabilities and Vern's legacy is outlined below:

1. In 1959, Verner Suomi's instrument on Explorer 7 made the first measurements of the Earth from space and defined the radiation balance that establishes our climate. Suomi NPP contains the Clouds and Earth's Radiant Energy System (CERES), continuing the climate record initiated by that first experiment.
2. The Applications Technology Satellites (ATS), launched into geostationary orbit in 1965 and 1966, carried the spin-scan camera conceptualized by Suomi to make movies from which cloud motion winds could be measured. The Visible Infrared Imager Radiometer Suite (VIIRS) on Suomi NPP will add to the long record of atmospheric winds with high latitude observations of cloud motions between consecutive polar orbits. Vern's drive to provide wind measurements for improving weather forecasts motivated SSEC's Man-computer Interactive Data Access System (McIDAS), the first serious computer system for processing satellite data.
3. Suomi's pioneering efforts in sounding temperature and water vapor profiles using infrared emitted radiation were realized in 1980, with the VISSR Atmospheric Sounder, the first sounder to fly in geosynchronous orbit. Suomi NPP includes the Cross-track Infrared Sounder (CrIS) sounder, its higher spectral resolution advancing the capabilities of heritage sounding instruments. Much of the development for CrIS was done at SSEC. Suomi NPP also carries the Advanced Technology Microwave Sounder (ATMS) that uses microwave emissions from the Earth to sound the atmosphere.

A fifth instrument, the Ozone Mapper Profiler Suite, extends the 25-plus year record of total-ozone and ozone-profiles and also monitors aerosol properties. Vern would be pleased by this, too.

We have years of interesting work ahead to make sure that the data, results, and impact of this new satellite live up to its new name.

Hank Revercomb
Director, SSEC

Inside This Issue

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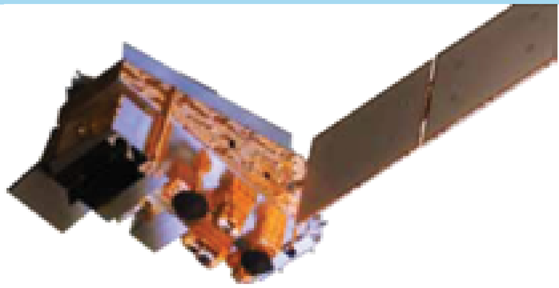
***Cover image:** The Suomi NPP satellite and an image of the Earth, taken from the Visible Infrared Imager Radiometer Suite instrument aboard Suomi NPP.*
Image Credits: NASA/NOAA/GSFC/Suomi NPP/VIIRS/Norman Kuring.

Satellite Meteorology History: A View from Madison



For more than 50 years, the University of Wisconsin-Madison has been a leader in devising ways to view our planet through the eyes of a satellite. In particular, scientists at the UW-Madison Space Science and Engineering Center (SSEC) have been at the forefront of developing the satellite technology that makes it possible to measure and study the intricate processes occurring on the Earth's surface and in the atmosphere. Some of the earliest experiments, beginning in the 1950s, were led by Professor Verner E. Suomi and Professor Robert J. Parent, co-founders of SSEC.

The world's fascination with space exploration followed quickly on the heels of the 1957 International Geophysical Year (IGY) and the Soviet Union's successful launch of Sputnik later that same year. The National Aeronautics and Space Administration (NASA), founded in 1958, paved the way for 'peaceful and scientific' exploration of space in the United States – not only funding scientific research programs, but providing funding to establish research centers like SSEC.

Professor Verner Suomi, 1915 - 1995

Thematically, the evolution of satellite meteorology at SSEC is characterized by eras of specific scientific needs and objectives realized by focused scientific programs and technologies. With the advantage of hindsight, one scientific achievement appears to lead seamlessly and logically to the next:

- solving the problem of how to measure the Earth's radiation budget from a satellite platform in the 1950s with the Suomi/Parent bolometer, and later, the low-resolution-omni directional radiometer that was to fly on the TIROS series of satellites; led to
- observing cloud dynamics and global wind distribution in the 1960s with the Spin Scan Cloud Camera on the Applications Technology Satellite; was followed by
- temperature and water vapor profiling and forecasting improvements in the 1970s with the development of the VISSR Atmospheric Sounder (VAS) and global-scale weather experiments like FGGE; this fostered
- the earliest Man computer Interactive Data Access System (McIDAS) in the 1970s and 1980s invented to measure cloud motion winds and to visualize and analyze the volumes of data; then
- forecasting improvements and the next generation high-resolution interferometric sounders in the 1990s and into the 21st century, including hyperspectral sounders and continued advancements with the GOES series of satellites and the naming of Suomi NPP.

Continuous observations of the Earth's atmosphere from space revolutionized scientists' understanding of the motions of the atmosphere, paving the way for more accurate weather forecasts and more timely and precise warnings for severe weather. Suomi's contributions set the foundation for the technologies that made the routine observing of the Earth's weather from space possible. For those contributions, he is widely considered to be the "father of satellite meteorology."

With the establishment at the UW-Madison of the Cooperative Institute for Meteorological Satellite Studies (CIMSS) in 1980, environmental satellite research was bolstered through a more formal working relationship with the National Oceanic and Atmospheric Administration (NOAA) and NASA. NOAA stations scientists at CIMSS to work side-by-side with Wisconsin researchers to continue the pioneering research begun by Suomi. But the work and innovation did not end with Suomi's passing in 1995. On the contrary, his vision set the stage for the next generation of advancement and innovation in the science of understanding our weather and climate.

The timeline in the center of this publication, captures significant events of SSEC's half century of milestones in satellite studies of the Earth in a visual and interactive format. In sum, these great achievements and advances made the case for renaming the NPOESS Preparatory Project (NPP) Suomi NPP, in honor of the late Verner E. Suomi.

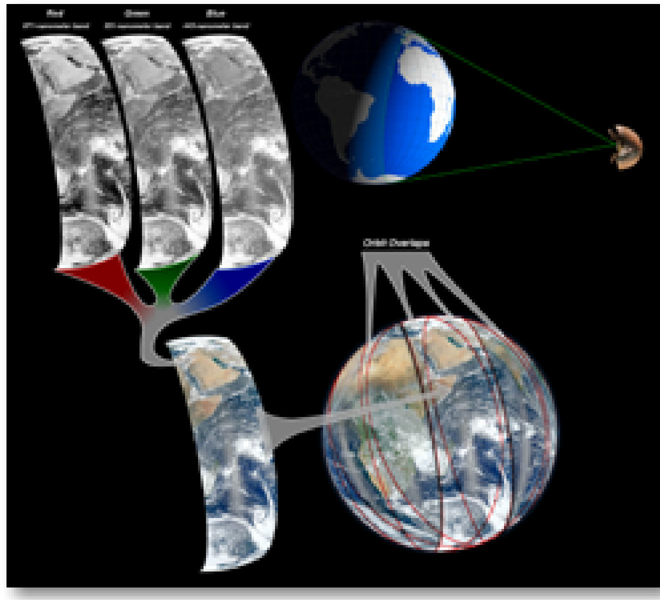
Jean Phillips
Leanne Avila

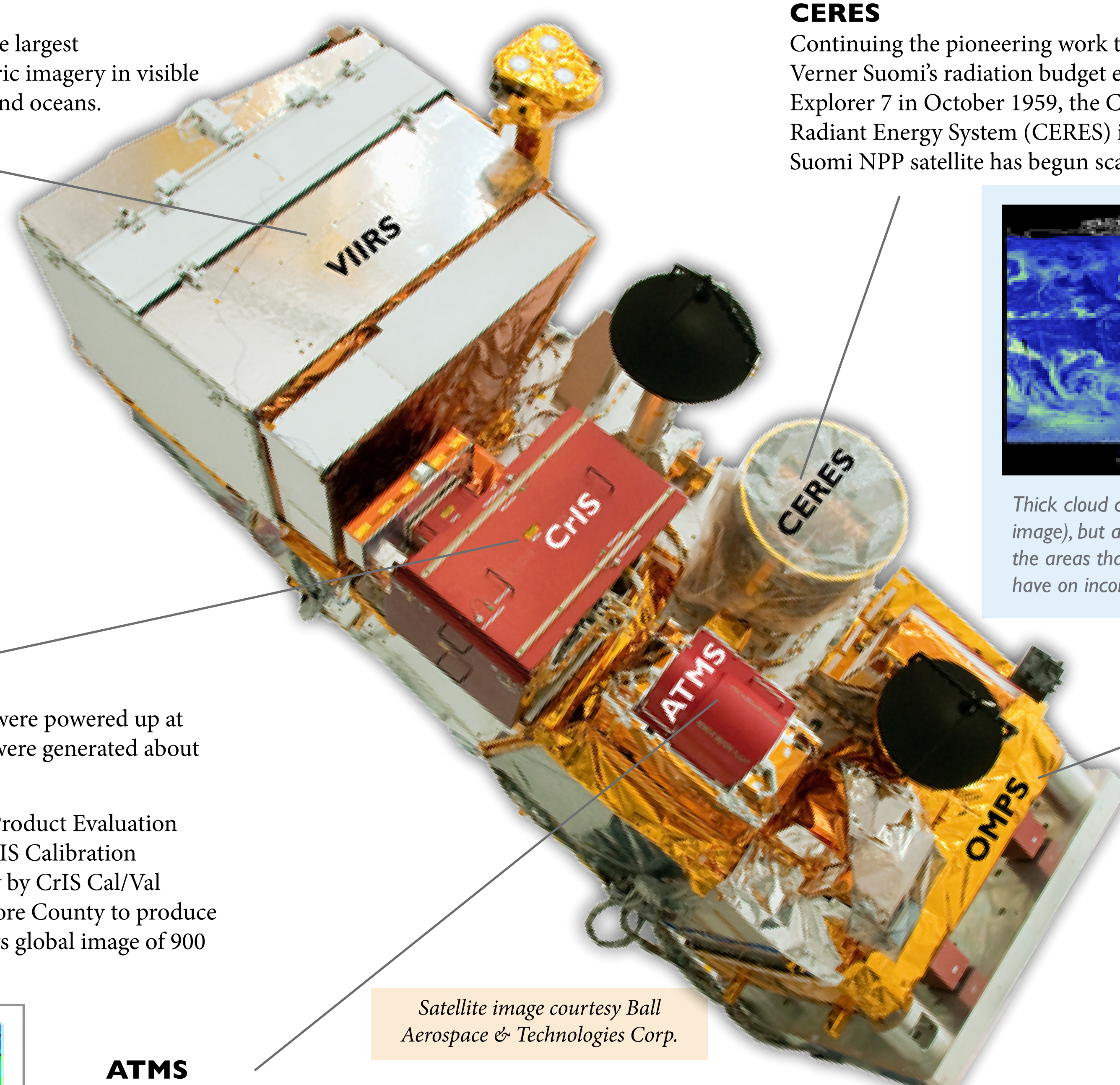
The Suomi National Polar-orbiting Partnership - NASA's Newest Earth Observing Satellite

A critical first step in building the next generation of satellite systems. Its many instruments are already providing key data critical for climate science.

VIIRS

The Visible Infrared Imager Radiometer Suite (VIIRS) is the largest instrument onboard the Suomi NPP and collects radiometric imagery in visible and infrared wavelengths of the Earth's land, atmosphere, and oceans.



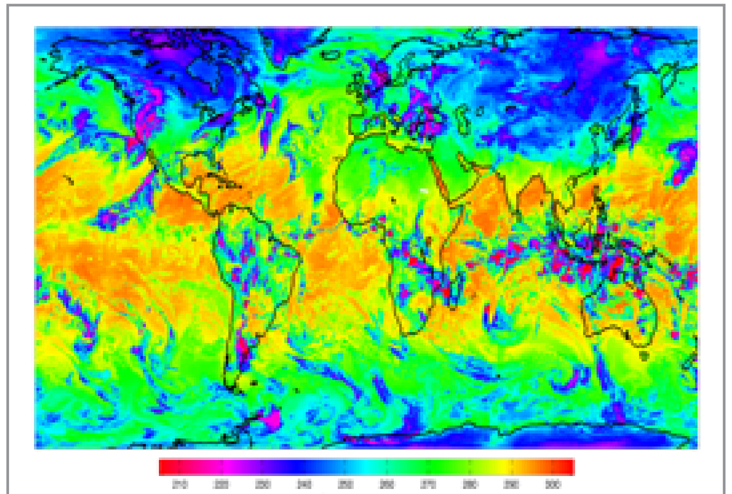


Satellite image courtesy Ball Aerospace & Technologies Corp.

CrIS

The Crosstrack Infrared Sounder (CrIS) signal processors were powered up at 7:48 EST on 20 January 2012. Calibrated radiance spectra were generated about 30 minutes after receiving the RDR data.

Raw data was received at SSEC via the NPP Atmospheres Product Evaluation and Test Element (PEATE) and then processed with the CrIS Calibration Algorithm and Sensor Testbed (CCAST), developed jointly by CrIS Cal/Val colleagues at SSEC and the University of Maryland-Baltimore County to produce calibrated/geolocated radiance spectra. Sample figure shows global image of 900 1/cm brightness temperature, and sample spectra.

