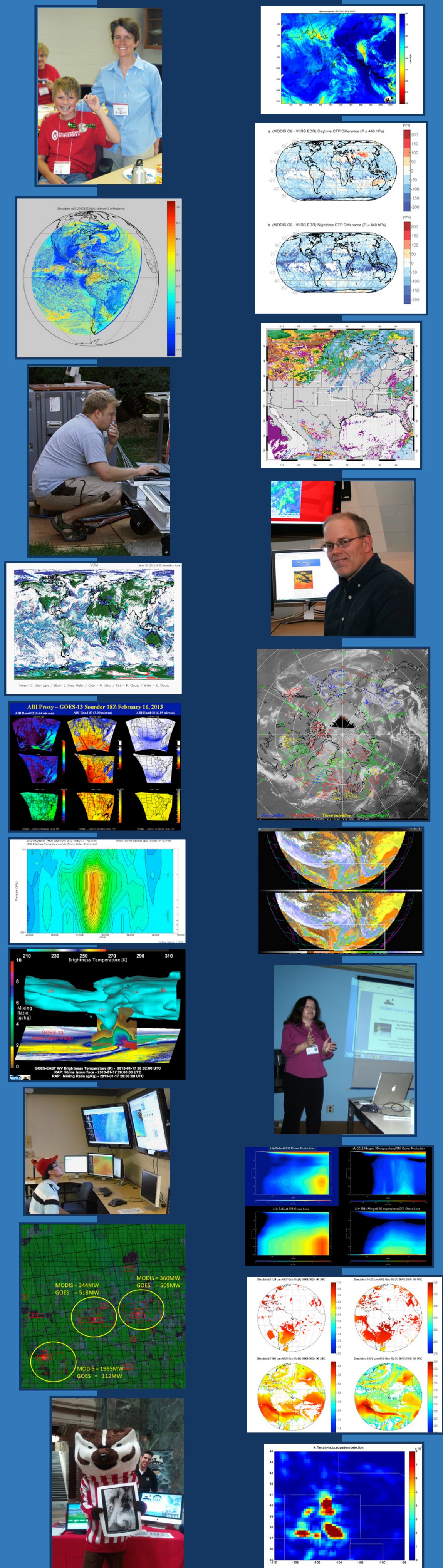

CIMSS

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

CIMSS Five-Year Review: The Science of CIMSS

Submitted by the
Cooperative Institute for
Meteorological Satellite Studies
University of Wisconsin-Madison

Meeting our Mission's Goals

...collaborating with NOAA,

...serving as a center of excellence in weather and climate studies,

...training the scientists and engineers of today and tomorrow...

18 September 2013

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Introduction

In this document you will find descriptions of CIMSS projects funded through the NOAA Cooperative Agreement. They range from efforts related to the current GOES instrument, preparations for GOES-R through risk reduction and algorithm development and proving ground activities, research to support the SuomiNPP and JPSS programs, improvements in the areas of data assimilation and modeling, calibration/validation, climate studies, and education and training. Through our research and outreach, we aim to help NOAA reach its own mission goals.

1 CIMSS Task 1B Support – Education and Outreach

CIMSS Project Leads: Margaret Mooney and Steve Ackerman

NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Outreach and Education

Project Overview

When NOAA established the Cooperative Institute for Meteorological Satellite Studies (CIMSS) in 1980 within the Space Science and Engineering Center (SSEC) at the University of Wisconsin-Madison, the location provided the perfect conduit to reach future generations of our scientific workforce. Since inception, CIMSS has supported NOAA and NASA sponsored student fellowships on an annual basis. In 1991 CIMSS established a summer workshop for high school students, one of the first in the nation, further supporting the pipeline to college and careers. In 2002, CIMSS began offering workshops for science teachers around the topics of satellite remote sensing, climate literacy and climate change. This proliferation of programming prompted CIMSS to formally establish an Education and Public Outreach Office in 2012. CIMSS EPO promotes satellite meteorology resources to advance weather and climate literacy through national initiatives like the American Meteorological Society's Weatherfest, Earth Science Information Partners (ESIP) meetings, Science-on-a-Sphere (SOS) support, and local events like student and teacher workshops and university science fairs. CIMSS EPO initiatives strive to maintain the highest level of excellence in education and outreach while working to ensure that CIMSS research products continue to provide maximum benefits to society.

Summary of Accomplishments and Findings

CIMSS has been a leader in educational software design for several decades, pioneering distance learning software and computer-based education tools like the popular applets which are highly interactive teaching and learning activities that allow users to explore physical processes such as tornadoes, air density effects on baseballs, thunderstorms, rainbows, snowflake crystals and more all on a computer screen. To keep up with software changes, CIMSS has been converting the applets from java to html5, a large but important task. More recently, CIMSS launched a unique technology lending library for middle and high school science teachers. The CIMSS iPad Library loans iPads to science teachers for an entire school year. The first units were distributed at the 2012 ESIP Teacher Workshop where participants learned about several climate-related Apps, including SatCam, an application for iOS devices where users collect observations of cloud and surface conditions coordinated with an overpass of the Terra, Aqua, or Suomi NPP satellite.

Over 400 high school students have attended the CIMSS Student Workshop through the years. An informal survey conducted via Facebook and postcards sent to the childhood homes of past participants indicated that respondents (n=12) had continued in science-related careers. For example, several cited graduate school studies while older workshop graduates listed jobs that ranged from the US Forest Service to masters-prepared social work to CIMSS research assistant.

CIMSS has also hosted over 500 middle and high science teachers at workshops in Madison and elsewhere, funded by NOAA, NASA and NSF with partners ranging from the AMS, other ESIP member organizations, Sally Ride Science, the Satellite Educators Association, and collaborating universities. CIMSS staff routinely makes guest presentations and Webinar lectures at workshops, conferences and science fairs. Collaborating to advance science literacy is a priority at CIMSS. This ethos is epitomized by CIMSS Director Steve Ackerman who takes every opportunity to share science in formal and informal education settings, such as the *WeatherGuys* blog (http://wxguys.ssec.wisc.edu/) and radio show.

Along with advancing weather and climate literacy via workshops, CIMSS EPO promotes satellite remote sensing via technology. On the UW-Madison campus this effort involves maintaining a 3D sphere similar but smaller than the Science On a Sphere (SOS) exhibits. CIMSS is also leading an effort to create regular visualizations for SOS exhibits using near real-time data such as the NCDC monthly climate reports and CPC seasonal outlooks. Concomitant to producing large animations for SOS with background content and trainings for museum docents, small videos (with audio) are being produced for mobile viewing and made freely available in the digital domain via a blog-style Web site called EarthNow (http://sphere.ssec.wisc.edu). Since the videos demonstrate what datasets look like on an SOS exhibit, they are spherically shaped (like Earth) and intuitively educational. For example, watching a monthly climate digest product conveys a global climate briefing in just a few minutes. Other Internet resources include the CIMSS Satellite Blog (http://cimss.ssec.wisc.edu/goes/blog/), Facebook, and on-line curriculums.

CIMSS is deeply involved in GOES-R education and outreach, starting with the development of a new module on next generation satellites which was added to the *Satellite Meteorology for Grades 7-12* on-line course. CIMSS/SSEC has also been creating Super Rapid Scan (1-minute interval) picture-in-a-picture animations for SOS exhibits to demonstrate future GOES-R capabilities. Finally, CIMSS has established the GOES-R Education Proving Ground to engage middle and high school science teachers and their students in activities based on the GOES-R mission. Working in teams of two, teachers will develop and test lesson plans related to GOES-R satellite instruments. Some or all of these teachers will present their lesson plans at the 27th Satellite Educators Conference, scheduled to take place in Madison at CIMSS in 2014.

Figure 1. Scenes from CIMSS Outreach activities.

Task 1 funds are also occasionally used to support graduate students at the start or end of their career. Two recent examples include:

Caitlin Hart: Thesis title: “Interpretation of Small Particle Signatures in Satellite Observations of Convective Storms.” Strong updrafts in mid-latitude convective storms eject supercooled water droplets into the tropopause and lower stratosphere. These droplets flash freeze at very low temperatures, causing them to be significantly smaller than the particles in the glaciated anvil top. Using the Daytime Cloud Optical Microphysical Properties (DCOMP) retrieval applied to GOES-East data, discrete minima are observed in the vicinity of the updraft core of severe thunderstorms in the effective radius retrieval. Several thunderstorms were analyzed for small particle signatures, which were compared to 30 dBZ NEXRAD echo to heights. An example from June 27, 2008 over Illinois of an effective radius retrieval using MODIS data indicates several particle signatures that were not observable in GOES retrievals. This example demonstrates the importance of spatial resolution in correctly identifying updraft-related small particle regions.

Agnes Lim: Thesis title: "Assimilation of AIRS Radiances of Short Term Regional Forecasts using Community Models.” The project assessed the forecast impact brought by assimilation of clear sky AIRS radiances on short term regional forecasts. The study used a community model (WRF) to carry out data assimilation and numerical weather prediction. Conclusions drawn from these study are non-operational systems need to be tuned prior to running experiments and that the assimilation of clear sky AIRS radiances is slightly positive for short term regional forecasts.

2 CIMSS Participation in the 2012 GOES Improved Measurements and Product Assurance Plan (GIMPAP)

2.1 Daytime Enhancement of UWCI/CTC Algorithm for Operation in Areas of Thin Cirrus

CIMSS Project Lead: Justin Sieglaff
CIMSS Support Scientists: Lee Cronce, Wayne Feltz
NOAA Collaborators: Michael Pavolonis, Andrew Heidinger
NOAA Strategic Goals Addressed:

- Serve society’s needs for weather and water information
- Support the nation’s commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The University of Wisconsin Convective Initiation/Cloud Top Cooling (UWCI/CTC) algorithm was developed by previous GIMPAP funded projects. The UWCI/CTC algorithm is designed to identify vertically growing and hence cooling convective clouds in GOES imagery both day and night. The cloud-top cooling rates are combined with GOES Cloud Phase retrievals to make convective initiation nowcasts. Forecasters at various test beds have evaluated the UWCI/CTC output over the past 3 convective seasons. While feedback from forecasters was generally positive, the largest deficiency identified by forecasters was the algorithm design to not operate in areas of cirrus clouds, even thin cirrus clouds. This decision was made because a cooling brightness temperature in presence of two cloud layers (upper thin ice cloud and lower water cloud) can be ambiguous. (The ambiguous nature is because a cooling brightness temperature in these situations can be any combination of thickening upper level ice cloud and/or vertically growing lower water cloud.) To resolve this deficiency identified by forecasters we propose to allow UWCI/CTC to diagnose/nowcast cloud-top cooling/convective initiation of newly developing convection covered by thin cirrus clouds during daytime hours. The inclusion and monitoring of temporal trends of retrieved GOES cloud optical depth during daytime hours within the UWCI/CTC algorithm has achieved this goal.

Summary of Accomplishments and Findings

During the past year, the UWCI/CTC algorithm has been modified to included the latest GOES visible optical depth (VOD) retrieval output. The inclusion of the GOES VOD has enabled detection of vertically growing cumulus clouds in regions of thin cirrus clouds, eliminating a previously identified deficiency of the UWCI/CTC algorithm. Figure 2 shows an example of the output of the UWCI/CTC prior to inclusion of GOES VOD retrievals and after inclusion of GOES VOD retrievals. The growing convection over eastern Illinois and western Indiana was largely missed in the original version of the UWCI/CTC algorithm (bottom left), but in the improved version is now successfully detected (bottom right).

The new version of the UWCI/CTC algorithm is being validated and compared to the output of the original algorithm version. The initial results indicate improved skill when validating against a variety of weather radar fields (e.g., reflectivity, radar estimated hail size, vertically integrated liquid). The validation efforts also revealed an additional unexpected improvement. In some cases the original UWCI/CTC algorithm missed the strongest vertical growth of a developing thunderstorm when the growth occurred *after* the cloud-top was sufficiently glaciated but the improved version more reliably detects these strongest periods of growth. The results of the validation study have been composed into a peer reviewed journal article that is currently in review (Sieglaff et al., 2013). The improved UWCI/CTC algorithm output continues to be processed in real-time and is available to National Weather Service Weather Forecast Offices and National Weather Service Experiments/Testbeds, including the NOAA Hazardous Weather Testbed.

A formal evaluation of the UW-CTC output is underway during the summer of 2013. The evaluation is being led by the NOAA/NWS Training Center in Kansas City and feedback is being collected from 12 NWS Weather Forecast Offices, primarily from the Central Region. Should the feedback be positive, combined with successful experiments at the NOAA Hazardous Weather Testbed, we will work with Chad Gravelle of the NOAA/NWS Training Center to advocate for the transition of UW-CTC from research to operations.

Publications, Reports, Presentations

Sieglaff, J. M., L. M. Cronce, and W. F. Feltz, 2013: Improving satellite-based convective cloud growth monitoring with visible optical depth retrievals. *J. Appl. Meteor. Climatol.*, In review.

Sieglaff, J. M. L. M. Cronce, and W. F. Feltz, 2013: Using UW-Cloud Top Cooling Rates in Convective Storm Warning Experiments. *2nd National Weather Service Eastern Region Virtual Satellite Workshop.*

Sieglaff, J. M. L. M. Cronce, and W. F. Feltz, 2012: Using UW-Cloud Top Cooling Rates in Convective Storm Warning Experiments. *37th Natl. Wea. Assoc. Annual Meeting*, Madison, WI, Natl. Wea. Assoc.

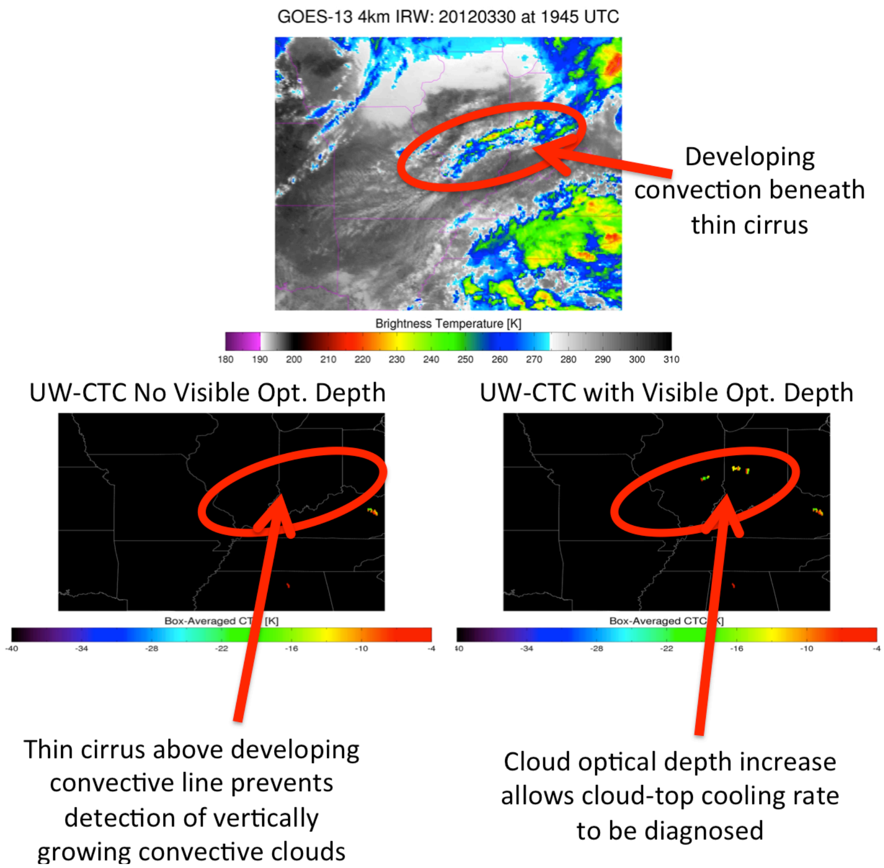

Figure 2. Top panel is GOES-13 11 µm brightness temperature valid at 1945 UTC 30 March 2012; developing convection beneath thin cirrus clouds is highlighted over eastern Illinois and central Indiana. Bottom left panel is UW-CTC output without visible optical depth and bottom right panel is UW-CTC output with visible optical depth both valid at 1932 UTC 30 March 2012. The addition of visible optical depth to the UWCI/CTC algorithm enables detection of these storms that were missed with the original version of the algorithm.

2.2 Fusing GOES Observations and RUC Model Output for Improved Cloud Remote Sensing

CIMSS Project Lead: Andi Walther
NOAA Collaborators: Andrew Heidinger, NOAA/NESDIS/STAR, Stan Benjamin NOAA/OAR
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The GOES-R AWG cloud algorithms have been modified for and are running on current GOES data. Our validation indicates that these data are high quality and the results approach the expected GOES-R performance for many scenarios.

We are working with the RAP team to optimize the 3-d cloud hydrometeor distributions using the initial RAP analysis and the results (including the uncertainties) from the Optimal Estimation (OE) cloud retrievals with the existing radar and METAR data. We are using CALIPSO and CloudSat data when possible for verification.

The RAP team will develop the techniques to use the GOES cloud properties and lead the efforts to ensure the satellite derived 3d hydrometeor fields are beneficial to the RUC/RAP. The Rapid Refresh (RAP) mesoscale model system replaced the RUC as an NCEP operational model in May 2012. The RAP uses a similar cloud/ hydrometeor analysis (within GSI) as the RUC, in which 3-d hydrometeor fields for cloud water and ice mixing ratios modified based on current METAR ceiling and GOES cloud retrieval data. The RAP is the only current NCEP model/ assimilation system to use either GOES or METAR cloud data, making it one the leading NWP model in its use of cloud information from satellites. As part of the project, we will implement a real-time feed of GOES-R analog cloud products from CIMSS to the ESRL RAP team to allow for experimentation. The GOES-R AWG analog products used here generated using the NESDIS CLAVR-x system.

Summary of Accomplishments and Findings

Currently, direct use of the cloud fields observed by satellites has been found to introduce significant high relative humidity (RH) biases relative to radiosonde verification. In this project, we are developing techniques that allow the Rapid Refresh (RAP) to use the GOES-R cloud products without inducing the RH biases.

Some details on the issue and the work to resolve it are as follows:

- It was discovered in Dec 2010 that cloud-building from NASA GOES cloud retrievals resulted in a significant RH moist bias and higher RH forecast error.
- To solve this problem, we further examined the cloud assimilation with the GOES-R AWG products and developed ways to use the retrieval uncertainties with the RUC/RAP background fields and improve mixed-phase saturation definition to reduce the RH biases.
- Recent work has focused on utilizing the GOES-R Effective Cloud Amount (ECA) field to perform more selective clearing and building of clouds

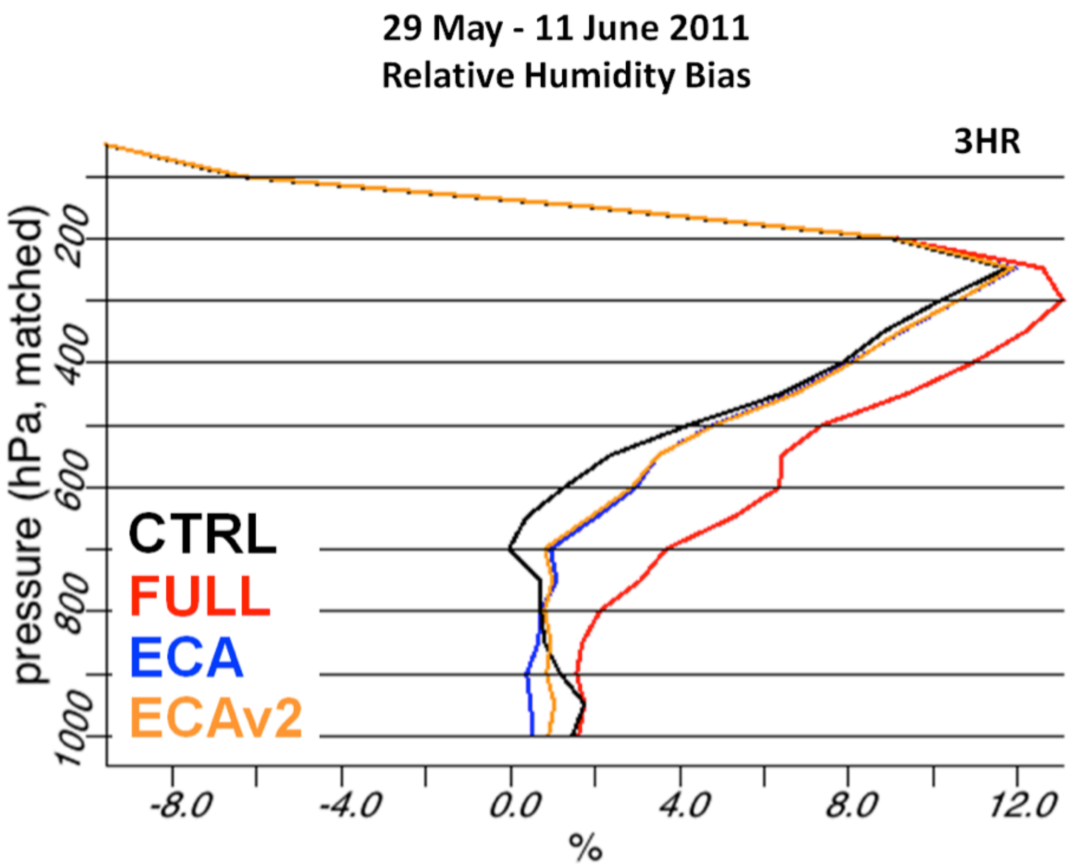

Figure 3. Impact of cloud building on RAP relative humidity biases. CONTROL: RAPV2, with cloud building below 1200m. FULL BUILDING: Full column building using a cloud top pressure-based cloud fraction. ECA BUILDING: Full column building using effective cloud amount (ECA), which uses cloud emissivity as a proxy for true cloud fraction. ECA BUILDINGv2: ECA BUILDING, but no clearing from partially cloudy regions. ECA is the effective cloud amount from the NOAA AWG algorithms runs in CLAVR-x. Results indicate ECA filler improves biases compares to FULL (unfiltered) cloud building

Significant progress on 13km Rapid Refresh cloud assimilation:

- Baseline testing completed confirming that full column cloud building introduces mid-level high moisture bias, while cloud building for GOES cloud top < 1200m AGL (above model ground level) does not introduce bias.
- Generation of hypotheses and initial testing results indicate that use of 75% ECA threshold for clearing / building allows full-column cloud building without introducing moist bias (the target for our GIMPAP project), but associated skill degradation for ceiling analysis and forecasting occurs.
- Refinement in use of ECA to allow separate level and threshold dependencies for clearing and building of clouds has yielded the desired results of full-column cloud building, without introducing high relative humidity bias and without degrading ceiling forecast skill, for a warm season (29 May – 11 June 2011) RAP retrospective assessment (see Figure 4). This is illustrated in Figure 3, which show two different sets of error statistics for each of four CLAVR-x related RAP retrospective experiments. As can be seen in the relative humidity (RH) bias curves on the left, introduction of a simple full column cloud building produces a significant positive RH bias throughout much of the troposphere (red "FULL" curves relative to black "CTRL" curves). Introduction of a

more selective building algorithm using the Effective Cloud Amount field of the CLAVR-x data reduces the positive RH bias, but also degrades the ceiling forecast skill (blue "ECA" curves relative to red "FULL" curves). Finally, modification of the algorithm to make no changes to the background cloud hydrometeor fields (building or clearing) for regions with intermediate ECA values (indicating partly cloudy conditions) yields the desired results of a reduction in the high RH bias, with little degradation in the ceiling forecast skill (yellow "ECAv2" curves relative to all other curves).

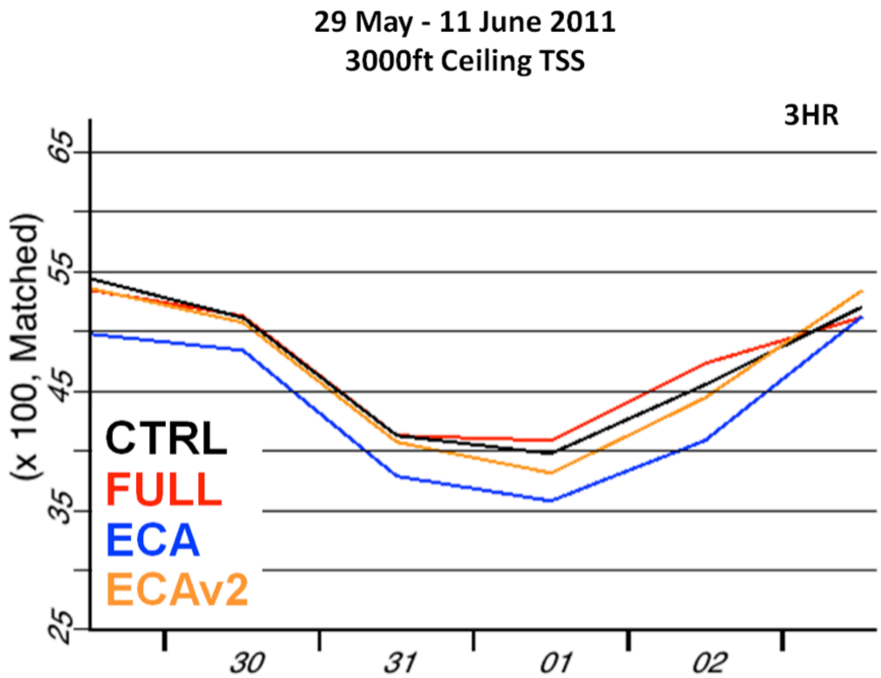

Figure 4. Impact of cloud building on RAP low cloud ceiling forecast performance. Definitions of experiments are given above. Results indicate the ECAv2 does not impact ceiling forecast appreciably.

Publications, Reports, Presentations

RAP model experiments using GOES-R AWG Cloud Products in CLAVR-x data was showcased in an oral presentation and a poster presentation at the American Meteorological Society Annual Meeting in Jan 2013 in Austin, TX.

Oral, presented in the 16th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS):
Application of GSI for cloud, radar, and near-surface assimilation within 13-km RAP and 3-km HRRR hourly updated forecast systems. Patrick Hofmann, CIRES/Univ. of Colorado, Boulder, CO; and M. Hu, S. Benjamin, S. S. Weygandt, C. R. Alexander, and D. C. Dowell.

Poster, presented in the 16th Conference on Aviation, Range, and Aerospace Meteorology (ARAM):
Improvements to ceiling/visibility forecasts from the 13-km RAP and 3-km HRRR hourly updated forecast systems. Patrick Hofmann, NOAA/ESRL, Boulder, CO; and M. Hu, S. Benjamin, S. Weygandt, and C. Alexander.

2.3 GOES Imager Sky Cover Analysis Product

CIMSS Project Lead: Jordan Gerth
CIMSS Support Scientists: James Nelson III, Anthony Schreiner
NOAA Collaborators: Robert Aune (ASPB), Andrew Heidinger (ASPB), Jeff Craven (National Weather Service Weather Forecast Office Milwaukee/Sullivan, WI), Eric Lau (National Weather Service Pacific Region Headquarters, Honolulu, HI)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The goal of this project is to increase the frequency of Cloud Mask, Effective Cloud Amount (ECA), and Cloud Top Pressure (CTP) products from the current GOES, and eventually GOES-R, imagers. These cloud products are used to produce an average sky cover grid, nationwide, once per hour using multiple scans. Subsequent work will focus on other methods and inputs to complete the grid and produce a blended analysis where ECA and CTP are not valid indicators of sky cover – the amount of the celestial dome covered with cloud visible to a human observer at a point on earth – as defined by the National Weather Service's operational requirements.

Numerous NWS forecasters have directly requested such a product to verify an operationally required forecast sky grid because (1) purely numerical weather prediction methods do not account for radiative transparency of clouds and (2) current satellite-based techniques and algorithms, used alone or in existing analysis tools, do not match the forecasters' interpretation of the NWS-established definition.

This two-year project began in 2012. Previous efforts at CIMSS in this area focused on the development of cloud products using the GOES Sounder. This work follows CIMSS research topics during the 1990s to create a continental United States cloud climatology based on GOES Sounder cloud retrievals, and develop a point-based satellite cloud product using information from the GOES Sounder.

Summary of Accomplishments and Findings

An automated composite image of ECA is now available from the GOES-13 and GOES-15 imagers with every routine scan. A celestial dome ECA is produced from this gridded ECA. The GOES Imager Celestial Dome ECA is an average of the standard effective cloud emissivity within a box of 11 by 11 pixels, centered on each grid point, and includes a correction for high cloud where the cloud fraction and cloud probability are greater than 95%, but the effective cloud emissivity is less than 50%, and the cloud phase consists of ice. In such cases, the adjusted effective cloud emissivity is the product of the cloud fraction and cloud probability, divided by 100%. The GOES Imager Sky Cover Product is a time-average of the celestial dome ECA within a one-hour window. The average is all scans after the valid time, within one hour. Figure 5 shows the GOES Imager Effective Cloud Amount and GOES Imager Sky Cover Product for the same initial valid time. The intent is for the GOES Imager Sky Cover Product to provide a better depiction of cloud cover from the perspective of the human observer.

These are available in a gridded format, composited to the same grid at approximately 10 km horizontal resolution. The current domain is National Centers for Environmental Prediction

(NCEP) Grid 197, which covers the continental United States. Final output will match the formatting standards of General Regularly-distributed Information in Binary form 2 (GRIB2).

A Hawaii domain, NCEP Grid 196, is also available.

In addition, gridded surface observations of sky cover over the United States are used in concert with the new GOES Imager Sky Cover Product to produce a blended sky cover analysis. The blended sky cover analysis leverages the strengths from each observing platform. In the case of the geostationary satellite, the strength is identifying clear skies. Surface observations are better at quantifying the amount of cloudiness when it exists and is reported. The blended sky cover analysis uses the GOES Imager Sky Cover Product over open oceans, where surface observations are generally unavailable.

Applying relationships between sky cover, mixing ratio, and relative humidity from peer-reviewed literature, a new optimal sky cover quantity is produced from High-Resolution Rapid Refresh (HRRR) output, which is a result of linear and mixed integer optimization of the mean absolute error between moisture variables and the optimal sky cover produced from the blended sky cover analysis. An optimal HRRR sky cover analysis is produced in addition to three-, six-, and nine-hour forecasts. This is compared to the HRRR cloud cover output and validated against the blended sky cover analysis.

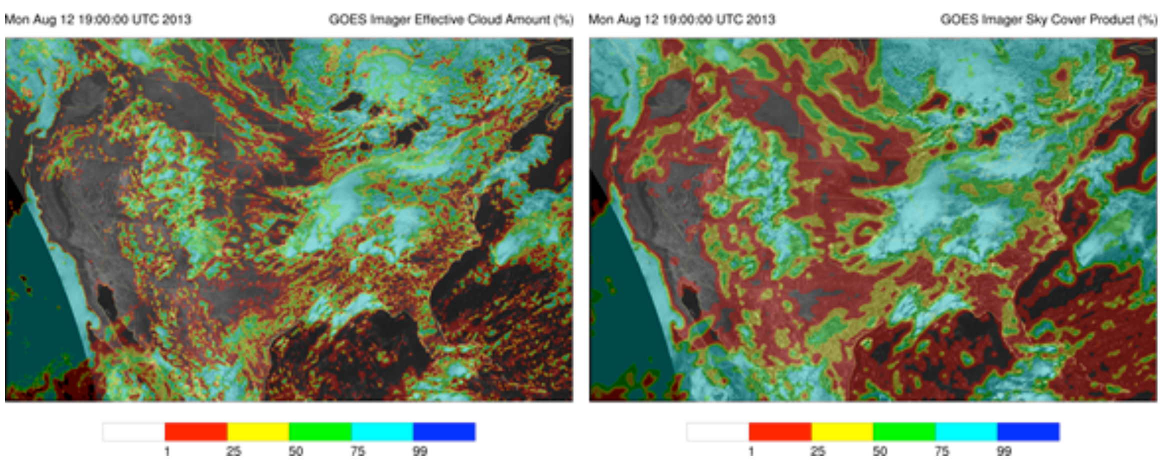

Figure 5. This two-panel plot shows the original GOES Imager Effective Cloud Amount (left) and the GOES Imager Sky Product (right), which accounts for the type of cloud, celestial dome, and cloud trend over the following hour, valid at 19:00 UTC on 12 August 2013. The background image is a visible band from GOES-13 (GOES-East), valid at the same time.

Publications, Reports, Presentations

Gerth, Jordan: 2012: Linear Optimization as a Solution to Improve the Sky Cover Guess, Forecast. National Weather Association Annual Meeting, Madison, Wisconsin, October 10, 2012 (oral presentation). Also presented during Eastern Region Virtual Satellite Workshop, February 26, 2013.

Gerth, Jordan: 2013: Sky Cover: Shining Light on a Gloomy Problem. CoRP Symposium, Madison, Wisconsin, July 23, 2013 (oral presentation).

2.4 Improvements to the Advanced Dvorak Technique (ADT)

CIMSS Project Leads: Chris Velden and Tim Olander
CIMSS Support Scientist: John Sears
NOAA Collaborators: Mike Turk (SAB), Jack Beven (NHC)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications

Project Overview

The Advanced Dvorak Technique (ADT; Olander and Velden, 2007, *Weather and Forecasting*) is a satellite-based algorithm designed to provide objective estimates of hurricane intensity from GOES and other geostationary satellites. Its long-term development has been partially supported by the NOAA GIMPAP program, and the latest algorithm has recently been transitioned through a NESDIS PSDI effort into operations at the Satellite Analysis Branch. The National Hurricane Center (NHC) now routinely accesses the ADT data as part of its hurricane analysis and forecast suite of tools.

User feedback drives further development or refinement of the algorithm. In the latest evaluations of the ADT by the aforementioned operational Tropical Analysis Centers, one of the primary requests is to extend the applicability of the algorithm to operate on pre-depression systems. These systems are typically the tropical disturbances that warrant an "Invest", and often have Dvorak T-numbers of 1.0 or 1.5. The current ADT must "wait" for the first official Center bulletin identifying an invest system as a Tropical Depression, to begin supplying objective intensity estimates. The forecasters would like an algorithm that objectively identifies weak systems, and picks up the ones that eventually develop into tropical cyclones. In effect, the request is to develop a "front end" for the current ADT to help with guidance on TC systems undergoing genesis, and that is what the project is currently addressing.

Summary of Accomplishments and Findings

The primary accomplishment over the last 5 years was getting the research version of the ADT into operations at SAB. The ADT now routinely produces operational hurricane intensity estimates on a global basis for users of the NESDIS SAB products.

As mentioned above, the most recent user request is for the ADT to be able to operate on pre-genesis tropical disturbances, and this is the primary current goal of the CIMSS Tropical Cyclone group scientists working on this project. A prototype algorithm to identify and track coherent tropical cloud clusters (TCCs; candidate TCs) has been developed at CIMSS (the Tropical Cloud Cluster Tracking (TCCT) algorithm. Adaptation of this algorithm to operate on real-time imagery has been completed, and assessment is underway (example, figure below). A subsequent methodology to estimate the likelihood of TCC development (probabilistic) has been obtained from collaborators on the project.

An example of the CIMSS TCCT is given in the figure below. Clusters are identified by the combination of four parametric fields. The first two fields are the percent of pixels within empirically-prescribed radii of each grid point in the IR image domain (1-deg. Resolution grid), that exceed either the 255K or 230K brightness temperature (BT) thresholds, respectively. The third field is a correlation analysis, created by comparing a BT template from a prototypical tropical storm to all grid points in the selected image. The last field is a latitude function, which maximizes at 10 degrees latitude and minimizes outside the climatological zone (95% likelihood) for TC genesis defined by the HURDAT dataset. These four fields are averaged into single "final score," where local maxima must exceed an empirically-determined 0.45 in order to be tracked. In the event that multiple maxima occur within 2 degrees of one another, all such maxima are iteratively averaged by a weight assigned from the 230K percentage until only a single cluster remains. This algorithm is currently being modified and evaluated.

Publications, Reports, Presentations

Olander, T. and C. Velden, 2012: The Current Status of the UW-CIMSS Advanced Dvorak Technique, 30th AMS Hurricanes and Tropical Meteorology Conference, Ponte Vedra Beach, FL, April 15-20.

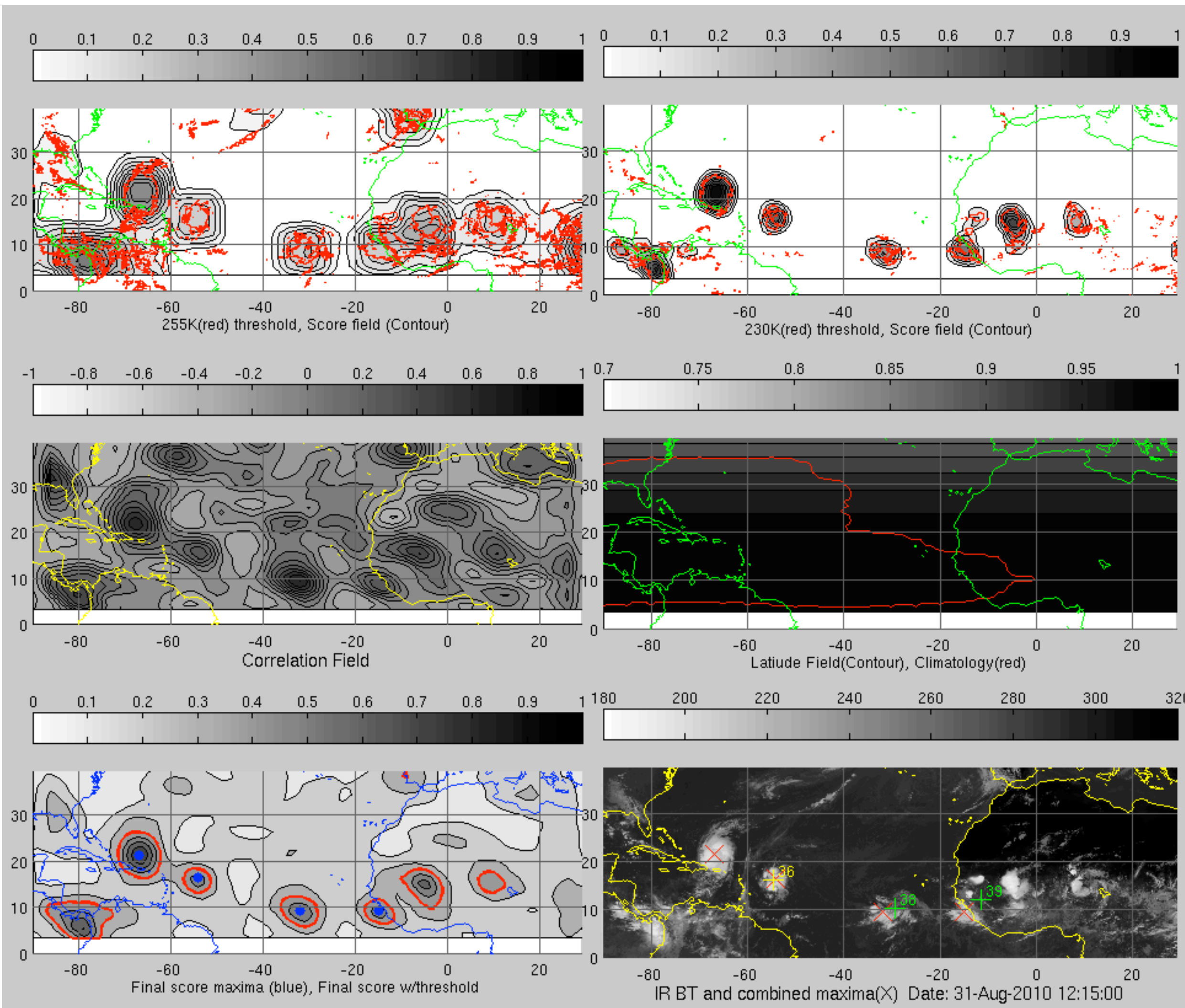

Figure 6. Example from 31 Aug., 2010. Top Left: IR 255K BT contour (red), 255K BT scoring field [%] shaded. Top Right: IR BT 230K contour (red), 230K BT scoring field [%] shaded. Middle Left: Correlation field of IR BT with prototype tropical storm template (shading). Middle Right: Climatological extent of Atlantic genesis in red contour, shading for latitude weighting. Bottom Left: Combined BT scoring field [%] shaded, local scoring maxima (blue), and threshold (0.45) for accepted maxima (red contour). Bottom Right: IR image and final cluster algorithm center fixes (red X), and PREDICT field campaign designated centers (crosses/numbers; yellow=TD, and system north of Puerto Rico is Hurricane Earl).

