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.

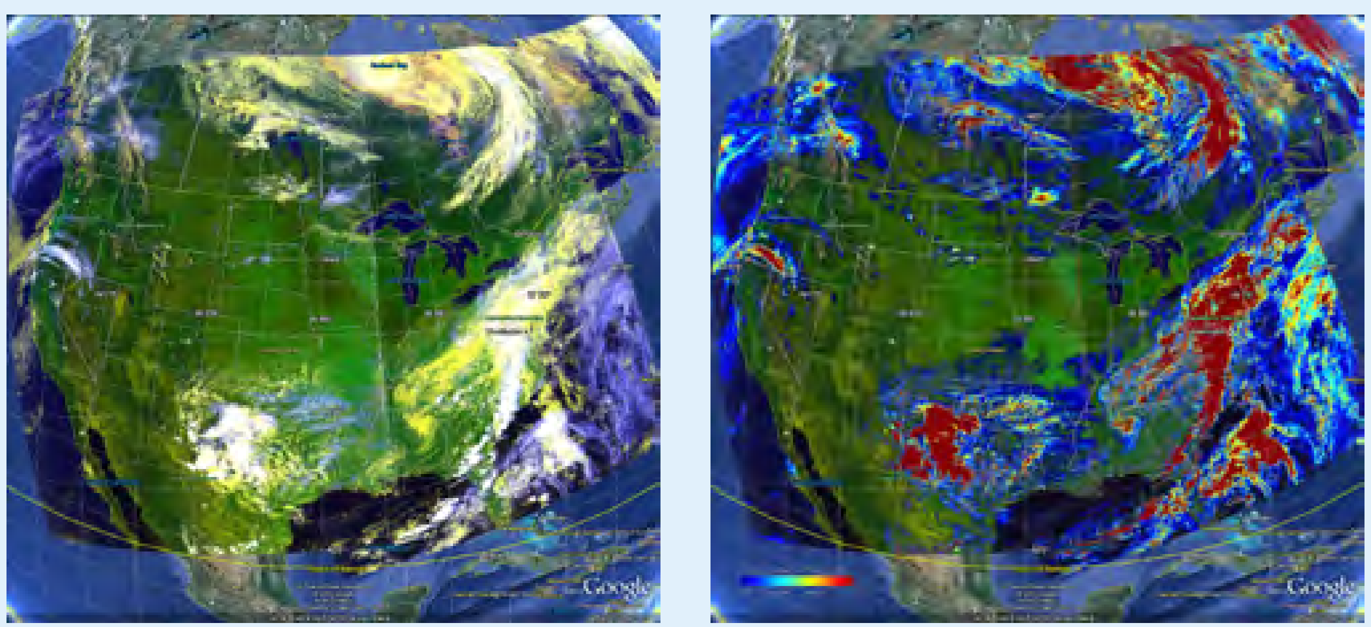

Figure 1. The above images show a result from the Daytime Cloud Optical and Microphysical Properties algorithm. The image on the left is a false color image constructed from the 0.65, 0.86 and 11 mm channels. The image on the right shows the cloud water path overlaid onto the false color image. These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