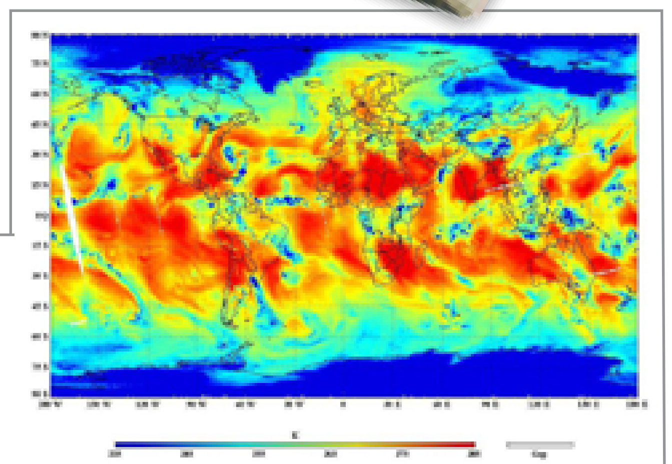


CrIS 900 1/cm brightness temperatures collected on 20 January 2012. Credit: NASA/NOAA.

ATMS

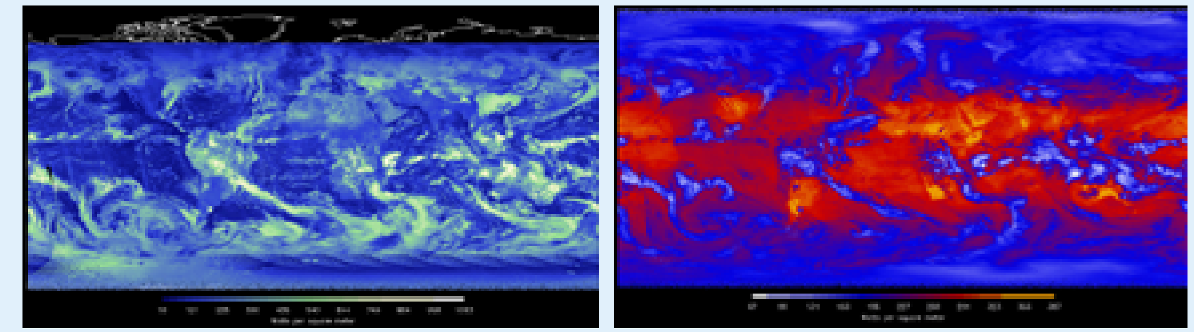
The Advanced Technology Microwave Sounder (ATMS) is a cross-track scanner with 22 channels that provides sounding observations to measure atmospheric temperature and moisture useful for both weather forecasting and climate monitoring.

This global image shows the ATMS channel 18-microwave antenna temperature at 183.3 GHz on 08 November 2011. This channel measures atmospheric water vapor; note that Tropical Storm Sean is visible in the data, as the blue patch, in the Atlantic off the coast of the Southeastern United States. Credit: NASA/NOAA



CERES

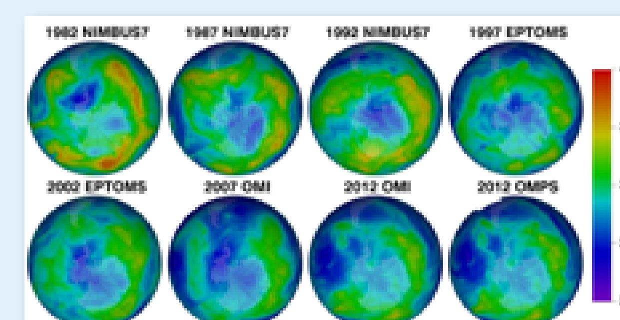
Continuing the pioneering work that commenced with Verner Suomi's radiation budget experiment launched on Explorer 7 in October 1959, the Clouds and the Earth's Radiant Energy System (CERES) instrument onboard the Suomi NPP satellite has begun scanning Earth, taking measurements of the energy leaving the Earth-atmosphere system. The CERES results help scientists to determine the Earth's energy balance, providing a long-term record of this crucial environmental parameter that will be consistent with those of its predecessors.

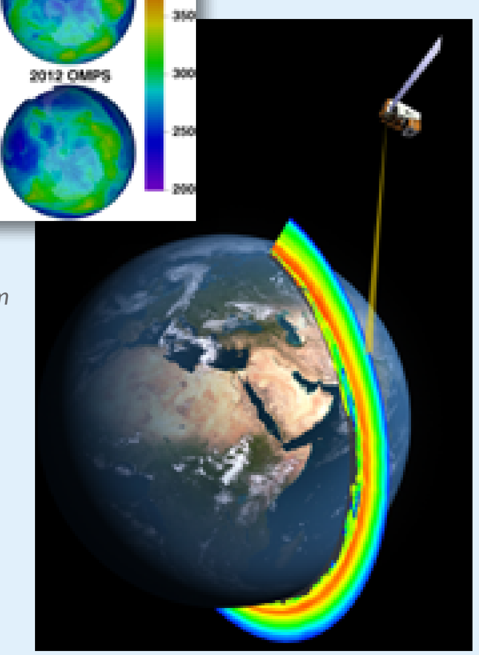


Thick cloud cover tends to reflect a large amount of incoming solar energy back to space (blue/green/white image), but at the same time, reduce the amount of outgoing heat lost to space (red/blue/orange image). Contrast the areas that do not have cloud cover (darker colored regions) to get a sense for how much impact the clouds have on incoming and outgoing energy. Credit: NASA/NOAA/CERES Team.

OMPS

The Ozone Mapper and Profiler Suite (OMPS) is now sending back detailed information about the health of the Earth's ozone layer, the shield that protects the world's population from harmful levels of the sun's ultraviolet radiation.





The above images show the thickness of the Earth's ozone layer on 27 January from 1982 to 2012. This atmospheric layer protects Earth from dangerous levels of solar ultraviolet radiation.

In the image to the right, the thickness is measured in Dobson units. Smaller amounts of overhead ozone are shown in blue, while larger amounts are shown in orange and yellow.

Credit: NASA/NOAA.

VIIRS - A Better Look at Clouds

"The clouds move – not the satellite."

With these words Verner Suomi captured the success of his then new spin-scan camera on board the first Applications Technology Satellite (ATS) launched in 1966. Since then SSEC scientists and their NOAA research partners have made their mark on the world of cloud research, whether refining methods such as the CO_2 slicing technique, creating a cloud climatology from HIRS data, or developing and testing cloud algorithms for the current and next generation satellite instruments.

Evaluating the Suomi NPP Cloud Algorithms

With the launch of the NASA Suomi NPP mission, the next generation of operational polar-orbiting satellites from the USA was born. The largest sensor on Suomi NPP is the Visible and Infrared Imaging Radiometer Suite (VIIRS). VIIRS is officially required to generate 22 products, of which one-third are classified as cloud products.

One of the main goals of our work is the evaluation of the official VIIRS cloud products. A new paradigm was developed for the Joint Polar Satellite System (JPSS) in which industrial partners developed the official VIIRS algorithms. Given their experience with developing cloud algorithms for NOAA and NASA and evaluating them with other data sets, the SSEC Cloud Team was tasked with conducting a thorough evaluation of the official VIIRS products and reporting our findings to the JPSS Program Office. Our evaluations will help decide the role of these industrial algorithms in the future.

VIIRS offers several advantages for cloud remote sensing over the previous operational polar-orbiting imager flown by NOAA, the Advanced Very High Resolution Radiometer (AVHRR). For example, VIIRS contains more spectral bands. In the solar-reflectance region, VIIRS provides much of the same information as the NASA MOderate Resolution Imaging Spectroradiometer (MODIS) imager. In the infrared spectral region, VIIRS lacks the H_2O and CO_2 bands of MODIS, but does provide the 8.5 mm channel which was absent on the AVHRR. In recognition of this lack of IR information, researchers at SSEC are developing methods that combine VIIRS observations with those from the CrIS hyperspectral sounder to fill this spectral gap.

Beyond the obvious spectral comparisons to AVHRR and MODIS, VIIRS does provide some capabilities that are absent on both heritage sensors. Through the use of pixel aggregation, VIIRS provides a significant increase in spatial resolution over MODIS. In addition, the five imagery bands of VIIRS provide AVHRR-like spectral information at a spatial resolution of 375 meters. While not yet demonstrated, the ability to generate AVHRR-like cloud retrievals at such a fine scale should reveal a new and previously undetected scale of variability.

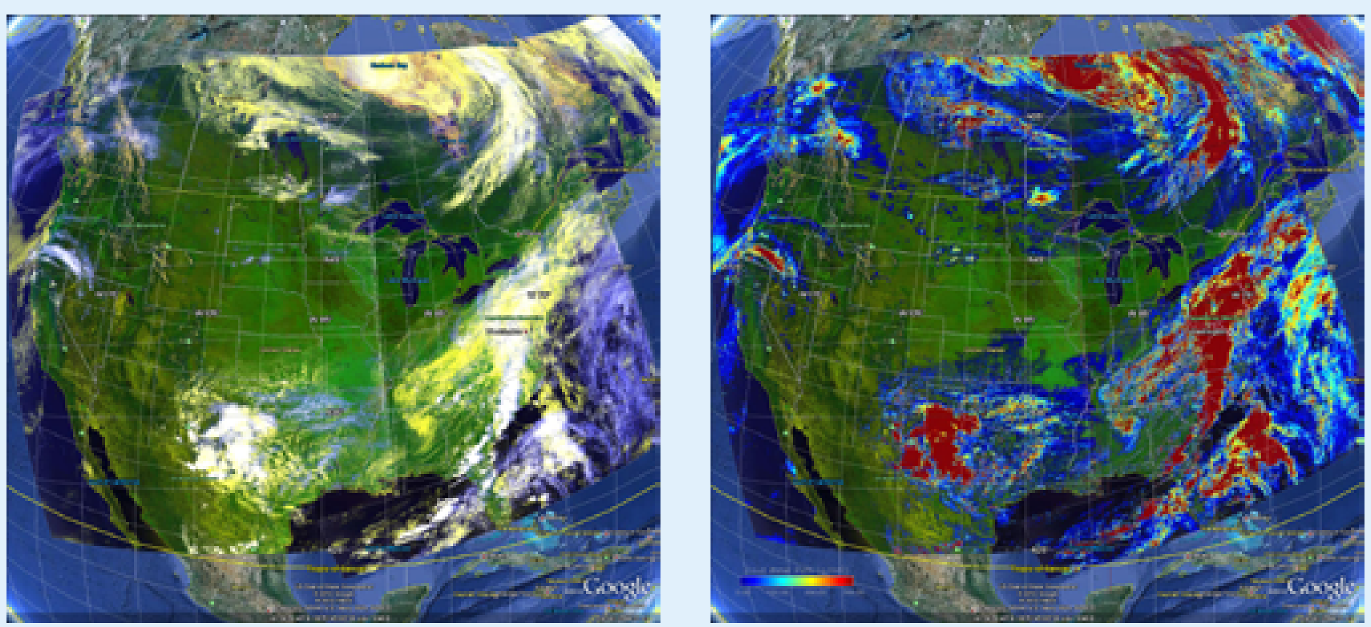


Figure 1. The above images show a result from the Daytime Cloud Optical and Microphysical Properties algorithm. The image on the left is a false color image constructed from the 0.65, 0.86 and 11 mm channels. The image on the right shows the cloud water path overlaid onto the false color image. These images are generated using the direct broadcast data from SSEC.

Another new capability on VIIRS is the presence of the well-calibrated and very sensitive Day-Night Band (DNB) which provides daytime-like observations in the visible region during most nighttime scenes. Researchers at SSEC are using the DNB information to make estimates of cloud optical depth that do not suffer from the limits imposed on infrared-only techniques. Along with uses in cloud detection and typing approaches, the DNB offers a real hope for creating day/night consistent cloud properties.