2.5 GOES Biomass Burning Algorithm and Application Improvements

CIMSS Project Lead: Chris Schmidt
CIMSS Support Scientists: Jay Hoffman, Jason Brunner, Elaine Prins (UW-Madison/CIMSS-Consultant)
NOAA Collaborators: Mark Ruminski (NOAA/NESDIS), Robert Rabin (NOAA/NSSL), Phillip Bothwell (NOAA/NWS/SPC)
NOAA Strategic Goals Addressed:

- Understand climate variability and change to enhance society's ability to plan and respond
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

The GOES Wildfire Automated Biomass Burning Algorithm (WFABBA) has been an Operational product since 2001. The upgraded WFABBA Version 6.5 (v65) has been running at NESDIS Operations since 2010, providing fire detections and characterizations, as well as metadata, for the GOES satellites and the Meteosat and MTSAT series of satellites, as well as Korea's COMS. The WFABBA data is used in NOAA's Hazard Mapping System (HMS). While the algorithm performs well overall, the false alarm rate can be lowered. This project researches and develops techniques to reduce false alarms in WFABBA data, an issue that has been a challenge for the HMS operators. GIMPAP tasks had previously funded work analyzing WFABBA data, work on emission projects, collaborations with users and international partners, and the research of a "fire potential" product. The "fire potential" product utilized the Version 6.5 WFABBA database to create a climatology of wildfires from the WFABBA data (1995-2011) and examined whether that data could be used in conjunction with other ancillary information to improve upon fire weather indices. Support for India's INSAT-3D will be created if the data becomes available. CIMSS continues to work with GEOSS, GTOS GOFC/GOLD, CEOS, and CGMS to foster the development and implementation of a global geostationary fire monitoring network with international involvement. CIMSS also continues to support improved product utilization by supporting integration of the WFABBA into smoke and aerosol forecasting efforts.

Summary of Accomplishments and Findings

Work on false alarms began by examining the long-standing 3.9 µm band saturation point issue that has impacted product quality and the false alarm rate. For the GOES satellites it has been observed that the saturation point of the 3.9 µm band will change over time, in some cases by a Kelvin or more. The change can be due to a number of factors, but primarily appears to be the accumulation of material within the optical assembly, attenuating the signal and causing the saturation point to rise. Occasionally that material is "baked off" and the saturation point will drop abruptly. These changes have a substantial impact on the quality and reliability of fire detection and characterization, causing both false alarms and missed detections. When the saturation point is under-estimated a large number of pixels are classified as saturated fires which may in fact not be. This situation can lead to false alarms that are not true fire pixels but because they are treated as saturated fires do not receive all of the screening that a non-saturated potential fire pixel does. It also leads to mischaracterization of the fire. A saturated pixel should not be characterized for size, temperature, and fire radiative power (FRP) as the radiance data does not reflect the properties of the fire and at best represents a lower bound for the FRP. Size and temperature are useless for a saturated pixel given the nature of the retrieval.

When the saturation point is set too high, legitimate fires may in fact be missed if they are very large. The following figure illustrates this situation for GOES-11 during a large fire event in Southern California in October 2007. The large fire passes the contextual algorithm appearing as a large area of uniformly hot surface because the algorithm classifies it as hot, unsaturated surface. At the time the value was set to 340.0 K, based on earlier analysis of GOES-11 data. The temperature had in fact dropped and was approximately 337.9 K for one detector and 337.7 K for the other on that day, so the saturation point was set to 337.5 K and the algorithm was rerun. It is important to set the saturation point a little low given the slight daily variations it shows due to various factors onboard the spacecraft (temperature of the body of the satellite and time of day seem to be related to those variations). The dynamic determination of the saturation point is being tested to address both of these issues.

Figure 7. Complex of major fires, GOES-11 3.9 µm band, 21 October 2007 (center); Original WFABBA metadata mask, fires in red (left); WFABBA metadata mask with adjusted saturation point, fires in red (right)

One of the biggest changes with the new version of the WFABBA was the processing of all available satellite data. This change led to issues with the temporal filter, which had been designed for 30 minute and greater data frequency, issues that plagued the analysts at NOAA's HMS. The old technique required a minimum of 6 scans in the preceding 12 hours to initiate the filtering and counted a fire as "temporally filtered" if it was detected two times or more. CIMSS took a number of case studies and ran a set of scenarios on them to see how different filtering criteria would modify the results. The raw results were broken down into 29 categories that were a combination of scenarios such as "the previous fire was detected within 5 (or 5-15, or 15-30, or 30-60, or 60-180) minutes", whether the fire spanned more than 3 hours, and by the fraction of times in the window when it was possible to see a fire. The spatial window was varied from just the fire pixel's location itself to windows that extended out by 1, 2, and 3 pixels in every direction. The 7x7 box approximates the old filtering's use of 0.1° by 0.1° boxes.

The distribution of fires that passed various criteria varied substantially case by case in a fashion reflective of the scan schedule. The case studies included multiple days with Rapid Scan Operations (RSO) and Super RSO (SRSO) scan schedules, as well as non-GOES schedules from MSG and MTSAT. The changes due to scan schedule and geographic coverage were most evident in the GOES-14 cases in late August of 2012 (2012235-2012239; 22-26 August 2012), which were all during SRSO operations. Days 2012235 and 2012236 had SRSO centered over the western US. On day 2012237, the coverage was changed to track a tropical storm.

Correspondingly, the number of fires detected multiple times in a short temporal window dropped tremendously, and the number of single detects, a number of which were likely false alarms in this case, increased as the coverage moved to the tropics. GOES-13 was also in RSO mode on 2012235, and the fraction of temporal matches made within the first 30 minutes correspondingly increased due to the larger number of scans (as often as every 5 minutes).

The analysis showed that anywhere from 5-50% of the fires passing the temporal filter on a given day are doing so because the nearest temporal match is within 30 minutes or less, which corresponds to the concerns raised by HMS operators about increased false alarms. Not all of those fires are false alarms, however. As a result, CIMSS is exploring changes to how temporal filtering is presented. Instead of a binary distinction between "filtered" and "unfiltered", users may be presented with information on when the first and last detections were made and the number of clear scans in that time frame, allowing users to determine their own criteria as to whether to keep or discard the fire pixel. CIMSS will coordinate with the HMS team in developing the outputs and changes.

The GIMPAP project of the previous funding cycle focused on the development of a "fire potential" product that used the WFABBA database of fire detections (1995-present) in conjunction with databases of temperature, dewpoint, Fosberg Fire Index, and lightning strikes to see if any of those pieces of information (or some combination thereof) correlated to higher rates of detected fires. The research did show some correlation between detected fires and lightning data in certain regions, but the signals were relatively small. Due to that lack of strong signal an operational product was not pursued, but further research on the relationship of WFABBA detected fires to lightning could yield useful results.

Publications, Reports, Presentations

Brunner, Jason C.; Schmidt, C. C.; Prins, E. M.; Hoffman, J. P.; Schroeder, W. and Csiszar, I.. Western Hemisphere diurnal fire activity 1995-2011: Description and initial fire trend analysis of the GOES-East Version 6.5 WF-ABBA data archive. Boston, MA, American Meteorological Society, 2012, abstract only.

Brunner, Jason C.; Schmidt, C. C.; Prins, E. M.; Hoffman, J. P.; Schroeder, W. and Csiszar, I. A. Western Hemisphere diurnal fire activity 1995-2012: Description and initial fire trend analysis of the GOES-East version 6.5 WFABBA data archive. Conference on Applied Climatology, 20th, Austin, TX, 6-10 January 2013. American Meteorological Society, Boston, MA, 2013, abstract only.

Schmidt, Christopher C.; Prins, E. M.; Hyer, E.; Hoffman, J. P.; Brunner, J. and Reid, J. S.. The global geostationary Wildfire ABBA: Current implementation and future plans. Boston, MA, American Meteorological Society, 2012, abstract only.

2.6 Using GOES and NEXRAD Data to Improve Lake Effect Snowfall Estimates

CIMSS Project Lead: Mark Kulie
CIMSS Support Scientists: Andi Walther, Ralf Bennartz
NOAA Collaborator: Andrew Heidinger
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally

sound transportation

- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

This lake effect snow (LES)-related project is a new GOES and NEXRAD data fusion research endeavor that has just completed its first year of work. LES bands commonly occur in the Great Lakes region and are prolific snowfall producers, yet the NEXRAD network often does not effectively observe LES since the lowest radar elevation angle can overshoot shallow LES structures. In an effort to mitigate these NEXRAD observational shortcomings and improve nowcasting and remotely sensed quantitative snowfall estimates for LES events, we utilize satellite products to improve both nowcasting capabilities and remotely sensed snowfall estimates. Methods to extend NEXRAD coverage in regions currently devoid of radar observations are being developed by first collocating NOAA Algorithm Working Group AWG cloud products and NEXRAD-derived snowfall rates within 100 km of Great Lakes radar sites to 'calibrate' AWG products for LES events. Next, empirical relationships between NEXRAD-derived snowfall rate and AWG cloud properties are being developed using this collocated dataset to enable snowfall rate estimates that are generated directly from AWG products. We are also collaborating with the Marquette, MI National Weather Service Forecast Office (NWSFO) – and eventually other Great Lakes NWSFO's - during the testing phase of this project for both operational feedback and snowfall estimate validation.

Summary of Accomplishments and Findings

A database has been compiled for 2012-2013 Great Lakes LES events for testing purposes, and software has been written and tested to collocate radar and satellite products. The matching methodology has been recently refined to improve the NEXRAD-AWG product collocation procedure by interpolating the native radar data to a cartesian grid at the 1 km height level that mimics the satellite products' resolution. NEXRAD reflectivities (Z) are then converted to snowfall rates (S) using a Z-S relationship ($Z=115S^{1.67}$) that is appropriate for NEXRAD radars sensing lake effect snow events (Rasmussen et al., 2003; Braham 1990). The top panels in Figure 8 illustrate both NEXRAD observations and radar-derived snowfall rates associated with a LES event near Marquette, MI. The radar snowfall rates are then spatio-temporally matched with the nearest satellite product (e.g., cloud water path (CWP) shown in Figure 8).

The first major task of this project is to identify AWG products that are best correlated to NEXRAD-derived snowfall rates. While some products (e.g., cloud top pressure) struggle to distinguish finer LES structures and are not well correlated with the NEXRAD snowfall rates, other AWG products (e.g., CWP) can resolve the detailed LES features indicated by NEXRAD observations (Figure 8). An empirical fit between CWP and snowfall rate to derive a first-order relationship between these two geophysical parameters is also shown in Figure 8.

Figure 9 shows the direct application of this sample snowfall rate-CWP empirical relationship to provide snowfall estimates for a LES case on 17 February 2013 that is not effectively sampled by radar. The LES event in Figure 9 contains multiple mesoscale vortices along a mid-lake convergence band and is a prime example of how potentially useful the satellite snowfall product can be to assess the relative snowfall intensity of LES cloud structures out of NEXRAD range, especially for monitoring and providing advanced warning for localized snow squalls that develop over the lakes and progress toward land and/or snow bands that directly affect regions without adequate LES NEXRAD coverage.

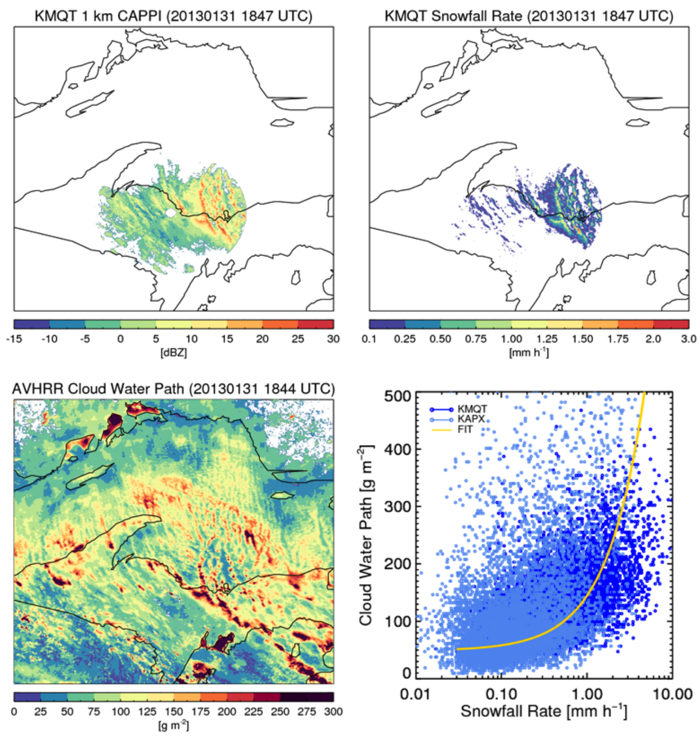

Figure 8. KMQT reflectivity (top left), radar-derived snowfall rate (top right), and AVHRR cloud water path (CWP; lower left) from 31 January 2013. Collocated NEXRAD-derived snowfall rates from the KMQT (dark blue) and KAPX (light blue) radar sites and AVHRR CWP are also shown (lower right). The empirical best fits between CWP and snowfall rate is also indicated in the lower right panel (yellow line).

Year 2 goals are to bolster the radar-satellite matching dataset to refine the empirical AWG-radar fit, stratify matching results by LES regime, and compare matchup results using lower resolution GOES AWG products. Furthermore, Z-S relationships will be refined by comparing radar-derived snowfall accumulations with the ground-based observations.

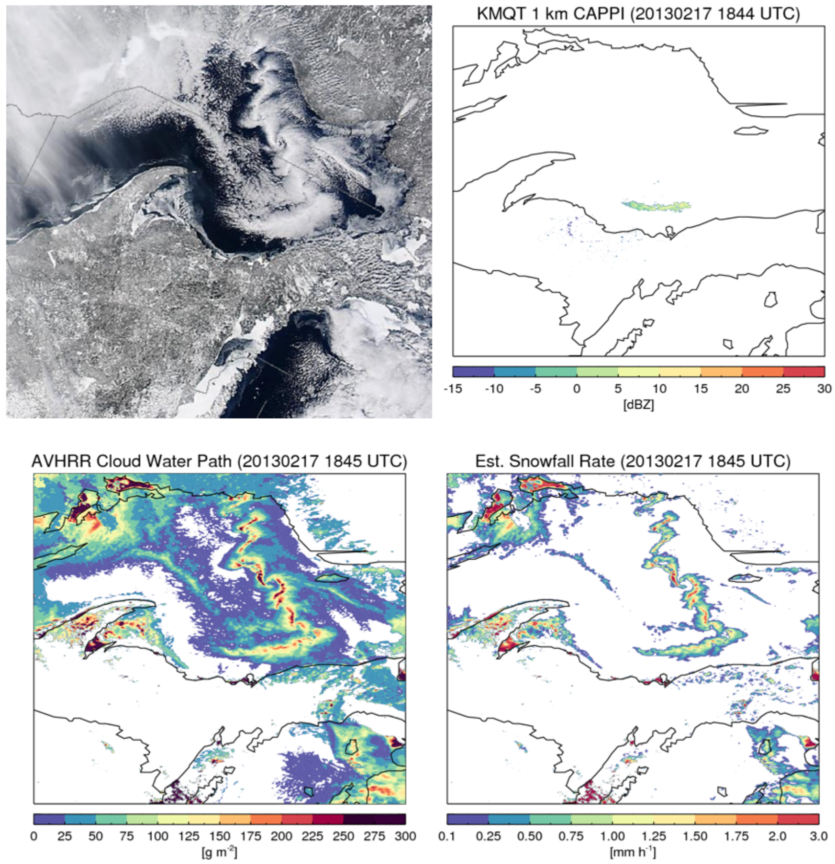

Figure 9. AQUA MODIS true color (top left), KMQT reflectivity (top right), AVHRR CWP (lower left), and CWP snowfall estimates (lower right) for a LES case on 17 February 2013. The AVHRR snowfall rates are estimated from the CWP-NEXRAD snowfall rate line fit shown in Figure 8.

Publications, Reports, Presentations

Anticipated presentation at the upcoming AMS 4th Conf. on Transition of Research to Operations.

2.7 Enhanced Downslope Windstorm Prediction with GOES Warning Indicators

CIMSS Project Lead: Anthony Wimmers
NOAA Collaborator: Dan Lindsey (NOAA STAR / CIRA)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

This project seeks to improve the prediction of downslope wind events at select western U.S. locations using a combination of GOES imagery and output from numerical models. A statistical method was previously developed by Dr. Lindsey under NOAA funding to predict downslope windstorm events in Ft. Collins, CO using model output such as midtropospheric directional shear and thermal stability. Our project extends this work to add GOES predictors that are not well resolved in numerical models (such as evidence of orographically-forced mesoscale vertical motion), as well as to create similar models for other locations that are prone to severe downslope winds.

The objectives set for FY2012 are:

- Choose surface stations and collect several years of data
- Collect and examine North American Regional Reanalysis (NARR) data to determine ideal model predictors for each site
- Develop an updated version of the GOES-derived downslope signatures algorithm to work with the prediction model

Summary of Accomplishments and Findings

Our accomplishments in meeting the objectives for the year are as follows:

- Choose surface stations and collect several years of data.
  As a first step in the project we are using the Fort Collins, CO station. In coordination with Randy Graham at the SLC NWS office, have selected three additional stations in Utah. Surface observations have been obtained for these stations, and the North American Regional Reanalysis (NARR) dataset will be used to help select the numerical model predictors.
- Collect and examine NARR data to determine ideal model predictors for each site.
  NARR data have been collected and extensively studied for the Fort Collins location. We have also recently gathered the NARR data for observed high wind cases at Hill Air Force Base in Utah (north of Salt Lake City, just west of the Wasatch Mountain Range). A preliminary look at the conditions favorable for downslope windstorms at this location show some promising signals. Figure 10 shows the means of several fields for the observed high wind cases at Hill AFB. One noteworthy signal is the 700 mb easterly wind speed maximum in southwestern Wyoming; this will likely be used as one of the non-satellite predictors.
- Develop an updated version of the GOES-derived downslope signatures algorithm to work with the prediction model.
  GOES Water Vapor (WV) imagery was collected for about 1250 events to examine potential predictors for Ft. Collins high wind events. A set of 9 potential predictors was tested using a logistical regression method, and several of the predictors showed great promise in improving the forecasts for downslope winds. One example is shown in below in the next figure: the “Terrain Pattern Score.” This derived product indicates the amount of alignment between the patterns in WV brightness temperatures and the terrain underneath, which serves to identify downslope wind conditions such as drying patterns and updraft-induced cloud banks. Figure 11 is from 4 January 2006 at the time of an observed downslope windstorm in Ft. Collins.

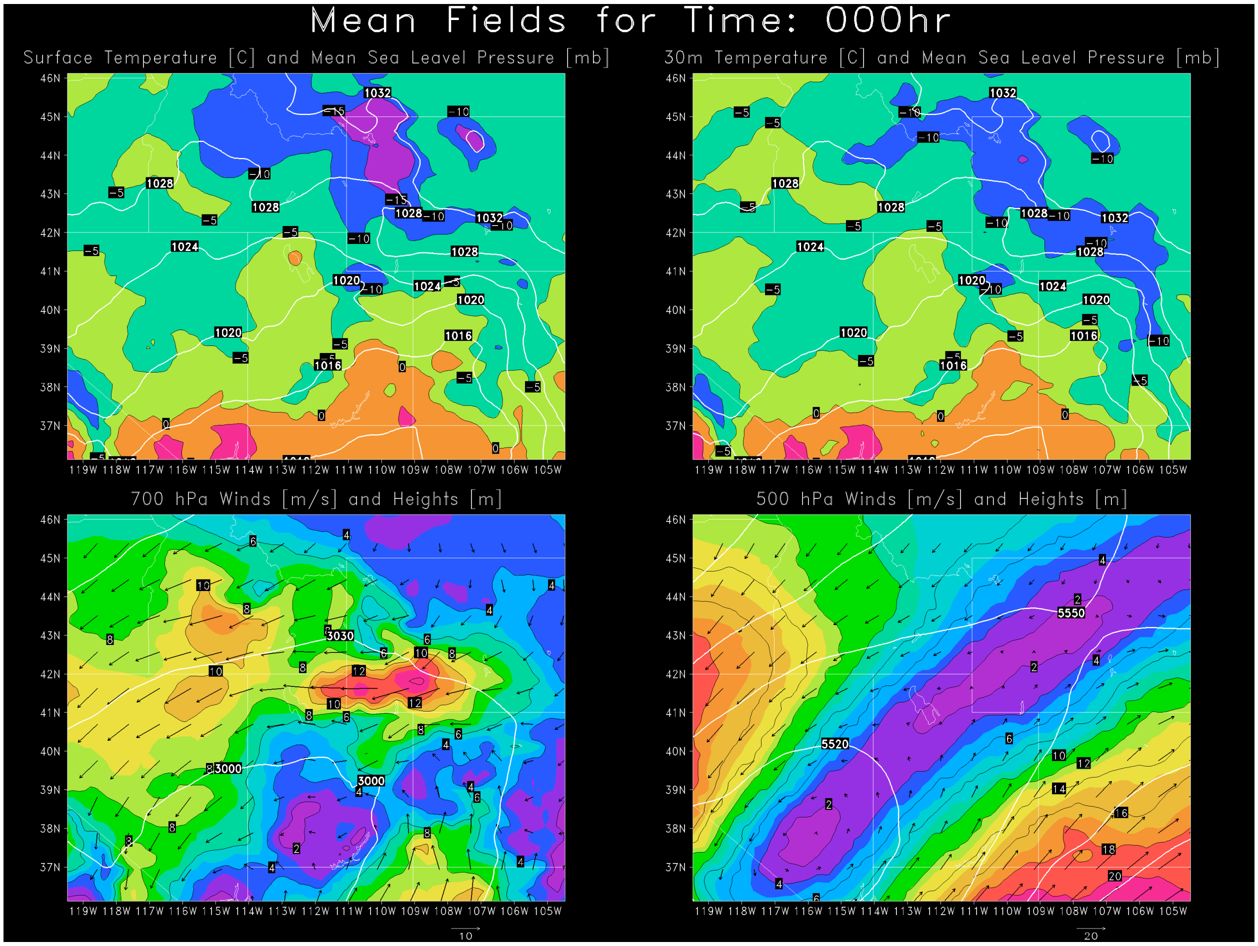

Figure 10. Mean fields of Surface Temperature and Mean Sea Level Pressure (top left), 30 m Temperature and Mean Sea Level Pressure (top right), 700 mb wind and height (bottom left), and 500 mb wind and height (bottom right), for all downslope wind events at Hill Air Force Base since 1979, from the North American Regional Analysis.

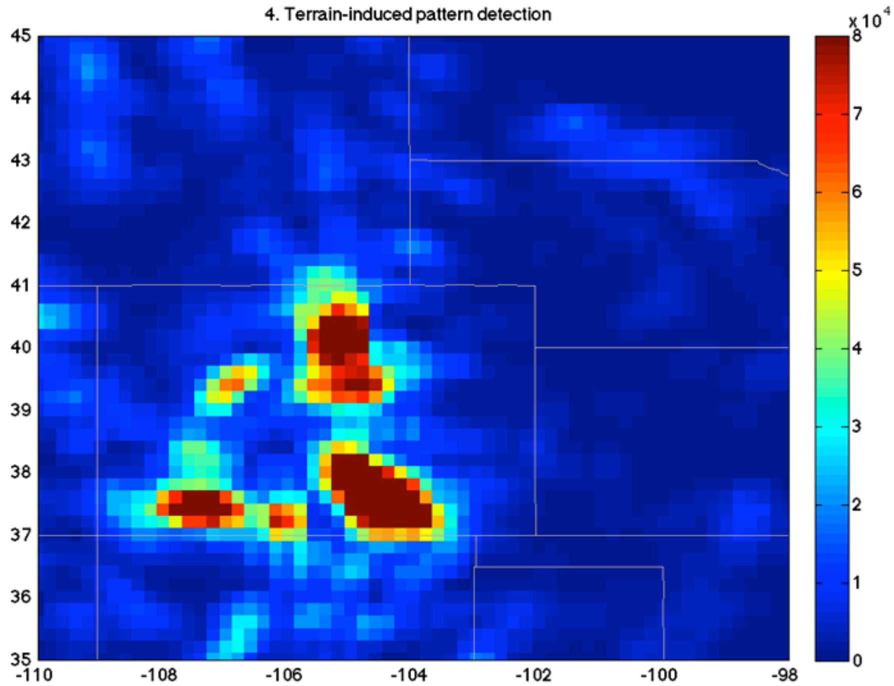

Figure 11. GOES Water Vapor-derived Terrain Pattern Score over Colorado valid at 0015 UTC on 4 January 2006, at the same time as an ongoing downslope windstorm in Ft. Collins, CO.

2.8 Probabilistic Nearcasting of Severe Convection using the Temporal Evolution of GOES-derived Deep Convective Properties, NEXRAD and NWP

CIMSS Project Leads: John Cintineo, Justin Sieglaff
NOAA Collaborators: Michael Pavolonis NESDIS/ASPB, Daniel Lindsey NESDIS/RAMMB
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The goal of this project is to utilize temporal trends in GOES-derived cloud properties (e.g., emissivity, cloud phase, optical depth, etc.), NWP fields (e.g., CAPE and shear, etc.), and NEXRAD-derived products to objectively determine the probability that a growing cumulus cloud object will produce severe weather in the near-term (0-60 min). A flexible probabilistic model is utilized such that additional data sources (e.g., lightning) can be incorporated at a later time. Results achieved thus far indicate that the probabilistic model fused together with data from each aforementioned observation source can often predict that severe weather may occur 10 minutes or more prior to the issuance of National Weather Service (NWS) severe weather warnings. This project has been ongoing for 3 years, with the eventual end goal of improving the timeliness and accuracy of severe weather warnings and condensing the pertinent information from the "fire hose" of data for NWS forecasters in order to aid in their warning decision.

Summary of Accomplishments and Findings

A statistical model (naïve Bayesian classifier) was trained with features found in severe and non-severe storms, or "cloud objects." The cloud object identification and tracking method (Sieglaff et al., 2013) finds objects in satellite imagery, which are used to save temporal information and compute time trends in robust GOES-derived properties, such as the vertical growth and glaciation rates of storms. Cintineo et al. (2013) found that these metrics were skillful in discerning severe from non-severe convection. NWP products derived from Rapid Refresh (RAP) model analysis and short-term forecast data are also computed for each cloud object, in order to ascertain the potential of the environment of the growing convection. The RAP products currently used are the MUCAPE and effective bulk shear. The Warning Decision Support System – Integrated Information (WDSS – II) is employed to track objects in NEXRAD imagery (i.e., developing storms). The maximum expected size of hail (MESH), a NEXRAD and NWP-derived product, is saved for every scan of each identified radar object.

The GOES-derived growth trends, RAP-derived environment fields, and NEXRAD-derived MESH are all used as predictors into the trained statistical model to generate a probability that a developing storm will produce severe hazards such as tornadoes, large hail, or high winds. Thus, this algorithm fuses data from three different observation sources, which contribute information from different stages of storm development, to predict the likelihood that a storm will become severe.

The fused probabilistic model has been running in real-time at CIMSS from April through August 2013. There have been numerous examples where the model exhibits lead time to NWS warnings (from 10 min up to 60 min), and even examples where the model produces a high probability prior to the occurrence of severe weather, which occurred before an NWS warning was issued. False alarms have not increased substantially, and several NWP fields have been identified to reduce the false alarms that do occur (including mixed-layer lifted index, and height of the wet-bulb 0^{o}C isotherm). The output probability data may be ingested into AWIPS-II, in shapefile format, with contours referenced to radar or satellite objects. Please see Figure 12 for an example.

Thus far, algorithm performance has been generally good, as evidenced from many examples. A formal evaluation has begun, which has demonstrated that the algorithm is fairly well-calibrated (e.g., 60% of the time the algorithm produces a 60% probability, severe weather occurs), exhibits good skill for an algorithm of this variety (maximum CSI > 0.4), and shows promise to help forecasters increase lead time and accuracy of warnings (Figure 13 and Figure 14).

This research has demonstrated the potential to aid forecasters during severe weather warning-issuance by fusing together data from different sources quantitatively. The advent of next-generation observation systems (e.g., GOES-R, polarimetric radar, high resolution mesoscale models) may necessitate products that forecasters can quickly interrogate to make decisions. For severe warning purposes, the algorithm developed from this research may be a good first step in that direction.

Publications, Reports, Presentations

Cintineo, J. L., M. J. Pavolonis, J. M. Sieglaff, and A. K. Heidinger, 2013: Evolution of severe and non-severe convection inferred from GOES-derived cloud properties. *J. Appl. Meteorol. Climatol.*, doi:10.1175/JAMC-D-12-0330.1, in press.

Cintineo, J. L., M. J. Pavolonis, J. M. Sieglaff, and D. T. Lindsey, 2012: Probabilistic Forecasting of Severe Convection. *37th Natl. Wea. Assoc. Annual Meeting*, Madison, WI, Natl. Wea. Assoc., F18.1.

Sieglaff, J. M., D. C. Hartung, W. F. Feltz, L. M. Cronce, and V. Lakshmanan, 2013: Development and application of a satellite-based convective cloud object-tracking methodology: A multipurpose data fusion tool. *J. Tech.*, accepted.

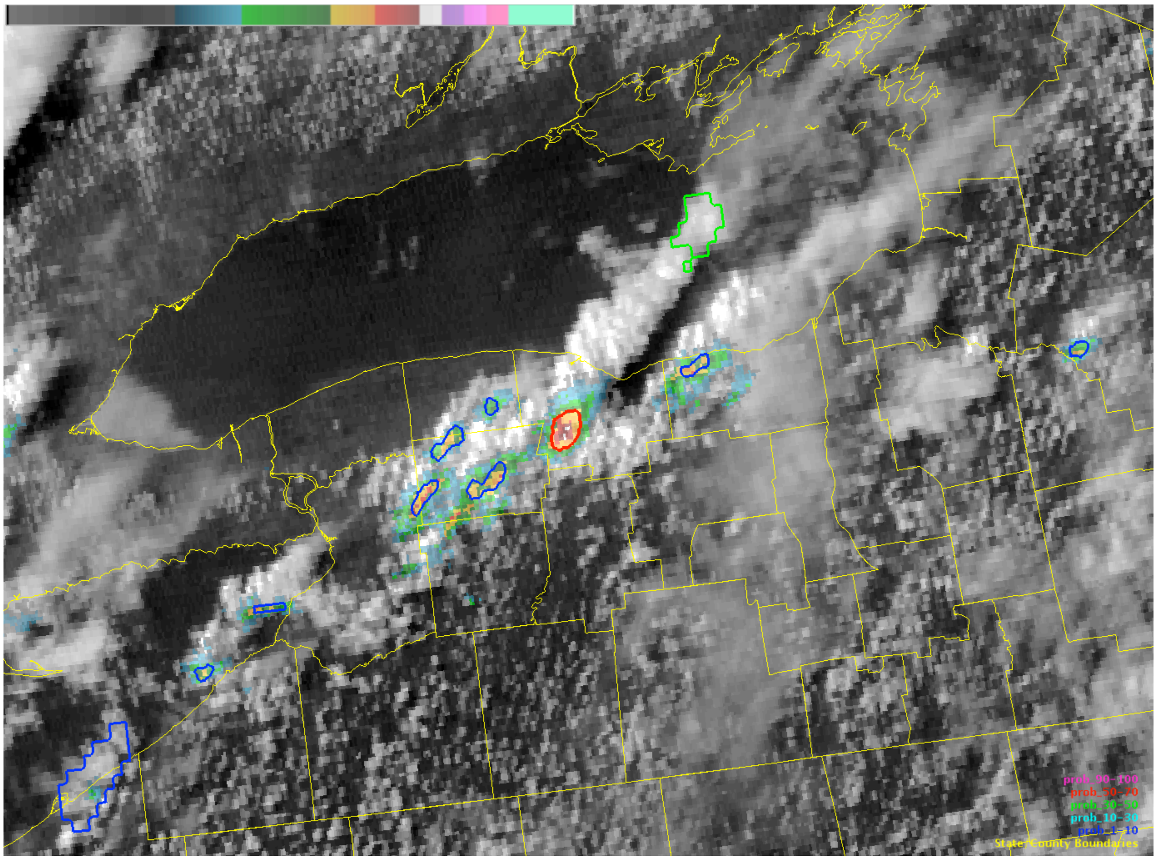

Figure 12. This is a demonstration of an AWIPS – II display with GOES-East visible reflectance (valid 3 July 2013, 20:15 UTC), merged radar reflectivity (valid 20:19 UTC), and the radar/satellite object contours, colored by probability. The red contour in western NY shows that the statistical model produced a 50-70% probability of severe weather for this storm. This probability was a result of a favorable environment, good satellite growth rates, and the radar signal beginning to intensify. At 20:39 UTC, a 58 mph wind gust was measured at the Rochester International airport (20 min after this image time). At 20:52 UTC, the NWS in Buffalo issued the first severe thunderstorm warning for this storm (33 min after this image time). This storm would go on to produce numerous wind damage reports. Radar data is provided by the NOAA/NSSL and OU/CIMMS.

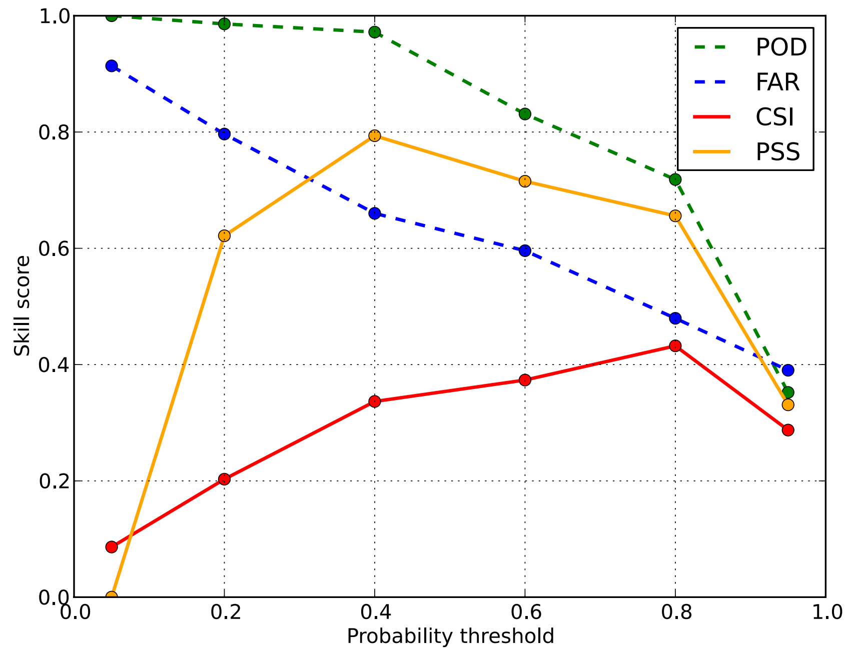

Figure 13. Probability of detection (POD), false alarm ratio (FAR), critical success index (CSI), and Pierce skill score (PSS), as a function of probability forecast threshold. Hits and misses are scored against severe local storm reports. CSI measures skill for rare events and PSS measures skill against unbiased random forecasts.

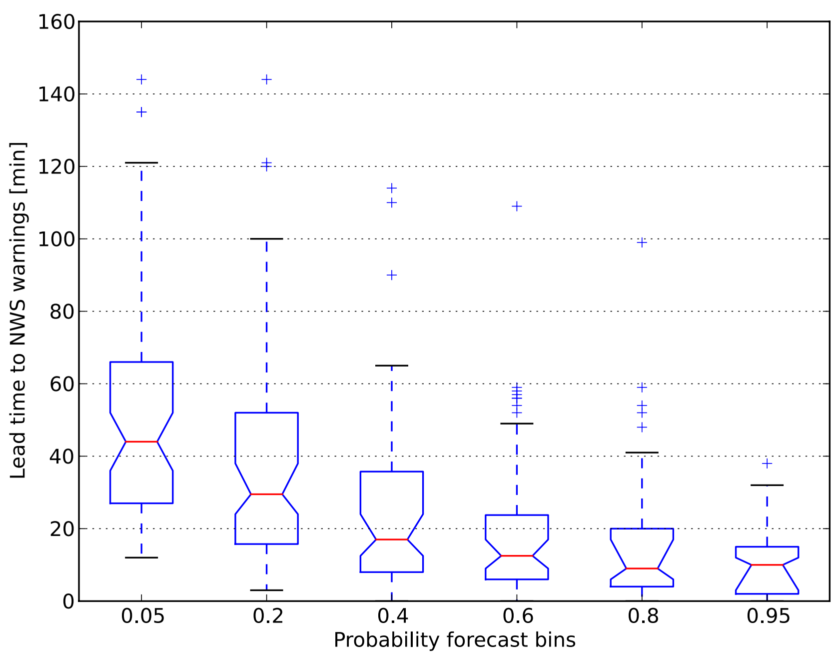

Figure 14. Distributions of lead time to NWS-issued severe thunderstorm or tornado warnings for probabilistic forecasts of severe weather. Horizontal red lines mark the median lead time for each probability bin and boxes denote the inter-quartile range. The notches in each box represent a 95% confidence interval of the median lead time, derived empirically from a sample bootstrapped 5000 times.