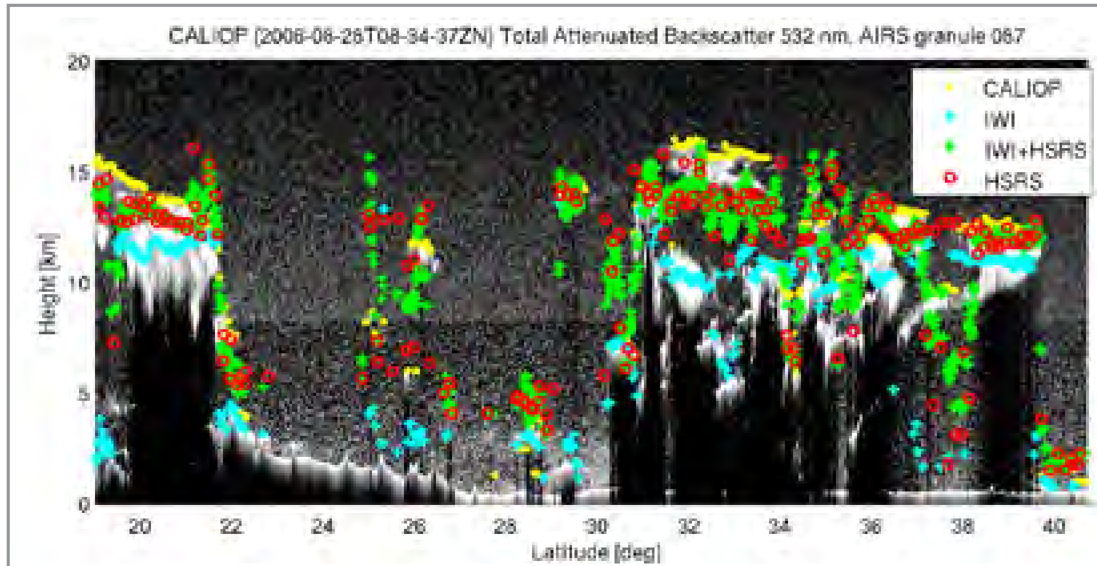

Figure 2. Cross-section along the CALIPSO track for AIRS granule 87 (28 August 2006). CALIOP 532 total attenuated backscatter /km/steradian (background). Cloud top heights from CALIOP, IWI, IWI+HSRS, and HSRS are plotted as yellow dots, cyan pluses, green pluses, and red circles, respectively. IWI and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

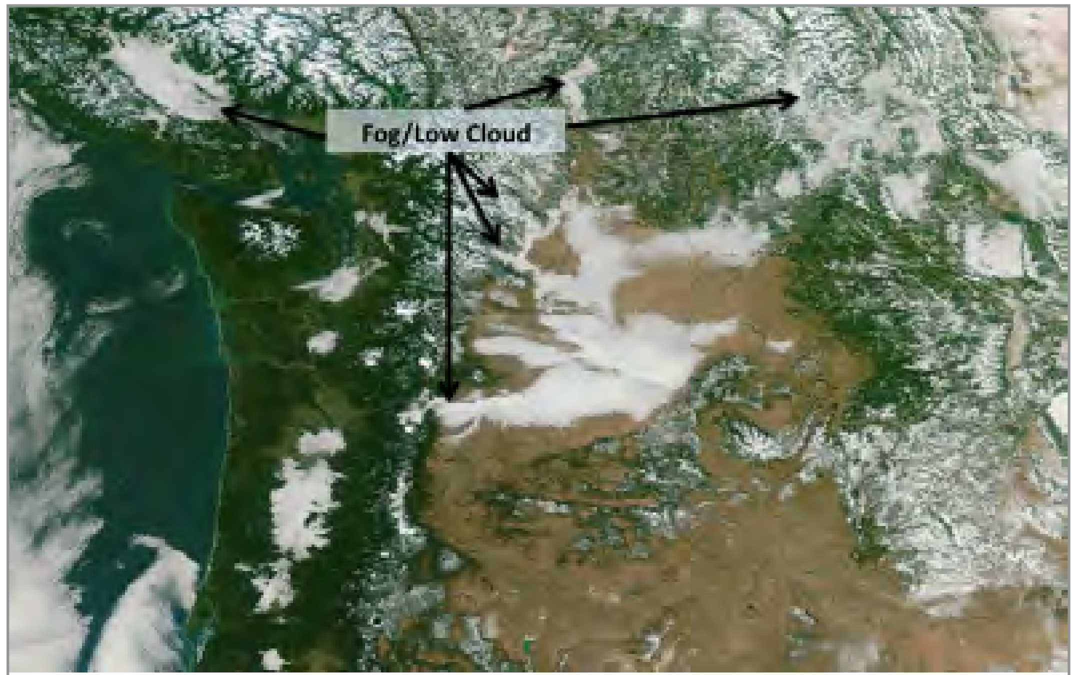

Figure 3. On 9 December 2011, VIIRS depicts an area of freezing fog over the Pacific Northwest of the United States.

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.