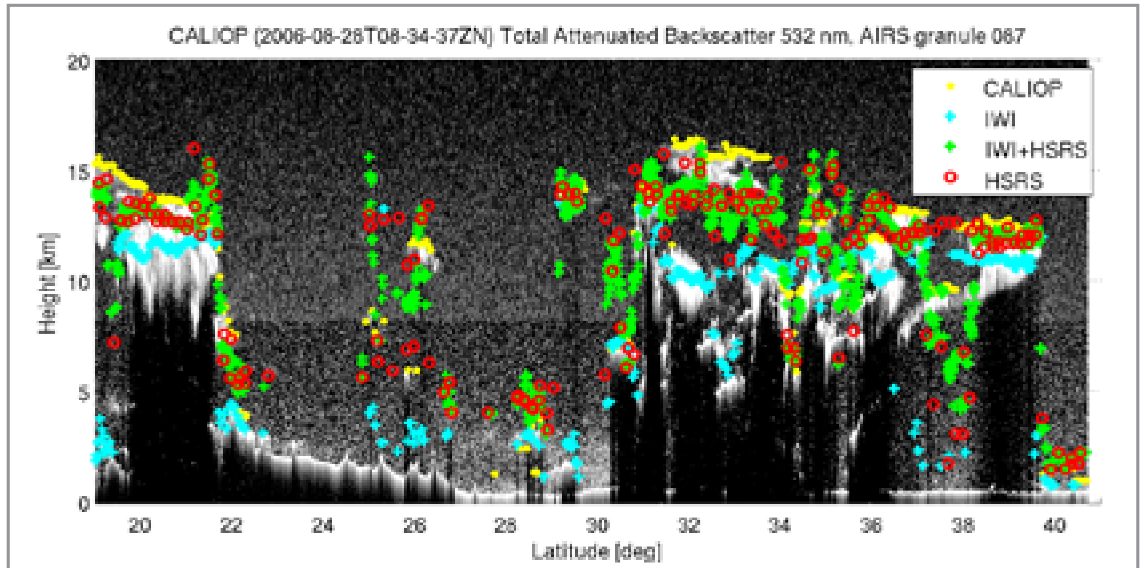


Figure 2. Cross-section along the CALIPSO track for AIRS granule 87 (28 August 2006). CALIOP 532 total attenuated backscatter /km/steradian (background). Cloud top heights from CALIOP, IWI, IWI+HSRS, and HSRS are plotted as yellow dots, cyan pluses, green pluses, and red circles, respectively. IWI and HSRS denote infrared window imager and high spectral resolution infrared sounder, respectively.

Additionally, the SSEC Cloud Team is funded to migrate the algorithms they developed for NOAA within the GOES-R Algorithm Working Group (AWG) program to VIIRS. Some of these GOES-R AWG algorithms are working already on VIIRS. Access to the SSEC Direct Broadcast (DB) data allows for real-time processing of VIIRS data and generation of products for the JPSS Proving Ground.

Ensuring the Continuity of Cloud Products

SSEC researchers have a number of goals for their research on cloud properties using Suomi NPP data. We are evaluating the current NPP cloud-top-property environmental data records (EDRs) and determining their suitability for providing continuity with those obtained from current operational MODIS (both Collection 5 and future Collection 6) cloud products. Over the long term we are developing a comprehensive set of long-term climate data records (CDRs) that are consistent across multiple missions and satellite sensors. For this effort, we need to compare products from different sensors and even different science teams on a fair basis. The product comparison effort requires that we develop a new way to compare products consistently from the various data streams, which involves designing a process to build monthly statistics from daily gridded maps. Our team is following a number of avenues towards building a set of cloud properties that will satisfy NASA's goal of consistent, long-term cloud products.

The derivation of cloud parameters is complicated by the fact that the imagers used for polar-orbiting and geostationary platforms do not have the same set of spectral channels. This implies that the cloud retrieval algorithms can be designed to use more or less of the information available, but this can lead to differences in the resulting cloud products. Because the VIIRS imager does not have absorbing infrared channels as does MODIS, we anticipate that the VIIRS information content is insufficient to infer accurate cloud top heights for optically thin clouds such as cirrus.

To obtain continuity in cloud products between morning and afternoon polar-orbiting platforms, i.e., between MetOp-A/B, MODIS Terra/Aqua and NPP, we need to implement a suite of algorithms to attain consistency. Since each platform has both an imager and a sounder, we can mitigate cloud property differences by merging data from the two instruments. For Suomi NPP, we are therefore supplementing the VIIRS data with that from the Crosstrack Infrared Sounder (CrIS). The same approach can be used with historical data by merging the AVHRR with HIRS on NOAA and MetOP platforms, and MODIS with AIRS.

In Figure 2 (taken from Weisz et al. 2012), we use the Infrared Window Imager (IWI) to denote generic high spatial resolution IR window imager

continued on page 6

measurements and HSRS to denote generic high spectral resolution sounder measurements. The combined imager plus sounder algorithm for cloud top pressure determinations at imager resolution is demonstrated by using infrared window measurements from MODIS for IWI and using the full spectral coverage from AIRS for the High Spectral Resolution Infrared Sounder (HSRS). The IWI based cloud top heights are derived using an optimal estimation approach (Heidinger et al. 2009); this approach is applied to MODIS IR window measurements. The granule shown in Figure 2 is located mostly over land (southern US and Mexico). The cross section is taken from the data co-located with the CALIOP track.

In the region between latitudes 20° and 22°, IWI underestimates the actual cirrus CTHs given by CALIOP, but the IWI+HSRS results are able to approach CALIOP values of this optically thin cirrus cloud. The deep convective element at latitude 31° is very well depicted by all three retrieval methods. The small transparent cloud around latitude 26° is captured by the HSRS and IWI+HSRS retrievals but not by the IWI retrievals. Most of the thin cirrus clouds with CTHs higher than 12 km between latitudes 29° and 39° are captured by IWI+HSRS but not as well by the IWI method alone.

New Capabilities for Fog Detection and Monitoring

VIIRS is uniquely capable of detecting and characterizing areas of fog and low cloud. Fog and low stratus clouds are a hazard to transportation. Visibility under foggy conditions can be drastically reduced, creating dangerous situations for vehicles on roadways as well as airplanes, trains, boats, and other means of transport.

From 1995 to 2005 the National Highway Traffic Safety Administration (NTSA) determined an average of 38,700 vehicular accidents that were directly related to fog. Each year, foggy conditions are responsible for 16,300 injuries and 600 deaths in the United States. In the same time period, the National Transportation Safety Board reported an annual average of 81 airplane crashes, 61 of which resulted in at least one fatality, were caused by reduced visibility due to low clouds. In addition, millions of dollars are lost each year by commercial airlines from cancellations, delays, and rerouting forced by low visibilities at airports due to fog and low stratus clouds.

Unlike surface observations, which are very localized and can be quite sparse in parts of the country, the VIIRS will provide a spatially continuous depiction of fog/low cloud with very high spatial resolution. The 375-meter resolution 3.75 and 11 mm imaging band on VIIRS will allow for unprecedented monitoring of difficult to detect small-scale valley fog events. Valley fog events are often responsible for traffic accidents. Thus, the new capabilities offered by the VIIRS can be used to improve traffic safety. In order to ensure that the VIIRS is being fully utilized for fog/low cloud applications, computer algorithms are being developed to automatically determine the probability that hazardous low cloud conditions are present. The results of this processing will allow forecasters to more accurately identify hazards caused by reduced visibility and/or low ceilings, and relay the information to the public.

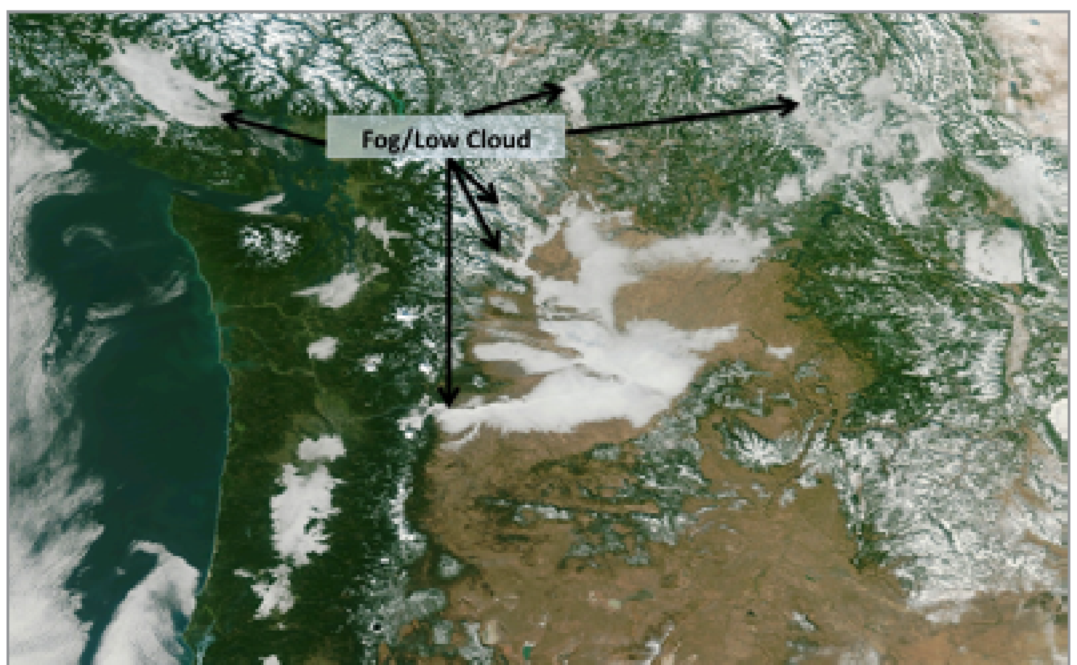


Figure 3. On 9 December 2011, VIIRS depicts an area of freezing fog over the Pacific Northwest of the United States.

Andrew Heidinger
Michael Pavolonis
Bryan Baum

Highlights of Recent Publications

MODIS cloud-top property refinements for Collection.

Journal of Applied Meteorology and Climatology, v.51, no.6 , 2012.

Baum, Bryan A.; Menzel, W. Paul; Frey, Richard A.; Tobin, David C.; Holz, Robert E.; Ackerman, Steve A.; Heidinger, Andrew K., and Yang, Ping.

The Collection-6 refinements in the Moderate Resolution Imaging Spectroradiometer (MODIS) operational cloud-top properties algorithm are summarized. The focus is on calibration improvements and on cloud macrophysical properties including cloud-top pressure–temperature–height and cloud thermodynamic phase.

Detection and tracking of subtle cloud features on Uranus.

Astronomical Journal, v.143, no.6, 2012.

Fry, P. M.; Sromovsky, L. A.; De Pater, I. ; Hammel, H. C., and Rages, K. A.

Recently updated Uranus zonal wind profiles sample latitudes from 71° S to 73° N. But many latitudes (outside 20°-45° S and 20°-50° N) remain grossly undersampled due to a lack of trackable cloud features. Offering some hope of filling these gaps is our recent discovery of low-contrast cloud that can be revealed by imaging at much higher signal-to-noise ratios than previously obtained.

On-orbit absolute blackbody emissivity determination using the heated halo method.

Metrologia, v.49, no.2, 2012.

Gero, P. Jonathan; Taylor, Joseph K.; Best, Fred A.; Garcia, Raymond K., and Revercomb, Henry E.

A novel method to measure the absolute spectral emissivity of a blackbody cavity in situ using the heated halo, a broadband thermal source is presented. Laboratory demonstrations have yielded spectral emissivity measurements of a 0.999 emissivity blackbody that are in agreement with results based on Monte Carlo ray trace modeling.

Applications of full spatial resolution space-based advanced infrared soundings in the preconvection environment.

Weather and Forecasting, v.27, no.2, 2012.

Li, Jun; Liu, Chian-Yi; Zhang, Peng, and Schmit, Timothy J.

Advanced infrared sounders such as the Atmospheric Infrared Sounder and Infrared Atmospheric Sounding Interferometer provide atmospheric temperature and moisture profiles with high vertical resolution and high accuracy in preconvection environments.

Predicting hurricane intensity and structure changes associated with eyewall replacement cycles.

Weather and Forecasting, v.27, no.2, 2012.

Kossin, James P. and Sitkowski, Matthew.

New statistical models based on a recently documented climatology of intensity and structure changes associated with eyewall replacement cycles in Atlantic Ocean hurricanes are introduced. The model input comprises environmental features and satellite-derived features that contain information on storm cloud structure.

Comparison between GOES-12 overshooting-top detections, WSR-88D radar reflectivity, and severe storm reports.

Weather and Forecasting, v.27, no.3, 2012.

Dworak, Richard; Bedka, Kristopher; Brunner, Jason, and Feltz, Wayne.

Convective storms with overshooting-top (OT) signatures in weather satellite imagery are often associated with hazardous weather. An objective satellite-based OT detection product has been developed using 11-μm infrared window channel brightness temperatures for the upcoming R series of the (GOES-R) Advanced Baseline Imager.

Honors and Awards

Professor Verner Suomi
Satellite Renamed The National Polar-orbiting Operational Environmental Satellite System Preparatory Project (NPP) satellite renamed Suomi NPP -- the Suomi National Polar-orbiting Partnership.

Christopher Velden
Received the UW Chancellor's Award for Excellence in Research.

Steven Ackerman
Named UW-Madison Associate Dean for the Physical Sciences.

Mathew Gunshor, Anthony J. Schreiner, James P. Nelson III, A. Scott Bachmeier, Dave Stettner, Steve Wanzong, Christopher C. Schmidt, Wayne Feltz, Justin Sieglaff, William Straka, Christopher Velden and the SSEC Data Center
Received NOAA-CIMSS Collaborations Awards.

VIIRS - A Better Look at Polar Winds

The Visible Infrared Imager Radiometer Suite (VIIRS) onboard NASA's newest Earth-observing satellite, Suomi NPP, acquired its first measurements on 21 November 2011, and is already providing a bridge between previous satellite technologies and those to come.

Fully automated cloud-drift wind production from Geostationary Orbital Environmental Satellites (GOES) became operational in 1996. The resulting wind vectors are routinely used in operational numerical models of the National Centers for Environmental Prediction (NCEP) and other numerical weather prediction centers.