3 CIMSS Participation in the Product Systems Development and Implementation (PSDI) for 2012

3.1 Operational Implementation of the CIMSS Advanced Dvorak Technique

CIMSS Project Leads: Chris Velden and Tim Olander
CIMSS Support Scientist: Tony Wimmers
NOAA Collaborators: Liqun Ma and Mike Turk (SAB)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications

Project Overview

The Advanced Dvorak Technique (ADT; Olander and Velden, 2007, *Weather and Forecasting*) is a satellite-based algorithm designed to provide objective estimates of hurricane intensity from GOES and other geostationary satellites. Its long-term development has been partially supported by the NOAA GIMPAP program, and the latest algorithm has recently been transitioned through a NESDIS PSDI effort into operations at the Satellite Analysis Branch. The National Hurricane Center (NHC) now routinely accesses the ADT data as part of its hurricane analysis and forecast suite of tools.

In support of the importance of the ADT in hurricane analysis at the U.S. operational centers, a joint User Request was submitted to the NESDIS SPSRB by NHC, CPHC (Central Pacific Hurricane Center), and JTWC (Joint Typhoon Warning Center). The request, Title: "Continue operational transition and upgrade support of the ADT", was approved by the SPSRB for funding considerations starting in FY12. This PSDI project follows the above User Request guidance, and addresses the operational transition component proposed upon successful completion of new science added to the ADT.

Summary of Accomplishments and Findings

The primary accomplishment was getting the research version of the ADT into operations at SAB. The ADT now routinely produces operational hurricane intensity estimates on a global basis for users of the NESDIS SAB products.

Efforts have focused on adapting the latest ADT version code into the operational framework at OSPO. Specifically, CIMSS:

- Provided ADT v8.1.4 upgraded version builds to OSPO
- Integrated Fortran90 version of microwave module into ADT v8.1.4
- Responded to OSPO feedback on ADT v8.1.4 implementation, testing, and performance evaluation during/after transition
- Performed verification and validation previously assigned to SAB
- Updated documentation

Publications, Reports and Presentations

Olander, T. and C. Velden, 2012: The Current Status of the UW-CIMSS Advanced Dvorak Technique, 30th AMS Hurricanes and Tropical Meteorology Conference, Ponte Vedra Beach, FL, April 15-20.

3.2 VIIRS Polar Winds Products

3.2.1 VIIRS, MODIS/AHRR

CIMSS Project Leads: David Santek, Chris Velden
CIMSS Support Scientists: Steve Wanzong, Rich Dworak
NOAA Collaborator: Jeffrey Key NESDIS/STAR/CRPD/ASPB
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

Fully automated cloud-drift wind production from GOES became operational in 1996, and wind vectors are routinely used in operational numerical models of the National Centers for Environmental Prediction (NCEP) and other numerical weather prediction (NWP) centers. Winds over the polar regions have been generated with Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on NASA's Terra and Aqua satellites and the Advanced Very High Resolution Radiometer (AVHRR) on NOAA satellites at CIMSS since 2001, and by NESDIS operations since 2005 (MODIS) and later (AVHRR). A timeline of polar wind product development is shown in Figure 15.

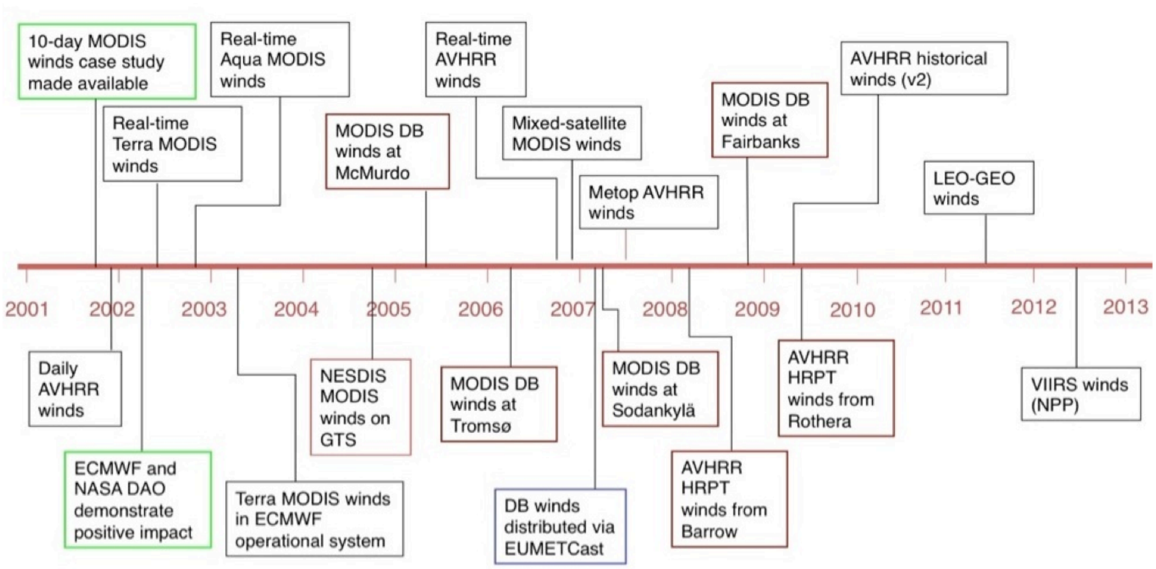

Figure 15. The polar winds product history, from 2001 to the present.

The objective of this project is to develop a polar wind product using the Visible/Infrared Imager/Radiometer Suite (VIIRS) instrument on the Suomi National Polar-orbiting Partnership satellite (NPP). NPP was launched 28 October 2011. The product will also be generated with the VIIRS instrument on future Joint Polar Satellite System (JPSS) satellites.

Summary of Accomplishments and Findings

The real-time generation of polar winds products from Terra and Aqua MODIS and AVHRR on NOAA-15, -16, -18, -19 and Metop-A continues at CIMSS. Metop-B was launched in mid-September 2012 and the AVHRR winds processing at CIMSS was updated in November 2012 to include Metop-B.

The focus of the project, however, is the development of a method to generate winds from VIIRS. VIIRS is a 22-band imaging radiometer that 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:

- Wider swath than MODIS;
- Higher resolution (750 m for most bands; 375 m for some) compared to 1 km MODIS resolution;
- Constrained pixel growth: better resolution at edge of swath; and
- Day-night band (DNB).

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.

VIIRS has a wider swath (3000 km) than MODIS (2320 km), so the coverage will be better; the AVHRR swath width is nearly 3000 km. A wider swath means more winds with each orbit triplet.

The VIIRS method of aggregating detectors and deleting portions of the scans near the swath edge results in smaller pixels at large scan angles. For thermal bands, VIIRS is 0.56 km^2 (0.75 x 0.75 km) at nadir and 2.25 km^2 at the edge of the swath (0.37 -> 0.8 km for imager bands; 0.74 -> 0.74 km for the day-night (DNB) band). In contrast, AVHRR and MODIS are 1 km^2 at nadir and 9.7 km^2 at edge of swath. Additionally, VIIRS scan processing reduces the bow-tie effect. The impact of this on a wind product is that tracking features will be better defined, resulting in more good winds toward the edges of the swath.

VIIRS polar winds processing will utilize the new GOES-R Advanced Baseline Imager (ABI) atmospheric motion vector (AMV) algorithm. A fundamental difference from our traditional procedure is that the cloud-drift wind heights are determined by using an externally generated cloud height product rather than internal routines. The Clouds from AVHRR Extended (CLAVR-x), NOAA's operational cloud product system for AVHRR, has been adapted for the VIIRS instrument. It employs a naïve Bayesian cloud mask, and uses the GOES-R AWG Cloud Height (ACHA) algorithm.

A full VIIRS AMV case consists of combining several 10.763 μm granules (SVM15) into a polar stereographic projection, for three consecutive passes. Each composite image is approximately 100 minutes apart. The latest version of the ABI AMV software has been modified to work with the polar stereographic re-projected VIIRS data; an example of the wind coverage is shown in Figure 16. At this time, the VIIRS processing at CIMSS is only for case studies. The VIIRS polar winds product is scheduled to be operational in NESDIS in late calendar year 2013.

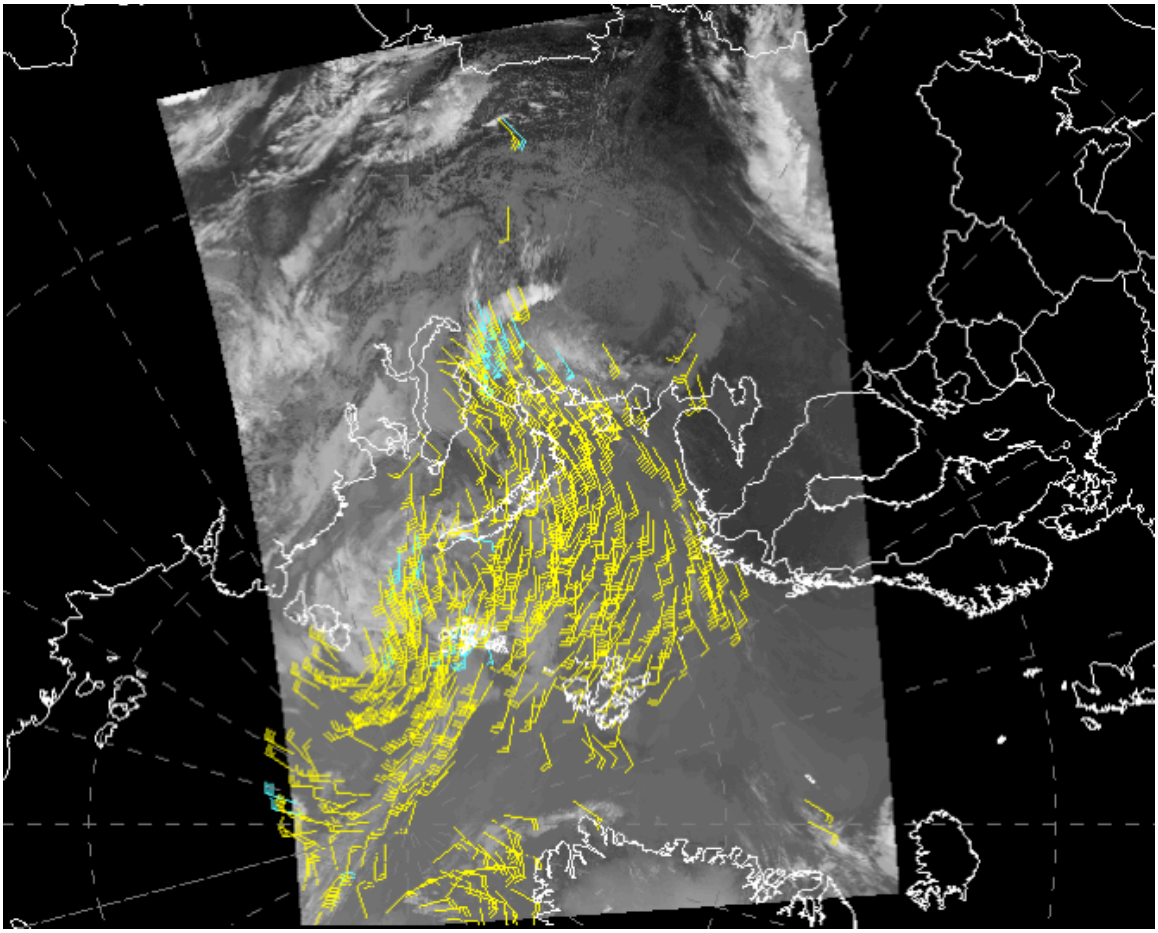

Figure 16. Arctic AMVs using the VIIRS/ABI processing system for a case on from 14 August 2012. Cyan vectors range from 100 – 400 hPa. Yellow AMVs are below 400 hPa.

We continue to work with 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).

Many of these centers will include the VIIRS winds in their operational systems after testing.

We have been working closely with the NPOESS Data Exploitation (NDE) integration team. This is a NESDIS/STAR group developing the product generation system for NOAA-unique products such as the VIIRS polar winds. We have contributed to the development of coding standards, delivery package contents, documentation, ancillary data requirements, and other issues of concern for the operational implementation of our research code.

Publications, Reports, Presentations

Dworak, R., and J. R. Key, 2009: 20 years of polar winds from AVHRR: Validation and comparison to the ERA-40. *J. Appl. Meteor. Climatol.*, **48**, 24-40.

Dworak, R. and J. Key, 2009: 25 Years (1982-2007) of polar winds from AVHRR: Validation and comparison to the ERA-40 reanalysis. Proceedings of the 10th Conference on Polar Meteorology and Oceanography, Madison, Wisconsin, 18-21 May 2009.

Key, J., R. Dworak, D. Santek, W. Bresky, S. Wanzong, J. Daniels, A. Bailey, C. Velden, H. Qi, P. Keehn, W. Wolf, 2012: Polar Winds from VIIRS, 11th International Winds Workshop, Auckland, 20-24 February 2012.

Santek, D., 2009: The impact of satellite-derived polar winds in global forecast models. Proceedings of the 10th Conference on Polar Meteorology and Oceanography, Madison, Wisconsin, 18-21 May 2009.

Santek, D., 2010: The impact of satellite-derived polar winds on lower-latitude forecasts. *Mon. Wea. Rev.*, **138**, 123–139.

3.2.2 Metop-B Readiness for CLAVR-x

CIMSS Project Lead: William Straka III
CIMSS Support Scientist: Szuchia Moeller
NOAA Collaborator: Andrew Heidinger
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications

Proposed Work

On September 17, 2012, the second satellite of the EUMETSAT's Polar System (EPS), MetOp-B, was launched. National Environmental Satellite, Data, and Information Service, Center for Applications and Research (NESDIS/STAR) and the Cooperative Institute for Meteorological Studies (CIMSS) propose to integrate in data from MetOp-B into the Advanced Very High Resolution Radiometer (AVHRR) processing system, CLAVR-x (The Extended Clouds from AVHRR processing system). This project includes updating the code, upgrading the algorithms to their latest versions, and upgrading necessary lookup tables. By doing this, CLAVR-x will not only support ongoing operational needs at NCEP, but also extend the CLAVR-x climatology to include MetOp-B. By doing this, there will be a data record from a single sensor over 35 years, allowing for long term climate studies.

Summary of Accomplishments and Findings

CLAVR-x was modified in order to accommodate the processing of AVHRR data from MetOp-B. This included the update of the lookup tables used by the Pressure Layer Optical Depth (PLOD)/ Pressure layer Fast Algorithm for Atmospheric Transmittances (PFAAST) (Hannon et al., 1996) radiative transfer model (RTM). In addition, CLAVR-x was modified to incorporate the latest cloud mask, cloud top height/temperature/pressure and cloud optical properties algorithms. These algorithms were originally developed by the GOES-R Cloud Algorithm Working group, and expanded for use on multiple sensors. This means there is consistency between the algorithms used by GOES-R and AVHRR, allowing for comparisons once GOES-R is launched. This update also provides data needed by the IASI post-processing team as well as users at NCEP.

The updated CLAVR-x code was delivered to the Office of Satellite Data Processing and Distribution (OSDPD) in the Winter of 2012 for pre-operational implementation. The updated version of CLAVR-x was successfully tested on a non-operational test computer in OSDPD. It was then ported over to the operational machine in mid-2013. There have been some scripting changes at OSPO due to issues that have found during operations. These have been issues with ancillary data access issues, but were not code related.

Publications and Conference Reports

Donahue, D., A. K. Heidinger, W. C. Straka III, C. C. Molling. IPD CLAVR-x Interface Control Document, Clouds from AVHRR Extended (CLAVR-x) Operational Processing System. 2013

Straka, W. C., A. K. Heidinger, M. Pavolonis. Clouds from AVHRR Extended version 6.0 (CLAVR-x v6) Program Description Document. 2013

CLAVR-x Critical Design Review (CDR) was held on March 13, 2013.

References

Hannon, S. L. L. Strow, and W. W. McMillan, 1996: Atmospheric infrared fast transmittance models: A comparison of two approaches. *Proceedings of SPIE*, **2830**, 94-105.

3.3 Arctic Composite Satellite Imagery

CIMSS Project Lead: Dr. Matthew Lazzara
CIMSS Support Scientists: Dave Mikolajczyk, Rick Kohrs, Jerry Robaidek, Nick Bearson and Dr. Dave Santek
NOAA Collaborator: Dr. Jeff Key (NESDIS/STAR)

NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

For over 20 years, the Antarctic Meteorological Research Center has been making Antarctic satellite composite imagery using observations from both geostationary and polar orbiting satellite platforms (Lazzara et al., 2003; Lazzara et al., 2011). These satellite composites have inspired the development of an Arctic satellite composite, developed and demonstrated with funding from the National Science Foundation during the International Polar Year (Lazzara et al., 2011; Lazzara et al., 2013; Kohrs et al., 2013). As a result of this demonstration effort, the Ocean Prediction Center (OPC) formally filed a request to have these composites made routinely by NOAA to support their increasing forecast efforts and transportation in an increasingly ice-free Arctic. Other groups within NOAA have requested to make use of the composites including the Weather Prediction Center (formerly the Hydrometeorological Prediction Center), National Weather Service Alaska, and the National Ice Center. The composite is also provided to the Satellite Proving Ground for Marine, Precipitation, and Hazardous Weather Applications program.

The current effort calls for creating 4-kilometer nominal resolution composites on an hourly basis in 5 different spectral channels centered over the entire Arctic basin and adjacent continental regions. The five bands include the infrared window channel, visible channel, water vapor channel, shortwave and longwave infrared channel. All available geostationary and polar orbiting satellite observations are used in the composite. This project effort is currently funded, and will continue for an additional year as the methodology for generating the composites is refined and transferred to NOAA operations.

Summary of Accomplishments and Findings

A complete Arctic satellite composite generation system has been established using the latest methods (Lazzara et al., 2010; and Kohrs et al., 2013) and is working at CIMSS. This represents a step forward from current composite imagery over the poles generated by NOAA, which is only from polar orbiting satellites, and has a nominal resolution of 36 kilometers. Continued development of the Arctic composite product has taken place, especially tailoring it to meet users' needs. This included setting up projection and navigation as well as testing a high spatial resolution composite at 4 kilometers (an improvement over the original NSF composite imagery, which was set at 5 km nominal resolution). Composite imagery resulting from this project and imagery from prior test versions are being provided to end users for evaluation. Imagery can be found on the Web at http://arctic.ssec.wisc.edu as well as transferred to end users via Local Data Manager.

Publications, Reports, Presentations

Kohrs, R.A., M.A. Lazzara, D.A. Santek, J.O. Robiadek, and S.L. Knuth 2013: Global Satellite Composites – 20 Years of Evolution. *Atmospheric Research*. in press. doi:10.1016/j.atmosres.2013.07.023.

Lazzara, M.A., D.A. Santek, R.A. Kohrs, B.T. Hoover, and D.E. Mikolajczyk, 2013: Arctic and Antarctic Satellite Composites: Construction and Applications. NOAA Satellite Conference 2013, College Park, MD.

Additional References

Lazzara, M.A., A. Coletti, B.L. Diedrich, 2011: The possibilities of polar meteorology, environmental remote sensing, communications and space weather applications from Artificial Lagrange Orbit. *J. Adv. Space Res.*, **48**, doi:10.1016/j.asr.2011.04.026.

Lazzara, M.A., D.A. Santek, R.A. Kohrs, N.A. Bearson, J.O. Robaidek, and S.L. Knuth, 2010: Satellite composites: Techniques in combining geostationary and polar orbiting observations. 17th Conference on Satellite Meteorology and Oceanography, Annapolis, MD, 26-30 September 2010. Boston, MA, American Meteorological Society.

Lazzara, M.A., L.M. Keller, C.R. Stearns, J.E. Thom, and G.A. Wiedner, 2003: Antarctic Satellite Meteorology: Applications for Weather Forecasting. *Mon. Wea. Rev*., **131**, 371-383.

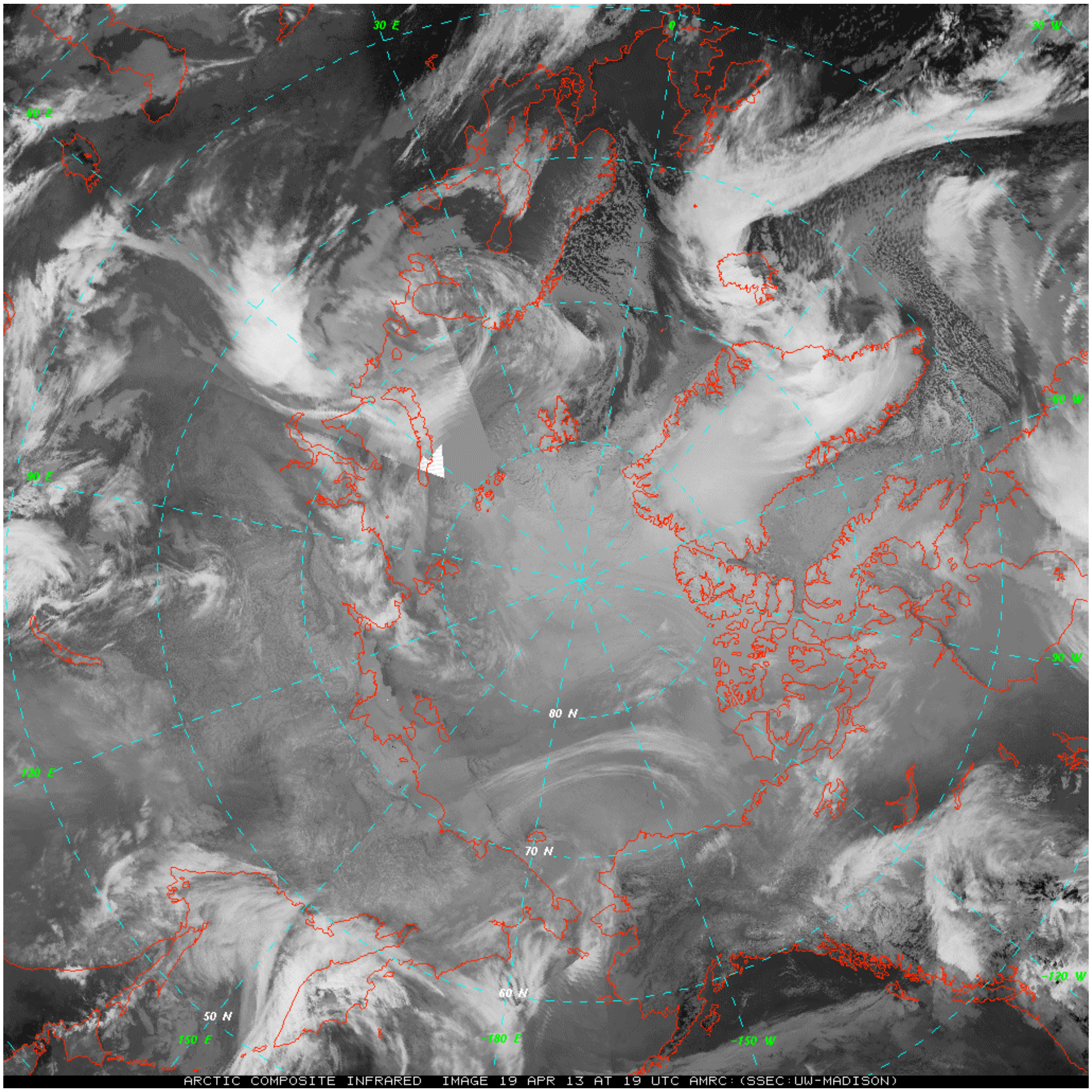

Figure 17. An example Arctic satellite composite from 19 April 2013 at 19 UTC displays the synoptic storm systems about the Arctic region and adjacent continental regions. Not all composites have complete coverage such as this as only data within the nominal hour of the composite is included in any single image.

4 Cloud Products Update for NCEP and NWS Alaska (G-PSDI)

CIMSS Project Lead: Anthony Wimmers
NOAA Collaborators: Andrew Heidinger, William Straka (Advanced Satellite Products Branch, NOAA/NESDIS), Peter Keehn (I. M. Systems Group, NOAA/NESDIS), Walter Wolf (NOAA/NESDIS)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The Clouds from AVHRR Extended (CLAVR-x) and GOES Surface and Insolation Project (GSIP) are the currently operational systems serving data to the National Weather Service (NWS) National Centers for Environmental Prediction (NCEP) and Weather Forecast Offices (WFO). The resolution and format of the data sets generated up to now was determined several years ago under outdated constraints, and increases in WFO user expectations as well as model resolutions warrant an increase in the horizontal, vertical and temporal resolution of satellite products served to NCEP. The Alaskan WFO has requested composites of cloud height information to assist in their aviation, ocean weather and general forecast duties. This project is designed to produce and deliver increased-resolution CLAVR-x and GSIP products and employ state of the art image compositing algorithms (using image morphing) to create imagery from the polar orbiters that can match the temporal resolution of geostationary imagery.

This program has primarily built off of the GOES-R Cloud Products Algorithm, and began in October 2012.

Summary of Accomplishments and Findings

The modifications of the CLAVR-x and GSIP codes to generate pixel-level hdf output are complete. Both these modifications are being transitioned in operations in FY13. CLAVR-x modifications include the addition of the needed parameters to the existing pixel-level output. Although GSIP was never designed to make pixel-level output, this project has successfully modified GSIP to generate output to CLAVR-x. In addition, the GSIP mapping tools have been implemented and tested at NESDIS STAR. The images below show pixel-level 11μm brightness temperature output from NOAA-19 AVHRR from Gilmore Creek, Alaska and GOES-West on 8 April 2013 2300 UTC.

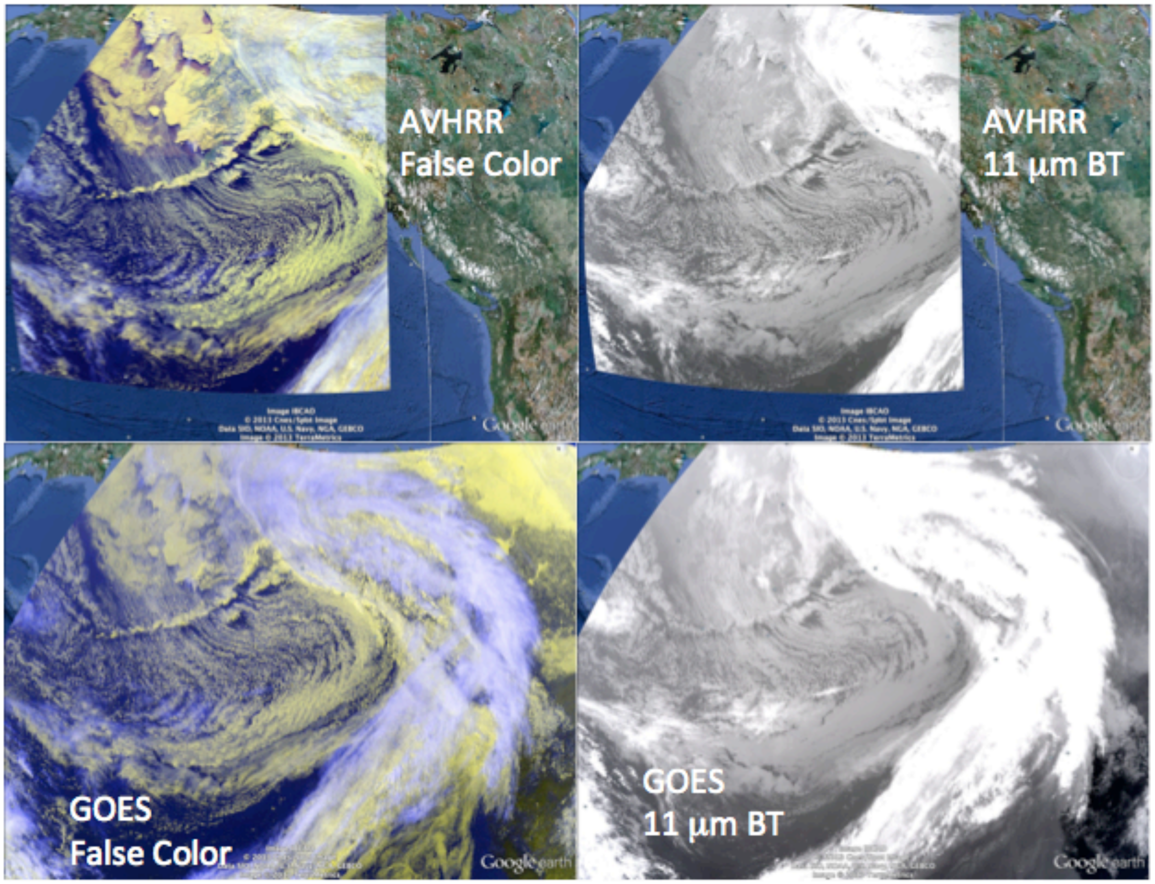

Figure 18. Pixel-level products for AVHRR (top row) and GOES (bottom row) generated by the new GSIP tools and displayed in Google Earth.

The image morphing/compositing for polar orbiter imagery has reached a mature state for application to the cloud products imagery. We have currently demonstrated the morphing/compositing algorithm on AVHRR 11μm data at sufficient accuracy and processing speed for operations. The algorithm employs Large-Displacement Optical Flow algorithms to intelligently constrain the image morphing process to matching features between sequential images from each contributing platform: Metop-A, B, NOAA-15, 16, 18 and 19. The end product is a 30-minute resolution composite of the NOAA Grid 207 domain (Alaska and its surroundings; see below) with minimal artifacts between satellite swaths. Routine gaps of more than four hours between satellites are filled with morphed imagery that accounts for advection of cloud patterns.

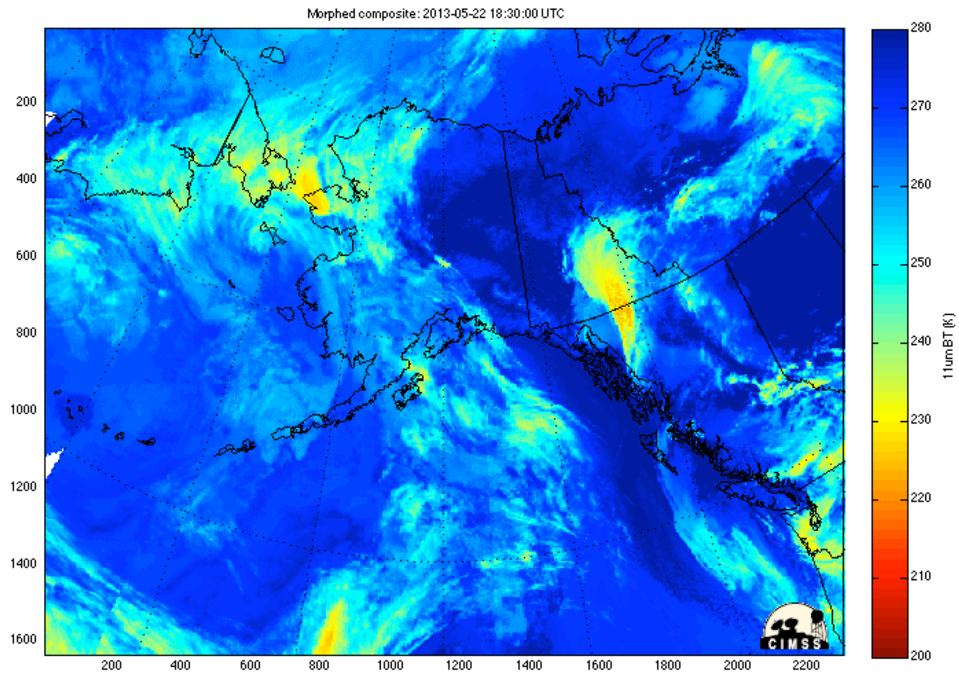

Figure 19. Morphed composite of AVHRR 11um scans from Metop A, B, NOAA-15, 16, 18 and 19 for 2013-05-22 1830 UTC.

The advection scheme used on the 11um imagery is designed to be completely transferrable to the other cloud products (CLAVR-x and GSIP) to allow for the same morphed composites to be produced for them as well.

Publications, Reports, Presentations

Wimmers, Anthony and Andrew Heidinger, "Morphing polar-orbiter imagery of cloud products for improved visualization and forecasting," National Weather Association Annual Conference, Madison, Wisconsin, 2012.

5 Monitoring and Incorporating the Stray Light Correction Process into GOES Imager and Derived Products

CIMSS Project Lead: Mathew M. Gunshor
CIMSS Support Scientists: Anthony J. Schreiner, James P. Nelson III
NOAA Collaborator: Timothy J. Schmit (NESDIS/STAR/ASPB)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

Historically, twice per year, during the spring and autumnal equinox GOES Imager and Sounder radiance data are intermittently not available for two reasons. First, the Earth comes between the Sun and the Geostationary Operational Environment Satellite (GOES) solar cell platform during the "local midnight" period and radiance data are not recorded or transmitted. Second, also during the same time ("local midnight") "leakage" of solar radiation within the GOES telescope occurs, thus significantly contaminating both the visible and the short wave IR bands of the Imager and Sounder instruments. For GOES-East this "local midnight" is centered on approximately 06:00 UTC, while for GOES-West it is centered on 10:00 UTC. The total impact of this is a data loss equivalent to six days over the course of one year.

With the launch of the three latest versions of the GOES platforms, GOES-N (13), -O (14), and – P (15), significant strides have been taken to alleviate both of these shortcomings. Loss of GOES radiance data due to a lack of electrical power to the instruments has been assuaged with the inclusion of longer lasting batteries on board the GOES platform. "Leakage" of solar radiation or "Stray Light" (SL) has required some ground station pre-processing of the data transmitted from the GOES before it is re-transmitted to GOES users via GVAR. The algorithm was developed by ITT and implemented by NOAA/NESDIS. As a result of these two modifications, more continuous coverage from the GOES platforms is now a reality independent of the time of year. This allows for improved monitoring of springtime storms and land-falling hurricanes.

Improved temporal coverage as a result of the first modification (more powerful batteries) is straight forward, and the fruit of this enhancement was realized immediately. More continuous data coverage resulting from SL correction (SLC) would require monitoring, however. This correction process incorporates two steps. First, inspection of the quality of re-transmitted and "corrected" imagery would be necessary in order to determine its physical "correctness." Secondly, as radiance information from the GOES Imager is used in the determination of quantitative products (e.g., Cloud Top Pressure and Clear Sky Brightness Temperature), monitoring and software development would also be required. Therefore, in conjunction with the spring 2012 test of the SLC for GOES-13 Imager, it was proposed to undertake the two tasks described above.

Summary of Accomplishments and Findings

The spring and autumnal equinox seasons were monitored for GOES-13 and GOES-15 during spring 2012, fall 2012, and spring 2013. The SLC provides better data than the eclipse data would be without it, but it is not a perfect solution. Generally speaking, it appears that the SLC allows dissemination of GOES data that were blocked historically, but that the data may not all be usable even now. Figure 20 demonstrates how stray light affects an image quantitatively. An example of GOES-15 cloud top pressure is shown in Figure 21 and shows how stray light affects products. Unaltered GOES-15 data were provided to CIMSS by NESDIS for this purpose.

The uncorrected data (top of Figure 21) miss detecting the low clouds around the southeastern portion of the white box, but correctly leave part of the western half of that white box clear. In the SLC data (bottom of Figure 21) the low cloud in the southeastern portion of the box are detected but the clear area on the western half of the box are now marked incorrectly as low cloud.

The milestones met include:

- Implementing a subroutine/function to read the McIDAS area line prefix header in spring 2012.
- Comparing "corrected" versus "uncorrected" Stray Light with respect to quantitatively derived GOES-13 Imager products from spring of 2012 data.

- Making available subroutines to NOAA/NESDIS for incorporation into operational processing algorithms.
- Testing sample corrected versus uncorrected GOES-15 Imager radiance information for fall 2012 data.
- Updating subroutines for possible incorporation into operational algorithms at the end of fall 2012.
- Now providing more information about how the stray light correction is applied to an image.
- Monitoring fall 2012 fall eclipse season.

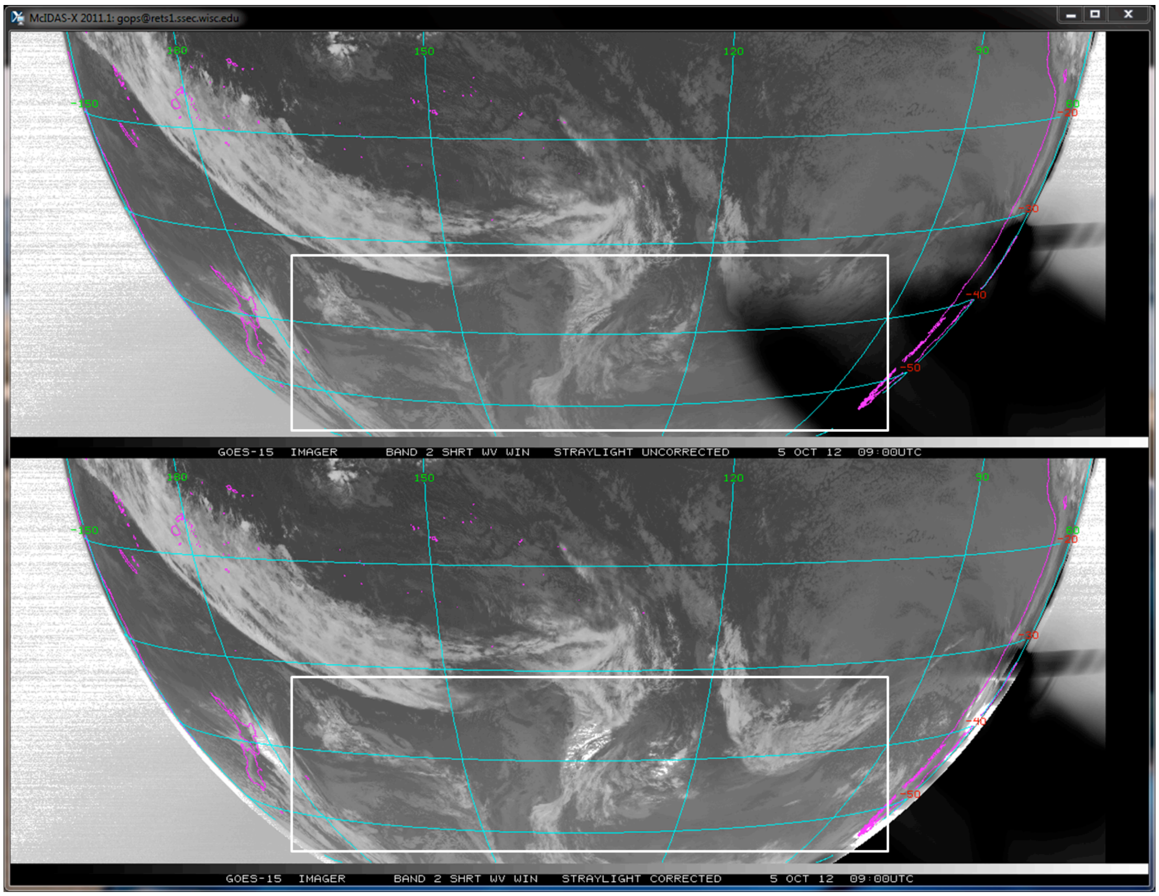

Figure 20. GOES-15 Imager band 2 (3.9 micrometer) at 9:00 UTC on 5 October 2012. Top panel is uncorrected data with stray-light affecting the southeast corner of the image. Bottom panel shows how the stray light correction (mostly) removes the effects of stray light on the earth viewing portion of the image.