Since 2001, wind products from over the polar regions have been generated at CIMSS with Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on NASA's Terra and Aqua satellites and the Advanced Very High Resolution Radiometer (AVHRR) on NOAA and Metop satellites. These same products have been produced operationally by the National Environmental Satellite, Data, and Information Service (NESDIS) using MODIS since 2005, and since 2007 using AVHRR. A timeline of polar wind product development is shown in Figure 1.

Real-time generation of polar winds products from Terra and Aqua MODIS and AVHRR on NOAA-15 through -19 and Metop-A continues, but since the launch of the Suomi National Polar-orbiting Partnership (Suomi NPP) on 28 October 2011, a new focus is on developing a method to generate winds from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on board the new satellite.

Unique Characteristics of VIIRS

VIIRS is a 22-band imaging radiometer that, in terms of features, is a cross between MODIS and AVHRR, with some characteristics of the Operational Linescan System (OLS) on Defense Meteorological Satellite Program (DMSP) satellites. It has several unique characteristics that will have an impact on a VIIRS polar winds product. These include:

- a wider swath,
- higher spatial resolution (750 m for most bands; 375 m for some),
- constrained pixel growth that yields better resolution at the edge of swath, and
- a day-night band (DNB).

VIIRS has a wider swath (3000 km) than MODIS (2320 km), so the coverage is better. The AVHRR swath width is between that of VIIRS and MODIS (2600 km). A wider swath means more winds with each orbit triplet. Figure 2 shows the overlap of three orbits, which are needed for wind derivation, for MODIS and VIIRS. The figure illustrates the improved coverage of VIIRS, with a larger area of overlap. Consecutive VIIRS swaths overlap even near the equator, so the area for which polar winds can be derived extends somewhat further south than for MODIS.

The VIIRS method of aggregating detectors and deleting portions of the scans near the swath edge results in smaller pixels (higher spatial resolution) at large scan angles. Additionally, VIIRS scan processing reduces the bow-tie effect. The impact of these on a wind product is that tracking features will be better defined, resulting in more good winds toward the edges of the swath.

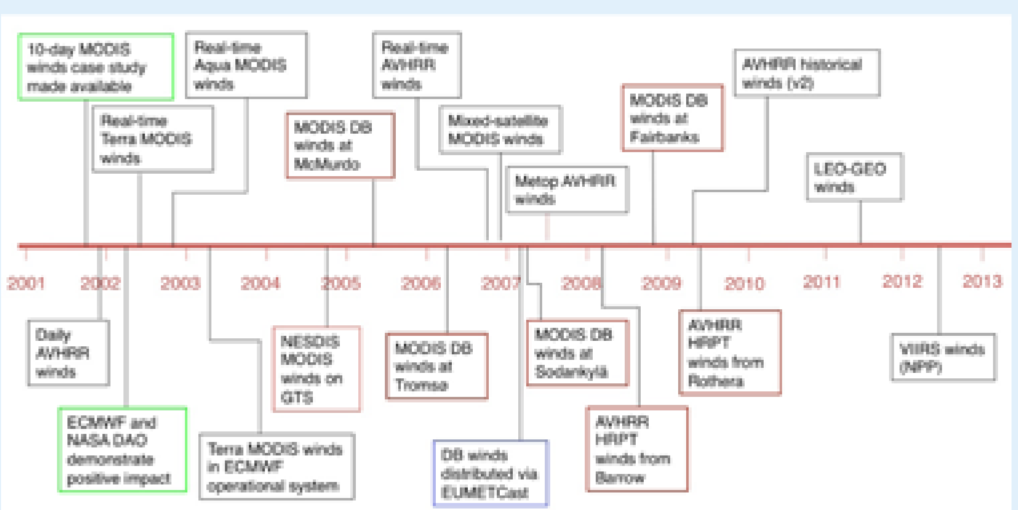


Figure 1. The polar winds product history, from 2001 to the present.

One disadvantage of VIIRS is that, unlike MODIS but similar to AVHRR, it does not have a thermal water vapor band. Therefore, no clear-sky winds can be retrieved.

The VIIRS day/night band offers an intriguing possibility for wind retrieval during the long polar night (winter). Visible information exists at night, but requires highly sensitive instrumentation to measure it. Satellite-based low light detection was pioneered by the OLS, which has flown continuously on the DMSP platforms since 1967. The winds algorithm will be used to track clouds illuminated only by moonlight.

GOES-R ABI and VIIRS Algorithm

VIIRS polar winds processing will utilize the new GOES-R Advanced Baseline Imager (ABI) atmospheric motion vector (AMV) algorithm. Unique features of the ABI wind retrieval methodology include:

Feature Tracking

The Sum-of-Squared Differences (SS) method is used in conjunction with a "nested tracking" algorithm. This combination is very effective at capturing the dominant motion in each target scene and to track the feature backward and forward in time.

Target Height Assignment

Externally generated cloud heights are used. This approach leverages experience and expertise of those involved in cloud property retrievals. It also takes advantage of pixel-level cloud heights contained within a target scene that offer the best opportunity to assign the most representative heights to targets being tracked in time and contain diagnostic performance metrics. It offers potential for future enhancements to target height assignment algorithms.

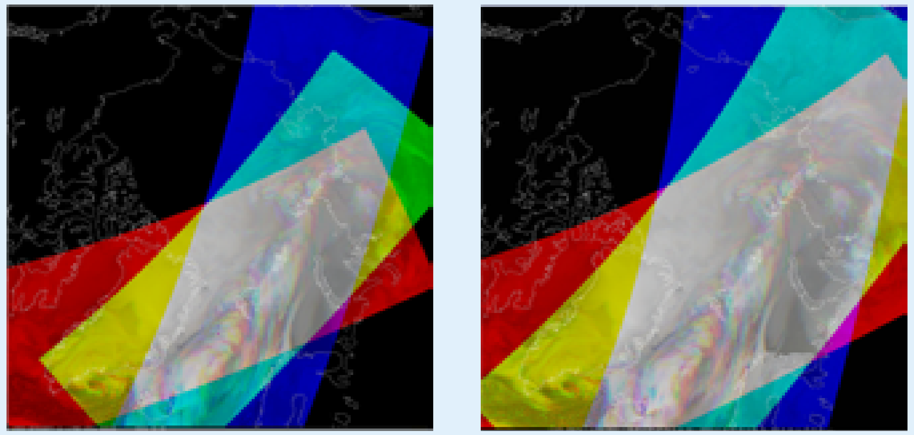


Figure 2. The gray region represents the overlap in three orbits where the polar winds are derived for MODIS (left) and VIIRS (right).

The first polar winds case study generated using the ABI algorithm with MODIS data is shown in Figure 3.

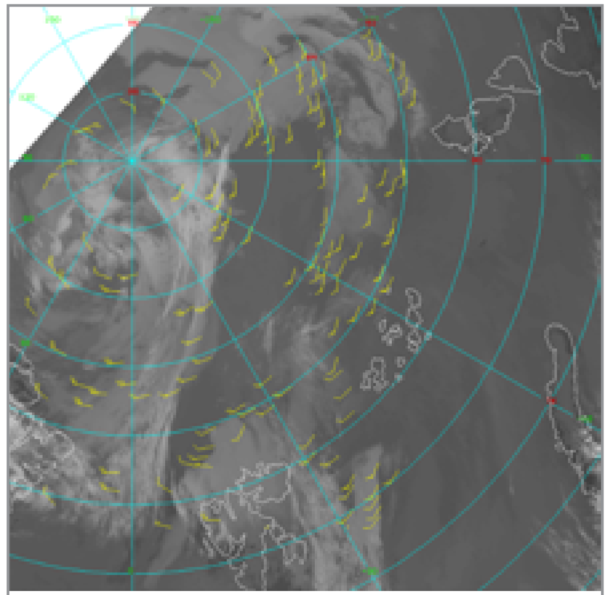


Figure 3. Polar winds based on MODIS data using the VIIRS/ABI processing system.

Use of Polar Winds in NWP

Work continues with numerical weather prediction (NWP) centers regarding product quality, use, and future enhancements. At present, MODIS and AVHRR polar wind products are used operationally by 13 NWP centers in nine countries:

- European Centre for Medium-Range Weather Forecasts (ECMWF),
- NASA Global Modeling and Assimilation Office (GMAO),
- Japan Meteorological Agency (JMA), Arctic only,
- Canadian Meteorological Centre (CMC),
- US Navy, Fleet Numerical Meteorology and Oceanography Center (FNMOC),
- (UK) Met Office,
- Deutscher Wetterdienst (DWD)
- National Centers for Environmental Prediction (NCEP/EMC),
- Meteo France,
- Australian Bureau of Meteorology (BoM),
- National Center for Atmospheric Research (NCAR, USA),
- China Meteorological Administration (CMA), and
- Hydrological and Meteorological Centre of Russia (Hydrometcenter).

The VIIRS polar winds product is scheduled to be operational in NESDIS in October 2012. It is expected that many of these centers will include the VIIRS winds in their operational systems.

Dave Santek
Jeff Key

Early Checkout of the Cross-track Infrared Sounder (CrIS) on Suomi-NPP

The Cross-track Infrared Sounder (CrIS), a high spectral resolution infrared sounder on the Suomi-NPP satellite, will complement and extend similar data records begun by the Atmospheric Infrared Sounder (AIRS) on EOS-Aqua and by the Infrared Atmospheric Sounding Interferometer (IASI) on METOP. As part of NOAA and NASA efforts, over the past several months CIMSS/SSEC researchers have played a key role in the early checkout of the sensor including fine tuning of various calibration coefficients and characterization of the sensor's performance.

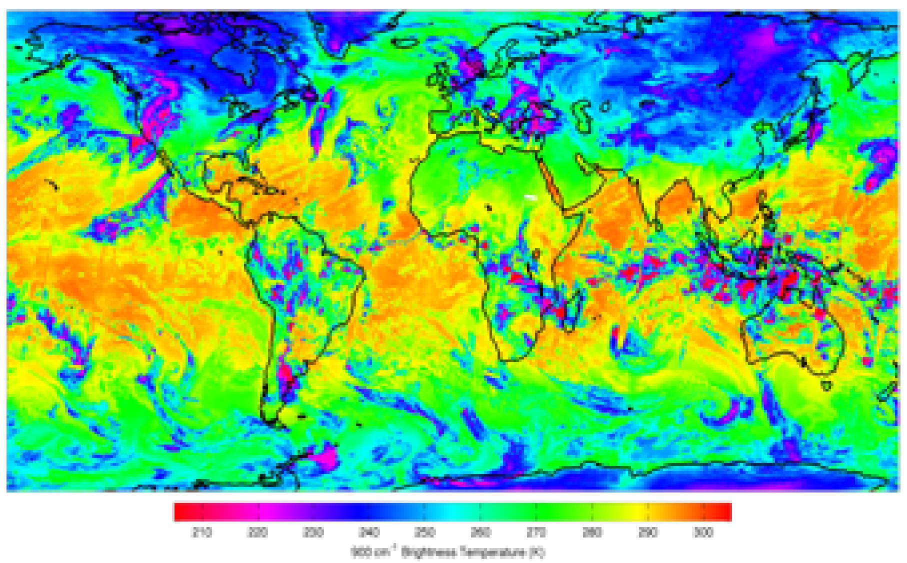


Figure 1. Data is flowing in from the Cross-track Infrared Sounder (CrIS) instrument aboard NASA's newest Earth-observing satellite, the Suomi National Polar-orbiting Partnership (NPP). This image is a composite of 900 cm-1 brightness temperatures from three days of CrIS data from January 21, 23 and 25, 2012. The orange colors represent very warm sea surface temperatures, while magenta represents both very cold temperatures as well as high-altitude cloud tops.

Following the Suomi-NPP launch on 28 October 2011, the CrIS was powered up on 20 January 2012. The CrIS sensor is a Fourier transform spectrometer, with an 8 cm clear aperture utilizing plane mirror interferometer technology. CrIS scans a 2200km swath width (+/- 50 degrees), with 30 Earth-scene fields-of-regard. Each field-of-regard consists of 9 fields-of-view (FOVs), arrayed as 3x3 array of 14km diameter spots (nadir spatial resolution). Each swath (with an 8-second repeat interval) also includes views of the internal calibration target (warm calibration point), and a deep space view (cold calibration point). For each FOV, longwave (9.14 - 15.38um), midwave (5.71 - 8.26um) and shortwave (3.92 - 4.64 um) interferograms are collected with a maximum optical path difference of 0.8 cm corresponding to a spectral resolution of 0.625 cm-1. Due to historical limits on the download data rate, however, the midwave and shortwave interferograms transmitted to the ground are currently truncated at 0.4 cm and 0.2 cm optical path difference, respectively. The overall instrument data rate is <1.5Mbps. Only photovoltaic detectors are used in the CrIS instrument. The detectors are cooled to approximately 81K using a 4-stage passive cooler with no moving parts. Primary uses of CrIS include assimilation of the radiance data into NWP models for medium range weather forecasting, retrievals of vertical profiles and temperature and water vapor, and various climate studies.