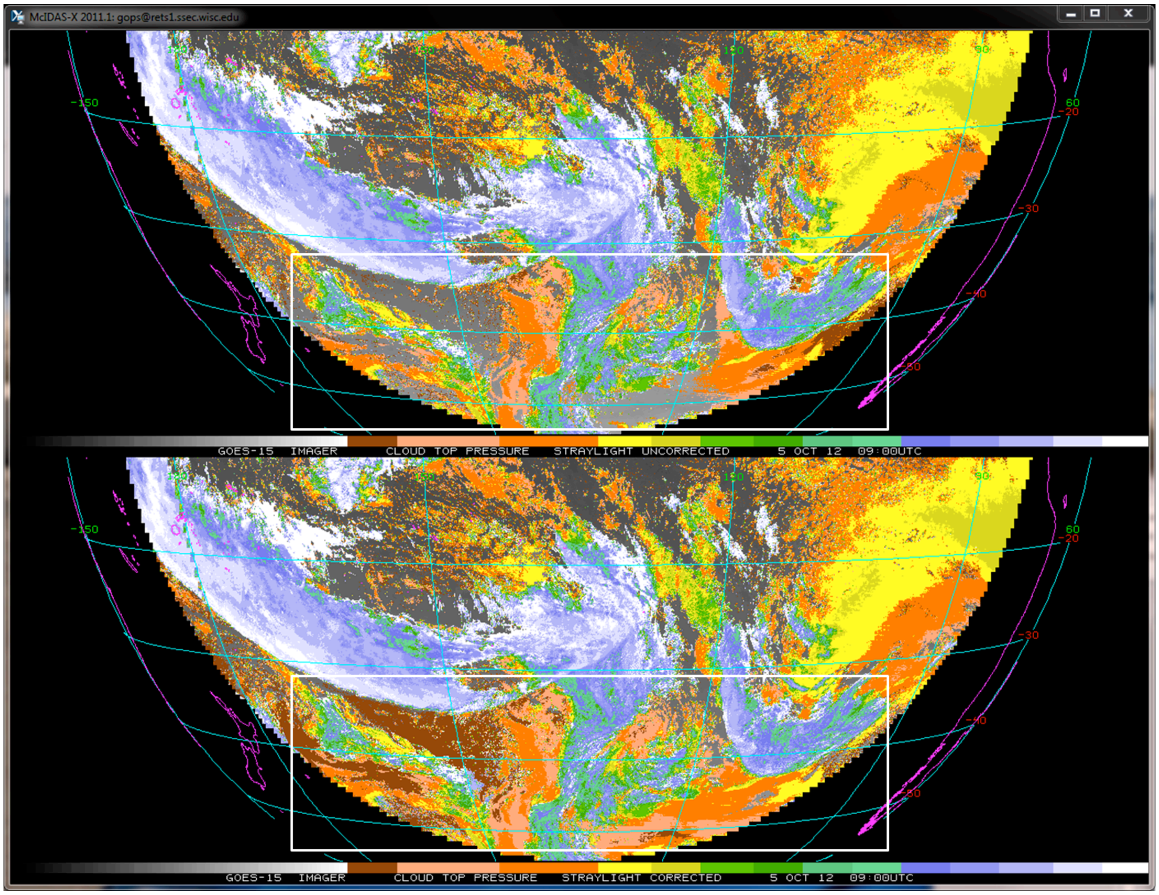

Figure 21. GOES-15 Imager Cloud Top Pressure (CTP) at 9:00 UTC on 5 October 2012. Top panel is generated with uncorrected data. Bottom panel displays CTP using stray light corrected data. The white box outlines of areas of interest where stray light correction helped in portions of the image to detect low cloud, but then caused the algorithm to incorrectly label some clear areas as having low cloud.

6 GOES-15 Post-Launch Test Support

CIMSS Project Lead: Mathew M. Gunshor
CIMSS Support Scientists: Scott Bachmeier, Jun Li, James P. Nelson III, Christopher Schmidt, Anthony J. Schreiner, David Stettner, William Straka, Chris Velden, Steve Wanzong
NOAA Collaborators: Timothy J. Schmit (NESDIS/STAR/ASPB), Gary Wade (NESDIS/STAR/ASPB), Don Hillger (NESDIS/STAR/RAMMB)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications
- Outreach and Education

Project Overview

During the science checkout of GOES-15 (August and September of 2010), CIMSS collected and began an analysis of data from the GOES-15 Imager and Sounder. The next phase will be a further analysis of the radiance data and then product generation and validations. This check-out of GOES-15 Sounder and Imager is a critical step toward operational use of the data.

The launch of GOES-P took place on 4 March 2010 and was designated as GOES-15 on 16 March 2010 when it successfully reached orbit. The main post launch science checkout data collection began 11 August 2010 and continued for 6 weeks through 22 September 2010, after which GOES-15 continued to send data until 25 October, at which time the instruments were put into storage mode. Before being used operationally, the quality of the data and products must be understood. Therefore, a routine processing system with data from GOES-15 was built. Work at determining radiance integrity was initiated. The steps required to complete the checkout are similar to previous post-launch check-outs (Hillger et al., 2003; Hillger and Schmit, 2007; Hillger and Schmit, 2009; Hillger and Schmit, 2010). This check-out is a critical step towards operational use in order to make sure GOES-15 is ready when called upon to be an operational satellite.

The first major step was the data collection phase, which was completed under the prior cooperative agreement. The remaining tasks were select product generation and the generation of the NOAA technical report. A number of tasks to complete the GOES-15 checkout included:

1. Operational Software Production issues. In preparation for the operational insertion of GOES-15, software modifications for various operational products, such as, but not exclusive to, Clear Sky Brightness Temperature, Imager and Sounder Cloud Products, Temperature/Moisture Retrievals, and Atmospheric Motion Vector algorithms will be forwarded to the Office of Satellite Products and Operations (OSPO) for subsequent operational production.

2. Material regarding the radiometric and product accuracy would be generated and provided for inclusion in the GOES-15 NOAA science technical report.

3. The GOES-15 NOAA Technical Report would be completed. Similar to previous instrument checkouts, these results are being added to previous outcomes on the Web.

Summary of Accomplishments and Findings

On December 6, 2011, GOES-15 began operational use as GOES-West, replacing GOES-11. Before this occurred, all operational software production issues were resolved. The Office of Satellite and product Operations (OSPO) received updated versions of operational software packages for Clear Sky Brightness Temperature, Imager and Sounder Cloud Products, Temperature/Moisture Retrievals, and Atmospheric Motion Vector algorithms. The NOAA science technical report for GOES-15 was completed on December 7, 2011. CIMSS was a key contributor to a majority of the figures and analysis contained in the report. These contributions included noise analysis, image generation, and product validation.

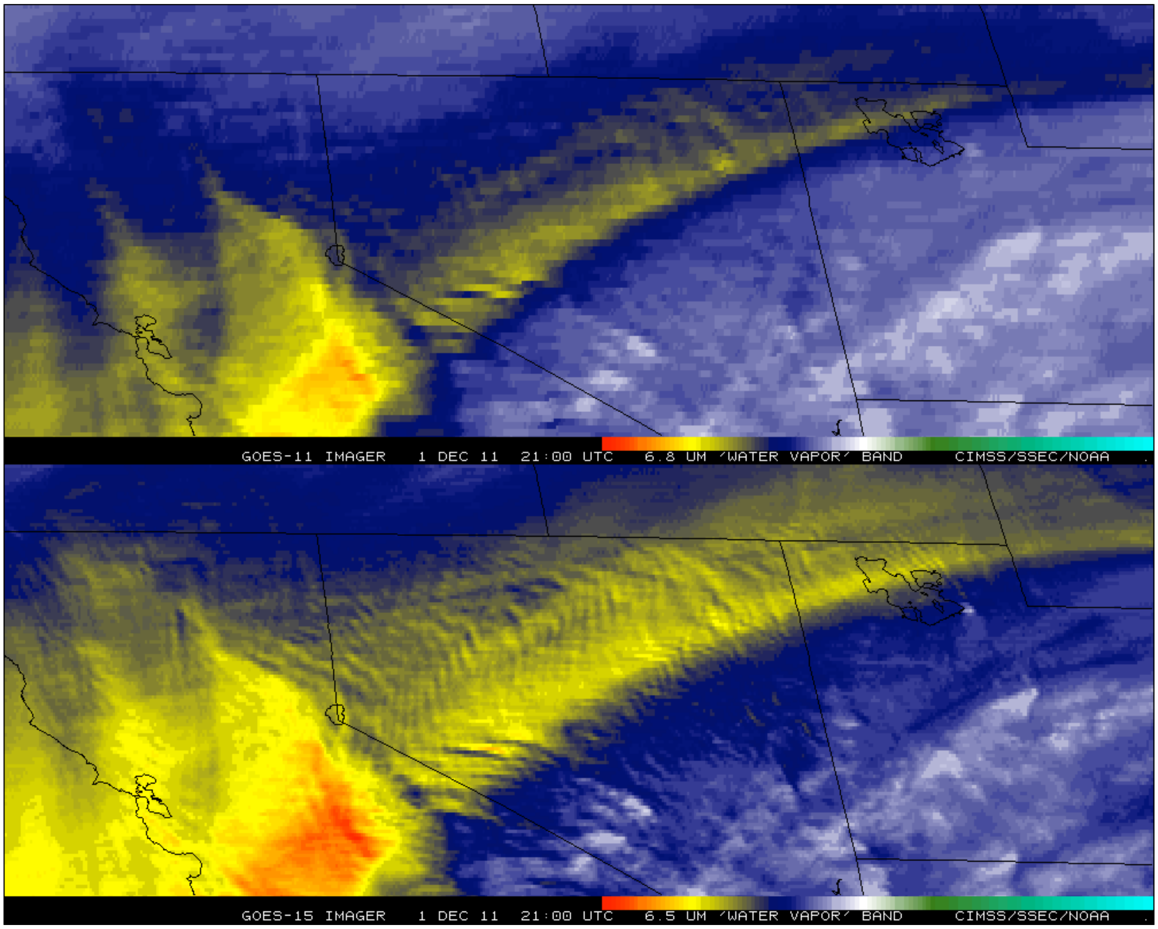

Figure 22. This two-paneled figure highlights the improved spatial resolution of the GOES-15 Imager water vapor band (bottom) compared to GOES-West predecessor GOES-11 (top), due to the increased number of detectors on this band.

Publications, Reports, Presentations

Hillger, D.W., and T.J. Schmit, 2011: Imager and Sounder Radiance and Product Validation for the GOES-15 Science Test, NOAA Technical Report, NESDIS 141, (November), 101 pp.

Hillger, Donald W.; Schmit, T. J.; Bachmeier, A. S.; Gunshor, M. M.; Knaff, J. A., and Lindsey, D. T. NOAA science test results from the GOES-14 and -15 imager and sounder. Annual Symposium on Future Operational Environmental Satellite Systems, 7th, Seattle, WA, 23-27 January 2011. Boston, MA, American Meteorological Society (AMS), 2011.

References

Hillger, D. W., T. J. Schmit, and J. M. Daniels, 2003: Imager and sounder radiance and product validations for the GOES-12 science test, NOAA/NESDIS Technical Report 115, U.S. Department of Commerce, Washington, DC.

Hillger, D. W., and T. J. Schmit, 2007: The GOES-13 Science Test: Imager and Sounder Radiance and Product Validations. NOAA/NESDIS Technical Report 125. U.S. Department of Commerce, Washington, DC.

Hillger, D.W., and T.J. Schmit, 2009: The GOES-13 Science Test: A Synopsis. *Bull. Amer. Meteor. Soc.*, **90**(5), 6-11.

Hillger, D. W., and T. J. Schmit, 2010: The GOES-14 Science Test: Imager and Sounder Radiance and Product Validations. NOAA/NESDIS Technical Report 131. U.S. Department of Commerce, Washington, DC.

Hillger, D.W., and T.J. Schmit, 2011: Imager and Sounder Radiance and Product Validation for the GOES-15 Science Test, NOAA Technical Report, NESDIS 141, (November), 101 pp.

7 CIMSS Participation in the GOES-R Algorithm Working Group (AWG) for 2012

7.1 Real-time Proxy Framework Support: CRTM Component and Validation

CIMSS Project Leads: Tom Greenwald and Allen Huang
CIMSS Support Scientists: Jason Otkin, Todd Schaack, Jim Davies, Kaba Bah, Marek Rogal, Eva Borbas
NOAA Collaborator: R. Bradley Pierce, NOAA ASPB
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

This project generates synthetic ABI data in near-real-time over CONUS using the Joint Center for Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model (CRTM) and model output from the WRF-Chem/RAQMS Real-time Proxy Framework. Data is provided to the Algorithm Integration Team (AIT) and Proving Ground partners for testing all GOES-R algorithms over a greater range of conditions than is possible with current proxy datasets. These data are also used to support GRAFIIR through Government-specified waivers. For ensuring reliable proxy ABI data, we have developed near-real-time validation capabilities based on MODIS and GOES radiances/retrievals obtained from direct broadcast data collected at SSEC.

Summary of Accomplishments and Findings

- An automated system was developed to generate simulated 16-band ABI imagery in near-real-time at 8km resolution over CONUS (as defined in the GOES-R Product Users' Guide, or PUG) using WRF-Chem model runs and the CRTM V2.1 on NOAA's S4 supercomputer at CIMSS. RAQMS forecasts are used to initialize chemistry in the WRF-Chem model and WF-ABA wildfire detection data are used to initialize fire emissions in the model.
- Significant improvements were made to the land surface radiative properties in the simulated imagery using 16-day composite Bi-directional Reflectance Distribution Function (BRDF) data derived from MODIS data collected by SSEC's direct broadcast system and monthly mean 8-km IR land surface emissivity datasets over CONUS derived from the UW-Madison/CIMSS high spectral resolution global IR land surface emissivity database.

- A Web site was created to view our simulated 16-band ABI imagery in near-real-time to support Proving Ground activities: http://cimss.ssec.wisc.edu/goes_r/proving-ground/wrf_chem_abi/wrf_chem_abi.html (see Figure 23).
- A procedure was developed for remapping the simulated radiance data from the model grid into the 2 km Fixed Grid Format (FGF), in compliance with PUG conventions, and converting them to CF compliant netCDF-4 files and eventually to GOES-R Re-Broadcast (GRB) files for distribution. This work was done in close collaboration with the AWG Visualization/Imagery team.
- Simulated 16-band ABI imagery data (i.e., GRB files) are currently being delivered to the AIT in near-real-time for testing ABI data throughput and retrieval algorithms.
- Support was added to GEOCAT to read the netCDF-4 GRB files. This work was done in collaboration with Graeme Martin who is a member of the AIT technical support team at CIMSS.
- An improved F90/95 interface for the WRF-Chem model output and CRTM was nearly completed that will provide better efficiency and more flexibility than the current interface.
- An automated system was developed to validate the simulated ABI radiances and selected Baseline products using MODIS products and GOES-13 Sounder data and derived products collected in real-time by SSEC's direct broadcast system. The validation system currently has a lag time of about 2 days but will be made to run with shorter latency in next year's effort.
    - An automated procedure was built to ingest MODIS direct broadcast products (cloud top pressure/temperature, cloud visible optical thickness, and cloud fraction) and compare them to similar products derived from WRF-Chem model output. To display the results we adapted our existing IDL code for near-real-time processing.
    - GOES-13 sounder data and products (10 km spatial resolution) are collected in real-time and converted to netCDF using McIDAS-X. Products include cloud mask, total precipitable water (TPW), convective available potential energy (CAPE), lifted index (LI), and cloud top pressure (CTP). These files are then remapped to the 2-km FGF netCDF files for direct comparison to the simulated data.
    - Simulated ABI radiance data are being validated using GOES-13 sounder observations. Statistics between the datasets are monitored daily using Glance, a Python software tool developed at CIMSS, and displayed on our Web site at http://cimss.ssec.wisc.edu/goes_r/proving-ground/crtm_goes_comps/. Automated IDL code is then used to graphically display the results as difference maps, probability distribution functions, scatter plots, and time series in clear and cloudy conditions. A Web site to view these results is available at http://cimss.ssec.wisc.edu/goes_r/proving-ground/wrf_chem_abi/ABI-VAL/index2.html.
    - Simulated ABI baseline products produced from GEOCAT (e.g., cloud top pressure/height, TPW, LI, CAPE) are just beginning to be validated. One example is shown in Figure 24. Preparation of the cloud products was done in collaboration with Andy Heidinger, AWG Cloud lead.
- The validation system was instrumental in identifying a number of issues with the CRTM and the WRF-Chem model through comparisons of simulated GOES-13 sounder data with observations.
    - A significant bias was identified for the surface shortwave reflectivity in the CRTM for the Lambertian BRDF. To solve this problem, the BRDF was

simplified as an albedo. This change was eventually included in the official CRTM V2.1 release.

- Another issue concerned the shortwave reflectance calculation in CRTM V2.1 when using the user-defined surface emissivity and surface reflectance option. We implemented a fix and submitted a ticket to the CRTM development team.
- Two major issues were discovered in the CRTM's calculation of 3.9 µm brightness temperatures. The first related to the BRDF calculation in rough seas. We implemented a temporary fix in our processing stream and submitted a ticket regarding the problem to the CRTM developers. Second, the CRTM excluded the solar reflection term for 3.9 µm calculations in cloudy conditions during the daytime. A temporary fix was made and another ticket was submitted to the CRTM developers.
- A related issue involved extremely large differences (> 50 K) that were found between the simulated and observed 3.9 µm brightness temperatures in cloudy regions even when solar reflection was accounted for. It turned out the microphysics scheme used in our WRF-Chem model runs (i.e., WSM6) generated far too much cloud ice. Further testing with another parameterization, the Thompson scheme, greatly improved the agreement with the observations. This scheme will be used in future WRF-Chem runs.

Publications and Conference Reports

Ding, S., P. Yang, B. A. Baum, A. Heidinger, and T. Greenwald, 2013: Development of a GOES-R Advanced Baseline Imager solar channel radiance simulator for ice clouds. *J. Applied Meteor. and Clim.*, **52**, 872-888.

Greenwald, T., B. Pierce, J. Otkin, T. Schaack, J. Davies, E. Borbas, M. Rogal, K. Bah, G. Martin, J. Nelson, J. Sieglaff, W. Straka, and H.-L. Huang, 2013: Near-real-time simulated ABI imagery for user readiness, retrieval algorithm evaluation and model verification, 93rd American Meteorological Society Annual Meeting, Ninth Annual Symposium on Future Operational Environmental Satellite Systems, 5-10 January, Austin, Texas.

Rogal, M., K. Bah, T. Greenwald, B. Pierce, A. Lenzen, J. Nelson, J. Otkin, T. Schaack, J. Davies, E. Borbas, J. Sieglaff, and H.-L. Huang, 2013: Near-real-time validation of simulated GOES-R ABI radiances and derived products using the WRF-Chem model forecast over CONUS for all 16 ABI bands, NOAA Satellite Science Week, virtual meeting, 18-22 March.

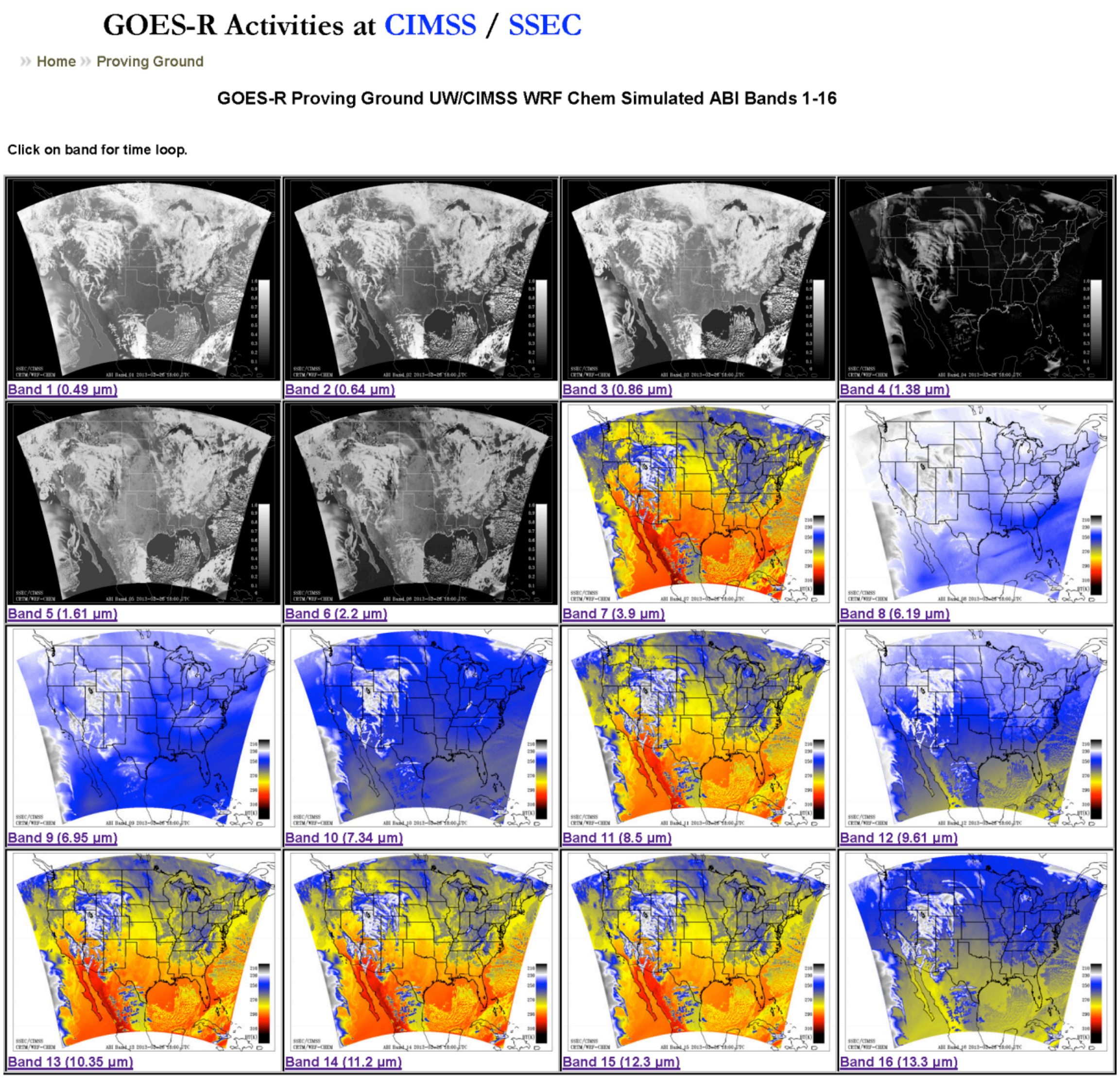

Figure 23. GOES-R simulated ABI imagery available through our Web site.

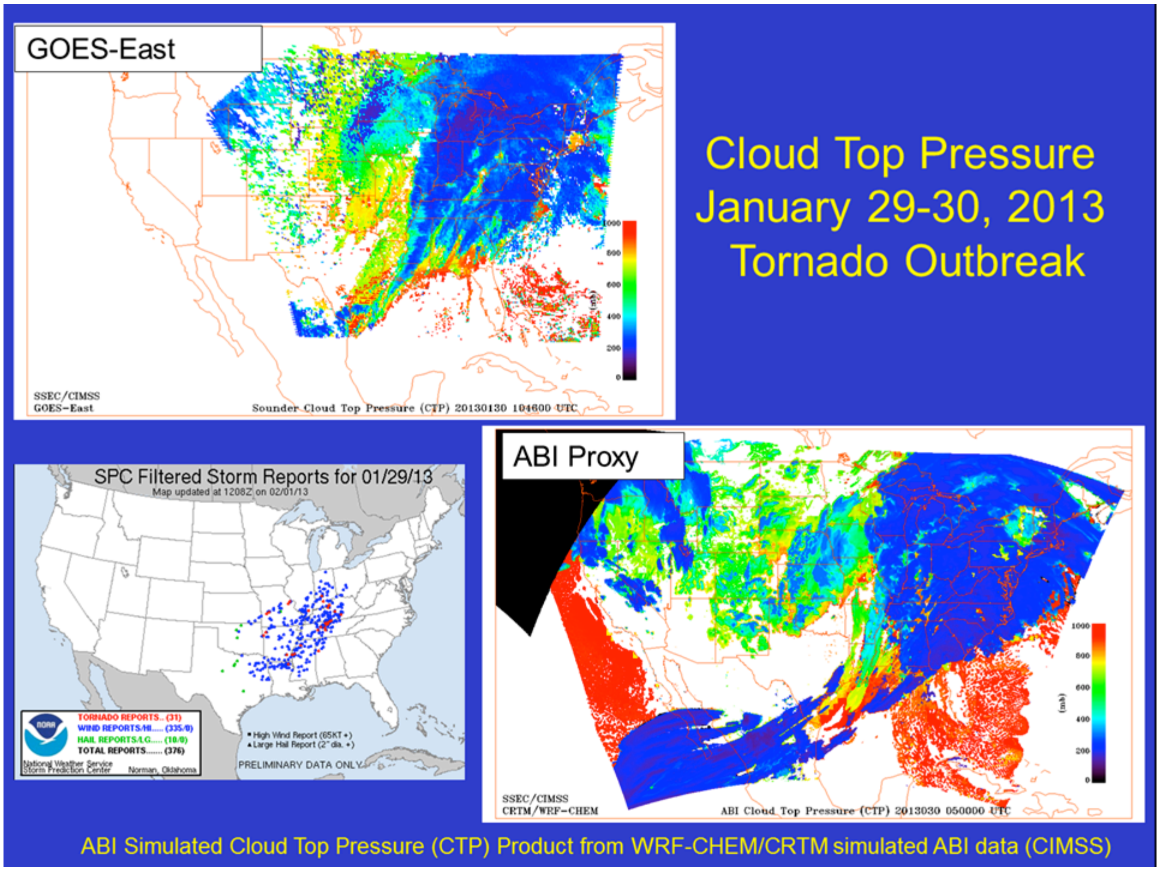

Figure 24. Comparison of GOES-13 sounder cloud top pressure observations and cloud top pressure retrieved from simulated ABI radiance data using the ABI cloud top height algorithm for the tornado outbreak of January 29-30, 2013.

7.2 GOES-R Analysis Facility for Instrument Impacts on Requirements (GRAFIIR)

CIMSS Project Leads: Mathew M. Gunshor, Allen Huang
CIMSS Support Scientists: Hong Zhang, Eva Schiffer
NOAA Collaborators: Timothy J. Schmit (NESDIS/STAR/ASPB), Walter Wolf (NESDIS)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

The GOES-R Analysis Facility for Instrument Impacts on Requirements (GRAFIIR) project has been developed by the scientists and researchers that are also GOES-R AWG product team members and system developers working on ABI. The primary goal of the GRAFIIR project is to connect the pieces of the GOES-R AWG to create a system approach to determining the effects of instrument flaws on the products. The approach CIMSS undertook to accomplish the GRAFIIR project includes:

- Implementing facility environment to allow easy and consistent use of AWG application team proxy data and product algorithms;
- Designing an efficient approach in coordination with ABI sensor and algorithm scientists to demonstrate multiple datasets simulated for the ABI with different specifications of sensor components such as noise, navigation, band to band co-registration, striping and other effects identified to be significant;
- Conducting processing to produce ABI products such as cloud mask, sounding, winds and others to demonstrate the effects of different sensor components on the products produced; and
- Documenting and analyzing the processing results to identify sensor components that might significantly impact the product performance and specification requirements.

Beyond these technical approaches, the CIMSS GRAFIIR team continually interacts with AWG program managers, application and integration team members to react to new directions and needs to support associated analysis using GRAFIIR's existing and/or expanded capability. Additionally, the CIMSS GRAFIIR team continues to interface with the government teams tasked with assessing potential ABI instrument waivers (formerly the Integrated Modeling Working Group and currently the Product Working Group) to assist the government's efforts with ABI waiver analysis and response.

When requested, the AWG will utilize the GRAFIIR team and tool set to measure the effects of Government-specified waivers and deviations (perturbations to instrument capabilities or functionality) on ABI level 1B data and L2+ products. The GRAFIIR project built off of the AWG product team and Algorithm Integration Team (AIT) Technical Support team's work, utilizing the processing system built at CIMSS which has been built over the past seven years.

Summary of Accomplishments and Findings

The GRAFIIR project has addressed ten ABI waivers/deviations to date. This includes simulating the instrument effect on proxy data, assessing instrument impact on products, gathering information from expert algorithm developers, and presenting a report to the government team in charge.

A diagnostic tool, called Glance, was developed specifically for GRAFIIR. This tool compares two files and provides a report of the statistical differences between the two. This is particularly useful for comparing output files from product algorithms to determine the results of whatever was changed in the inputs. It has been used beyond the GRAFIIR project, most notably by the AIT team to verify correct installation and implementation of the processing package. This tool continues to be expanded and improved throughout the project life. Updates of Glance are provided to the AWG's Algorithm Integration Team 4 times during the year (at the end of each project quarter). The GRAFIIR team continues to consult with the Product Working Group (used to interface with the now defunct Integrated Modeling Working Group) on behalf of the AWG.

Some of the specific updates to Glance recently include, but are not limited to: collocation upgrades, tracking system bug fixes, reading formatted text files so that current GOES retrieval data (and other McIDAS formatted data) could be utilized, allowing multiple file collocation statistics to be generated, and a land surface emissivity package was installed. Perhaps the most significant change to Glance has been the addition of a GUI mode. Using the GUI makes operating Glance much simpler and reduces the learning curve to make it a more enticing tool for AWG teams to adopt for validation activities.

A case study of cloud top pressure product compared the ABI simulation and "truth" data from the WRF model output that produced the ABI simulations. Due to different sizes of the data, WRF cloud data (2048,3456) were remapped to match ABI projection (1222,2654). The results show the retrieved cloud top pressures and cloud top temperatures are consistently lower (height) and warmer (temperature) than the model values since the IR brightness temperatures see deeper into the cloud layer. This case study was performed due to questions of the GRAFIIR methodology where the assumption is that the retrieval value is treated as a "truth" measurement and perturbed simulated data results are compared. The underlying difficulty is that a satellite measurement is one kind of truth and in the case of some products, such as cloud top height, where a meteorologically defined cloud top begins is not where a satellite instrument can necessarily detect it. GRAFIIR must continue to use satellite retrieved information with a pure data set as a truth and perturb the pure data to reflect an instrument change, to provide the delta in measurement capability introduced by the instrument change, not as a function of an absolute truth that is difficult to determine.

The GRAFIIR team assisted the Imagery Team using Glance as a validation tool. Glance was used to validate data sets generated by the Imagery team to compare sub-sampling and averaging methods. McIDAS-V and GLANCE were used as visualization and statistical analysis tools to validate downscaled (sub- sample/average) netCDF files generated at CIMSS against those generated through the AIT Framework.

The GRAFIIR team continues to advocate for AWG teams to use Glance as a validation tool. A presentation was given via teleconference to the AWG validation workshop. Along those lines, a bug was discovered by the GRAFIIR team in the cloud algorithm code where the cloud top pressure could contain more than one value as "missing."

The AWG team at CIMSS updated the cluster computing system where GRAFIIR applies instrument perturbations to proxy data. The GRAFIIR proxy data perturbation software was tested on the new cluster computing system and while there were bugs to work out and there may still be room for optimization, especially with a new storage system, the data perturbation software is running on the new system. This exercise also gave the opportunity to update a few things that have changed in terms of proxy data, imagery requirements, and the way perturbed data sets are output (such as missing data value codes, quantization of data).

The GRAFIIR team continues to push the idea of a smarter algorithm for remapping raw ABI data to the fixed grid. The remapping algorithm could help mitigate a number of the waiver/deviation issues that have come up over the years, for example, by down-weighting or even omitting a bad detector.

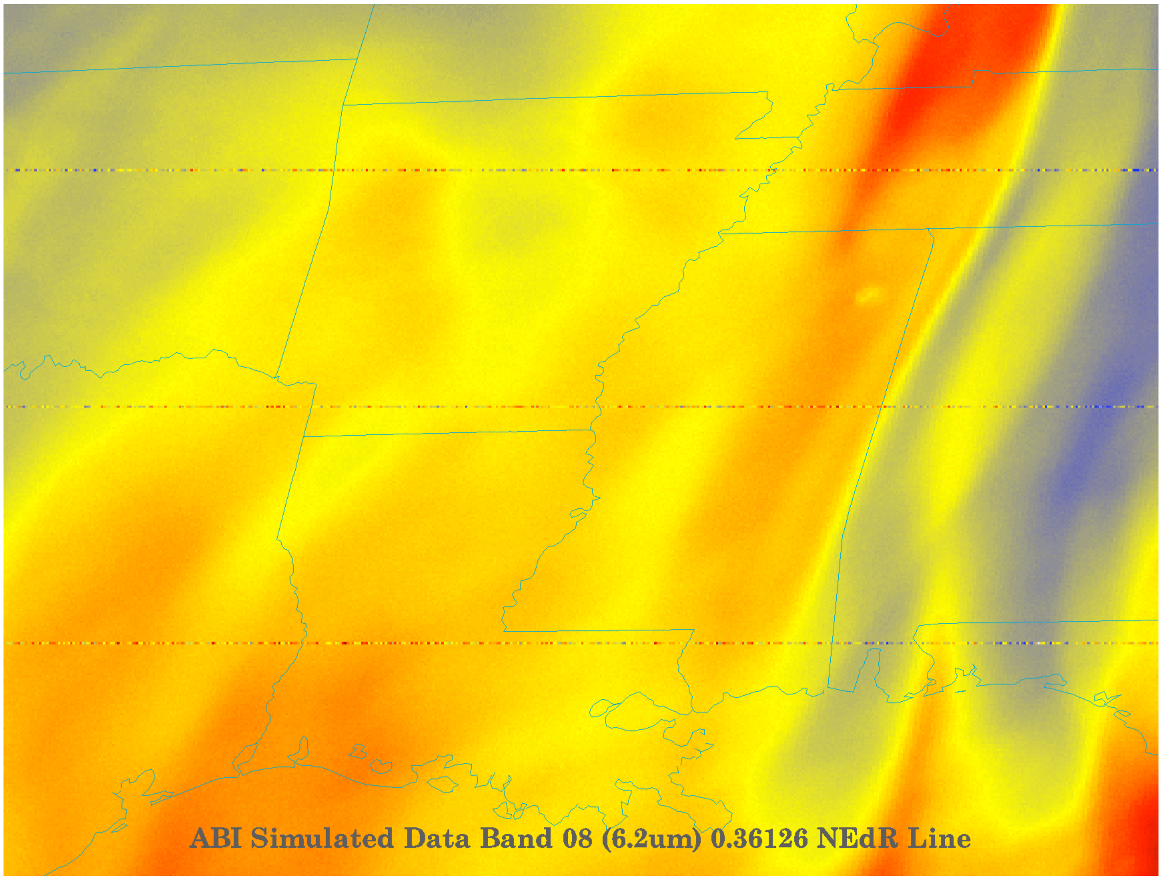

Figure 25. Simulated ABI data for one of the water vapor bands showing the effects of a noisy detector applied every 100 lines. These data show an example of how proxy data can be used to demonstrate and address a potential instrument effect on ABI.

Publications, Reports, Presentations

Zhang, Hong, Mathew Gunshor, Allen Huang, Eva Schiffer, William Straka, Ray Garcia, and Graeme Martin: "GRAFIIR – An Efficient End-to-End Semi Automated GOES-R ABI Algorithm Performance Analysis and Implementation Verification System" - a poster presented at the 8th Annual Symposium on Future Operational Environmental Satellite Systems, AMS 92nd annual meeting, New Orleans, LA, 22-26 January 2012.

Gunshor, Mathew, Hong Zhang, Allen Huang, Eva Schiffer, William Straka, Ray Garcia and Graeme Martin: "GRAFIIR and JAFIIR – Efficient End-to-End Semi-Automated Algorithm Performance Analysis and Implementation Verification Systems" – poster presented at the NOAA 2013 Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users; NOAA Center for Weather and Climate Prediction (NCWCP) College Park, MD; April 8-12, 2013.

7.3 AIT Technical Support

CIMSS Project Lead: R. K. Garcia
CIMSS Support Scientists: G. D. Martin, E. N. Schiffer, W. C. Straka III
NOAA Collaborator: W. Wolf
NOAA Strategic Goals Addressed:

- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Proposed Work

The AIT-Midwest handles aspects of computer science cross-cutting AWG algorithm development teams at CIMSS/SSEC, and works in cooperation with the AIT-East in Washington, DC. This includes software development practices, software process management, documentation, testing and automation, infrastructure, general computing assistance, and systems design and optimization.

Summary of Accomplishments and Findings

Test Framework Development

GEOCAT, the CIMSS algorithm development framework, and the NOAA AIT testing framework saw many improvements and several software releases. Additional algorithms were integrated, and the NOAA framework was tested at CIMSS to support GOES-R testing. Use of the reference science implementations demonstrated via these software systems has led to clarifications of theory and implementation for the operational code in development. Use and study of simulated and proxy datasets run through the reference software led to refinements in the test data sets used for verification of contractor implementations of GOES-R algorithms. These efforts contributed toward the GOES-R AWG algorithm development, improvement, and verification effort.

Over the past five years, GEOCAT has supported AWG goals in several ways. By performing tasks commonly required by science algorithms (ingest of satellite and ancillary data, calibration, navigation, satellite geometry calculation, calling RTM, writing output and utility operations), GEOCAT has freed algorithm developers from having to develop and implement this functionality independently. It has eased integration of algorithms into operational systems by abstracting common functionality, and has also served as a prototype for operational systems. GEOCAT development will be ongoing to support GOES-R algorithm maintenance as well as other science activities at CIMSS. Current efforts include development of a callable library encapsulating GEOCAT's major functionality, which will allow greater collaboration and code-sharing among different research and pseudo-operational processing systems.

Software Delivery and Development Support

In the past 5 years, AIT-Midwest supported all of the Baseline and Future Capabilities algorithms through 100% delivery from CIMSS to AIT-East for integration into the reference software, and provided further patch-ports where inconsistencies or implementation details required improvements in reference algorithm software, test frameworks and theory documents. CIMSS algorithms account for roughly 60% of all of the Baseline and Future Capability products for GOES-R. The integration of the algorithms in to the AIT Framework included several re-deliveries of test data and ATBDs (theory documentation) as part of integration support for GOES-R. In addition, AIT-Midwest supported both AIT-East and the CIMSS AWGs in the interactions with the GOES-R prime contractor (Harris Corp. and AER), including Technical Interchange Meetings, documentation of shared and support algorithms, reviews and preparation for upcoming contractor software deliveries.

In addition to the support of the algorithms at CIMSS, AIT-Midwest has supported other GOES-R algorithm working groups by providing documentation and support of ancillary and proxy datasets. Verification and development tools such as ‘glance’, a generalized large dataset comparison tool, were conceived, implemented and delivered to help support AWG activities.

Support work was broadened to include experiment and demonstration applications of GOES-R algorithms to SNPP sensors as well as simulated ABI data. In the coming year an expansion of activities is likely to be required along these lines, continuing the push toward multi-instrument algorithms running portably on multi-organization software frameworks capable of achieving accuracy, latency and flexibility goals useful for both research and pre-operational deployment.

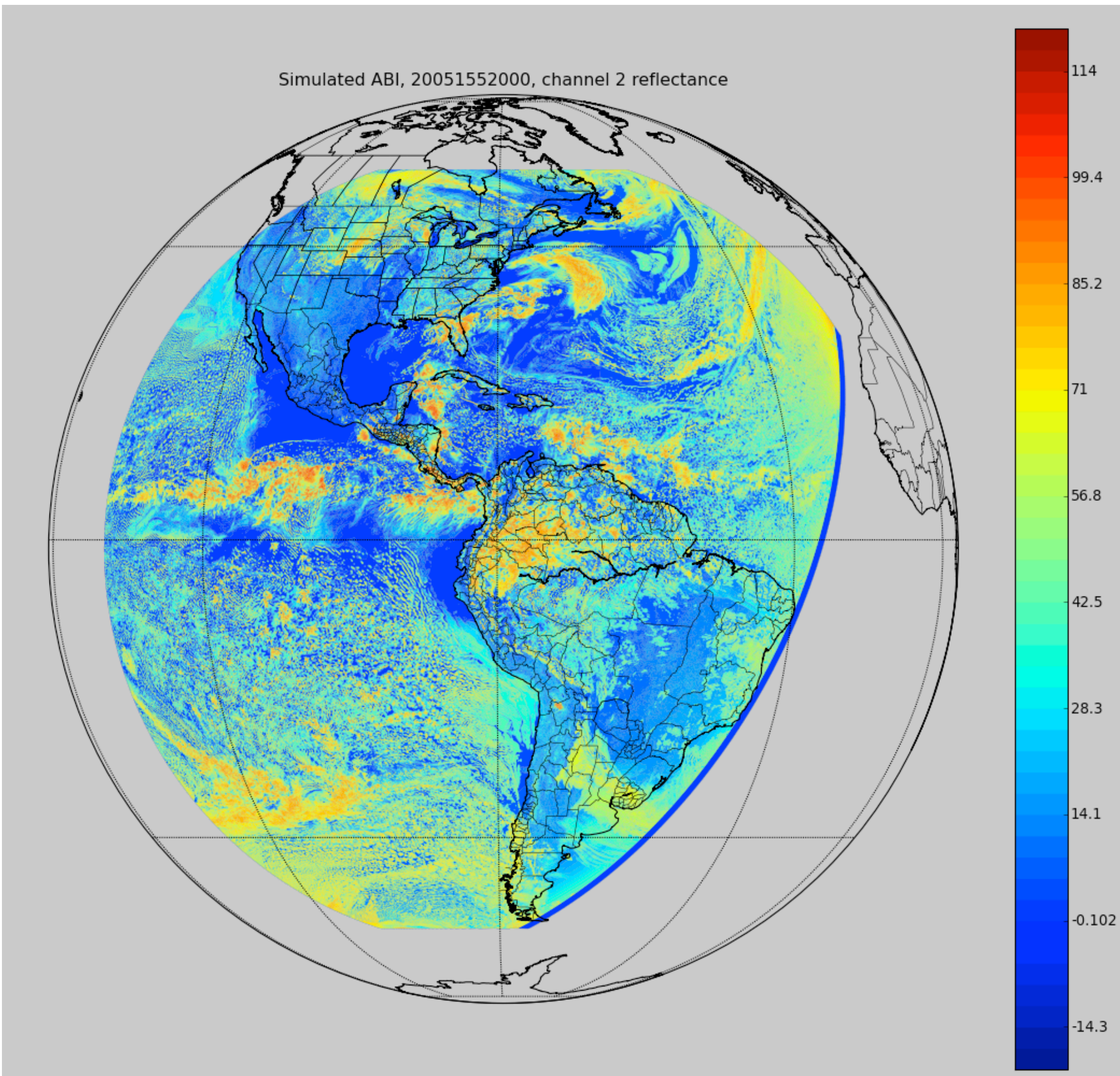

Figure 26. 0.6 µm Simulated ABI reflectance image, as output from Geocat.

7.4 GOES-R Collocation

CIMSS Project Lead: Robert Holz
CIMSS Support Scientists: Greg Quinn, Ralph Kuehn, and Fred Nagle
NOAA Collaborator: Walter Wolf
NOAA Strategic Goals Addressed:

- Provide critical support for the NOAA mission

CIMSS Research Themes:
- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

Decades of experience in applying vector algebra and analytic geometry to problems in satellite navigation at CIMSS have led to a variety of techniques for efficiently collocating observations from different sensors. These tools enable months or years of data to quickly be collocated and compared for statistical analysis. As part of the GOES-R AWG effort, the collocation project supports the following goals:
- Develop a maintainable and extensible toolkit capable of orbital analysis (overpass calculations for satellite-to-satellite or satellite-to-ground) and pixel-to-pixel collocation for both GEO and LEO instruments. This effort involves development of new techniques and algorithms in addition to refactoring and organizing legacy code;
- Support the collocation needs of GOES-R AWG teams as they work to validate their algorithms. The collocation toolkit will become part of a standard validation framework being developed by the AIT; and
- Leverage the collocation tools to build an inter-calibration system to allow near real-time monitoring of instrument performance and long-term analysis of radiometric trends.

Summary of Accomplishments and Findings

The collocation library has been expanded to include the NPP/JPSS VIIRS and CrIS observations. The current collocation capabilities are summarized in Figure 27. The code base provides flexibility to easily accommodate new observations systems as they become available.

Using the collocation library we are currently developing a GOES-R AWG processing system that will provide near real time validation products to support validation of the AWG product. This system will provide the a primary source of validation data to both Cloud and Winds AWG teams. Initial results of SEVIRI proxy cloud products is presented in the figure. Both the inter-calibration and validation features have been integrated into a system that allows for near real-time processing using a compute cluster. Thus as instrument data is made available, inter-calibration data or validation results can be made available within hours.

Slave / Master	AVHRR	CALIOP	CLOUDSAT	GOES	MODIS	POLDER	SEVIRI	VIIRS
AIRS		X	X	X	X		X	
AMSR-E					X			
CLOUDSAT		X						
CrIS								X
GOES		X			X			
HIRS	X							
MODIS		X				X		
SEVIRI		X			X			

Figure 27. The collocation matrix describing the supported instruments and platforms

Our current activities are focused on continued development of a centralized GOES-R validation system that will provide near real-time GOES-R proxy (SEVIRI and GOES) validation results using both the NASA A-Train observations (CALIPSO, MODIS, CloudSat) and JPSS (CrIS, VIIRS,ATMS) observations. We will work with the GOES-R products teams to customize the quick look and validation products. This effort will leverage significantly from our JPSS cal/val activities at UW-Madison with the goal of developing the foundation for a validation system for GOES-R post launch cal/val activities and facilitating better integration of JPSS and GOES-R. An example of the current version of the GOES-R validation site is presented in Figure 28. The site can be viewed at: http://kepler.ssec.wisc.edu/sevcalweb/cth/2012/12

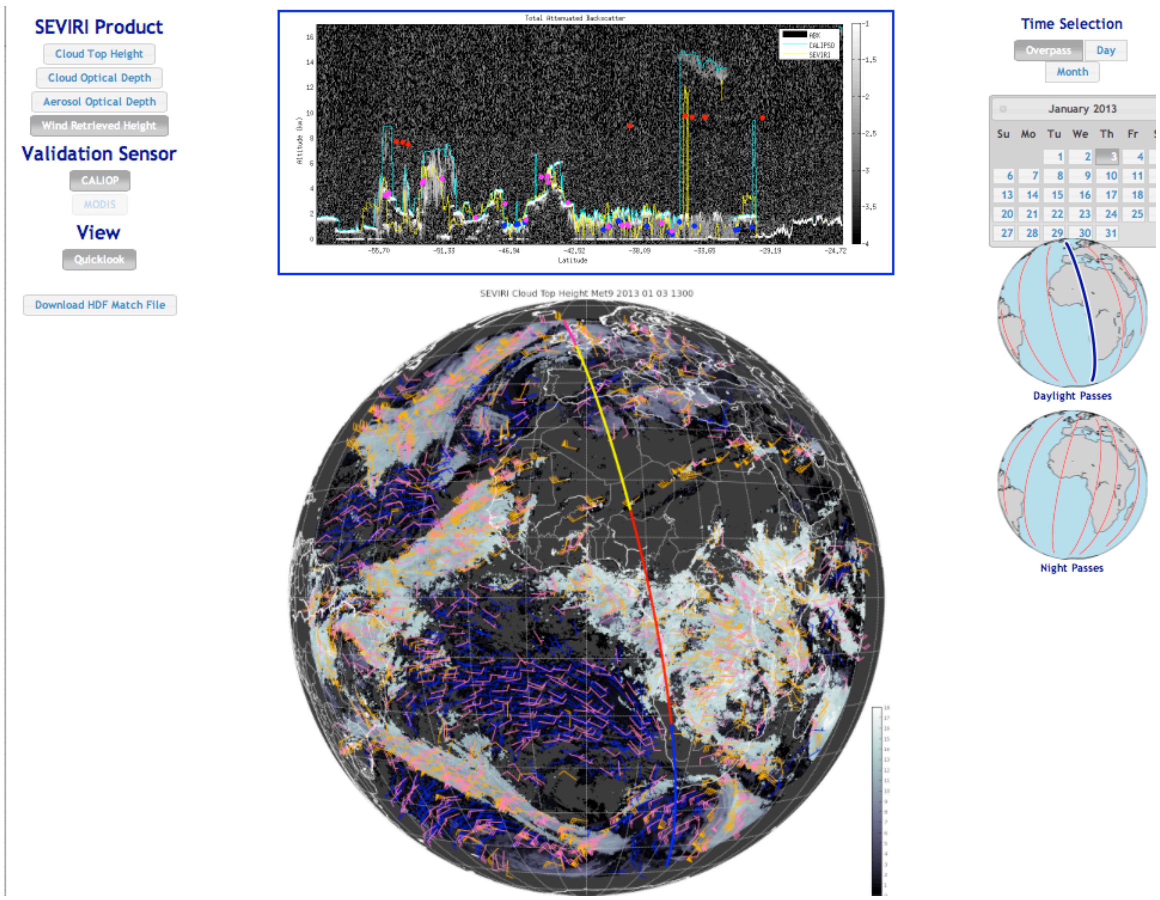

Figure 28. An example from the GOES-R validation Web interface for GOES-R winds evaluation. The multi-colored line is the CALIPSO track with the GOES-R winds overlaid the global cloud top height image. The top figure is the CALIOP attenuated backscatter image with collocated GOES wind heights overlaid. This years effort will be focused on continued development of the validation Web site leveraging the collocations software.

Publications, Reports, Presentations

Nagle, F. W. and R. E. Holz, 2009: Computationally Efficient Methods of Collocating Satellite, Aircraft, and Ground Observations. *Journal of Atmospheric and Oceanic Technology*, **26**, 1585-1595.

7.5 ABI Cloud Products

CIMSS Project Lead: William Straka III
CIMSS Support Scientists: Andi Walther, Pat Heck, Steve Wanzong
NOAA Collaborators: Andrew Heidinger, Michael Pavolonis
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water

- Support the nation’s commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Proposed Work

National Environmental Satellite, Data, and Information Service, Center for Applications and Research (NESDIS/STAR) and the Cooperative Institute for Meteorological Studies (CIMSS) have been developing a suite of products that will offer advanced cloud detection and retrievals of cloud properties utilizing the GOES-R ABI instrument. The Cloud Algorithm Working Group (Cloud AWG) has developed five algorithms that generate fourteen independent cloud products. These include the clear sky mask, cloud type and phase, cloud top height, cloud top pressure, cloud top temperature, and both day and nighttime cloud microphysical properties. This project has been ongoing for 5 years.

Summary of Accomplishments and Findings

The Cloud AWG has done a significant amount of work over the last 5 years on the development of the Cloud algorithms, along with the validation of the various cloud algorithms.

In 2011, the Cloud AWG delivered the final code delivery for the GOES-R Ground System (GS). In iterating with the GOES-R Ground Segment System Prime, Harris Corporation and Atmospheric and Environmental Research (AER), there were a few issues, which were answered in a timely manner regarding the implementation of the GOES-R cloud products. In addition to the final code delivery, the Cloud AWG also delivered updated Algorithm Theoretical Basis Documents (ATBDs) that described the algorithms in detail.

Since the delivery of the code to the GS, the Cloud AWG has continued to improve upon each of the algorithms. While the ABI has not been launched at this point, the Cloud AWG continues using the SEVIRI instrument onboard the EUMETSAT Meteosat Second Generation (MSG) geostationary orbiters as a proxy. In addition, several of the algorithms have been modified to work on other sensors, such as current GOES, MTSAT, MODIS and VIIRS. Also the Cloud Mask, Cloud Type/Phase, Cloud Height and Daytime Optical Properties algorithms were tested on simulated ABI data provided by the GOES-R proxy data team.

In addition, the Cloud AWG has undertaken several validation studies, extensively using other satellite sensors, such as spaceborne lidars, (CALIPSO), passive microwave satellite sensors (AMSU, AMSR-E), ground microwave profilers (MWR at ARM site) and passive imagers (MODIS, AVHRR), as independent data sources. In addition, the Cloud AWG has made extensive use of the lidar on-board CALIPSO to tune the cloud mask for the least number of false detections. Using processed GOES Imager data as a proxy for ABI, we have developed tools to validate the cloud mask using skin temperature, total insolation and diffuse/total insolation measured at the surface. Figure 29 shows one such validation using the ratio of diffuse insolation to total insolation to determine cloudy/not cloudy at the Bondville, IL SURFRAD site, along with the GOES cloudiness fraction and the cloud mask’s Probability of Correct Detection.

A large part of the AWG validation work involved the service of AWG cloud products from CIMSS to various field experiments. During 2013, the Deep Convective Clouds and Chemistry (DC3) Experiment took place in April, May and June in the central USA. AWG cloud products were served into the DC3 Data Catalog (http://catalog.eol.ucar.edu/cgi-bin/dc3_2012/ops/index).

Figure 30 shows an example image from the data catalog. These data were used in flight planning since once of the goals of the mission was to sample cirrus clouds. AWG cirrus heights were used in this planning process. HSRL data was used to validate the cloud heights. Validation of other properties including cloud optical depth using the University of Colorado SSFR instrument is continuing. In addition, the AWG cloud products are being used in the Hurricane and Severe Storm Sentinel (HS3) mission (2012 thorough 2014). The cloud height products are one source of data used in guiding the Global Hawk away from potentially damaging convection. The HS3 is also a good source of validation as several aircraft instruments are included in the mission. Figure 31 shows cloud height values from GOES-13 in good agreement with the Cloud Physics Lidar (CPL) and the Scanning High-resolution Interferometer Sounder (S-HIS).

Another source of ongoing validation is collaboration with the EUMETSAT Cloud Retrieval and Evaluation Workshop (CREW), which the Cloud AWG is an active member of. The GOES-R Cloud products are compared to other leading algorithms and validated against A-train data during three workshops in Norrköping, Sweden (2006), Locarno (2009) and Madison (2012). The Cloud AWG team set up and maintains a common data set including analysis and visualization tools, which has been using as a test bed for ongoing and continuous validation and development work. This all-hand evaluation helped to identify the strengths and weaknesses of present retrievals. Figure 32 shows an example for cloud height products, where the Cloud AWG retrieval was compared to the SEVIRI proxy data and CALIPSO lidar measurements.

Finally, the Cloud AWG team continues to work with the other Algorithm Working Groups, such as the Derived Motion Winds AWG, as well as other groups to continue to validate and improve the algorithms. This has included numerous validation studies of the cloud height algorithm from current sensors, which the Derived Motion Winds AWG has been using in a near-realtime sense. The DMW AWG is currently using the pixel level cloud phase, cloud type, and cloud top pressure product to assign the height of each DMW. Real-time processing includes Meteosat-10, GOES-13 and GOES-15. It is also important to point out that the Cloud AWG algorithms, as adapted to the current GOES sensors, will be used operationally by the Winds team in the production of GOES Winds. Also, the Cloud algorithms, as applied to AVHRR, are being produced operationally at OSPO within the CLAVR-x processing system.

The Cloud team has presented validation results at several conferences, including the EUMETSAT Satellite Conference, AMS annual meeting, the annual GOES-R Science Week and NOAA Satellite Conference. These are listed in the “Publications and Conference Reports” section.

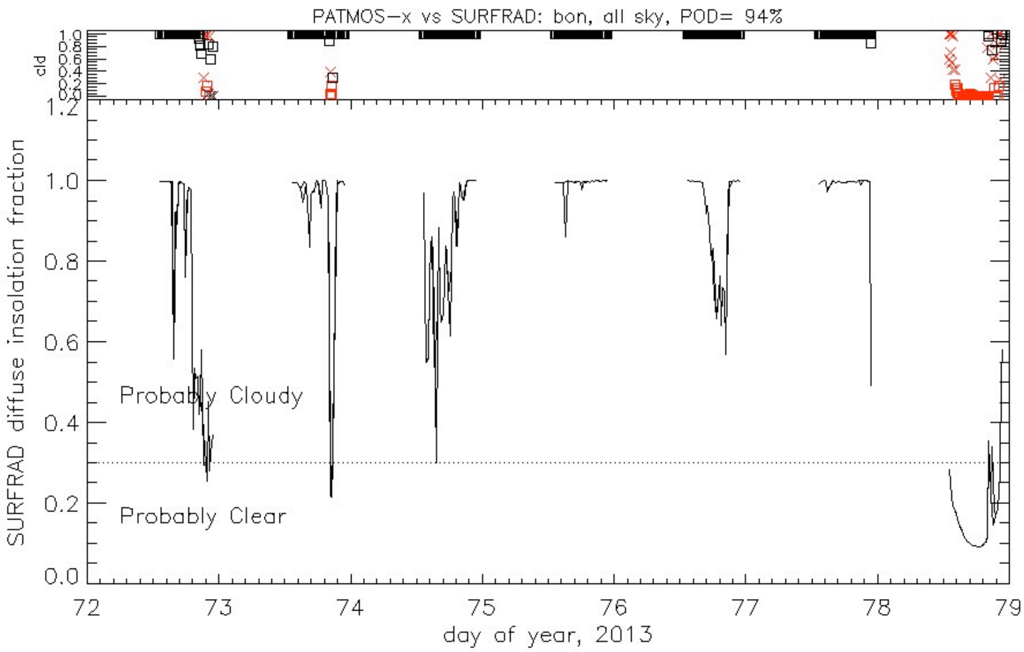

Figure 29. Cloud mask validation using the ratio between diffuse and total insolation measured at the Bondville, IL SURFRAD site (bottom axis). The probability of correct detection (POD) written above the figure is an evaluation of the cloudiness fraction (top axis) based on the cloud mask values within 10km of the site. The cloud mask is from GOES Imager data using the PATMOS-x cloud mask algorithm.

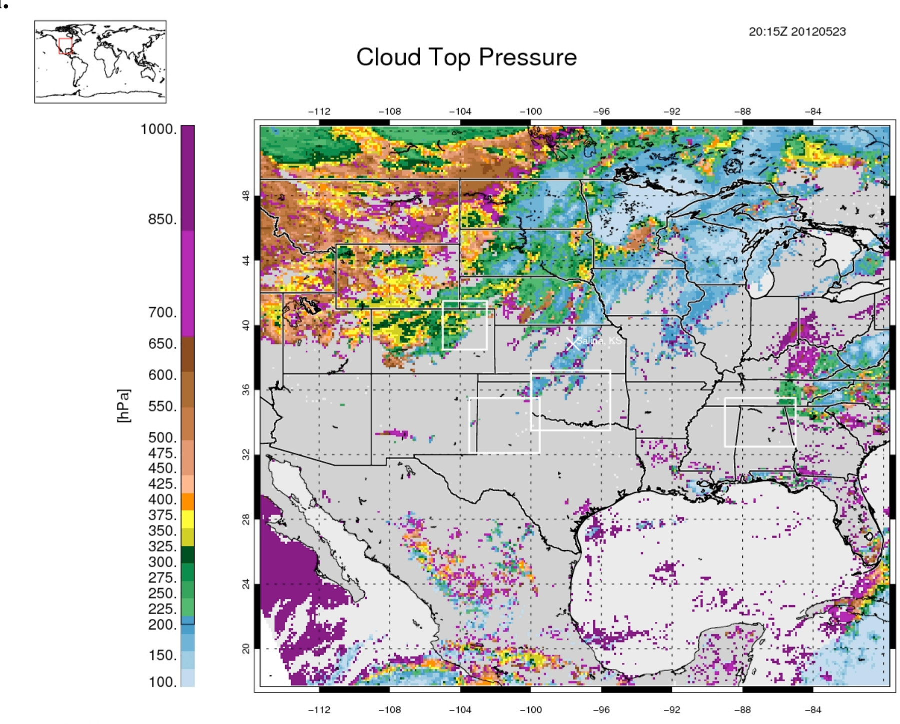

Figure 30. Example image from the Deep Convective Clouds and Chemistry (DC3) Experiment Data Catalog (http://catalog.eol.ucar.edu/cgi-bin/dc3_2012/ops/index).

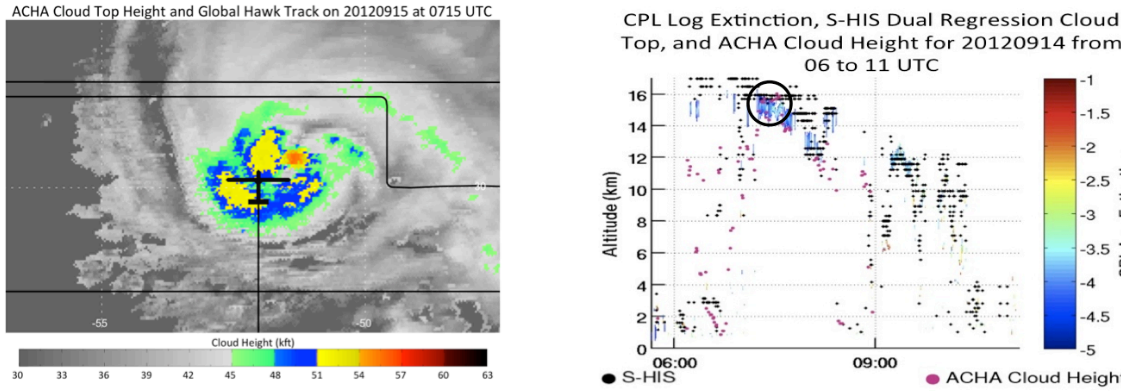

Figure 31. Geometric cloud top height estimates of approximately 50,000 feet at the location of the airplane tail over TC Nadine (left). GOES-13 cloud top heights compare well to CPL and S-HIS for the Global Hawk flight portion over Nadine's cold convection shown inside the circle (right).

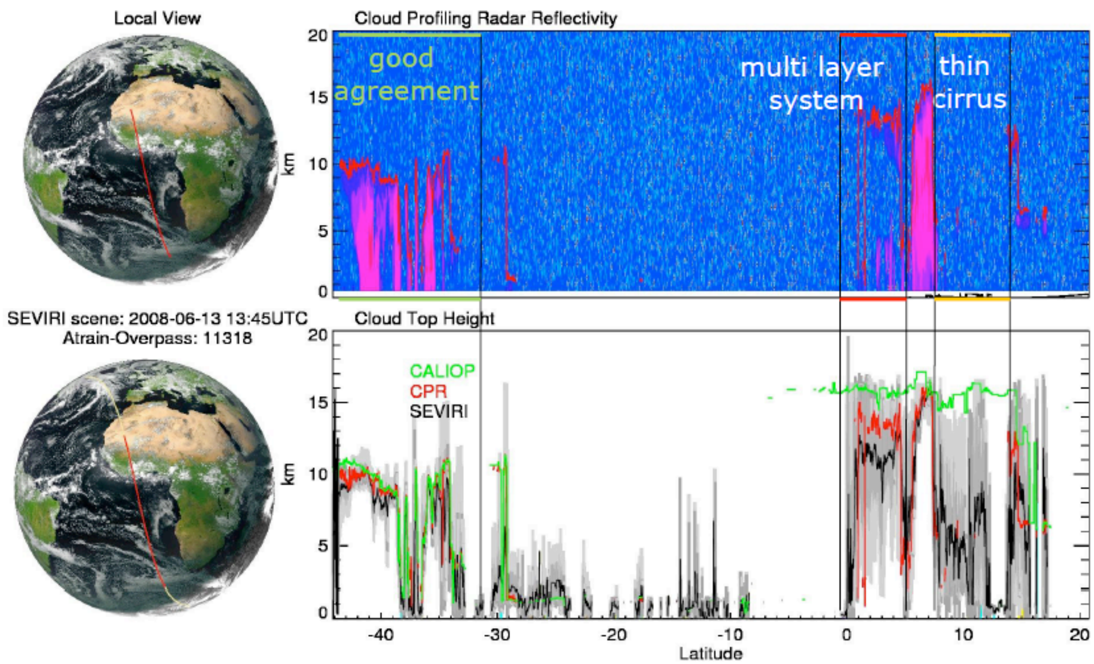

Figure 32. Example of cloud top height retrievals validation from CREW workshop in Locarno. The upper image shows the CPR radar reflectance. The lower image shows CALIOP, CPR cloud height retrieval together with SEVIRI average of all 12 contributing algorithms with SEVIRI average of all 12 contributing algorithms with the 90 and 60% agreement interval (different gray tones).

Publications and Conference Reports

Walther, Andi, Andrew K. Heidinger, 2012: Implementation of the Daytime Cloud Optical and Microphysical Properties Algorithm (DCOMP) in PATMOS-x. *J. Appl. Meteor. Climatol.*, **51**, 1371–1390.

Daniels, Jamie; Bresky, Wayne; Wanzong, Steve and Velden, Christopher. Atmospheric Motion Vectors derived via a new nested tracking algorithm developed for the GOES-R Advanced Baseline Imager (ABI). Annual Symposium on Future Operational Environmental Satellite Systems, 9th, Austin, TX, 6-10 January 2013. American Meteorological Society, Boston, MA, 2013, abstract only.

Bresky, Wayne C.; Daniels, Jaime M.; Bailey, Andrew A. and Wanzong, Steven T. New methods toward minimizing the slow speed bias associated with Atmospheric Motion Vectors. *Journal of Applied Meteorology and Climatology*, **51**, Issue 12, 2012, pp.2137-2151.

Daniels, Jamie; Bresky, Wayne; Wanzong, Steve; Bailey, Andrew and Velden, Christopher. Atmospheric Motion Vectors derived via a new nested tracking algorithm developed for the GOES-R Advanced Baseline Imager (ABI). International Winds Workshop, 11th, Auckland, New Zealand, 20-24 February 2012. EUMETSAT, Darmstadt, Germany, 2012.

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GOES-R ABI Cloud Mask Algorithm Theoretical Basis Document (100% delivery)

GOES-R ABI Cloud Type/Phase Algorithm Theoretical Basis Document (100% delivery)

GOES-R ABI Cloud Height Algorithm Theoretical Basis Document (100% delivery)

GOES-R ABI Daytime Cloud Optical Properties Algorithm Theoretical Basis Document (100% delivery)

GOES-R ABI Nighttime Cloud Optical Properties Algorithm Theoretical Basis Document (100% delivery)

7.6 Active Fire/Hot Spot Characterization

CIMSS Project Lead: Chris Schmidt
CIMSS Support Scientists: Jay Hoffman, Elaine Prins (UW-Madison/CIMSS-Contractor), Jason Brunner
NOAA Collaborators: Yunyue Yu (NOAA/NESDIS/STAR), Ivan Csiszar (NOAA/NESDIS/STAR)
NOAA Strategic Goals Addressed:

- Understand climate variability and change to enhance society's ability to plan and respond
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques
- Outreach and Education

Project Overview

Fire detection and characterization with the current generation of GOES came about by taking advantage of bands that were included on the GOES-8 through -15 Imager for other purposes. Effective fire detection and characterization was a consideration during ABI's design, and CIMSS was involved in developing the specifications for the 4 and 11 μm bands. This meant having a sufficiently high 4 and 11 μm saturation temperatures for the footprint, low noise equivalent detector radiance (NEDR), good co-registration between the 4 and 11 μm bands, and a good understanding of the bands' point spread function (PSF). CIMSS adapted the current GOES Wildfire Automated Biomass Burning Algorithm (WFABBA), building on its historical and current expertise in fire algorithm development for the GOES Imager and the global geostationary fire observation network. The Fire Detection and Characterization Algorithm (FDCA) utilizes the improved fire monitoring capabilities on GOES-R and contains updates to the modules that identify and characterize sub-pixel fire activity.

Summary of Accomplishments and Findings

In 2011 CIMSS delivered the ATBD for the FDCA along with reference code and a set of test data to be used to verify that the implementation created for the operational framework could reproduce the results from CIMSS. As the operational implementation was developed the ATBD was refined and some detailed flowcharts of the algorithm operations were created by CIMSS. In early 2013 the algorithm was confirmed to be meeting the reproducibility requirements.

Throughout algorithm development CIMSS relied upon two sources of proxy data for algorithm testing: MODIS data remapped to ABI's resolution and projection, and model data provided by the proxy data team at CIRA. Proxy data for a fire detection algorithm is a complicated problem. While it has the same kind of radiometric accuracy needs as other algorithms, if not requiring even higher accuracy, fires additionally add the complication that, as subpixel entities, they are sensitive to the PSF of the sensor and any additional steps taken to manipulate the data, such as remapping. Both the MODIS->ABI converted proxy data and the CIRA model data assumed certain characteristics of the 4 and 11 μm band PSFs, however neither went as far as to mimic the remapping that will occur with ABI data. The quantitative impact of the remapping for ABI data has yet to be calculated.

The CIRA model data allowed CIMSS to identify a likely minimum detectable fire radiative power (FRP) value of approximately 75 MW, a value that appears to be a function of the algorithm and parameters of the instrument. Figure 33 shows the fires plotted by the sizes and temperatures assigned to them in CIRA's model, with the points color-coded by fire type. A fairly distinct division between detected and not-detected fires occurs roughly along the 75 MW line of constant FRP. This division appears in all of the model case studies. Previous work with GOES WFABBA data has suggested a comparable threshold, but a lack of validation data for instantaneous fire size, temperature, and radiative power made quantifying that threshold difficult.

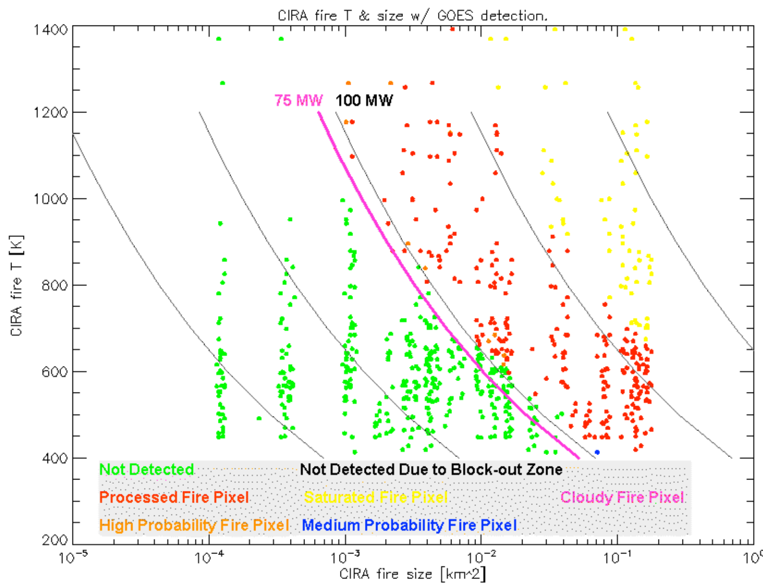

Figure 33. ABI fire proxy data for 23 October 2007 (model data credit: CIRA); The defined fire size and temperature are plotted and color-coded to reflect fire type; black curves of constant FRP are 1, 10, 100, 1,000, and 10,000 MW (left to right)

Validation tools are the current focus of ABI baseline algorithm work. Routine validation for FDCA is qualitative, comparing the ABI fire product and other satellite fire products that will be available at the time. CIMSS has been collaborating with STAR and Dr. Wilfrid Schroeder of CICS on the "deep-dive" validation tool for the ABI Fire algorithm. "Deep-dive" tools are quantitative validation tools that require human intervention or data sources that are unavailable in a realtime operational sense. The FDCA deep-dive tool takes high resolution data (such as 30m resolution Terra/ASTER or Landsat 7/ETM+ data) and uses that to validate the FDCA. Due to lack of accurate ground truth data, application of high resolution satellite data is the preferred method of validation. The high-resolution data is remapped to ABI's projection using a method that attempts to account for the PSF (and, eventually, the remapping performed on ABI data).

Figure 34, courtesy of Dr. Schroeder, illustrates the comparison between GOES and MODIS fire pixel locations and FRP, overlaid on top of an ASTER image from the same time. While locations match, the characterizations do not match extremely well, which may be due to the PSF of GOES being much broader than that of MODIS. Fires near the center of a GOES pixel are likely to appear too hot, and fires near the edge are likely to appear too cold.

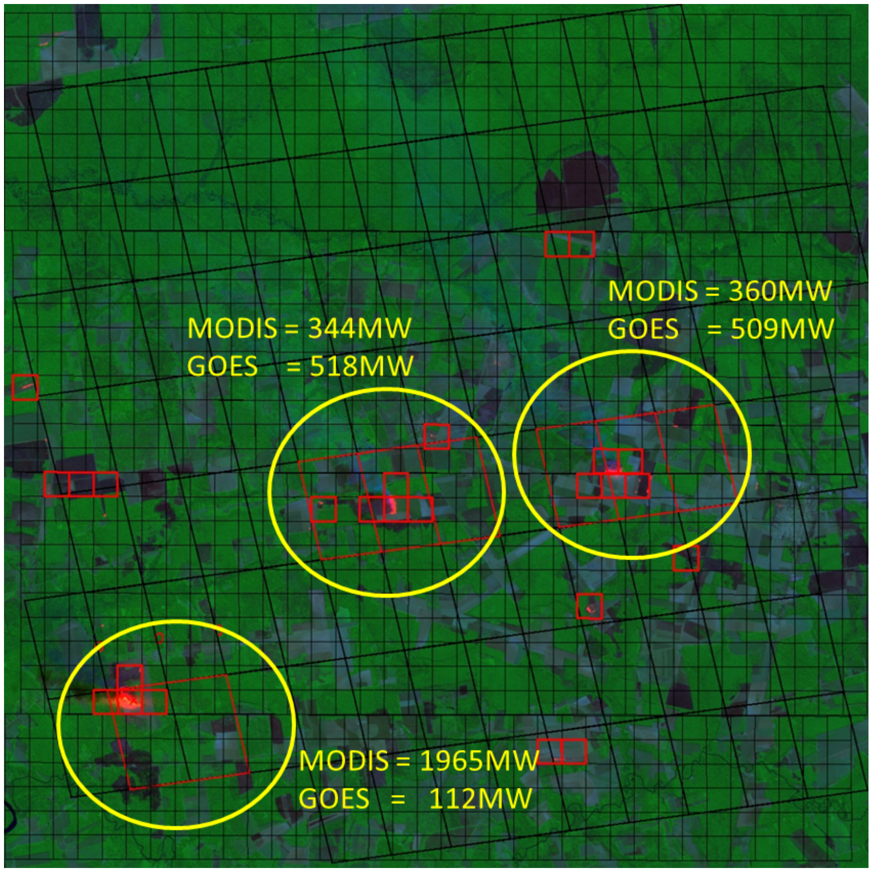

Figure 34. FDCA deep-dive validation tool prototype; Base image is ASTER, red indicates hot pixels/likely fires; MODIS pixels are small boxes, red indicates detected fires; GOES pixels are tilted boxes, WFABBA fires are red.

Publications, Reports, Presentations

Hoffman, J.; Schmidt, C. C.; Prins, E. M. and Brunner, J. C.. The GOES-R ABI Wild Fire Automated Biomass Burning Algorithm. Washington, DC, American Geophysical Union, 2011, abstract only.

Hoffman, Jay P.; Schmidt, C. C.; Prins, E. M. and Brunner, J. C.. The GOES-R fire detection algorithm from research to operations. Boston, MA, American Meteorological Society, 2012, abstract only.

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7.7 GOES-R Legacy Atmospheric Profile, Total Precipitable Water (TPW) and Atmospheric Instability Indices

CIMSS Project Lead: Jun Li
CIMSS Support Scientists: Yong_keun Lee, Zhenglong Li, Jim Nelson, Graeme Martin, Jinlong Li
NOAA Collaborator: Tim Schmit, NESDIS/STAR
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

This task is part of CIMSS GOES-R algorithm working group (AWG) project started in 2006. The main focus of this task is to develop the legacy atmospheric profile (LAP) algorithm for the next generation Geostationary Operational Environmental Satellite (GOES-R) Advanced Baseline Imager (ABI) (Schmit et al., 2005) product generation. Since the Hyperspectral Environmental Suite (HES) has been removed from GOES-R, the ABI is used to continue the current GOES Sounder products (Schmit et al., 2008). The algorithm retrieves GOES-R baseline atmospheric temperature and moisture profiles and the derived products including total precipitable water (TPW), layer precipitable water (PW), lifted index (LI), convective available potential energy (CAPE), total totals index (TT), Showalter index (SI), and the K-index (KI) from the clear sky infrared (IR) radiances within a 5 by 5 ABI field-of-view (FOV) box area. This project requires CIMSS scientists to develop the GOES-R LAP algorithm to be able to process high temporal and spatial resolution ABI data efficiently. This project provides science codes to the GOES-R algorithm integration team (AIT) for algorithm integration and helps the system provider to implement the algorithm and codes into the GOES-R ground system. CIMSS scientists also validate the GOES-R LAP algorithm to assure that the GOES-R atmospheric temperature and moisture profiles, TPW, LI, CAPE, TT, SI and KI products meet the science requirements and applications.