CIMSS/SSEC has been integrally involved in the CrIS project over the past decade, including design of the sensor and algorithms, participation in the Thermal Vacuum testing of the sensors, and most recently in the post-launch Early Checkout activities. Goals of the Early Checkout phase of CrIS included fine-tuning of various sensors parameters and calibration coefficients, evaluation of the software algorithms and processing system responsible for producing Sensor Data Records (SDRs) (aka calibrated radiance spectra) from the Raw Data Records (RDRs) (aka interferograms), and declaration of the CrIS SDRs as "beta" status and subsequent dissemination of the radiance data via CLASS, NWP data assimilation, and Environmental Data Record (EDR) (aka temperature and water vapor soundings) evaluation efforts. Some examples of the Early Checkout activities performed at CIMSS/SSEC include analysis of the interferometer operation, radiometric noise performance assessment, spectral calibration, radiometric nonlinearity corrections and radiometric calibration, and evaluation of the on-board numerical filter. Highlights of these findings are described below.

Interferometer Fringe Counting and Imaginary Parts of the Calibrated Radiance Spectra

A requirement for proper calibration of the CrIS radiance spectra is the ability of the interferometer to maintain fringe counts of the metrology laser signals and/or a robust algorithm to account for fringe count errors. Due to various issues, the fringe count error detection and correction algorithm in the operational CrIS SDR algorithm has been disabled. However, analyses shows that the interferometer has not experienced any fringe count errors to date. This result is very important in terms of confirmation of the design and operation of the interferometer and also in the high quality of the resulting radiance spectra. An important diagnostic on this aspect of the radiometric calibration is obtained by using the imaginary part of the calibrated radiances, which is included in the SDR product files. If the fringe counting and basic radiometric calibration has been performed correctly, the imaginary part of the calibrated spectra will have zero mean and characteristics of random noise across the spectrum. Figure 2 shows a sample of these imaginary parts for ascending node data on 18 April. The lack of structure and non-zero imaginary parts confirms the proper fringe counting of the CrIS interferometer and resulting radiometric calibration.

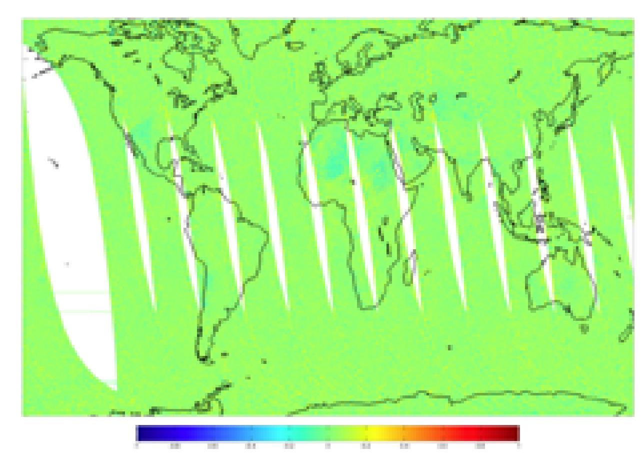


Figure 2. Imaginary parts of calibrated radiance spectra on 18 April 2012. The lack of structure and non-zero imaginary parts confirms the proper fringe counting of the CrIS interferometer and resulting radiometric calibration.

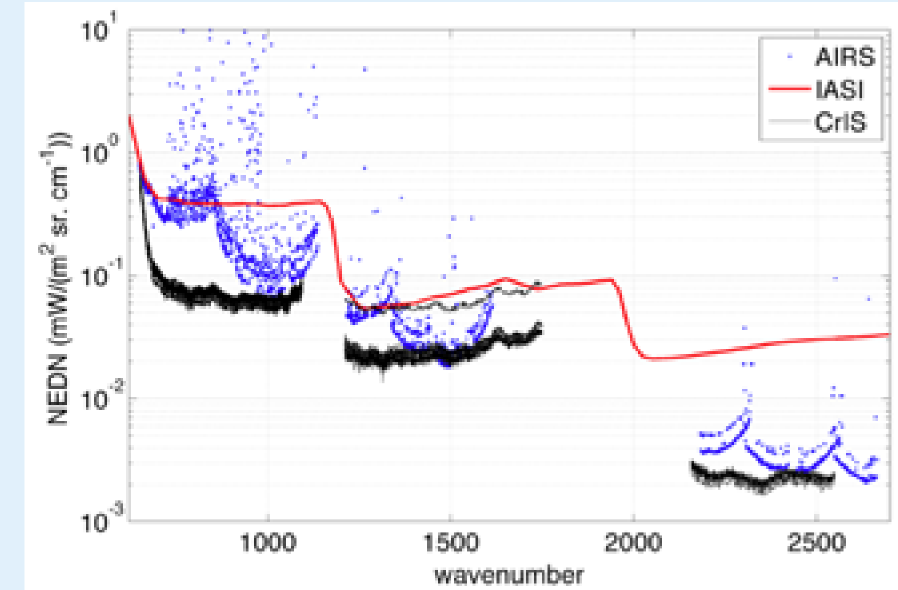


Figure 3. CrIS radiometric noise performance compared to AIRS and IASI.

Radiometric Noise Performance Assessment

As expected, the noise performance of CrIS is excellent. Figure 3 shows an estimate of the CrIS radiometric noise performance compared to the noise performance of both AIRS and IASI. This CrIS noise estimate was derived from an ensemble of ICT and space view data and represents the random component of the noise. As shown, the random noise performance of CrIS in the longwave spectral region is approximately four times better than AIRS and IASI, and comparable to AIRS in the midwave and shortwave spectral regions. In contrast to AIRS, other analyses performed to date have shown that non-random components of the CrIS noise are very small, and most likely negligible for most science and climate applications.

Spectral Calibration

One of the main advantages of high spectral resolution, and interferometers in particular, is the ability to obtain high accuracy in terms of spectral calibration. The spectral calibration of CrIS is proving to be excellent, with spectral accuracy of approximately 1 ppm (parts per million). CrIS utilizes the novel concept of including a neon lamp, and periodic views of the neon lamp are used to assess and/or adjust the spectral calibration of the sensor. More traditionally, clear sky Earth view observations and calculations can also be used to assess the spectral calibration. To date, these analyses have shown the spectral calibration knowledge and stability to be significantly better than 1 ppm (the CrIS spec at 10 ppm). As part of the CIMSS/SSEC efforts, we also used

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an analysis method to assess inter-FOV spectral calibration that was developed previously for IASI data. Spectral consistency among FOVs is very important, and this method which assesses the spectral calibration of FOVs with respect to the center FOV (FOV5) observations has some significant advantages over approaches which use clear sky calculations as the reference. This type of analysis was used to make refinements in the FOV positions of the detectors which impacts the spectral characteristics of the data. Figure 4 shows an example result from this type of analysis for data collected on 27 March (after the refinements) showing spectral consistency among the nine longwave FOVs on the order of a few tenths of ppm.

Radiometric Nonlinearity Correction and Radiometric Calibration

During the thermal vacuum testing of CrIS, the longwave and midwave photovoltaic detectors were found to exhibit significant nonlinearity. This behavior was characterized and found to be very similar to quadratic nonlinear behavior previously experienced and characterized in other sensors such as our aircraft sensor, the Scanning-HIS. For CrIS we developed nonlinearity characterization tests and correction algorithms that were adopted by the program. The nonlinearity behavior of some of the CrIS detectors was also found to change during shut-down/warm-up cycles of the sensor, and so post-launch characterization and refinement strategies were also developed for the Early Checkout phase. These efforts included collection and analysis of "diagnostic mode" data which provides out-of-band harmonic signals useful for characterization of the nonlinearity and an analysis technique used to refine the nonlinearity correction coefficients which draws upon the differential behavior of the nonlinearity among FOVs. Figure 5 shows an example of the magnitude of the radiometric nonlinearity correction for FOV7, which exhibits large nonlinearity in both the longwave and midwave bands. As shown, the nonlinearity correction approaches ~1K and has significant spectral shape, and so an accurate correction algorithm is very important. Following our post-launch nonlinearity refinements, Figure 6 shows differences between clear sky observed and calculated spectra (c/o L. Strow at UMBC) using the at-launch and refined nonlinearity correction coefficients. After the nonlinearity refinements, the agreement between FOVs (and the overall agreement with calculated spectra) is very good, less than ~0.1K in the longwave spectral region and less than ~0.2K in the midwave region.

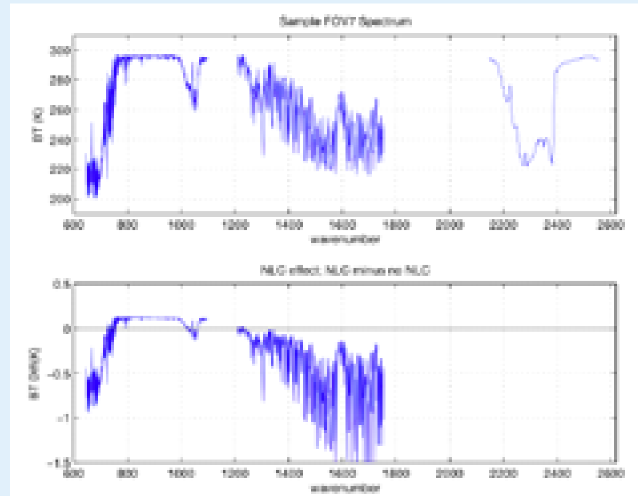

Figure 5. An example of the magnitude of the radiometric nonlinearity correction for FOV7. The spectral shape and magnitude of the nonlinearity corrections can vary significantly from one Earth view to another.

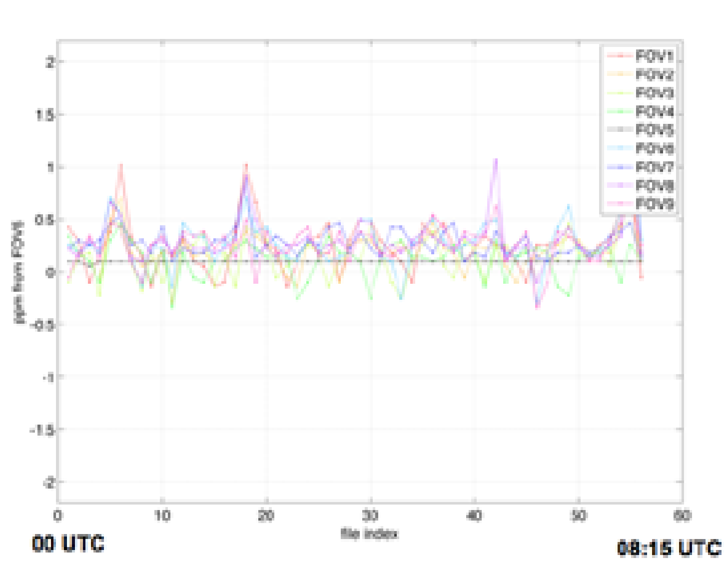

Figure 4. An example result of inter-FOV spectral calibration for 27 March 2012, following a sensor shut-down/warm-up event on 24/25 March. The left hand panel shows the spectral calibration determined with respect to FOV5 for each 8 minute segment of data, and the right hand panels show the distributions (ppm) of spectral shifts for each FOV.

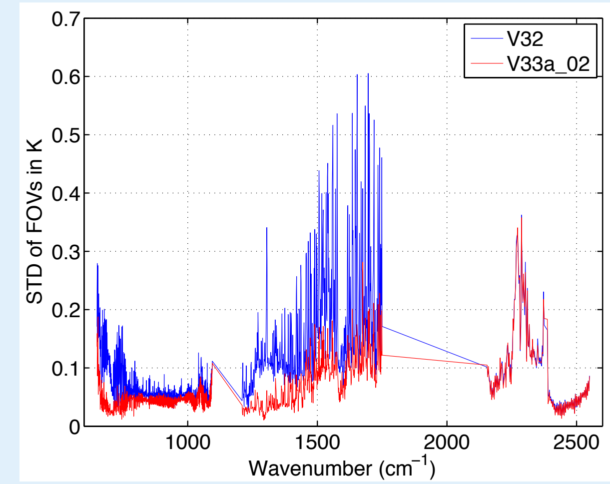

Figure 6 (c/o L. Strow at UMBC). Standard deviation among FOVs of clear sky obs-calcs using the at-launch (blue) nonlinearity correction coefficients and using refined coefficients determined with post-launch out-of-band harmonic and Earth view consistency analysis (red).

In terms of the overall radiometric uncertainty of the CrIS data which incorporates nonlinearity facts and all other calibration contributions, analyses are still on-going, but we expect the in-flight CrIS radiometric uncertainty estimates to be less than 0.2K 3-sigma for all scene temperatures and wavelengths.

Interferometer Sweep Direction Biases and Adjustments to the On-board Numerical Filter

As part of our analyses of the CrIS data, a small bias in the calibration of the data from one interferometer sweep direction versus the other was discovered. This bias was as large as ~0.4 K in the longwave end of the longwave spectral band, relatively small throughout the rest of the longwave band and midwave band, and also significant in some regions of the shortwave spectral band. After various analyses, we diagnosed this issue to be due to the performance of the on-board numerical filter. Simulations of the effect were performed, and a new numerical filter was designed and uploaded to the sensor. Figure 7 shows data collected on the day the new filter was uploaded, showing the sweep direction bias prior to the upload (which looks like along track "striping" of the data) and afterwards, where this source of striping is significantly reduced.

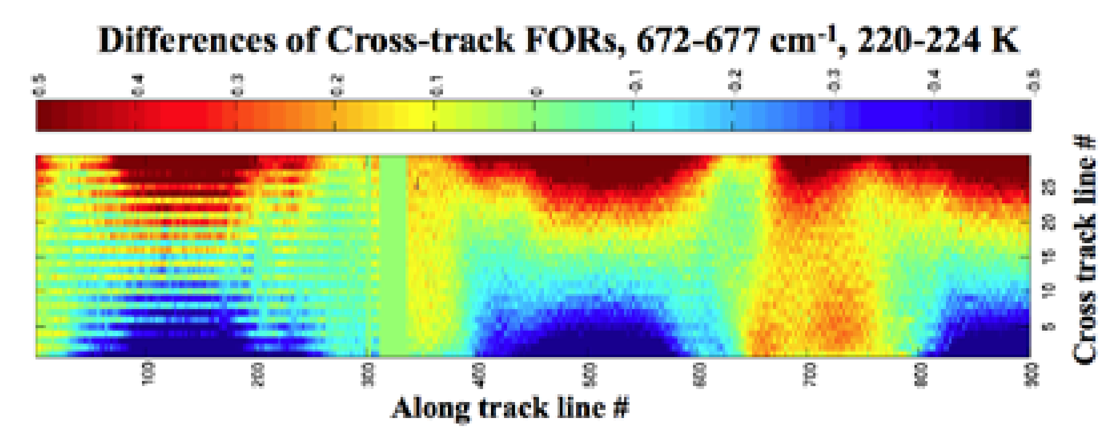

Figure 7. Longwave spectral region sweep direction biases on 18 April, with the at-launch numerical filter (prior to along track line # 300) and after upload of the new numerical filter.

Summary

CIMSS/SSEC is an integral participant in the post-launch evaluation of CrIS. The Early Checkout phases of these efforts have been very successful, with upload of refined "v33" calibration coefficients and on-board numerical filter coefficients in April, and subsequent declaration of the CrIS radiance prodcuts as "beta" quality. Going forward, the radiance cal/val efforts will continue, with further analyses to investigate remaining issues in the CrIS data and processing. CrIS radiance data will also start being disseminated to NWP centers for data assimilation efforts, and used by researchers to evaluate and refine the EDR (retrievals) from CrIS.

Dave Tobin

Sounding the Atmosphere – from TIROS to Suomi NPP

A new era of remote sensing began with the successful launch of the Suomi National Polar-orbiting Partnership (NPP) on 28 October 2011. From the first radiometer to measure the Earth's heat balance from a satellite envisioned by Verner Suomi (1959) to the current suite of instruments on Suomi NPP, the Space Science and Engineering Center has pioneered advances in remote sensing research aimed at improving our understanding of the Earth and its atmosphere.

Satellite Meteorology - A History

The United States launched the first meteorological satellite, TIROS-1 (Television Infrared Observational Satellite) on 1 April 1960. From this vantage point, scientists could see, for the first time, complete pictures of the clouds associated with large weather systems. The operational meteorological satellite program evolved rapidly thereafter.

In 1964 researchers successfully created a global picture of the earth's surface and atmosphere. A new initiative then attempted to measure the atmosphere's vertical distribution of temperature and moisture to better initialize global numerical weather prediction models, otherwise known as atmospheric sounding. By the late 1950s, J. King and Lewis Kaplan, had advanced the theoretical underpinnings of soundings with research that showed it was possible to infer atmospheric temperature and the concentration of attenuating gas such as water vapor as a function of atmospheric pressure.

Temperature profile retrievals were first accomplished in 1969 with the Satellite Infrared Spectrometer (SIRS), a grating spectrometer aboard NIMBUS-3. This instrument demonstrated the capability of indirectly measuring these parameters from a satellite platform, rather than from direct measurements systems such as radiosondes. The advantage of satellite measurements is that they provide much improved spatial and temporal coverage than radiosondes.

Despite these early successes, clouds remained an issue for retrievals using measurements in the infrared portion of the spectrum. Researchers explored the best spectral bands for retrievals and various mathematical techniques to eliminate the influence of clouds. In 1972 a scheme was devised to reduce the influence of clouds by employing a higher spatial resolution (30 km) and by taking spatially continuous sounding observations, now possible with cross-track scanning on the seven-channel Infrared Temperature Profile Radiometer (ITPR) on board NIMBUS-5 (Smith et al, 1974).

From the available results and studies in the early 1970s, scientists recognized that optimum temperature profile results would be achieved by taking advantage of the unique characteristics offered by the 4.3 micron and 15 micron CO_2 absorption bands. The Nimbus-6 High resolution Infrared Radiation Sounder (HIRS) experiment was then designed to accommodate channels in both regions.

Current generation NOAA polar-orbiting satellites carry improved AVHRR imager (addition of a channel at 1.6 microns for cloud, ice and snow discrimination) and HIRS sounder instruments that continue to provide their basic measurements. Important improvements to microwave sounding instruments such as the Advanced Microwave Sounding Unit (AMSU), provide all-weather temperature sounding information at about 50 km horizontal resolution and moisture sounding information at about 15 km horizontal resolution. The all-weather sounding capability was established in 1998 with the advent of this enhanced microwave sounder (more channels, better spatial resolution) and continuation of the high spatial resolution infrared (good spatial resolution, evolving to higher spectral resolution). The data have become part of the operational practices of weather services internationally.

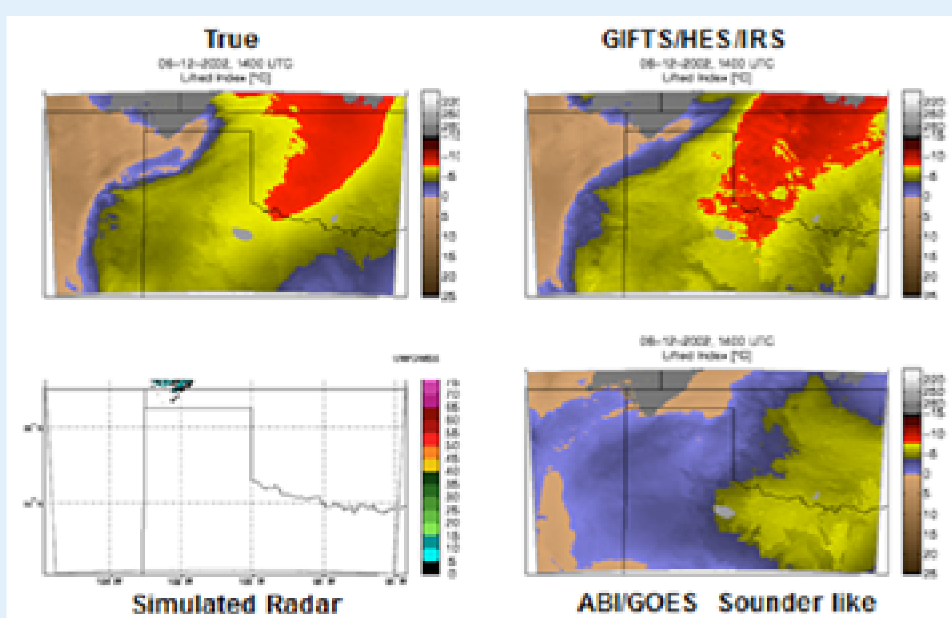

Figure 1. Observing System Simulation Experiment for 1400 UTC on 12 June 2002 during IHOP; a significant convective storm appeared at 2100 UTC in the unstable region of Oklahoma (upper left). Simulation of the true lifted index at 1400 UTC (upper right). Simulation of the LI from a geostationary high spectral resolution infrared sounder (lower left). Simulation of radar echoes (lower right). Simulation of Lifted Index from the current sounder or the planned Advanced Baseline Imager. Only the geostationary advanced IR sounder captures the atmospheric instability well in advance of the subsequent severe weather.

Geostationary Satellites Join the Effort

By 1980, the U.S. Geostationary Operational Environmental Satellite (GOES) system had evolved to include an atmospheric temperature and moisture sounding capability with the addition of more spectral bands to the spin scan radiometer known as the VISSR Atmospheric Sounder (VAS). The first GOES-VAS, GOES-4, was launched in September 1980. Recognizing the limitations of the VAS instrument, but realizing the importance of geostationary sounding, NOAA introduced a 16-channel broadband GOES sounder to its current generation of geostationary satellites (Menzel and Purdom, 1994) with the launch of GOES-8 on 13 April 1994.

The scientific community recognized the need for geostationary sounding with high-spectral resolution instruments (Schmit et al. 2009). By using an interferometer, focal plane detector arrays, and on board data processing to observe from 3.7 to 15.4 microns with 2000 plus channels, it was determined that contiguous coverage of 6,000 x 5,000 km could be accomplished in less than 60 minutes. The trend for more spectral channels at higher spatial resolution with faster coverage to capture the rapid weather changes and improve high impact weather warning and short-range forecasting will bring a crucial new capability to geostationary sounding.

Advanced IR Sounder

CIMSS scientists have demonstrated the importance of an advanced IR sounder from geostationary orbit to replace the current GOES Sounder. A convective initiation event from the International H_2O Project (IHOP) field experiment established the potential utility of a geostationary high spectral resolution IR sounder for severe storm nowcasting and regional NWP applications. Such a sounder would provide detailed stability information (e.g., lifted index and other parameters) with high temporal resolution critical for determining favorable locations for convective initiation. This important information about extreme destabilization is provided hours earlier than is possible from the current observing system.

In the IHOP example (Figure 1), an observing system simulation experiment showed that a geostationary high spectral resolution IR sounder provides accurate Lifted Index instability information about four hours earlier than the current sounder and about eight hours earlier than radar. This improvement suggests that nowcasting and short-term forecasts of 0–6 hours for severe weather would benefit significantly from the advanced geo sounders better and more frequent monitoring of low-level moisture and temperature conditions.

CIMSS scientists are also examining the use of water vapor and temperature observations from polar-orbiting advanced IR sounders (AIRS, IASI and CrIS). These high vertical resolution soundings provide excellent global coverage for severe weather detection and forecasting. One study conducted at CIMSS seeks to improve path and intensity forecast for tropical cyclones. A lack of good temperature and water vapor information appears to be a limiting factor for accurate forecasts from these systems. In a case study for Hurricane Irene conducted at CIMSS, the high vertical resolution atmospheric temperature and moisture profiles from AIRS were used to analyze the development of a hurricane.

The Weather Research and Forecast (WRF) model and Data Assimilation Research Testbed – DART (WRF/DART) developed by the National Center for Atmospheric Research (NCAR) were used to assimilate AIRS data and to generate forecasts. Assimilation of the sounding measurements resulted in better representation of model environmental conditions around the hurricane, thus improving the path and intensity forecasts. The hurricane path and intensity forecasts were examined with and without the satellite atmospheric temperature and moisture information.

From the initial GFS global analysis, both control and AIRS runs show the relatively large errors in sea level pressure at the beginning stages; these errors are gradually reduced as model progresses with time. However, the AIRS soundings consistently show the improvement of intensity forecasts during the process (Figure 2). Results of additional experiments with WRF/3DVAR were consistent with those from WRF/DART. Research has demonstrated the potential positive impact of available advanced

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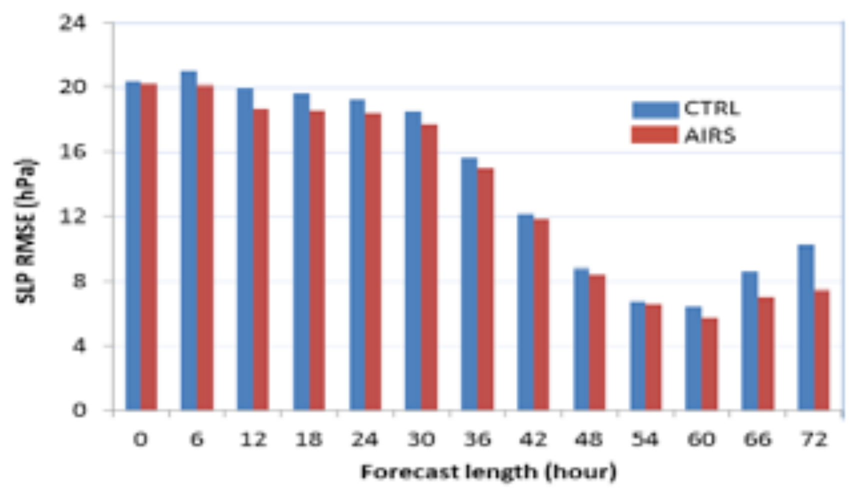

Figure 2. Tropical Cyclone Irene (2011) central sea level pressure (SLP) forecast RMSE for 0-h (analysis), 6-h, to 72-h forecasts. Every 6 hours between 06 UTC 23 and 00 UTC 25 August 2011 the data are assimilated with WRF/DART followed by a 72-hour forecast. The SLP RMSE is calculated from comparisons with the best track observations from National Hurricane Center.