Summary of Accomplishments and Findings

The GOES-R ABI LAP algorithm has been developed and delivered for operational implementation. CIMSS scientists have also conducted the pre-launch validation of the LAP algorithm with SEVIRI, the current GOES Sounder and the Moderate Resolution Imaging Spectroradiometer (MODIS) IR radiance measurements as proxy for GOES-R ABI, because of the spectral similarity between ABI and those instruments. For validation purpose, the GOES-R LAP algorithm has been adapted to process SEVIRI, the current GOES Sounder and MODIS IR band radiance measurements. Validation tool is also designed and developed to help the evaluation of GOES-R LAP algorithm and the tool has deep dive capability to investigate the environment (temperature and dew-point temperature profiles) of any time input by the user. The major accomplishments are highlighted below:
(a) Algorithm has been developed and delivered for operational implementation.
(b) The algorithm has been adapted to process SEVIRI, the current GOES Sounder and MODIS.
The GOES-R LAP algorithm has been implemented in IMAPP to generate the atmospheric product in real time for regional applications. Also the real time GOES Sounder products with GOES-R LAP algorithm will be generated in GEOCAT at CIMSS in 2013.

(c) GOES-R LAP algorithm has been validated using one year GOES-13 Sounder as proxy. Five reference ("truth") measurements: radiosonde observation (RAOB) and microwave radiometer (MWR) measured total precipitable water (TPW) at the Atmospheric Radiation Measurement (ARM) Cloud and Radiation Testbed (CART) site, conventional RAOB, Global Positioning System-Integrated Precipitable Water (GPS-IPW) NOAA network TPW measurements, and TPW from the Advanced Microwave Scanning Radiometer for EOS (AMSR-E), are collected over east Continental United States (CONUS) from February 11, 2011 to August 30, 2012. With the GOES-R LAP algorithm, the GOES-13 Sounder provides better water vapor profiles over GFS forecast fields at the levels between 300 hPa and 700 hPa. Root mean square error (RMSE) and standard deviation (STD) of the GOES-13 Sounder TPW with the GOES-R LAP algorithm are consistently reduced from those of the GFS forecast no matter which measurements are used as the truth (See Table 1). The reference data is MWR measured TPW at the ARM CART site and the data are valid during the period between Jun. 1, 2012 and Aug. 30, 2012. RMSE for TPW from the GOES-13 Sounder with GOES-R LAP retrieval algorithm is substantially better than the previous operational GOES Sounder algorithm (Ma et al., 1999) (operational before Jan 2013), and slightly better than the current operational GOES Sounder algorithm (Li et al., 2008) (operational after Jan 2013) (see Figure 35). The results indicate that the GOES-R LAP algorithm provides substantial improvement from the GFS forecast fields. Based on these results, the GOES-R LAP algorithm is well prepared for providing quality continuation to the current GOES Sounder, and the algorithm can potentially be transferred to process the current GOES Sounder measurements for operational product generation.

Table 1. RMSE and STD from GOES-13 Sounder with GOES-R LAP algorithm compared with various references (for AMSR-E comparison the period is between Feb. 11, 2011 and Oct. 4, 2011 due to the AMSR-E operation issue).

References	GOES-13 LAP				GFS forecast				Samples
	RMSE (mm)	BIAS (mm)	STD (mm)	Corr	RMSE (mm)	BIAS (mm)	STD (mm)	Corr	
MWR	2.19	0.84	2.03	0.99	2.57	0.88	2.42	0.98	6338
ARM RAOB	2.93	1.52	2.50	0.98	3.15	1.56	2.73	0.98	1079
Conventional RAOB	3.12	0.28	3.10	0.97	3.29	0.29	3.28	0.97	25529
GPS	2.29	0.38	2.25	0.98	2.45	0.20	2.44	0.98	1010609
AMSR-E	2.36	-0.83	2.21	0.98	2.89	-1.52	2.45	0.98	3847196

Publications, Reports, Presentations

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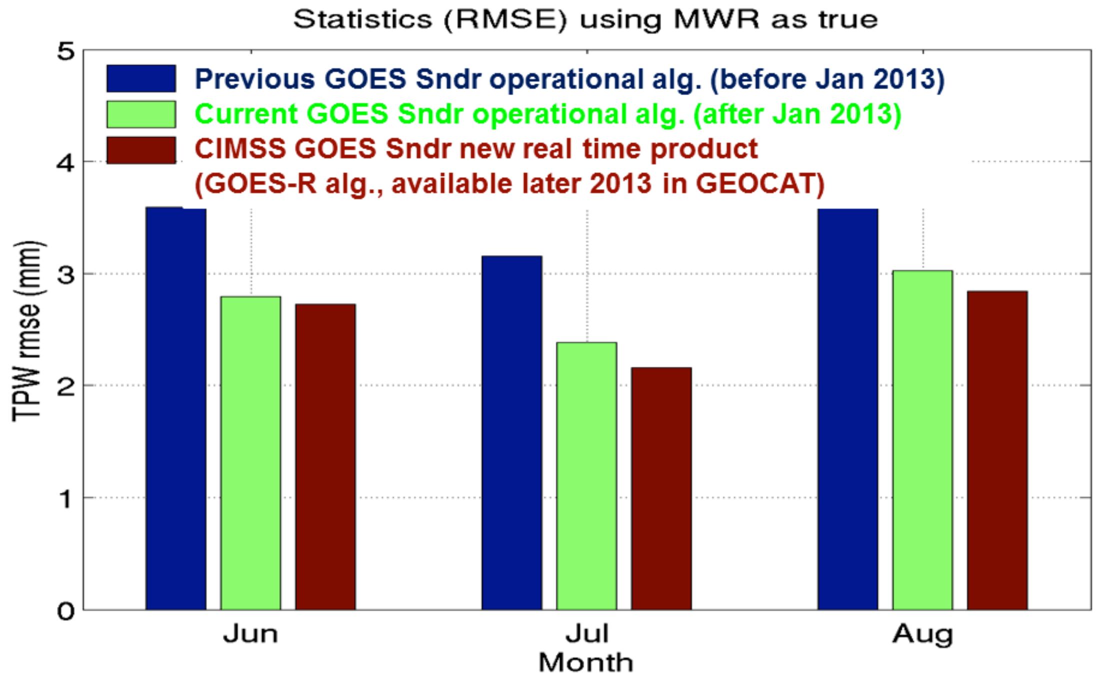

Figure 35. RMSE of TPW from the GOES-13 Sounder with LAP retrieval algorithm, the previous operational GOES Sounder algorithm (operational before Jan 2013), and the current operational GOES Sounder algorithm (operational after Jan 2013). The reference data is MWR measured TPW at the ARM CART site and the comparisons are between Jun. 1, 2012 and Aug. 30, 2012.

7.8 GOES-R AWG ABI Winds

CIMSS Project Leads: Chris Velden and Steve Wanzong
NOAA Collaborator: Jaime Daniels (STAR)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

In preparation for the launch of GOES-R, the NOAA GOES-R Algorithm Working Group (AWG) winds team is actively developing atmospheric motion vector (AMV) derivation algorithms and using them in demonstration studies. The AMV algorithm development has reached a mature stage and the project is now in a validation mode. The software is being tested in a near real-time demonstration mode using Meteosat-9 SEVIRI data as ABI proxy imagery, with the resultant AMVs validated against "truth" data sets. Hourly AMVs from Meteosat-9 will be produced in near real-time and validated against the GFS analysis wind fields. Visible AMVs from band 1 (0.6 μm) are produced hourly from 08 UTC until 19 UTC. Short wave IR (SWIR) AMVs from band 4 (3.90 μm) are run from 00 UTC until 07 UTC and then again from 20 UTC until 23 UTC. Band 1 and band 4 produce complimentary AMVs (low-level only), so our processing strategy does not allow for product overlap. Cloudy water vapor AMVs (upper-level only) from band 8 (6.2 μm) and long wave IR (LWIR) AMVs from band 14 (11.2 μm) are produced every hour. Match files comparing AMVs to the GFS analysis winds are produced 4 times daily at 00, 06, 12, and 18 UTC. We also are looking at AMV height assignment in more depth with the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations/Cloud-Aerosol Lidar with Orthogonal Polarization (CALIPSO/CALIOP) observations.

Summary of Accomplishments and Findings

The primary activity involves the analysis of AMV height assignments using the CALIPSO observations as a benchmark comparison dataset. AMV-CALIPSO collocations provide a novel way to look into the validity of the AMV height assignment within the GOES-R nested-tracking software. In the example to follow, we look at AMVs from a typical proxy dataset using Meteosat-9 SEVIRI from 15 September 2011 at 00 UTC.

The figure below (Figure 36) shows an altitude-time x-section image of the total attenuated CALIPSO (532 nm) backscatter (/km/sr) plotted along with the collocated AMV locations in red, and the CALIPSO cloud top height estimates in yellow. AMVs in the southern Atlantic Ocean off the coast of Africa are considered in this image. Good agreement in low-level water cloud tops is observed between the AMV heights compared to the CALIPSO cloud top height product in this particular example. Further evaluation is continuing and the results will be used to refine the GOES-R AMV height assignments.

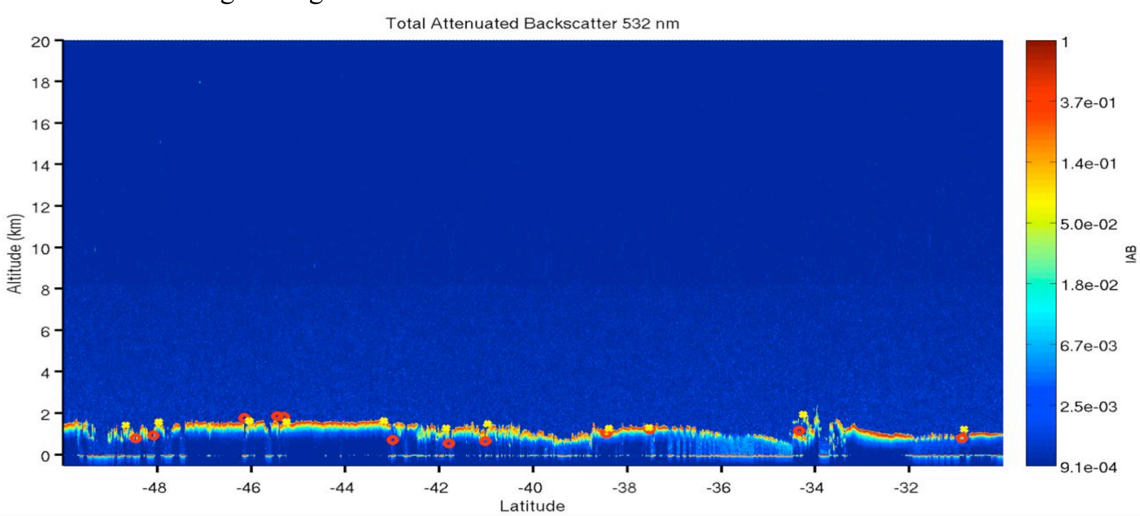

Figure 36. CALIPSO total attenuated backscatter with collocated AMV-estimated cloud height assignments plotted in red dots, and CALIPSO-estimated cloud tops in yellow dots.

Publications, Reports and Presentations

Daniels, Jamie, Bresky, Wayne, Wanzong, Steve and Velden, Christopher: Atmospheric Motion Vectors derived via a new nested tracking algorithm developed for the GOES-R Advanced Baseline Imager (ABI). Annual Symposium on Future Operational Environmental Satellite Systems, 9th, Austin, TX, 6-10 January 2013. American Meteorological Society, Boston, MA.

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Wanzong, Steve, Bresky, Wayne C., Velden, Christopher S., Daniels, Jaime M. and Bailey, Andrew A.: GOES-R readiness: Atmospheric Motion Vector (AMV) validation activities. International Winds Workshop, 11th, Auckland, New Zealand, 20-24 February 2012. EUMETSAT, Darmstadt, Germany, 2012.

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7.9 GOES-R AWG Hurricane Intensity Estimation (HIE) Algorithm

CIMSS Project Leads: Chris Velden and Tim Olander
NOAA Collaborator: Jaime Daniels (STAR)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The CIMSS Advanced Dvorak Technique (ADT; Velden and Olander, 2007, *Weather and Forecasting*) was selected to be the operational Hurricane Intensity Estimation (HIE) algorithm to operate within the GOES-R framework. The HIE will provide tropical cyclone (TC) intensity estimates using the GOES-R Advanced Baseline Imager (ABI) infrared imagery. The ADT was selected due to its longstanding use at several operational TC centers worldwide, and because of its proven record for accuracy and reliability in providing TC intensity estimates, especially where aircraft reconnaissance is not available.

Summary of Accomplishments and Findings

CIMSS Tropical Cyclone group scientists are supporting the re-writing of the HIE algorithm into operational code by Harris/AER programmers within their system through documentation review and answering questions raised by code developers and document writers. A vast majority of the work has focused on addressing HIE algorithm code questions and issues found by AER/Harris programmers during their conversion process. All issues are being addressed and responded to sufficiently and in a timely manner. In addition, clarification of the related sections of the HIE Algorithm Description Document (ADD), based upon the HIE Advanced Theoretical Basis Document delivered previously by CIMSS scientists, were provided to AER/Harris, as necessary. The ATBD was also updated to reflect the ADD modifications and continues to be updated as new questions and clarifications are requested by and provided to AER/Harris programmers.

Review of the HIE output netCDF files was performed to assess the accuracy of the variables stored in these files. Specific focus was given to the derivation of the wind speed output values and making sure the correct default/missing variables were stored in the file at the proper time.

Publications, Reports and Presentations

Olander, T., and C. Velden, 2012: The current status of the UW-CIMSS Advanced Dvorak Technique (ADT), 30th Conf. on Hurricanes and Tropical Meteorology, Ponte Vedra Beach, FL, April 15-20.

7.10 Volcanic Ash Detection, Retrieval, and Automated Alerting in support of GOES-R AWG, GOES-R Risk Reduction and JPSS Risk Reduction

CIMSS Project Lead: Justin Sieglaff
CIMSS Support Scientist: John Cintineo
NOAA Collaborator: Michael Pavolonis NOAA/NESDIS
NOAA Strategic Goals Addressed:

- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The volcanic ash research at UW-Madison/CIMSS encompasses multiple projects supporting multiple sensors. Originally the volcanic ash research group was assembled to support the GOES-R Algorithm Working Group (AWG) volcanic ash requirement of retrieving the volcanic ash cloud-top height and column mass loading. The GOES-R AWG work resulted in a two-step approach for meeting these requirements—first an algorithm designed to detect volcanic ash and a second algorithm performs the physical retrievals to determine the cloud-top height, column mass loading, and effective particle size using a 1-D var approach. The GOES-R AWG algorithms have been completed and delivered to the program office. The GOES-R AWG volcanic ash group continues to support the AWG by participating in technical interchange meetings and answering questions related to the algorithm theoretical basis document (ATBD).

More recently, GOES-R Risk Reduction (GOES-RRR) determined that the AWG volcanic ash requirements would under utilize the GOES-R capabilities (e.g., the AWG products are not designed (or required) to issue alerts to forecasters when an ash cloud was identified; which is necessary to fully utilize the 5-minute refresh rate expected from GOES-R ABI to support 5-minute volcanic cloud warning criteria established by the international aviation community). As such, GOES-RRR funding was awarded for the development of a fully automated volcanic cloud alert system for GOES-R. Specifically, the goal is to identify volcanic clouds with skill comparable to a well-trained human analyst in a computationally efficient manner, with very low false alarm rates, and have the ability for multiple methods of product dissemination.

Most recently, the JPSS Risk Reduction program identified volcanic ash detection and physical retrievals as a missing component to the suite of VIIRS products. The VIIRS instrument has fewer spectral channels than the GOES-R ABI (e.g., missing 13.3 μm channel used by GOES-R volcanic ash retrieval algorithm), but does contain an 8.5 μm channel—which is critical for volcanic ash detection. The JPSS Risk Reduction program awarded funding to modify the GOES-R volcanic ash detection and retrieval algorithms for optimal performance with the available VIIRS spectral channels.

Summary of Accomplishments and Findings

During recent years volcanic ash detection and retrieval algorithms were developed and validated as part of the GOES-R AWG project. The retrievals of ash cloud-top height and column mass loading were shown to have accuracy exceeding GOES-R AWG requirements. The validation methodology utilizes satellite-borne cloud lidar (CALIOP) to determine the truth cloud-top height of volcanic clouds. The validation requires the spatial/temporal matchups of CALIOP observations with passive infrared radiance observations from SEVIRI and/or MODIS (these instruments have similar spectral channels to GOES-R ABI). The ash cloud heights retrieved using the GOES-R algorithm using SEVIRI as a proxy for ABI showed a negative bias (-0.77 km) relative to CALIOP cloud top heights (Pavolonis et al., 2013). The negative bias was expected because CALIOP has much higher vertical resolution compared to SEVIRI is effectively observing a layer within the ash cloud opposed to the absolute cloud-top viewed by lidar. While the column mass loading cannot be directly validated, assumptions can be made about the ash particle composition, size, and shape—combined with the CALIOP truth cloud-height to perform vicarious validation of column mass loading. This validation approach indicates the GOES-R approach has bias of 0.42 ton/km^2 and precision of 1.17 tons/km^2. The GOES-R ash detection and retrieval algorithms are being modified for use with the more limited spectral coverage available from the VIIRS instrument. This work is ongoing and similar validation approaches will be utilized to determine the accuracy of the algorithm for the VIIRS instrument. Initial results are encouraging and the very high spatial resolution of the VIIRS instrument (750 m for M-bands) will allow for the detection of small volcanic ash plumes that other, coarser spatial resolution imagers may otherwise miss.

The requirements of the GOES-R AWG did not require automated alerting capability. As data rates increase to every 5-minutes with GOES-R ABI and to support 5-minute volcanic cloud warning criteria established by the international aviation community it is impractical to assume trained human analysts will be able to examine all satellite data in a timely manner. The automated volcanic cloud alert capability requires an improved volcanic ash detection approach that results in an extremely low false alarm rate—on the order of 1-2 false alarms per week.

The GOES-R AWG volcanic ash detection algorithm relies on the spectral separation of volcanic ash clouds compared to meteorological (water and ice) clouds. While a large deal of separation exists between ash and meteorological clouds, spectral information alone is insufficient to determine the full extent of volcanic ash clouds while maintaining very low false alarm rates (the spectral ambiguity of volcanic ash often occurs for very thin ash clouds—away from the robust ash spectral signatures—but a trained human analyst is capable of correctly depicting the spatial extent of volcanic ash). A two level approach to volcanic ash detection that utilizes a naïve Bayesian statistical model has been developed with very good success under the GOES-RRR project. The two level detection algorithm first determines the probability that pixel is volcanic ash based upon spectral information alone (based upon a large set of training data of ash and non-ash observations). The second step groups spatially adjacent pixels into cloud objects and computes various statistical metrics of spectral quantities for each cloud object. A second naïve Bayesian model is used to determine the probability a given cloud object is volcanic ash. The GOES-R AWG retrievals are performed for all pixels that belong to a cloud object. Finally a post-processing methodology uses the spectral, spatial, and retrieval output in determining whether a cloud object meets alert criterion (configurable on a per user basis). Any cloud objects that meets alert criterion are sent to users via email and/or SMS text message. The alerts contain a unique URL with volcanic alert report information (e.g., height of ash cloud, location of cloud, list of nearby volcanoes) and associated alert imagery (that is also automatically generated).

The automated volcanic cloud alert system is currently capable of generating alerts for three different volcanic related features: 1) volcanic clouds that generally have spectral signatures consistent with volcanic ash, 2) hot spots associated with lava at or just beneath the surface at volcano summits, and 3) extreme cloud growth rates that exceed even that of the most intense non-volcanic convection, often when spectral ash signatures are obscured due to tremendous water/ice content of some volcanic eruptions (using geostationary satellites with sufficient temporal resolution). The figures below show examples of automated alert report and imagery on the Web that is automatically sent to users (e.g., volcanic ash alert center forecasters). Figure 37 is an example of an eruption of Popocatepetl volcano in Mexico from 17 June 2013. This eruption is an example of an ash cloud with a spectral signature consistent with volcanic ash. The imagery and alert information shown are available as a link in the email/text message users automatically receive. Figure 38 is an example of an explosive eruption of the Tungurahua volcano in Ecuador from 14 July 2013 as observed by GOES-13. This example highlights a volcanic eruption that contains tremendous amounts of water and ice and therefore the cloud does not exhibit spectral signatures consistent with volcanic ash. However, the volcanic cloud cooled 63 K in the 32 minutes between GOES infrared window observations, which is in excess of 4 standard deviations above the mean of all cooling rates commonly observed by geostationary sensors. A volcano observatory indicated the eruption began at 1151 UTC and the GOES observation time over the volcano occurred at 1156 UTC—so the 63K cooling actually occurred in only 5 minutes. The coarse temporal resolution of GOES-13 in this case (32 minutes) effectively diluted the cooling rate of this eruption (although it was still detectable, but other, less explosive eruptions may not be with current GOES temporal resolution). The potential of 5-minute fulldisk resolution of GOES-R ABI will better capture the separation between the growth of volcanic driven convection and meteorologically driven convection.

The automated alert system has been running in real-time at UW-Madison/CIMSS for nearly a year, processing imagers aboard the GOES-EAST, GOES-WEST, MODIS, Meteosat, and MTSAT satellites. Operational personnel at the Anchorage and Washington DC Volcanic Ash Advisory Centers, as well as Alaska Volcano Observatory and United States Geological Survey scientists are evaluating the alerts. These partnerships and evaluation of the automated alert system will continue and grow during the remainder of 2013.

Publications, Reports, Presentations

Pavolonis, M. J., A. K. Heidinger, and J. Sieglaff (2013), Automated retrievals of volcanic ash and dust cloud properties from upwelling infrared measurements, J. Geophys. Res. Atmos., 118, doi:10.1002/jgrd.50173.

Pavolonis, M. J., 2010: Advances in extracting cloud composition information from spaceborne infrared radiances: A robust alternative to brightness temperatures. Part I: Theory. *J. Applied Meteorology and Climatology*, **49**, 1992-2012.

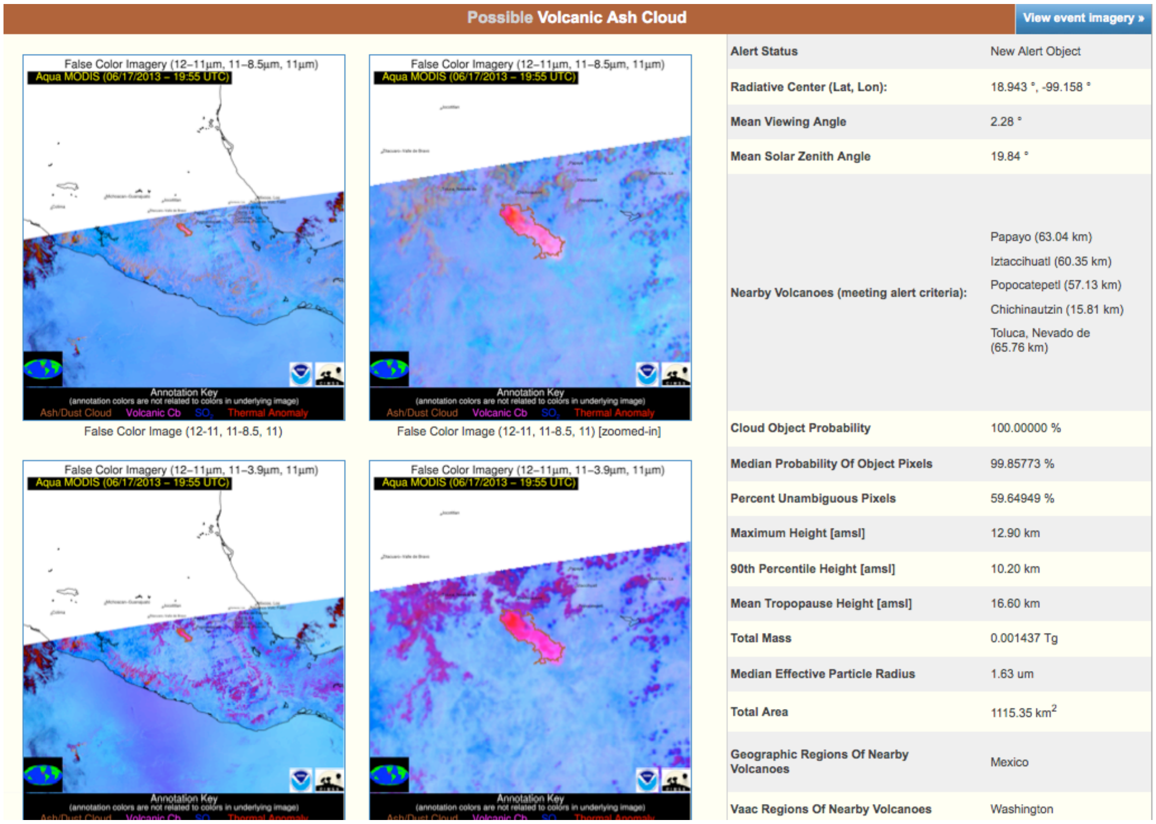

Figure 37. Example of an automatically generated volcanic ash cloud alert and associated imagery. A user will receive notification of the alert, including a link to the above URL. This example is an ash cloud from the Popocatepetl volcano near Mexico City, Mexico on 17 June 2013. This ash cloud has a spectral signature consistent with volcanic ash and is the pink/magenta region bounded by a brown outline. The satellite observations are from MODIS Aqua, which has similar spectral channels as GOES-R ABI. On the left are preview images that can be clicked for full-resolution imagery and on the right is alert information (e.g., ash cloud height, total column mass, Volcanic Ash Advisory Center responsibility, etc.).

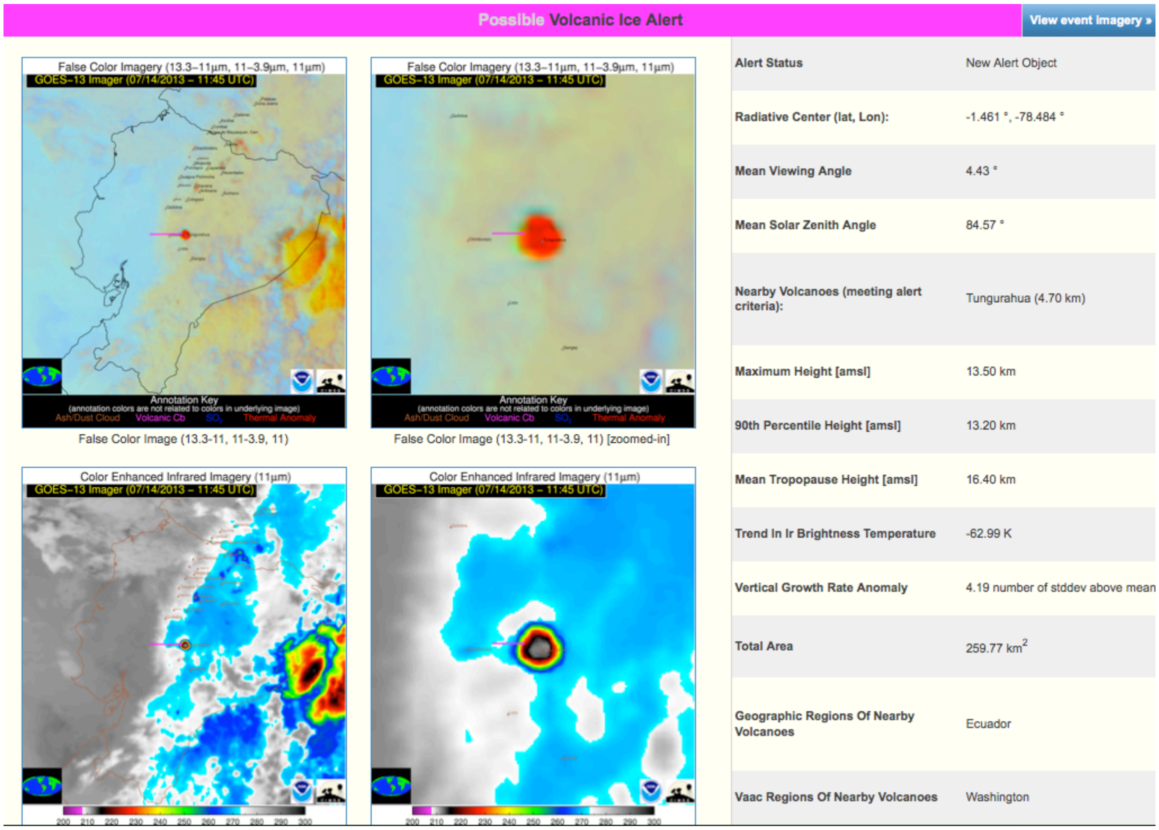

Figure 38. Example of an automatically generated volcanic ash cloud alert and associated imagery. A user will receive notification of the alert, including a link to the above URL. This example is an explosive ash cloud from the Tungurahua volcano in Ecuador on 14 July 2013. This ash cloud does not have a spectral signature consistent with volcanic ash due to tremendous amount of water and ice obscuring the ash. However, the intense cooling rate in infrared window imagery between subsequent GOES-13 observations allowed for detection of this eruption (-63 K in 32 minutes). On the left are preview images that can be clicked for full-resolution imagery and on the right is alert information (e.g., ash cloud height, cooling rate in infrared window imagery, nearby volcanoes, etc.).

7.11 CIMSS GOES-R Algorithm Working Group (AWG): Visibility

CIMSS Project Lead: Wayne Feltz
CIMSS Support Scientists: Allen Lenzen, Jason Brunner
NOAA Collaborator: R. Bradley Pierce, NOAA ASPB
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

This project's objective was to develop a visibility algorithm based on products that will be available on the Advanced Baseline Imager (ABI). This algorithm was produced using a number of proxy ABI products including the low-cloud/fog detection, cloud optical thickness, and aerosol optical depth. To determine the range of visibilities associated with low-cloud/fog the visibility product uses the proxy ABI cloud optical thickness (COT). To determine the range of visibilities associated with haze, dust, and smoke the visibility product uses the ABI aerosol optical depth (AOD) retrieval. Under low-cloud/fog, haze, dust, and smoke conditions the visibility algorithm must be able to relate COT and AOD (at a particular wavelength) to horizontal visibility within the planetary boundary layer. A regression retrieval was developed based on statistical regression of proxy satellite AOD and COT measurements and planetary boundary layer thermodynamic properties against Automated Surface Observing System (ASOS) extinction measurements. This regression retrieval is optimally combined with a first guess retrieval which is constructed by normalizing AOD or COT by the depth of the aerosol or fog/low-cloud layer, which is assumed to be determined by the depth of the planetary boundary layer (PBL) or fog depth. This project just completed the fourth and final year of funding.

Summary of Accomplishments and Findings

During this project period a progression of visibility algorithms were developed, tested, validated and delivered to the GOES-R Algorithm Working Group (AWG) Algorithm Integration Team (AIT) following the Program Office Project Timeline. The final Version 5 (V5) algorithm was delivered on schedule in September 2012.

Equation (1) expresses visibility (V) in terms of optical depth (τ) and the thickness of the material layer (x),

$$V = 3.0/(\tau/x) \qquad (1)$$

The V5 ABI Visibility algorithm uses retrieved Aerosol Optical Depth (AOD) to estimate τ under clear-sky conditions and uses retrieved Cloud Optical Thickness (COT) to estimate τ under cloudy conditions when fog or low clouds have been detected. In the V5 ABI aerosol visibility algorithm the Look Up Tables (LUT)'s are based on Version 5 MODIS AOD retrievals. Meteorological predictors are derived from the NOAA Global Forecasting System (GFS) Comprehensive Large Array-data Stewardship System (CLASS) archive. The aerosol and fog/low cloud LUT's include 12 sets of monthly multiple regression coefficients for both aerosol and fog/low cloud visibility retrievals. Optimal weighting between the first guess and multiple regression visibility estimates for aerosol and fog/low cloud visibility is determined based on the assessment of required categorical accuracy (percent correct classification), required precision (standard deviation of categorical error), Heidke Skill Score (fractional improvement relative to chance), and False Alarm Rate.

The ABI Visibility dataset consists of 10 km aggregated merged V5 ABI aerosol and fog/low cloud visibilities along with 4 visibility categories. These categories are called Clear (≥ 30 km visibility), Moderate (10-30 km visibility), Low (2-10 km visibility) and Poor (< 2 km visibility). The algorithm was validated using independent (not used in the LUT regression) ASOS 10-minute harmonically averaged raw (one-minute) extinction measurements from January 2010 through July 2013 and available ground, airborne, and space based cloud and aerosol extinction measurements. Merged V5 ABI Visibility retrievals using MODIS proxy data have been validated against ASOS extinction measurements during January 2010 through July 2013. Figure 39 shows categorical histograms of the coincident ASOS and V5 ABI merged visibilities. The merged aerosol and low-cloud/fog visibility retrieval results in a 64.5% categorical success rate for coincident ASOS/ABI measurement pairs during January 2010 through July 2013. The merged aerosol and fog/low cloud visibility retrieval overestimates the frequency of Clear visibility and underestimates the frequency of Moderate, Low and Poor visibility during this time period.

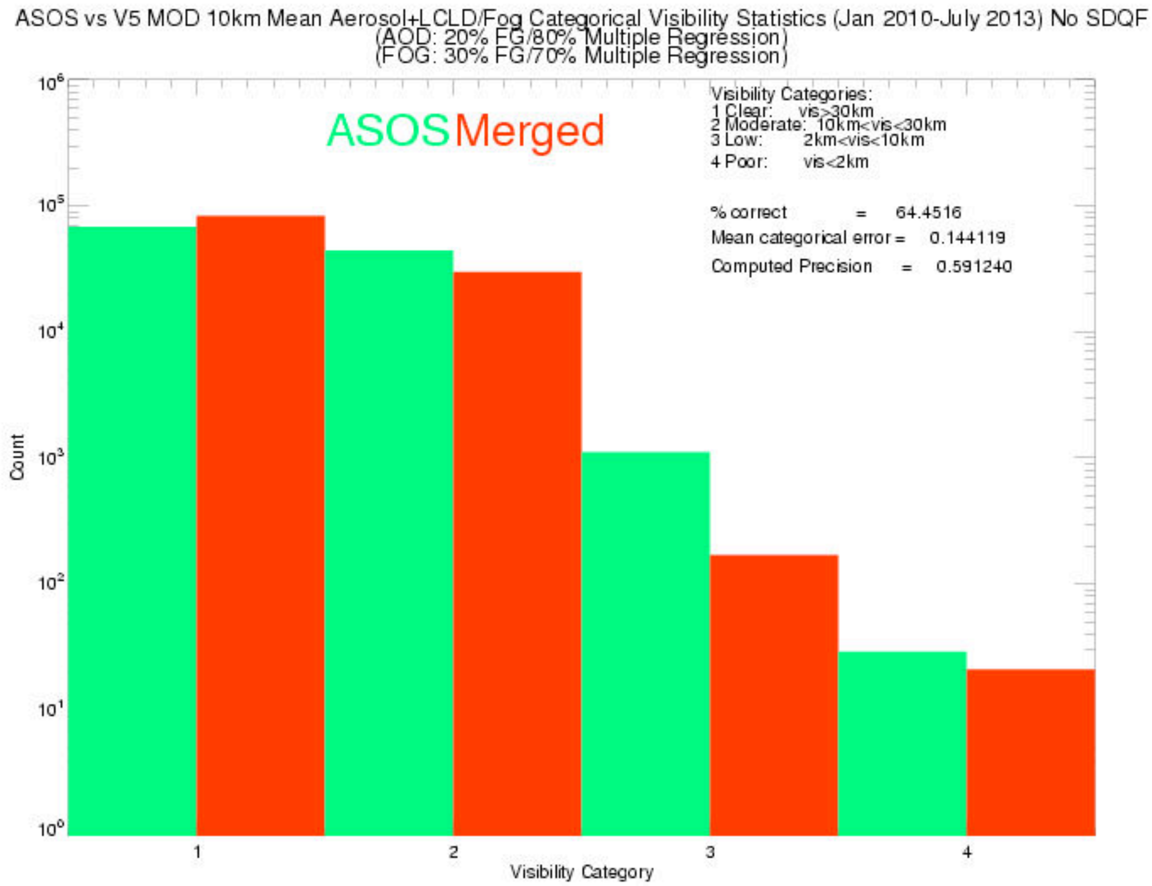

Figure 39. Categorical Histogram of Merged V5 ABI (red) and ASOS (green) aerosol and fog/low cloud visibility for January 2010 through July 2013 coincident pairs.

The main validation statistics used to assess how well the V5 ABI Visibility algorithm performs are Heidke Skill Score (fractional improvement relative to chance), assessment of required categorical accuracy (percent correct classification) and False Alarm Rate. Figure 40 shows a monthly time series of the validation statistics for the V5 ABI Visibility algorithm validation from January 2010 through July 2013. Heidke Skill Score values (red line plot) between 0.2 and 0.4 are considered good, values between 0.15 and 0.25 are considered moderate and values less than 0.15 are considered poor. The good Heidke Skill Score values generally tend to occur from June through September (green shading), moderate values occur from January through March (yellow shading), poor values occur from October through December (red shading) and mixed results occur in April and May. The percent correct classification values (blue line plot) ranges from 55 to 72 percent and generally shows higher values from April through November (except for November 2012) and lower values from December through March. The False Alarm Rate values (dashed black line plot) range from 0.2 to 0.46 with the lowest values generally from January through March. Overall, the V5 ABI Visibility algorithm performs the best from June through September.

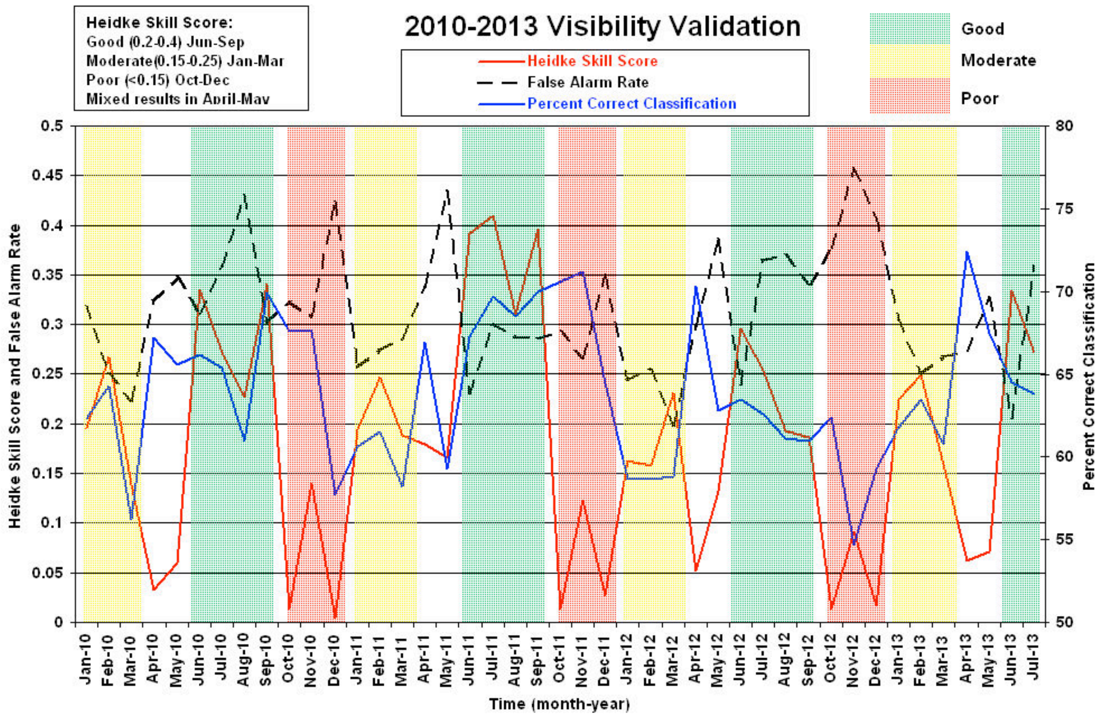

Figure 40. V5 ABI Visibility algorithm monthly validation statistics over the continental United States from January 2010 through July 2013. Heidke Skill Score (red line plot), Percent Correct Classification (blue line plot) and False Alarm Rate (dashed black line plot) are shown with dashed shadings of Heidke Skill Score values of Good (green), Moderate (yellow), and Poor (red) included.