IR sounder temperature and water vapor information from satellites for forecasting hurricane tracks and intensity.

AVHRR Transitions to VIIRS

With Suomi NPP's successful launch and the current NOAA satellite series transitioning to the new JPSS series, AVHRR is transitioning to a more capable visible and infrared imager called the Visible Infrared Imaging Radiometer Suite (VIIRS). VIIRS will be better calibrated than the AVHRR, with higher spatial resolution and 22-channel spectral capability.

HIRS is being replaced by the Cross Track Infrared Sounder (CrIS), a Michelson interferometer that is designed to enable retrievals of atmospheric temperature profiles at a much higher degree of accuracy. This accuracy is accomplished by the CrIS working together with the Advanced Technology Microwave Sounder (ATMS), the replacement for AMSU. A comparable sounding capability has been realized by the Infrared Atmospheric Sounding Interferometer (IASI) on the European Metop-A satellite in conjunction with the advanced microwave temperature sounding units (AMSU-A) and microwave humidity sounders (MHS). CrIS/ATMS is flying on the ascending afternoon orbit and IASI/AMSU is flying on the descending morning orbit.

SSEC's work in sounding and retrieval science covers both polar and geostationary platforms. CIMSS scientists are currently preparing Suomi NPP VIIRS, CrIS, and ATMS data for state of the art soundings aimed at advancing our capability to understand and predict severe weather. The CIMSS hyperspectral IR Sounder Retrieval (CHISR) algorithm has been developed to retrieve atmospheric temperature and moisture profiles from advanced IR sounder radiance measurements in clear skies and some cloudy sky conditions on a single field-of-view (SFOV) basis (Li and Huang 1999; Li et al. 2000; Weisz et al. 2007).

The algorithm is forecast independent and consists of three steps. The first step is the IR sounder sub-pixel cloud detection using a high spatial resolution imager cloud mask product (for example, the AIRS cloud detection can be derived from the MODIS cloud mask, and the CrIS cloud detection can be derived from the VIIRS cloud mask (Li et al. 2004)). The second step is to perform an eigenvector regression on the hyperspectral IR radiance measurements as the first guess of temperature and moisture profiles. The final step is to update/improve the first guess by performing a one-dimensional variational (1DVAR) retrieval algorithm with a Quasi-Newton iteration technique.

Radiance measurements from all IR channels are used in the sounding retrieval process. The CIMSS research product provides IR soundings with higher spatial resolution of approximately 12-14 km than the operational sounding product which is based on the AMSU or ATMS cloud-clearing algorithm (Susskind et al. 2003). The operational sounding product has a spatial resolution of approximately 45 km at nadir, which is much coarser than the resolution of most regional forecast models. CIMSS temperature and moisture soundings, retrieved from an advanced IR sounder at single FOV resolution, soundings in hurricane's environmental region can be assimilated in hurricane models for track and intensity forecasts. The single FOV soundings has also been used in the rapid refreshed model and has shown positive impact in forecast experiments (Li et al. 2012).

Building on decades-long research, CIMSS scientists continue to advance and refine the possibilities of advanced IR soundings from geostationary and polar orbit.

Jun Li
Paul Menzel

Community Satellite Processing Package Transforms Data from Suomi NPP

The Suomi National Polar-orbiting Partnership (NPP) satellite is the first of a new generation of sentinels in low earth orbit for observing the atmosphere, land, and oceans. Suomi NPP carries sensors for detecting wildfires, measuring the temperature structure of the atmosphere, and mapping ocean productivity, among other applications. The data acquired by these sensors are transmitted to a ground station in Svalbard, Norway. From there, the data are sent to NOAA/NESDIS in Washington DC, where it is analyzed and processed on large computer systems. While these data cover the whole globe and span many different uses, users must wait two or more hours for them to be available. For anyone needing to make decisions in "real-time," this may take too long. Fortunately Suomi NPP has the capability to instantaneously transmit everything it observes to ground stations on Earth. With the appropriate receiving equipment, anyone can receive these data in real-time, process them on their own computer, and in less than 30 minutes, use the products to make decisions. This process is known as "direct broadcast" (DB), and it enables government agencies, research centers, and universities in the US and around the world to benefit from Suomi NPP observations of the Earth in real time.

U.S. weather satellites have had this capability since the 1970s, starting with the TIROS-N weather satellite and continuing with the POES and EOS Terra and Aqua satellites of today. SSEC has supported the worldwide DB community since 1985 with software packages for processing real-time data from these polar-orbiting satellites. These "Processing Packages" (ITPP, IAPP and IMAPP) were the forerunners in transforming the DB signal into data products and images, and a new set of software from SSEC named the Community Satellite Processing Package (CSPP) continues this tradition.

Figure 1. Image of Florida, Cuba, and the Bahamas on 21 November 2011, from the VIIRS imaging sensor onboard the Suomi NPP satellite.

To acquire direct broadcast (or DB) from Suomi NPP, a tracking antenna with a movable reflector is needed. The antenna tracks the satellite as it rises above the horizon and flies overhead. Typically the satellite will be visible from a mid-latitude location 2-3 times during daytime, and 2-3 times during nighttime. As the satellite flies overhead, specialized electronics and computer systems convert the radio waves received by the antenna into digital signals (or "raw data") that are stored on a computer hard drive.

Specialized computer software is then needed for decoding, geolocating, and calibrating the raw sensor observations. This software converts the raw data received by the antenna to physical quantities such as reflectance and temperature, and also assigns a geographic location to each observed data point. SSEC/CIMSS is playing an important role in providing this software to Suomi NPP DB users around the world.

The operational Suomi NPP software was originally developed to run on the large computer systems at NOAA/NESDIS in Washington DC. SSEC is funded by the JPSS Program to adapt the software to run on modest computer hardware in real-time. In April 2012, SSEC released the first version of the Community Satellite Processing Package (or CSPP) for Suomi NPP VIIRS, ATMS, and CrIS data to more than 40 different users representing government agencies and educational institutions around the world. The CSPP project provides the global DB community with a simple and reliable way to start using the data from Suomi NPP as soon as possible.

To introduce new users to Suomi NPP DB, SSEC/CIMSS scientists often travel far and wide. Recently scientists Kathy Strabala and Jordan Gerth traveled to Alaska and worked with members of the Geographic Information Network of Alaska (GINA) to install CSPP and trained National Weather Service (NWS) forecasters on how the VIIRS image products can be useful for weather applications. For the Alaska region, CSPP automates the processing and distribution of Suomi NPP VIIRS data for display in the Advanced Weather Interactive Processing System (AWIPS) at the National Weather Service (NWS) forecast office in Anchorage.

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Figure 2. Jim Nelson, Science and Operations Officer (SOO) at the NWS Forecast Office in Anchorage, Alaska, examines the first image of the VIIRS Day/Night band as displayed in AWIPS. The data was captured using the DB antenna at GINA in Fairbanks, AK, automatically processed using CSPP software.

“The first step was to install CSPP,” Strabala says. “Then we remap, colorize, and convert the VIIRS Science Data Record (SDR) files into the format required for display in the National Weather Service’s AWIPS software. The next step is to introduce the NWS forecasters to the imagery and its applications. VIIRS data from the Suomi NPP offers new value to forecasters because of its new day/night band, its larger swath size, and its more consistent spatial resolution. Making these new data available in AWIPS will provide the NWS forecasters with better information to do their job.”

In the lower 48 states, NWS forecasters will use real-time VIIRS imagery for detecting water temperature in the Great Lakes, which has a strong influence on the air temperature for cities including Chicago and Milwaukee, as well as providing information for recreational and commercial users of the lake and coastal regions. The NWS will also use real-time VIIRS data at night for detecting fog close to the surface, which can be a hazard for transportation including airlines and highway travellers.

The VIIRS sensor onboard Suomi NPP also offers a new capability to capture images of clouds and the land surface at visible wavelengths at night, using only the illumination from the moon, or from surface and atmosphere features that emit light when there is no moon. This new feature of Suomi NPP will have an immediate impact in applications such as transportation safety by detecting low fog over highways at night, and also will provide new capabilities for detecting fires, smoke and snow cover at night.

SSEC operates its own X/L-band ground station on the UW-Madison campus, which captures DB data from Suomi NPP in real-time (Figure 3), as well as DB data from the Terra, Aqua, and NOAA POES satellites. Data processed with CSPP at SSEC/CIMSS are now distributed to users including the NWS, the US Naval Research Laboratory in Monterey CA, NASA Marshall Spaceflight Center, the US Forest Service, and the Canadian Ice Service. SSEC/CIMSS facilitates NWS users of polar-orbiting satellite products supplying data to AWIPS in real-time. Starting with the NWS Forecast Office in 2006, SSEC/CIMSS now supplies real-time image products from Suomi NPP, Terra, and Aqua to 57 NWS forecast offices around the United States.

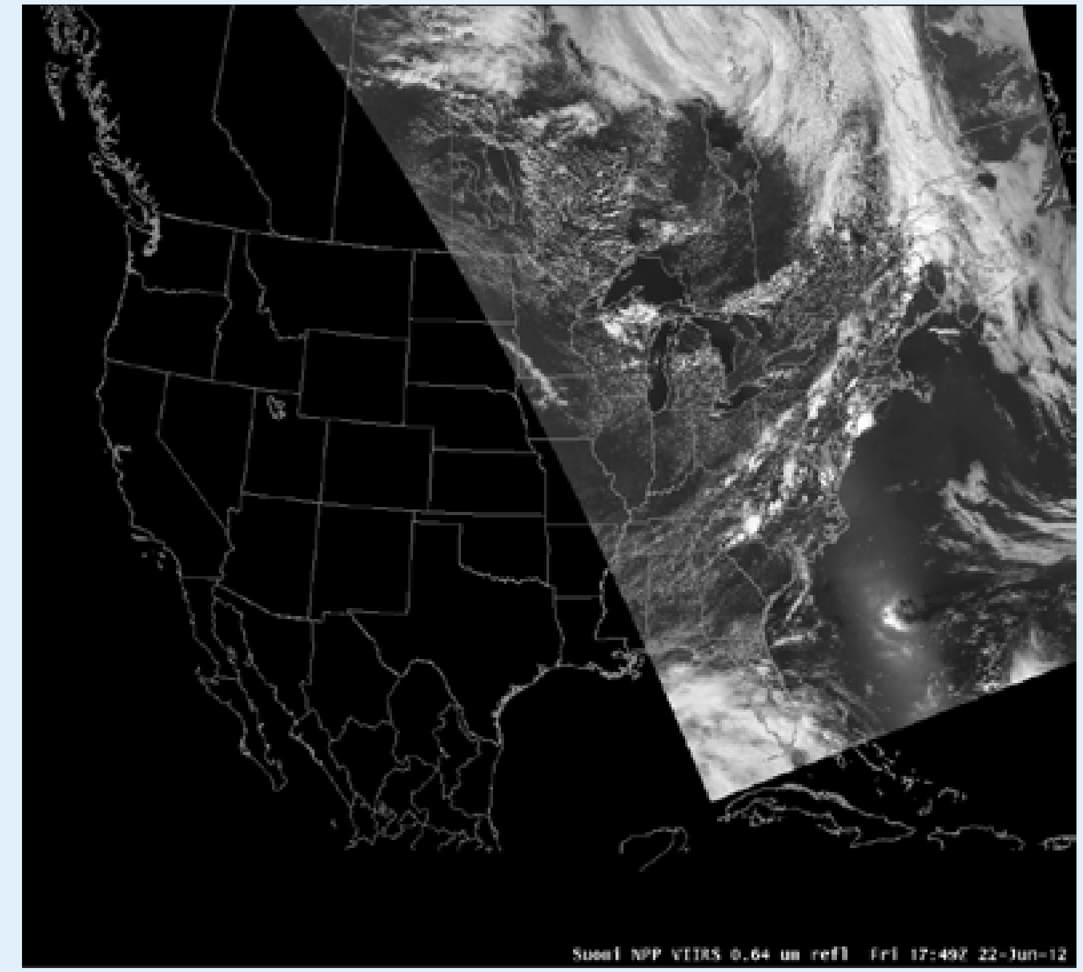
Figure 3. Installation of the SSEC X/L-band Direct Broadcast antenna on the UW-Madison campus in September 2011.

The Community Satellite Processing Package continues a 25-year tradition of supporting the US and international DB communities with free access to software for processing of data from polar-orbiting satellites. When combined with the relatively low cost of DB antenna systems, the opportunity to acquire data in their region of the world in real time, and the demonstrated value of polar-orbiter products, CSPP is promising a great future for those involved in weather forecasting and environmental monitoring.

Liam Gumley
Kathy Strabala
Tom Achtor

Important Disclaimer: CSPP is providing Suomi NPP processing functionality using preliminary algorithms and data to prepare users for real-time direct broadcast applications. Official algorithms are pending and the Suomi NPP calibration/validation checkout has not been completed.