Publications, Reports, Presentations

Brunner, J., A. Lenzen, and R. B. Pierce, 2012: GOES-R AWG Visibility Retrieval, Air Quality Applied Sciences Team 3rd Meeting (AQAST3), 13-15 June, Madison, Wisconsin.

Brunner, J., R. B. Pierce, and A. Lenzen, 2012: GOES-R AWG Visibility Retrieval, 37th National Weather Association Annual Meeting, 6-11 October, Madison, Wisconsin.

Brunner, J. C., B. Pierce, A. Lenzen, and J. Szykman, 2013: GOES-R AWG Visibility Retrieval and Visibility-Fires Analysis over Western United States for 2007-2008, 93rd American Meteorological Society Annual Meeting, Ninth Annual Symposium on Future Operational Environmental Satellite Systems, 5-10 January, Austin, Texas.

7.12 Imagery and Visualization

CIMSS Project Leads: Tom Rink, David Santek
CIMSS Support Scientists: Mat Gunshor, Kaba Bah, Joleen Feltz
NOAA Collaborator: Tim Schmit NESDIS/STAR/CRPD/ASPB
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Outreach and Education

Project Overview

The AWG Imagery Team has developed the format for ABI data which includes the fixed grid format and GRB-like data structure. Now in the validation phase, the next steps are to develop better methods by which ABI imagery will be quality controlled. Past efforts have primarily been theoretical approaches to data validation and now the project will move into practical applications of validation, perhaps testing on current GOES.

For visualization, McIDAS-V is CF-netCDF ready, meaning it understands the structure and semantics of CF conventions so the official product files of the GOES-R ABI can be immediately imported into the system without any additional programming. This free software is available to any scientist, researcher, or educator to analyze, visualize and synthesize with other data, including past and current GOES, common meteorological in-situ observations, model forecast and reanalysis.

McIDAS-V is the fifth generation of McIDAS (the Man computer Interactive Data Access System), and is a Java-based, open-source, freely available system. The software tool provides a powerful data manipulation and visualization environment to work with a large variety of geophysical data. McIDAS-V contains a flexible, extendable framework for integrating geophysical data into an interactive 4D visualization and computation environment. This new functionality builds upon 40 years of McIDAS work and over 10 years of VisAD/IDV development.

Summary of Accomplishments and Findings

GOES-R Fixed Grid Format

Since the ABI data will be broadcast in a Fixed Grid Format (FGF), it is critical that an understanding is gained for this projection. The visualization software, McIDAS-V and in a larger sense, the netCDF data format, need to be prepared to handle this projection type. This way each pixel does not need to carry a latitude and longitude value, instead the projection parameters must be understood. Early work with ABI proxy data employed a type of FGF based on EUMETSAT's Meteosat (SEVIRI) data. Subsequent attempts at duplicating the future ABI FGF involved using a CGMS defined "Normalized Geostationary Projection." The Imagery and Visualization team at CIMSS has iterated with Harris (the GOES-R ground-system contractor) personnel verifying the ABI FGF versus CGMS defined FGF. There has been a continued development of a beta version of software to compute transforms between the FGF coordinate systems to (and from) a longitude and latitude coordinate system. Preliminary comparisons of Earth locations for 2km FGF data between Harris and CIMSS code show a very close match. There is also a continuing effort to define critical metadata for geostationary projections to meet compliance with CF/CF-satellite netCDF standards.

AWG Imagery and Visualization Scripting Tools

The co-chairs of the Imagery and Visualization group have emphasized that background processing of satellite, weather data, imagery and products is an essential tool for real-time displays and routine scientific analysis. Scripting tools currently being developed under Imagery and Visualization will provide a simple and efficient means to access the diverse capabilities of McIDAS-V. In the first phase of development, simple Jython methods will allow scientists to access, display and perform simple statistical data analysis (Figure 41) for netCDF, HDF, and traditional McIDAS Area files. In the next phase, the tools will provide scientist with the capability to manipulate some of the 3D aspects of McIDAS-V. The ultimate goal of this effort is to give the scientists all the tools of the interactive display in a scripting language. This effort will free scientists from repetitive tasks, providing the opportunity for continual product validation, products and imagery.

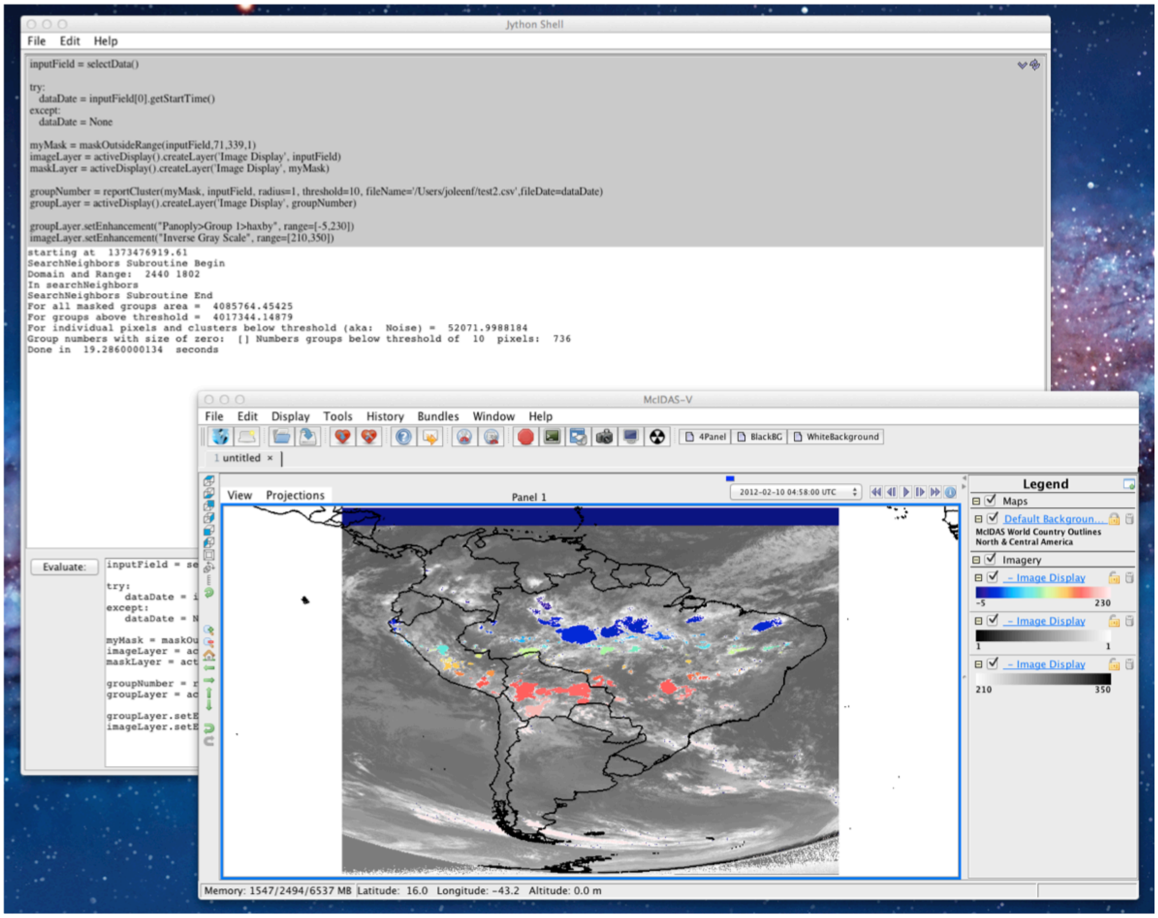

Figure 41. An example of a user-written McIDAS-V Jython script (top) which displays clusters of pixel values within value range, search radius, and vicinity threshold (bottom).

Visualization and Data Analysis

Quantitative analysis support is now integrated into the interactive scatter display tool. Descriptive statistics and correlation coefficient for input X,Y fields can be generated, and output, if desired, to csv or txt file. This analysis is accomplished by integrating a public domain statistics and math package from the Java Apache Foundation into the McIDAS-V internal data model. We will continue to adapt more powerful analysis capability from this package, such as linear and multiple regression.

Improved support for CALIOP and CLOUDSAT, Level 1 and Level 2 products is available through the McIDAS-V interactive mode. Users can select a portion of the orbit track from a geographic GUI selector, and either visualize or resample other fields via the Jython shell. For example, users can compare cloud height estimates from model output or satellite observations to CALIPSO cloud height measurements. This comparison method has been used in the validation of the AWG Cloud Top Height product derived from proxy data.

In addition to the fusion of satellite data and products described above, McIDAS-V can also incorporate model output and other observations into a single display. Figure 42 depicts moisture ascending (moisture cross section from the RAP) along the warm baroclinic conveyor belt (GOES water vapor image) associated with upper level jet (isosurface from the RAP).

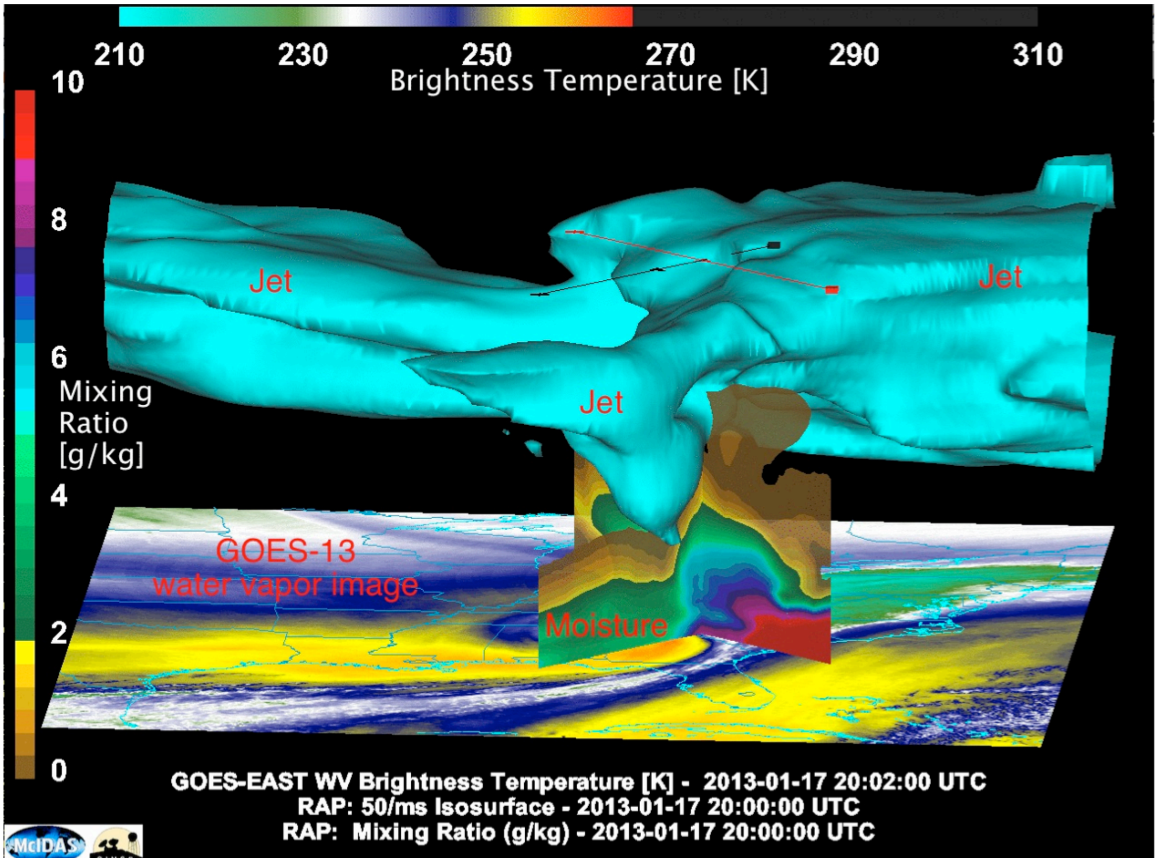

Figure 42. A GOES water vapor image (base) with moisture cross-sections (slices) and a 50 ms^{-1} isosurface (cyan) of wind speed from the Rapid Refresh (RAP) model at 2000 UTC on 17 January 2013.

7.13 WRF-CHEM Aerosol and Ozone Proxy Data Simulations

CIMSS Project Lead: Todd Schaack
CIMSS Support Scientist: Kaba Bah
NOAA Collaborator: R. Bradley Pierce, NOAA ASPB
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The main focus of this project is to augment the GOES-R AWG WRF Advanced Baseline Imager (ABI) proxy data capabilities with proxy data sets for aerosols and ozone. The aerosol and ozone proxy data sets are generated with WRF-CHEM air quality simulations (Grell et al., 2005) coupled to global chemical and aerosol analyses from the Real-time Air Quality Modeling System (RAQMS) (Pierce et al., 2007). Chemical data assimilation is used to provide observational constraints on the global chemical and aerosol analyses. Output from the coupled

RAQMS/WRF-CHEM ozone and aerosol simulations are used to construct simulated radiances using the NOAA Community Radiative Transfer Model (CRTM) (Han et al., 2006). The addition of aerosol and ozone distributions into the WRF proxy data set allow generation of synthetic radiances for all 16 ABI bands and thus facilitate the development of algorithms supporting retrievals of aerosol properties (optical depth, aerosol type, effective radius, fine vs. coarse mode fraction), total column ozone, and detection of dust, smoke and SO_2. This work is conducted in close collaboration with the existing GOES-R WRF proxy data simulation team at CIMSS (Lead, Allen Huang, CIMSS). This project has spanned five years.

Summary of Accomplishments and Findings

The WRF-CHEM Aerosol and Ozone proxy data activities have focused on production and delivery of multiple synthetic ABI radiance datasets for all 16 ABI bands for a number of different geographical regions and time periods. For these efforts, the WRF-Chem model is used to produce high temporal and spatial resolution forecasts to provide the required input for the CRTM. These WRF/Chem forecasts include near real time biomass burning emissions and high resolution anthropogenic emissions. Meteorological initial conditions (ICs) and lateral boundary conditions (LBCs) are provided by the NCEP GFS forecasts. Aerosol ICs, LBCs and ozone are provided from daily 1x1 degree global RAQMS forecasts performed at CIMSS. Both WRF-Chem and RAQMS include on-line aerosol modules from the Goddard Global Ozone Chemistry Aerosol Radiation and Transport (GOCART) model [Chin et al., 2002]. The addition of aerosol and ozone distributions into the CRTM input stream allows generation of more realistic synthetic (proxy) radiances for all 16 ABI bands. Hourly ABI synthetic radiance datasets have been generated and distributed for 1) a 24 hour period in August 2006 covering CONUS, 2) a 24 hour period in August 2006 over Africa, 3) a 24 hour period in May 2010 covering the GOES-W full disk domain and 4) a 60 day period in May-June 2010 over the west-southwest portion of the U.S. A key component of this work has been on evaluation of the uncertainties in the ABI simulated radiances associated with the WRF-CHEM/CRTM forward modeling system through comparisons with remote and in situ measurements of cloud and aerosol microphysics, aerosol dry mass, cloud and aerosol extinction, surface spectral albedo and ozone from airborne, ship, and surface measurements .

For the past two years this project has worked jointly with the project "Real-time Proxy Framework Support: CRTM/GEOCAT/GRB Components" (Task 8.1 in this document) to provide daily real-time proxy radiances over CONUS for all 16 ABI bands as part of the GOES-R AWG Real-time Proxy Framework Support effort. Combined, these two tasks support GOES-R ABI pre-launch activities by providing real-time GOES Rebroadcast (GRB) files containing synthetic ABI radiances in real-time. The GRB files are being distributed to AIT and Proving Ground partners for testing GOES-R algorithms and data systems. WRF-Chem simulations are archived and used for algorithm validation. These real-time ABI proxy radiances are produced and archived daily at 1 hour temporal resolution. The distributions are displayed at http://cimss.ssec.wisc.edu/goes_r/proving-ground/wrf_chem_abi/wrf_chem_abi.html and are updated daily.

As mentioned above substantial effort has been devoted to validation of the proxy datasets. Recently this effort expanded to include validation of select ABI proxy visible and IR bands against GOES-13 sounder data. Both simulated ABI data and observed sounder data are remapped to the GOES Re-Broadcast (GRB) 2 km fixed grid format for comparison. Routine validation procedures include 1) visualization and simple differencing, 2) scatter analysis (clear, cloudy, land, water), 3) PDF comparisons (clear, cloudy, land, water and 4) time series. Figure 43 shows a comparison of the ABI proxy versus GOES-13 Sounder data over CONUS for 18Z February 16, 2013 for the 0.64 micron, 3.9 micron and 6.15 micron channels.

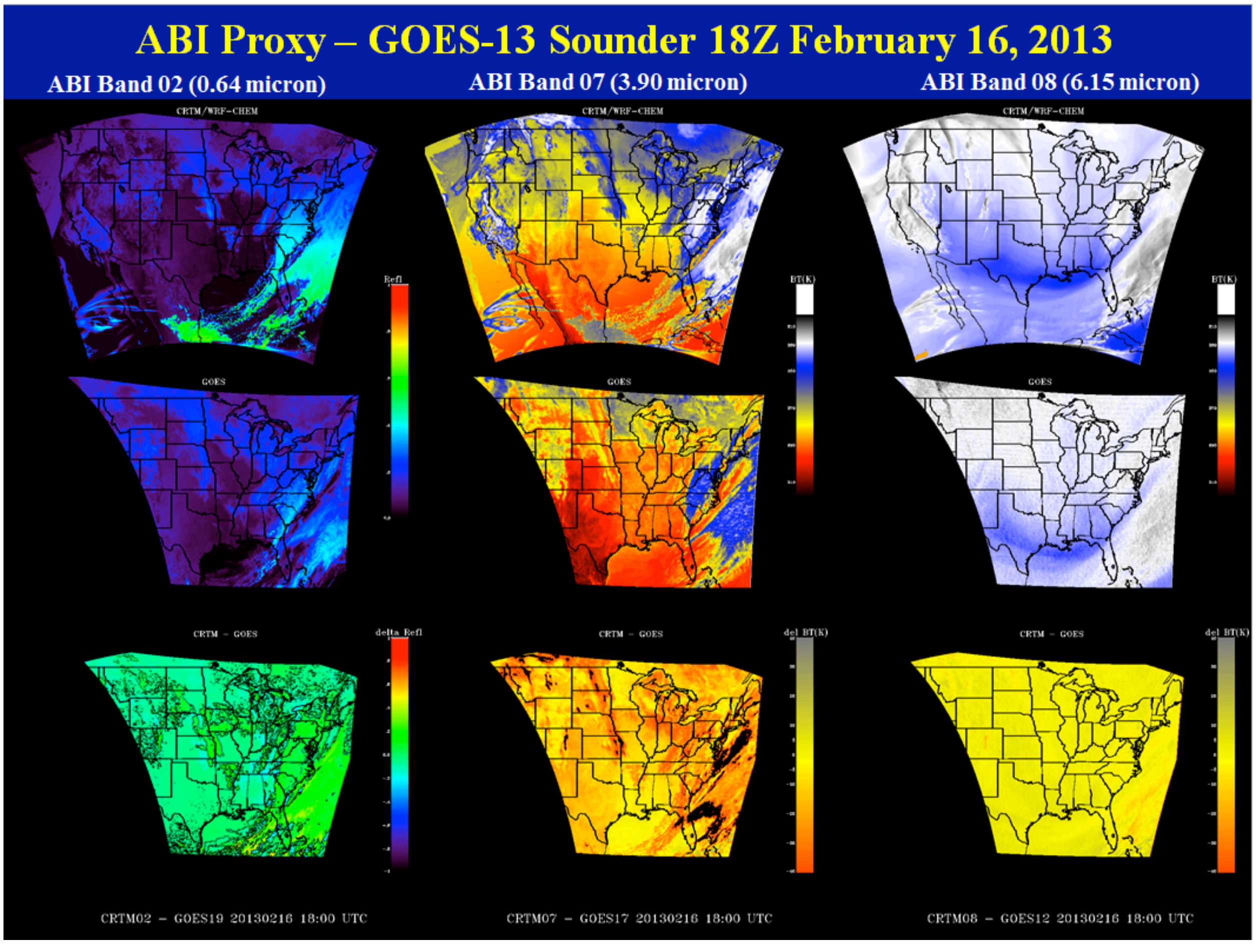

Figure 43. ABI proxy versus GOES-13 comparisons for 18Z February 16, 2013 for selected channels. Column 1 shows reflectance for 0.64 micron channel, column 2 brightness temperatures (K) for the 3.9 micron channel and column 3 brightness temperatures (K) for the 6.1 micron channel. The top (middle) row shows ABI (GOES-13) results and the bottom row is the difference fields ABI minus GOES-13.

Over the period of this project, validation efforts have identified a number of deficiencies/errors in the CRTM and weaknesses in WRF/Chem model. The CRTM deficiencies/errors have been reported to CRTM developers and the CRTM has been modified in response. As an example, it was determined though validation efforts that the 3.9 micron brightness temperatures were much too cold in cloudy regions relative to observed (see large differences in the bottom row of the center column of Figure 43). We determined that the CRTM did not properly account for solar reflectance in the calculation of 3.9 micron radiance leading to the large cold biases in cloudy regions. This problem has been reported to CRTM developers and a fix has been implemented in the CRTM version that we employ.

A second problem with the 3.9 micron proxy radiances was identified. It was determined that the microphysics scheme being used in the WRF/Chem (the WSM 6-class graupel scheme) produced too high ice mixing ratios in cirrus clouds leading to substantial brightness temperature biases (>50 K) for the 3.9 micron band in cloudy regions when using a version of CRTM V2.1 to include solar reflectance in the 3.9 micron radiance calculations. Figure 44a shows scatter plots of WRF/Chem-CRTM cloudy sky synthetic brightness temperatures (Tb) where the WSM6 microphysics scheme was employed versus GOES-13 Tb. The figure shows poor correspondence between distributions with near constant values of synthetic Tb near 295K resulting from the high ice cloud mixing ratios produced with the WSM6 scheme. A series of forecast experiments showed that the WRF/Chem Thompson graupel microphysics scheme significantly reduced the predicted cirrus cloud ice mixing ratios compared to the WSM6 scheme. Figure 44b shows greatly improved comparison (relative to WSM6) with GOES Tb for both high and low clouds when the Thompson microphysics scheme was used. As a result of these comparisons, we modified our WRF-Chem model set up to use the Thompson microphysics scheme.

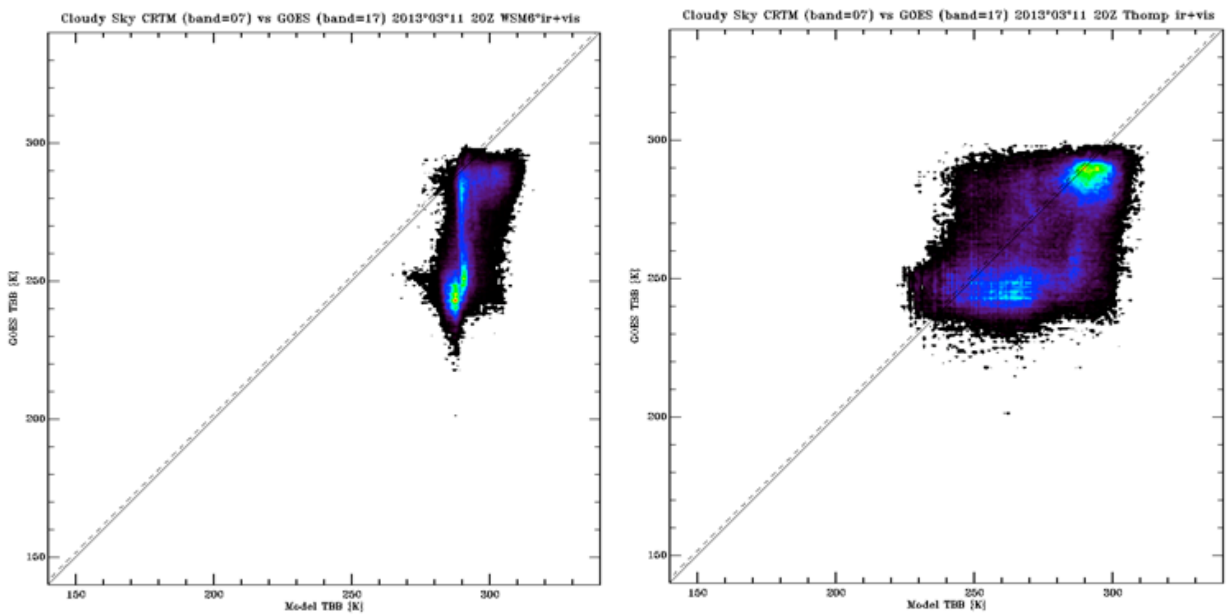

Figure 44. Scatter plots for cloudy scenes on 20Z March 11, 2013 of CRTM/WRF-Chem synthetic vs. GOES-13 ABI 3.9 micron brightness temperatures for (a) WRF/Chem using WSM6 microphysics package and (b) Thompson microphysics package.

Publications, Reports, Presentations

Rogal, M. J., Kaba Bah, Tom Greenwald, Brad Pierce, Allen Lenzen, Jim Nelson, Jason Otkin, Todd Schaack, Jim Davies, Eva Borbas (2013): Near-Real-Time validation of simulated GOES-R ABI radiances and derived products, using the WRF-Chem model forecast over CONUS for all 16 ABI bands. Abstract T-54 presented at 2013 NOAA Satellite Conference, College Park, MD, 08-12 April.

Greenwald, Tom, Brad Pierce, Todd Schaack, Jason Otkin, Kaba Bah, Jim Davies, Justin Sieglaff, Allen Lenzen, Jim Nelson, M. J. Rogal, and Hung-Lung (Allen) Huang (2013): Near-Real-Time Proxy ABI Products for GOES-R User Readiness. Abstract T-65 presented at 2013 NOAA Satellite Conference, College Park, MD, 08-12 April.

Bah, Kaba, Brad Pierce, Tom Greenwald, Todd Schaack, Allen Lenzen, M. J. Rogal (2013): Leveraging GOES-R ABI capabilities in partnership with the NWS offices, to significantly improve severe convection weather forecasting and monitoring. CoRP Symposium 2013, Madison, WI, 23-24 July.

Greenwald, T., B. Pierce, J. Otkin, T. Schaack, J. Davies, E. Borbas, M. Rogal, K. Bah, G. Martin, J. Nelson, J. Sieglaff, W. Straka, and H.-L. Huang, 2013: Near-real-time simulated ABI imagery for user readiness, retrieval algorithm evaluation and model verification, 93rd American Meteorological Society Annual Meeting, Ninth Annual Symposium on Future Operational Environmental Satellite Systems, 5-10 January, Austin, Texas.

Rogal, M., K. Bah, T. Greenwald, B. Pierce, A. Lenzen, J. Nelson, J. Otkin, T. Schaack, J. Davies, E. Borbas, J. Sieglaff, and H.-L. Huang, 2013: Near-real-time validation of simulated GOES-R ABI radiances and derived products using the WRF-Chem model forecast over CONUS for all 16 ABI bands, NOAA Satellite Science Week, virtual meeting, 18-22 March

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Han, Y., et al., Community Radiative Transfer Model (CRTM) - Version 1. NOAA Technical Report 122, 2006.

Pierce, R. B., et al. (2007), Chemical data assimilation estimates of continental U.S. ozone and nitrogen budgets during the Intercontinental Chemical Transport Experiment–North America. *J. Geophys. Res.*, **112**, D12S21, doi:10.1029/2006JD007722.

8 CIMSS Participation in the GOES-R Risk Reduction Program for 2012

8.1 Integrated GOES-R GLM/ABI Approaches for the Detection and Forecasting of Convectively Induced Turbulence

CIMSS Project Lead: Wayne Feltz
CIMSS Support Scientists: Sarah Monette and Tony Wimmers
NOAA Collaborator: Tim Schmit (ASPB/NESDIS/STAR)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

This two year GOES-R Risk Reduction research project focuses on improvement of turbulence nowcasting. Combined observations from the planned Geostationary Operational Environmental Satellite-R (GOES-R) series GLM and ABI instruments will provide an unprecedented opportunity to improve the multi-sensor diagnosis and short-term forecasting of CIT and other thunderstorm related aviation hazards. The proposed research will leverage and combine proven capabilities of current members of the GOES-R Risk Reduction (GOES-R3) Lightning Team

(Carey, Petersen) and the GOES-R Aviation Algorithm Working Group (AWG) (Feltz, Bedka) in using GLM and ABI proxy cloud top cooling, OT/enhanced-V, and total lightning flash rates and trends for the identification of hazardous convective weather. These distinct yet complementary research capabilities will be synthesized to develop knowledge and techniques toward the goal of demonstrating a new, gap-filling GOES-R integrated GLM/ABI CIT aviation hazard product.

CIT is tied directly and indirectly (via gravity wave production) to the evolution of thunderstorm updraft characteristics (e.g., intensity, diameter, depth, and lifecycle). Lightning flash occurrence and rate provide important metrics of updraft intensity, vertical structure and lifecycle that should complement IR satellite observations. As such, an important first step in this research will be the establishment of the temporal and spatial relationship between EDR turbulence reports, total lightning occurrence and flash rate/density, OT occurrence and IR cloud-top cooling as was recently accomplished for OTs, NLDN CG flashes and EDR reports in Bedka et al. (2010). Gravity waves, which can generate CIT at large distances from storms, are produced when rapid convective development subsequently results in the updraft overshooting the level of neutral buoyancy and rapidly decelerating (Lane et al., 2001, 2003). It is hypothesized that rapid IR cloud-top cooling and a jump in the total lightning flash rate are followed by OT occurrence and associated gravity wave production and increased CIT potential.

Therefore, carefully documenting and analyzing the temporal co-evolution of these GLM-ABI updraft intensity metrics from a significant sample of hazardous storms with EDR reports are the next key steps. Trends of integrated GLM-ABI metrics of convective intensity will be obtained by using multi-sensor cell (object)-oriented tracking tools in the NSSL Warning Decision Support System–Integrated Information (WDSS-II) software package (Lakshmanan et al., 2007, 2009). The co-evolving trends of lightning-IR intensity metrics leading up to EDR CIT events of various intensities (light, moderate, severe, extreme) in a large number of storms over LMAs will provide the primary basis for developing integrated GLM-ABI methodologies. By incorporating TRMM LIS/VIRS total lightning/IR overpass data when available and ground-based CG lightning data from LF/VLF networks (such as Vaisala's NLDN and Global Lightning Data set, GLD-360, which is currently being assessed against LIS and LMAs in ongoing risk reduction research at NSSTC) into these LMA studies, the GLM-ABI proxy results could possibly be extended to locations away from LMAs, such as over remote oceans and mountains. Since environmental conditions (e.g., stability and wind shear) affect gravity wave production associated with deep convection (Lane et al., 2003), we will use sounding or model analysis parameters to provide meteorological context for a better understanding of the relationship between CIT occurrence and GLM-ABI intensity metrics.

Summary of Accomplishments and Findings

Research continues to refine relationships between GOES-R convective intensity metrics (lightning, IR, visible) and the occurrence of Convectively Induced Turbulence (CIT) in varied environments.

In addition, work has been done to determine the predictability of CIT in the region of cloud-top cooling (CTC) events. A Bayesian scheme for predicting turbulence near a CTC will be compare to climatology through a probability analysis as well as a yes-no analysis. This is done is accordance with the project milestone "Establish temporal and spatial relationships between…cloud top cooling…and EDR_CIT events." Initial analysis has found this scheme to be skilful with respect to climatology.

The co-evolution of total-lightning, radar-derived fields, and GOES-14 1-min SRSO observations and overshooting top (OT) detections were analyzed for two individual long-lived and severe convective storm cells is shown in Figure 45. The analysis showed that rapid GOES IR cloud-top cooling (CTC) was well correlated with a rapid increase in total lightning flash rates in both storms. OTs were repeatedly detected while the storms were producing lightning and severe weather and discontinuation of OT detections signaled storm decay.

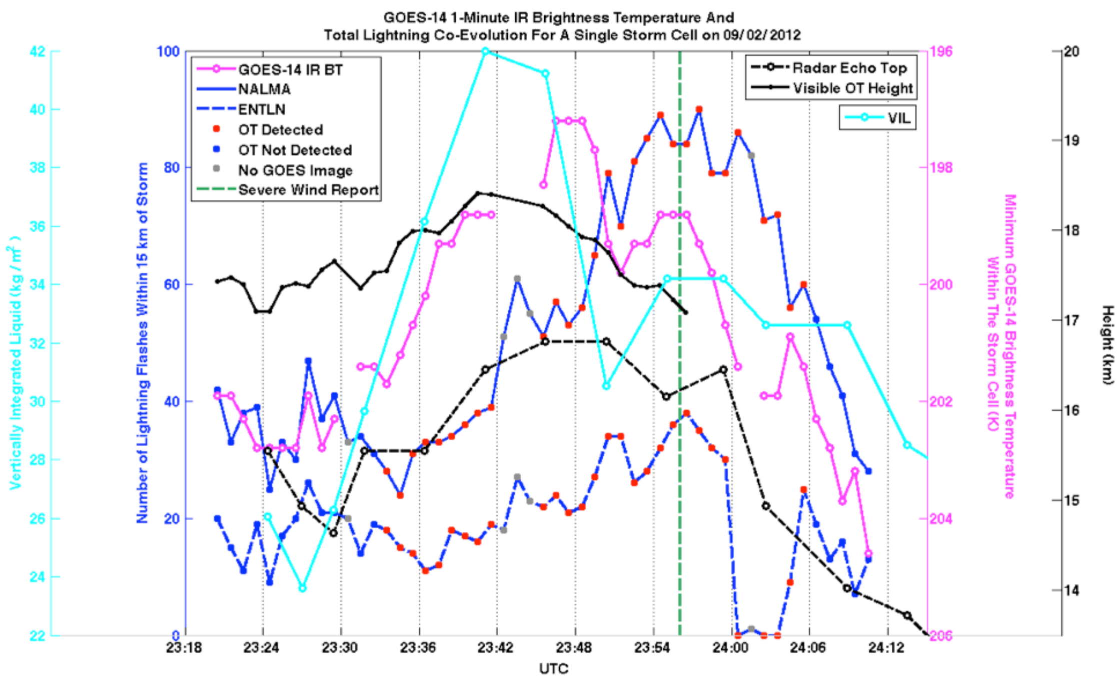

Figure 45. The co-evolution of total-lightning, radar-derived fields, and GOES-14 1-min SRSO observations and overshooting top (OT) detections for two individual severe storm cells.

Publications, Reports, Presentations

Monette, S. A. and W. F. Feltz, 2013: Using Cloud Top Cooling to Predict Aircraft Turbulence. *J. Appl. Meteor. Climatol.,* In preparation.

Identification of Convectively-Induced Aircraft Turbulence using Satellite Data, Sarah A. Monette, Kristopher M. Bedka, and Wayne F. Feltz. American Meteorological Society Annual Meeting, Austin, TX. Jan 6-10, 2013.

Total Lightning in a Multi-sensor Approach to the Detection and Forecasting of Convectively Induced Turbulence, Ryan Rogers, Larry Carey, Kris Bedka, Cecilia Fleeger, Wayne Feltz, Sarah Monette. American Meteorological Society Annual Meeting, Austin, TX. Jan 6-10, 2013.

The GOES Objective Overshooting Top Signature Detection Product: Algorithm Description, Validation, and Applications, Kristopher Bedka, Richard Dworak, Lee Cronce, and Wayne Feltz. 2nd National Weather Service Eastern Region Virtual Satellite Workshop, February 26, 2013.

Total Lightning in a Multi-sensor Approach to the Detection and Forecasting of Convectively Induced Turbulence, Ryan Rogers, Larry Carey, Kris Bedka, Cecilia Fleeger, Wayne Feltz, Sarah Monette. NOAA Satellite Science Week Virtual Meeting, March 18-22, 2013.

Analysis of the Co-Evolution of Total Lightning, Ground-Based Radar-Derived Fields, and GOES-14 1-Minute Super Rapid Scan Satellite Observations of Deep Convective Cloud Tops,

Kristopher Bedka, Cecilia Fleeger, Ryan Rogers, Larry Carey, Wayne Feltz, and Jan Kanak. NOAA Satellite Science Week Virtual Meeting, March 18-22, 2013.

8.2 Investigating the Effects of Detector-Averaged SRFs

CIMSS Project Lead: Mathew M. Gunshor
CIMSS Support Scientist: Szuchia Moeller
NOAA Collaborator: Timothy J. Schmit (NESDIS/STAR/ASPB)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

To study the possible effects of using detector averaged spectral response functions (SRFs) on GOES-R, the effects of using detector-averaged SRFs on current GOES sounder will be studied. The analysis will involve fast forward model radiative transfer calculations, using 32 RAOB atmospheres used previously for RTM training at CIMSS (informally known as the CIMSS-32), which contain a variety of atmosphere types from dry to wet and cold to hot. The fast forward model will be the PFAAST model. Transmittance coefficient files will be generated for PFAAST that are built from individual detector SRFs (those files are already available for detector-averaged SRFs). The differences in calculated radiance and brightness temperature between individual detector SRFs and detector averaged SRFs will be determined. These values can be compared to the measured and spec noise for each channel.

The first task proposed will be used to generate the methodology by which GOES-R ABI SRFs can be analyzed. The analysis will serve as the proof-of-concept for this methodology. By doing forward model calculations on a variety of atmosphere types, it is believed that the differences in the individual detector's measurements can be determined.

If time and funding allows, later an analysis could involve the generation of the Cloud Top Pressure (CTP) product using the GOES Sounder. This product is affected by striping in the sounder, the effects of which could possibly be mitigated in the future if individual detectors were considered. For this product, the fast forward model developments will be used to generate CTP using an individual detector forward model. This altered product will be compared to the typically generated product (using detector-averaged SRFs).