SSEC Partners with NWS to Support AWIPS



A swath of VIIRS visible imagery from 17:49 UTC (12:49 PM CDT) on 22 June 2012, in AWIPS.

Since 2006, SSEC has maintained a relationship with the National Weather Service (NWS) to foster the distribution of satellite imagery and science products to the Advanced Weather Interactive Processing System (AWIPS) at field offices. This collaboration began with the Milwaukee NWS office receiving MODIS imagery collected using an antenna atop SSEC and has since expanded to over 50 NWS offices nationwide.

One significant advantage of the polar-orbiting imagery from MODIS over traditional geostationary imagery is the higher spatial resolution and greater number of spectral bands, which allows for the production of more meaningful science products. For example, the sea surface temperature product provides water skin temperature for the Great Lakes and has been widely used to forecast coastal weather conditions.

VIIRS imagery continues the spatial and spectral legacy of instruments like MODIS in the polar-orbiting orbit with one significant addition, the day/night band. The day/night band is a high-gain visible band which is sensitive to reflected solar light from the moon cast upon clouds. The day/night band also is capable of sensing city lights, lightning, auroras, and fires. SSEC’s NWS partners are looking forward to receiving this imagery to solve a myriad of forecast problems where forecasters are literally “in the dark” during the overnight hours.

SSEC introduced this imagery to NWS Anchorage in May 2012. NWS Honolulu is receiving assistance from SSEC in preparing their antenna for collecting VIIRS imagery over the Pacific Ocean beginning in August 2012.

These demonstrations are known as proving grounds, which have been widely useful for supporting NWS operations.

Jordan Gerth

McIDAS-V - Suomi NPP ATMS, VIIRS, and CrIS Analysis and Visualization

With the October 2011 launch of the first JPSS satellite, Suomi NPP, SSEC's McIDAS-V scientific analysis and visualization software has proven a useful tool for early evaluation of these new data.

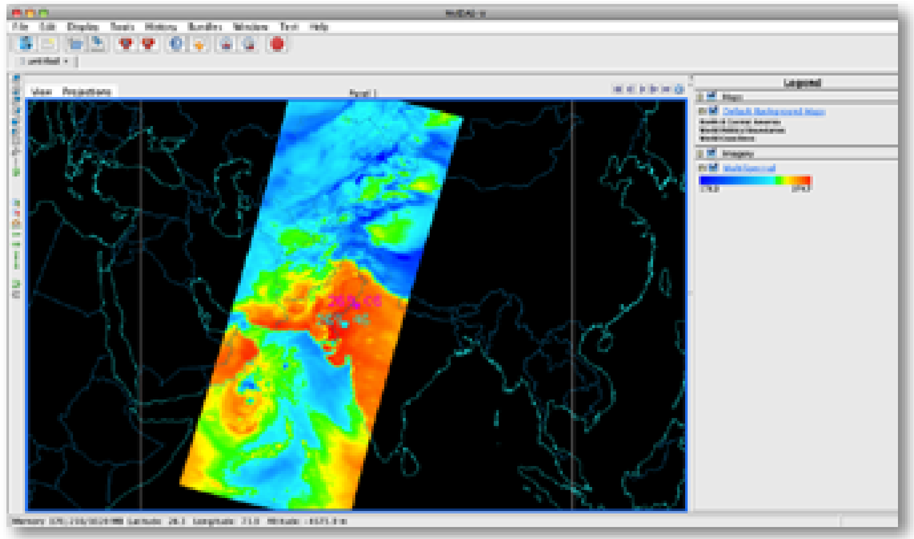


Figure 1. This image is from some of the first data received from the spacecraft.

ATMS

The first instrument from Suomi NPP to transmit data was ATMS on 08 November 2011. ATMS is the Advanced Technology Microwave Sounder, a cross-track scanner with 22 channels. Based on predecessor instruments AMSU-A1, AMSU-A2, and AMSU-B, it provides sounding observations to produce profiles of atmospheric temperature and moisture. These data are critical for weather forecasting and climate monitoring continuity.

The current release of McIDAS-V, Version 1.2, allows scientists to work with ATMS granules obtained from CLASS or the SSEC Atmosphere PEATE. An arbitrary set of contiguous granules can be aggregated for display. Once loaded, all core McIDAS-V capabilities are available, including subsetting, reprojecting, formulas, statistics, etc. Figure 2 is from some of the first data received from the spacecraft.

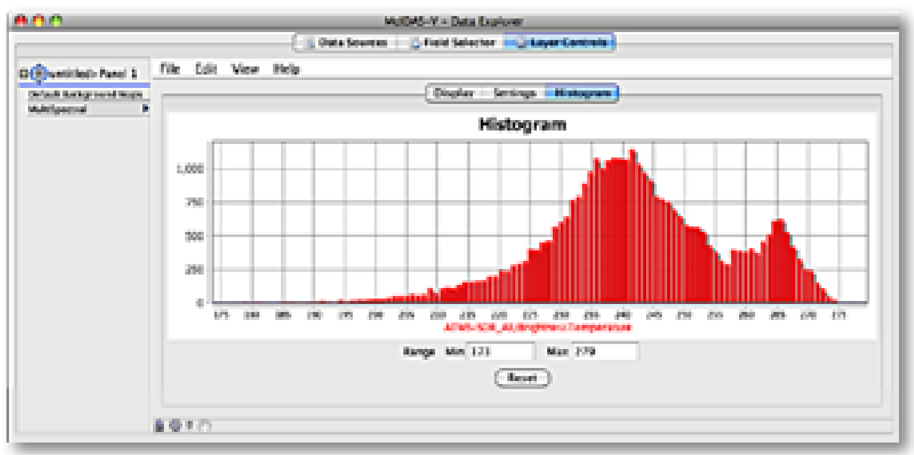


Figure 2. ATMS Channel 16 and brightness temperature histogram, Day1: 08-Nov-2011.

VIIRS

The second Suomi NPP instrument to transmit data was the next-generation imager, VIIRS. The Visible Infrared Imaging Radiometer Suite is a scanning radiometer producing visible and infrared imagery with many improvements over predecessor instruments MODIS, AVHRR, and OLS. Its 22 channels include 5 I-Bands, 16 M-Bands, and a Day/Night band. The true-color image to the right was produced with McIDAS-V within hours of the VIIRS sensor door opening.

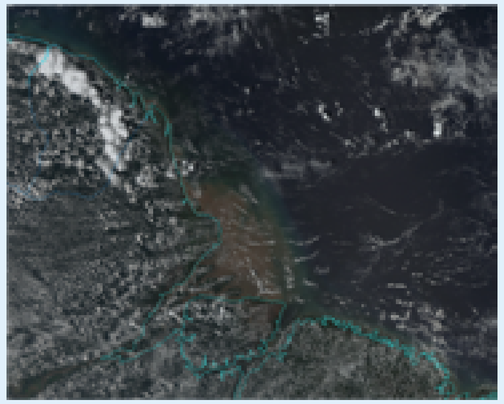
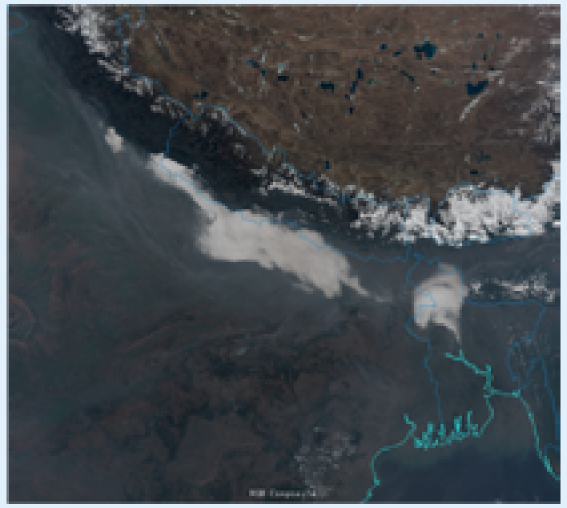


Figure 3. Amazon River Delta, created in McIDAS-V within hours of VIIRS activation. [Tom Rink, SSEC/CIMSS]



VIIRS (cont.)

The NESDIS/StAR team led by NOAA scientist Don Hillger, based at CIRA in Fort Collins, CO, was tasked with checkout and evaluation of Suomi NPP imagery. This team recognized early the value in utilizing McIDAS-V as one of their visualization and analysis tools. This team has identified, reported, and resolved many key issues with VIIRS imagery since launch. These images are just two examples of VIIRS data visualizations made by the NESDIS/StAR team.

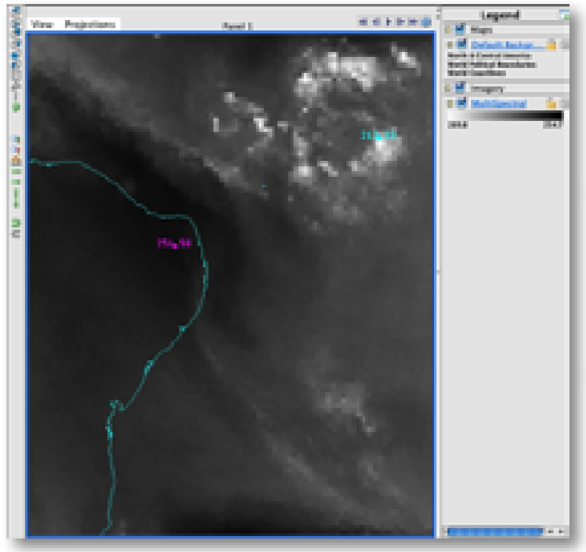
Figure 4. M-band (750 m) true-color/RGB image (for 14 December 2011) over northeastern India and Nepal. Note the large amount of pollution over India relative to Tibet, and how the mountains trap it to the south. [Dan Lindsey, NOAA/StAR]

CrIS

After several delays, much-anticipated data from CrIS, the Cross-track Infrared Sounder, started flowing on 20 January 2012. Due to an unexpected format change in the data organization for CrIS, support for CrIS is not present in McIDAS-V 1.2. However, it is available in the nightly builds and will be present in the next stable release.

CrIS ushers in the next era of hyperspectral data, with its 1,305 infrared spectral channels. Such data provide a high-resolution 3D view of the atmosphere. The ability for scientists to easily work with hyperspectral data was anticipated and developed many years ago at SSEC through the Hydra standalone application. The Hydra (Hyper-spectral Viewer for Development of Research Applications) capabilities are now integrated into McIDAS-V, and allow a very novel way of interactively manipulating data by spatial extent and spectral range at the same time.

Figure 5. The grey-scale image shows CrIS fields of view at 1502.5 cm-1, re-projected to a uniform grid, over the eastern coast of Brazil (2012-04-13, 03Z).



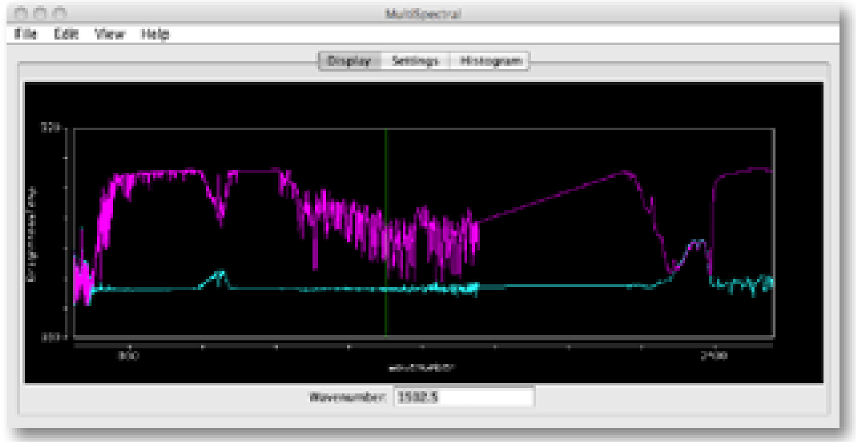


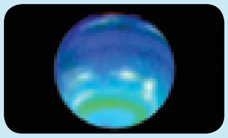
Figure 6. The spectra display aggregates the long wave (LW), medium wave (MW), and short wave (SW) products. The spectra graphs are updated automatically as the user drags the readout probes in the main display, finding the nearest FOV in the product file. Likewise, the image is updated as the green wavenumber selector is re-positioned along the spectral domain (x-axis).

These two figures provide a McIDAS-V interactive interrogation of a CrIS SDR (Sensor Data Record). The grey-scale image shows CrIS fields of view at 1502.5 cm-1, re-projected to a uniform grid, over the eastern coast of Brazil (2012-04-13, 03Z).

Suomi NPP brings the next generation technology of remotely-sensed land, ocean, and atmospheric data. Through their efforts on McIDAS-V, SSEC researchers continue to ensure that users have a powerful, freely-available visualization and analysis tool to realize the full potential of the Suomi NPP data.

Tommy Jasmin
Tom Rink

through the atmosphere



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Through the Atmosphere is a semiannual publication that features atmospheric and space science research, engineering projects, and accomplishments at UW-Madison's Space Science and Engineering Center (SSEC) and its Cooperative Institute for Meteorological Satellite Studies (CIMSS).

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