Summary of Accomplishments and Findings

The adaptation of PFAAST for individual SRF analysis is underway and coincides with a reorganization of PFAAST code. PFAAST is older software and was not written in a way to take advantage of today's multiple processor computers. Also, PFAAST was written as individual versions for each satellite scientists wanted to use it for. The result is that there is a great deal of duplicated code. Currently the code infrastructure is being reorganized to better reflect today's standards and to consolidate it so that one driver function can be used to generate forward model calculations for any of the satellites we have spectral response functions for (which includes the host of NOAA GOES and POES satellites as well as the instruments from our partner international agencies). This should make PFAAST easier to use and more practical to implement across a range of current and future GOES projects. PFAAST is the forward model being used for the generation of current operational GOES and POES products. It is also used operationally around the world and will be used for China's future hyper spectral sounder. While this code overhaul is outside the original scope of this project and is primarily funded by other projects at SSEC, it has slowed progress for this project.

It was decided the first task of quantifying the detector-to-detector differences and comparing them to the noise could be done another way: convolving the individual detector SRFs with the CIMSS-32 atmospheres. A poster was presented at the NOAA Satellite Science Week in Kansas City, MO in May of 2012 highlighting some of the findings of this study so far, using the method of convolution. Since the Sounder has four detectors per infrared band, as compared to only two for the Imager, the focus was on the Sounder to determine what the detector-to-detector differences are for each band. The poster showed the results from convolving with the US Standard Atmosphere, which is enough to demonstrate the variability between detectors for some sounder bands. It was demonstrated that even if detector-to-detector differences are larger than the noise in radiance space, the differences in temperature space might be less than the noise if individual detector SRFs are used in the conversion from radiance to temperature. If a detector-averaged SRF is used in that conversion, then differences larger than the noise in radiance space are also larger than the noise in temperature space.

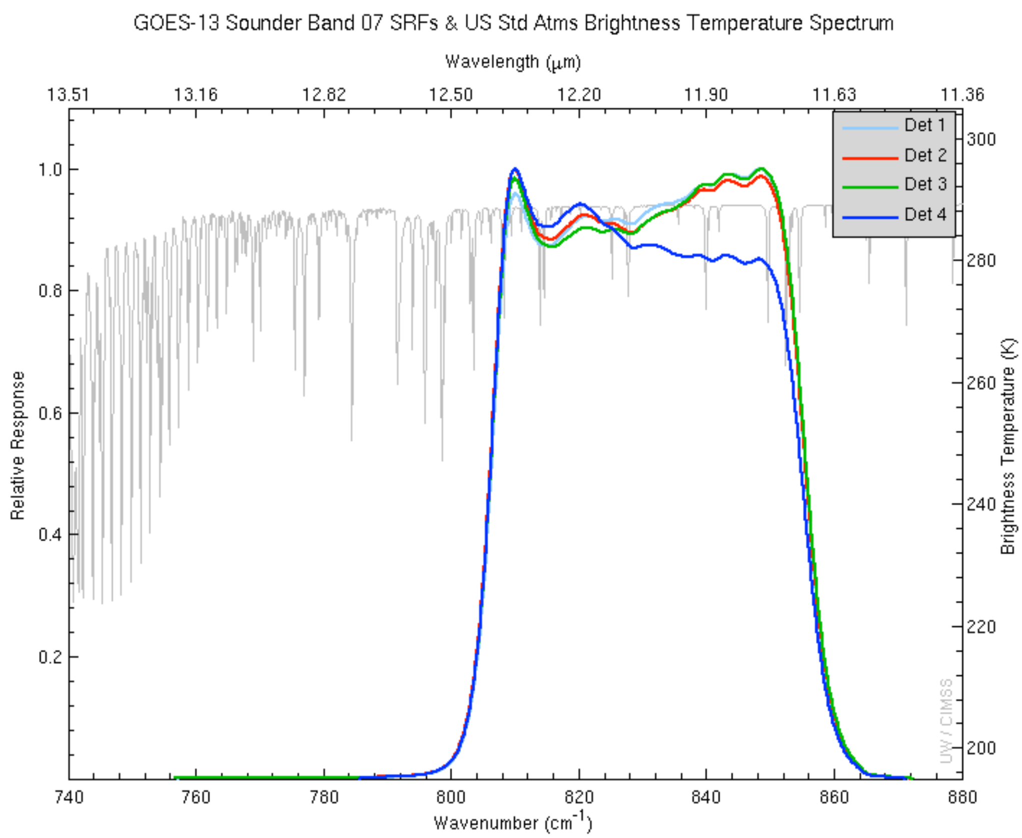

Figure 46. GOES-13 Sounder Band 07 (12um) individual detector SRFs, along with the US Standard Atmosphere brightness temperature spectrum. Note the differences, especially with detector 4.

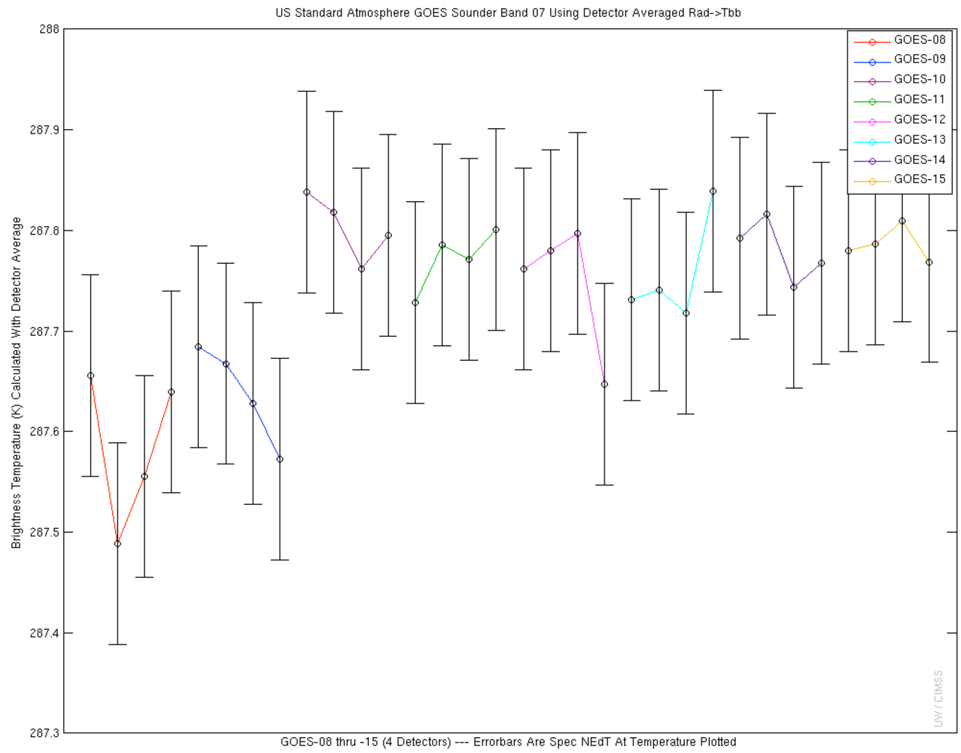

Figure 47. GOES-08 through -15 individual detector brightness temperatures calculated for the US Standard Atmosphere spectrum convolved with the GOES SRFs. The conversion from radiance to brightness temperature was calculated using detector-averaged (per satellite) SRFs, which introduces some error when the SRFs for the four detectors are not similar enough. The bars show +/- NEdT and the dots are the calculated brightness temperature for each detector. An example of an "out of family" detector is shown here as the fourth detector for GOES-12 where the dot is colder than the NEdT bars for the other three detectors.

Publications, Reports, Presentations

Gunshor, Mathew M., S. Moeller, and T. J. Schmit, 2012: "Investigating The Effects of Detector-Averaged SRFs," a poster presented at the NOAA Satellite Science Week, Kansas City, MO, May 2012.

8.3 McIDAS-V Support for GOES-R Risk Reduction Projects

CIMSS Project Leads: Tom Rink, Dave Santek
CIMSS Support Scientists: Ralph Peterson, Jun Li
NOAA Collaborator: Tim Schmit
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications

- Outreach and Education

Project Overview

Leverage McIDAS-V capabilities: interactive 4D visualization and disparate data type and format integration, to assist in the development and validation of GOES-R Risk Reduction projects where appropriate.

Summary of Accomplishments and Findings

The McIDAS-V system framework was extended to ingest and visualize NearCast forward trajectory model output. The figures below show McIDAS-V visualization of two NearCast forecast times (left is earlier). The colored image is an RGB composite of layer (800 to 400mb) temperature difference mapped to red, Theta-E layer difference mapped to green and Lifted Index mapped to blue for the forecast to grid product. Actual isentropic trajectory paths are rendered as lines and colored by initialized available moisture. Here trajectory paths with higher levels of moisture are seen converging in the region of higher (white) potential instability.

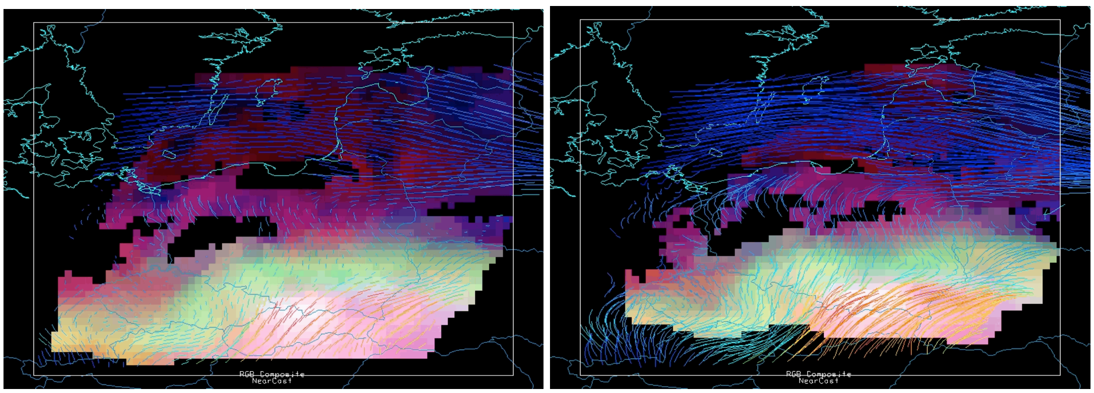

Figure 48. Isentropic trajectory paths over gridded NearCast forecast.

A McIDAS-V plug-in (facility for specific system customizations) has been developed to generate 3D displays of atmospheric pressure contours rendered on isentropic surfaces. This plug-in can be used to overlay other parameters on the terrain-like constant theta surface, such as equivalent potential temperature and wind. This provides the researcher a 3D view of isentropic surfaces in space, while advancing new capabilities for display of parameters computed in alternate vertical coordinate systems. Here, McIDAS-V 3D display of an isentropic surface colored by pressure with contours lines of constant pressure.

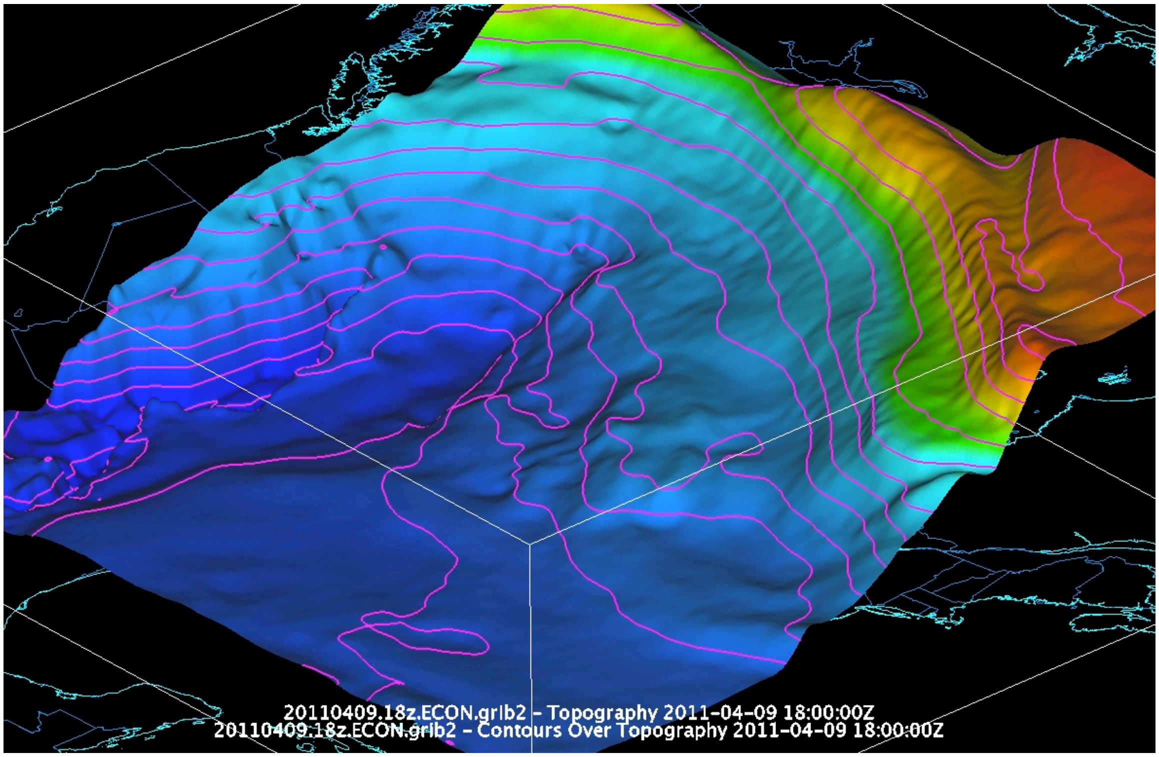

Figure 49. A 3D view of isentropic surfaces.

Publications, Reports, Presentations

Rink, Thomas D.; Peterson, R: McIDAS-V: Analysis and Visualization for NearCasting. EUMETSAT Satellite Conference, Oslo, Norway, September 2011.

8.4 Improvements to QPE Using GOES Visible ABI and Model Data

CIMSS Project Lead: Jason Otkin
NOAA Collaborators: Robert Rabin (National Severe Storms Laboratory), Robert Kuligowski (STAR, Environmental Monitoring Branch), and Valliappa Lakshmanan (National Severe Storms Laboratory)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The primary goal of this ongoing 3-year project is to address the need for remote sensing-based estimates of precipitation across portions of the U.S. and its coastal waters where WSR-88D radar coverage is limited due to the radar beam being blocked by topography or overshooting the areas of precipitation. Heavy precipitation poses threats of flash flooding, but existing satellite techniques often perform poorly in pinpointing locations experiencing heavy rain, especially when cloud tops are relatively warm. Methods to enhance the capabilities of the Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) precipitation retrieval algorithm were explored using high-resolution cloud structure information from GOES visible imagery, estimates of cloud top phase and particle size derived from GOES, and moisture and wind fields from numerical weather prediction (NWP) model forecasts.

Summary of Accomplishments and Findings

During this project, model-derived synthetic satellite datasets generated at CIMSS were made available to NSSL researchers to investigate the relationship between the spatial structure of visible and infrared satellite imagery and the model-simulated precipitation and cloud top height distributions. The first dataset containing synthetic GOES-R ABI visible reflectances and infrared brightness temperatures was created using model output from a very high resolution Weather Research and Forecasting (WRF) model simulation that tracked the evolution of severe thunderstorms across the Upper Midwest during 19-20 July 2006. Subsequent synthetic satellite datasets were generated using output from real-time NSSL-WRF model forecasts over the contiguous U.S. during 2012 and 2013. User support was provided for each of these datasets.

By using synthetic satellite imagery, methods were devised to extract information about the precipitation rate as a function of cloud albedo and brightness temperature that was subsequently applied to observed satellite imagery. Figure 50 shows a representative example of forecast precipitation rate estimated using simulated visible cloud top albedo and 11 µm brightness temperatures from one of the NSSL-WRF model forecasts. A Web-based assessment tool was created to compare real-time GOES imagery with cloud top products and with both observed and estimated quantitative precipitation estimates (QPE). Ongoing work includes testing the use of cloud optical depth rather than albedo and incorporating the QPE product and individual cloud top parameters into ScaMPR.

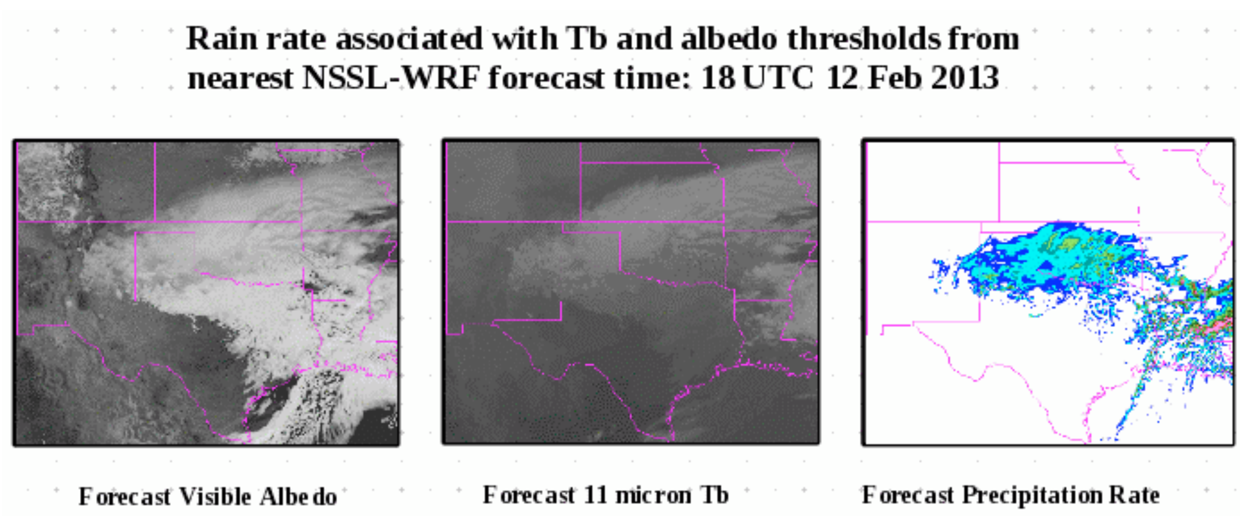

Figure 50. Example forecast visible albedo (left panel), 11 µm brightness temperatures (middle panel), and estimated precipitation rate (right panel), computed using data from the NSSL-WRF model forecast at 18 UTC on 12 Feb 2013.

Publications, Reports, and Presentations

Rabin, R., R. Kuligowski, J. A. Otkin, V. Lakshmanan, and L. Grasso, 2013: Improvements to QPE using GOES visible ABI and model data. NOAA Satellite Science Week Virtual Meeting.

8.5. Developing Assimilation Techniques for Atmospheric Motion Vectors Derived via a New Nested Tracking Algorithm Derived for the GOES-R Advanced Baseline Imager (ABI)

CIMSS Project Lead: James Jung
CIMSS Support Scientists: Sharon Nebuda, Dave Santek
NOAA Collaborator: Jaime Daniels NESDIS/STAR

NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

An Atmospheric Motion Vector (AMV) product has been developed for the Geostationary Operational Environmental Satellite series R (GOES-R) Advanced Baseline Imager (ABI) using a new tracking algorithm. The technique was developed by Bresky et al. (2012) of the GOES-R Algorithm Working Group (AWG). Proxy data has been created by applying the GOES-R algorithm to imagery from the Meteosat Spinning Enhanced Visible InfraRed Imager (SEVIRI). This proxy data provides the opportunity to determine software changes needed for the National Center for Environmental Prediction (NCEP) Global Forecast System (GFS) Gridpoint Statistical Interpolation (GSI) to successfully assimilate this data.

This project is designed to illustrate the future performance of the new GOES-R AMVs in the operational NCEP GFS. To achieve this end, a pre-implementation version of the GFS GSI software will be used. Quality control procedures will be reviewed by examining current quality control parameters as well as considering new parameters related to the nested tracking algorithm. Determining the appropriate observation error for this AMV product is also required. Once assimilation techniques have been selected and verified, software modifications to the GSI will be reviewed by NCEP Environmental Modeling Center (EMC). Analysis and forecast statistics will be collected for two months during two different seasons. The simulations which assimilate the GOES-R AMVs will be compared to a control simulation which does not assimilate AMVs in the SEVIRI region. Computing support is being provided by the Joint Center for Satellite Data Assimilation.

Summary of Accomplishments and Findings

Current Numerical Weather Prediction (NWP) AMV quality control procedures try to use parameters that are independent of the forecast model background state. Traditional AMV quality control parameters of Quality Indicator (QI, Holmlund, 1998) and Expected Error (EE, Le Marshall et al., 2004) have proven to be useful in predicting AMV quality. To maintain this preference, the modified QI parameter, which does not contain forecast information, was chosen as the quality control baseline for the initial testing. Likewise, the use of EE was limited to screening slow winds with large error by testing against a threshold of the ratio of EE to the observation speed. Two nested tracking parameters related to cluster size and cluster correlation were also included in initial quality control tests. The smallest values of these parameters showed an increase in wind vector difference RMSE with respect to the background state. The cluster standard deviation divided by the distance traveled has also shown a correlation to departure from rawinsonde data and is now being used in quality control for IR AMVs

Evaluation of the GOES-R AMVs assimilation statistics from two short GFS simulations during two different seasons was conducted. These results were examined to identify possible quality control procedures for the AMVs and provided an initial look at their performance in the GFS. The initial results did reveal a fast bias for the ABI Channel 8 Cloud Top Water Vapor (CTWV) AMVs which have since prompted an adjustment to the algorithm. The modified algorithm produces CTWV AMVs with increased height which subsequently reduces their bias. Results from these short GFS simulations have provided guidance for how to proceed with quality control settings for the longer seasonal simulations as well as identified a modification needed for the CTWV AMVs.

Initial results from the first season, May-July 2012, revealed an observation minus analysis wind vector difference RMSE which is not ideal for the ABI Channel 14 infrared AMVs. The large RMSE for the GOES-R AMVs indicates the quality control is too lenient and/or the specified observation error is too large. Tuning experiments, which varied the AMV observation error within the NCEP GFS, showed a positive response by the wind vector difference RMSE for all 4 AMV types when the error was reduced. Repeating the first season run with the AMV error set at 75% of current GOES AMV observation error has lowered the vector difference RMSE (Figure 51). Also included in the new summer season run is the application of a log normal vector difference threshold to replace the current component departure check. Analysis of the AMVs impact is underway and initial results indicate the GOES-R AMV data are behaving as expected in the NCEP GFS.

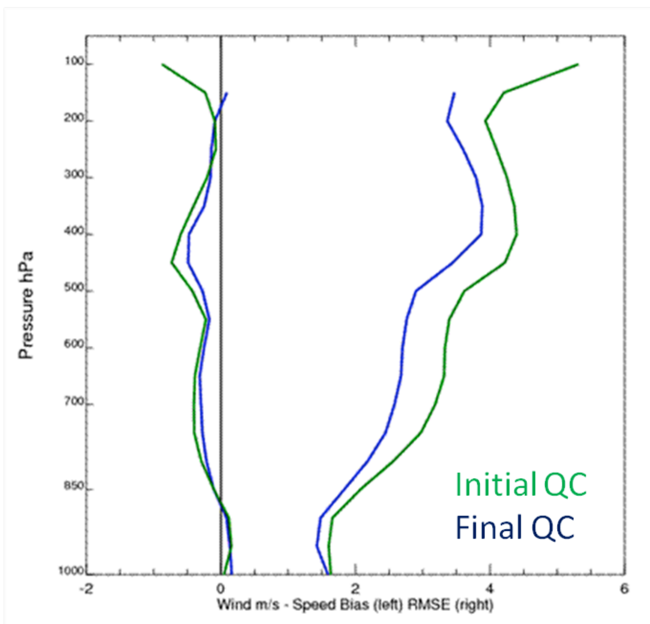

Figure 51. Vertical profiles of speed bias and wind vector difference RMSE for GOES-R proxy AMVs with respect to the GFS analysis. Observations are within the SEVIRI region for June, 2012. Initial QC are results using the GOES AMV observation error. Final QC are results with a 25% reduction in observation error.

The usefulness of assimilating the GOES-R proxy AMVs within the GFS has been confirmed with the results thus far. Feedback has been provided to the algorithm development team as well as determining the adjustments to current geostationary AMV quality control. The observation error has been reduced and is now under evaluation. The assessment of AMV impact on the analysis and forecast skill is underway for the first season. An example of the impact on the 200 hPa V component of wind in the analysis is shown in Figure 52. After completion of the second seasons experiment and its evaluation, software changes to the GSI will be reviewed for approval as well as testing the input of the GOES-R AMVs in the operational BUFR format.

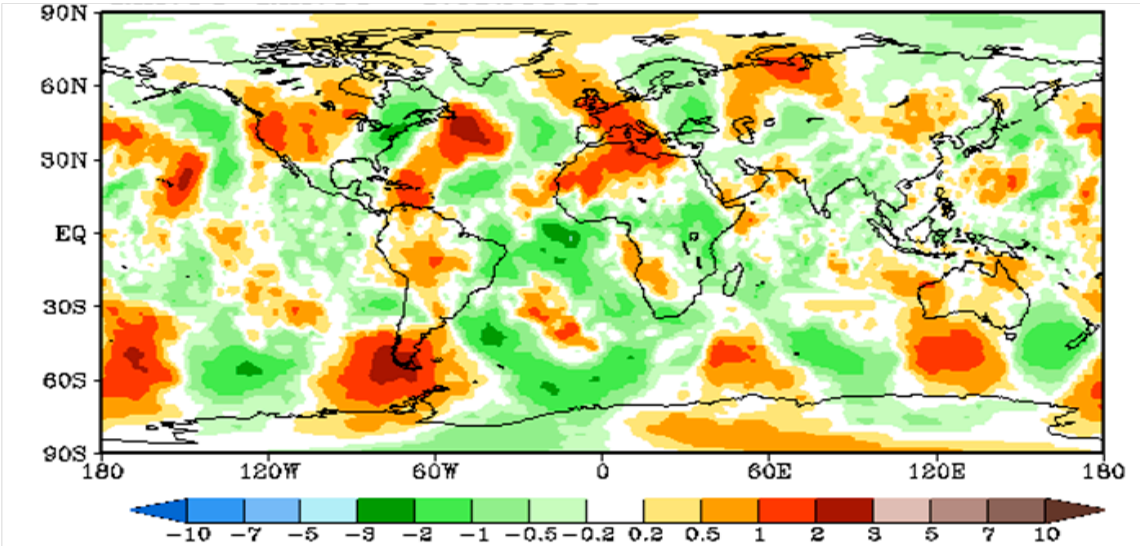

Figure 52. Average200 hPa analysis difference with and without the GOES-R proxy AMVs. The time period covered is 15 May – 21 July 2012. The reds/orange indicate a greater northerly component and the greens indicate a greater southerly component in the analysis with the GOES-R proxy AMVs.

Publications, Reports, Presentations

Nebuda, S., J. Jung, D. Santek, J. Daniels, and W. Bresky 2013: GOES-R AWG Atmospheric Motion Vectors: First Look at Assimilation in NCEP GFS. Special Symposium on the Joint Center for Satellite Data Assimilation, 93rd Annual AMS Meeting, Austin TX, 6-10 January 2013.

Nebuda, S., J. Jung, D. Santek, J. Daniels, and W. Bresky 2013: GOES-R Atmospheric Motion Vectors: Assimilation in NCEP GFS. NOAA Satellite Science Week Virtual Meeting, 18-22 March 2013.

References

Bresky, W. C., J. M. Daniels, A. A. Bailey and S. T. Wanzong, 2012: New Methods toward Minimizing the Slow Speed Bias Associated with Atmospheric Motion Vectors. *J. Appl. Meteor. Climatol.*, **51**, 2137-2151.

Holmlund, K. 1998. The utilization of statistical properties of satellite-derived atmospheric motion vectors to derive quality indicators. *Wea. Forecasting* **13**.1093–1105.

Le Marshall, J., Rea, A., Leslie, L., Seecamp, R. and Dunn, M. 2004. Error Characterization of Atmospheric Motion Vectors. *Aust. Met. Mag*., **53**, 123 – 131.

8.6 Improving GOES-R Temperature/Moisture Retrievals and Derived Products and NearCasts using Hyper-spectral POES Soundings and Validating NearCast Products for GOES-R Proving Ground

CIMSS Project Lead: Ralph A. Petersen
NOAA Collaborators: Robert Aune, Gary Wade, Tim Schmit
CIMSS Collaborators: William Line, Richard Dworak, William Straka
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Environmental Models and Data Assimilation

Project Overview

The overall objective of this effort is to provide data driven tools to help NWS forecasters expand their use of GOES moisture and temperature soundings by 1) enhancing and expanding existing observations using clear-air variables that GOES observes and 2) adding new products to forecast the near-future state of the pre-storm environment. (Note: No GOES clear-air sounder data are used in any operational NWP model over land.) The project has three primary tasks: 1) to determine how information contained in ancillary asynoptic data sets (including GPS-Total Precipitable Water (GPS/TPW), AMDAR aircraft profiles, Raman Lidar observations from the ARM CART site and hyperspectral POES retrievals) could be used to enhance GOES-R products by identifying and removing biases and also facilitating combination of GOES-R data with soundings from existing GOES satellites and then using these products in NearCasts covering the next 6-9 hours, 2) to incorporate these enhanced sounding products into multi-layer and isentropic versions of the NearCasting analyses and short-range forecasts, and 3) to perform assessments and validations of the NearCasting products using objective scores and at participating GOES-R Proving Ground sites. This project is in its last year and builds on 10 years of effort. The basic version of the NearCasting system has been successfully tested at the Storm Prediction Center, Aviation Weather Center, the European Severe Storms Laboratory (using SEVIRI data as a surrogate for GOES-R ABI) and will be tested at the Weather Prediction Center and Ocean Prediction Center in 2014.

Summary of Accomplishments

***Task 1** – Improving quality of GOES moisture retrievals:* Alternative approaches have been developed to calibrate the GOES retrievals using other surface-based systems including operational AMDAR WVSS-II aircraft observations, GPS /TPW and research-quality Raman Lidar profiles from the ARM CART site. Additional work using the combination of POES and GOES profiles was performed using data from AIRS retrievals that are classified as being 'completely cloud free", showed that the largest errors in the GOES TPW retrievals occurs in situations of scattered clouds, pointing to the importance of improving future cloud-clearing techniques (Figure 53a). Biases in the GOES TPW products are largely the result of biases in the NWP first guess fields from the NCEP-GFS used during the retrieval reprocess. Not only do the GOES sounding products mirror biases in TPW from the short-range GFS forecasts, the biases in the 3-layer GOES PW products also match the vertical variation in errors in the GFS in those layers. Errors in the GFS moisture fields also show strong changes in biases from cycle. GOES moisture data showed the greatest improvement in random errors over NWP products occurred during the warm months, a time of year when short-range NWP precipitation forecasts have their least skill. A bias removal method for the multi-layer GOES moisture data has been developed based on normalized bias statistics (Figure 53b).

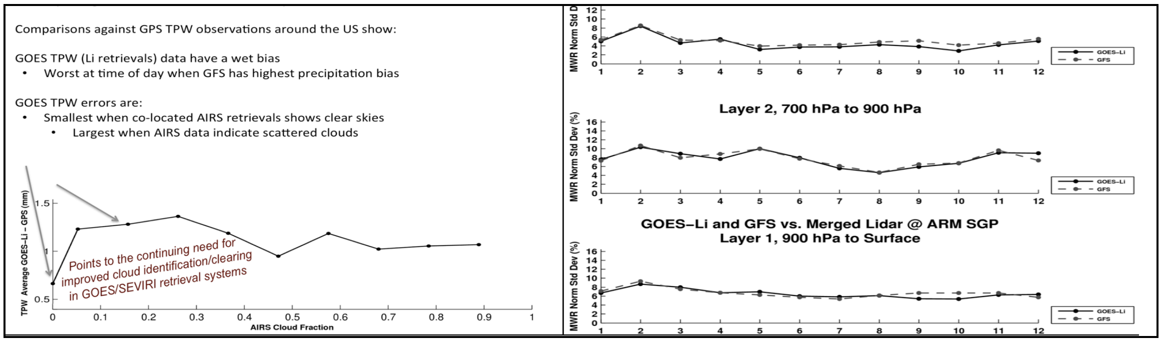

Figure 53. Left- Variation of GOES "LI" retrieved TPW Bias by AIRS cloudiness in 2011. Right - Normalized 3-layer "Li" retrieval error vs. ARM CART Raman Lidar observations.

Task 2 - *Converting the NearCasting system from an Isobaric to an Isentropic framework:* This effort was designed to enhance the impact of the satellite products in short-range forecasts and to provide forecasters a more complete picture of the total amount of moisture and energy observed by GOES in clear skies and being transported adiabatically into areas of interest and an improved understanding of near-term vertical motions. Figure 54 shows results of the original isobaric and new isentropic versions of the NearCast model for the case of a tornadic thunderstorm complex that formed around after 2300 UTC over far west-central IA. By 0000UTC, dry/cool air aloft (lower θe, upper left panel) was predicted to move over lower-level warm/moist air (higher θe, lower left panel), creating an area of increasing convective instability over far western IA at the time and location of the rapid storm development. Although the isentropic NearCasts show a similar area of destabilization moving into far western IA, the lower-level moisture supply moving northward from the Gulf and upper-level dryness overlaying it from the southwest are more distinct and well defined. The isentropic output also adds information showing sudden lifting as the lower-level parcels reach western IA where the convective destabilization is occurring. The isentropic depiction also allows areas that are prone for rapid development of severe convection to be separated from those that are being primed for heavy precipitation. Specifically, areas of heavy convective precipitation were found ahead of regions where the total moisture transport in lower-level isentropic layers [defined as the combination the isentropic mass (inverse static stability) and layer-average mixing] was maximized.

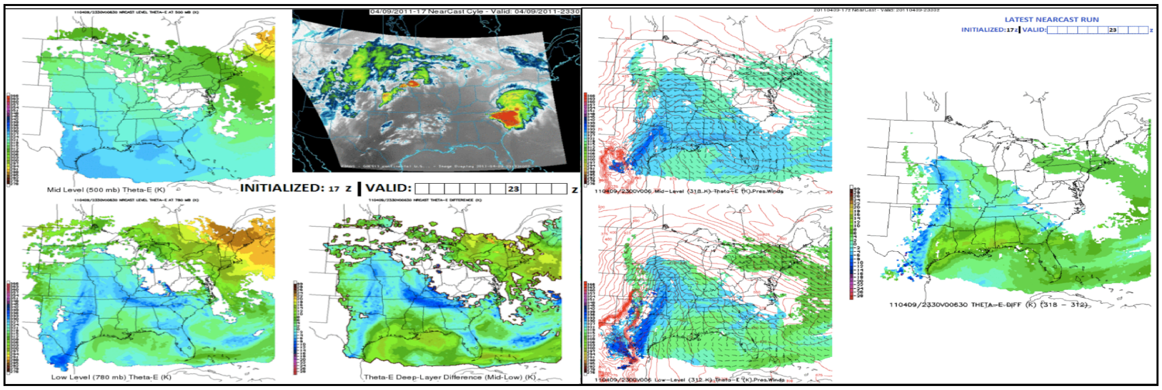

Figure 54. Left - Counter-clockwise from upper right - Validating satellite image for 2330 UTC 9 April 2012, 6.5 hour Isobaric NearCast of Mid-level θe, Lower-level θe NearCast and derived Convective Instability (vertical θe difference between isobaric surfaces), all valid at 2330 UTC. Right – Counter-clockwise from upper left – 6.5 hour Isentropic NearCast of Mid-level (318K) θe, Lower-level (312K) θe, and derived Convective Instability (vertical θe difference between isentropic surface) all valid at 2330 UTC. Pressure topography of isentropic surfaces and wind NearCasts also included as contours and barbs in left panels.

Recent Publications and Conference Reports

Posters

- Petersen et al. at NOAA Science Weeks in Kansas City, MO and College Park, MD (April 2012/13)
- Dworak et al. at NOAA Science Weeks in College Park, MD (April 2013)
- Line et al. at NWA Conference (Oct. 2012) Received conference "Best Poster" award
- Line et al. at EUMETSAT Users Conference (Sept. 2013),

Presentations

- Petersen et al. at NWA Conference (Oct. 2012)
- Petersen et al. at NWS Eastern Region Virtual Satellite Workshop (Feb. 2013)
- Line et al. at CIMMS, Norman, OK (March 2013)
- Petersen et al. at EUMETSAT Users Conference (Sept. 2012/13)

8.7 Convective Storm Forecasting 1-6 Hours Prior to Initiation

<u>CIMSS Project Leads</u>: Chris Velden, Steve Wanzong
<u>NOAA Collaborators</u>: Dan Lindsey (RAMMB), Bob Rabin (NSSL)
<u>NOAA Strategic Goals Addressed</u>:

- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

<u>CIMSS Research Themes</u>:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

One of the greatest difficulties in severe storm forecasting is deciding where and when storms will initially form. Current numerical models struggle with this problem and often have large errors in their 1-6-hour forecasts for convective initiation (CI). The Advanced Baseline Imager (ABI) aboard GOES-R will provide an unprecedented array of spectral bands at improved spatial and temporal resolution relative to the current geostationary satellites, and offers great promise in improving skill in short-term CI forecasts. In a combined effort among several institutes listed above, we are examining this problem from several different but related fronts. The overall goal of this project is to develop a single objective system that predicts where and when storms will form 1-6 hours prior to initiation. The collaboration includes analysis of chosen case study events over the U.S. (GOES/MODIS) and Europe (MSG SEVIRI), and a sharing of analysis strategies and data sets.

Included in addressing this task are five separate institutes/groups, each initially attacking the problem on different applied research fronts. As a team, we first focused on select CI events in a unified way, for data sharing and algorithm development. Then once the predictors were developed, we conduct a real-time demonstration to evaluate, refine and optimize the scheme. The summary of accomplishments described below reflects only those performed by CIMSS.

Summary of Accomplishments and Findings

Hourly model output from the 4-km NSSL WRF is used as a proxy for the GOES-R information that will become available. Since real GOES-R data won't be available until after launch, NSSL WRF output is used to simulate GOES-R ABI data. The advantage of this approach is 1) we have radiances that match the ABI spectral bands, and 2) we have the remaining model output and therefore know exactly where and when storms form (for example), along with the details of the near-storm environment.

As an example of the work the CIMSS winds team is conducting, we computed mesoscale Atmospheric Motion Vectors (AMVs) over a selected domain using simulated NSSL WRF fields as a proxy during the severe weather season of 2012, and considered what diagnostics from this output could be used as a CI predictor. Given the improved temporal and spatial resolution with GOES-R, cloud tracking using AMVs should allow for the identification of mesoscale features, such as low-level regions of convergence. Using the simulated ABI synthetic image data from the NSSL WRF, when a sufficient number of trackable clouds exist, it is shown that the AMVs can be used to improve a model first guess of low-level convergence (see figure below). Work continues on refining this product for eventual integration with the other team products to assess the short-term prediction of CI locations.

Publications, Reports and Presentations

R. Rabin, D. T. Lindsey, L. Grasso, Mecikalski, J., C. S. Velden, B. L. Vant-Hull, and S. Wanzong, 2013: GOES-R Tools to Improve Convective Storm Forecasting 1-6 Hours Prior to Initiation. 2013 NOAA Satellite Science Week Symposium, College Park, MD.

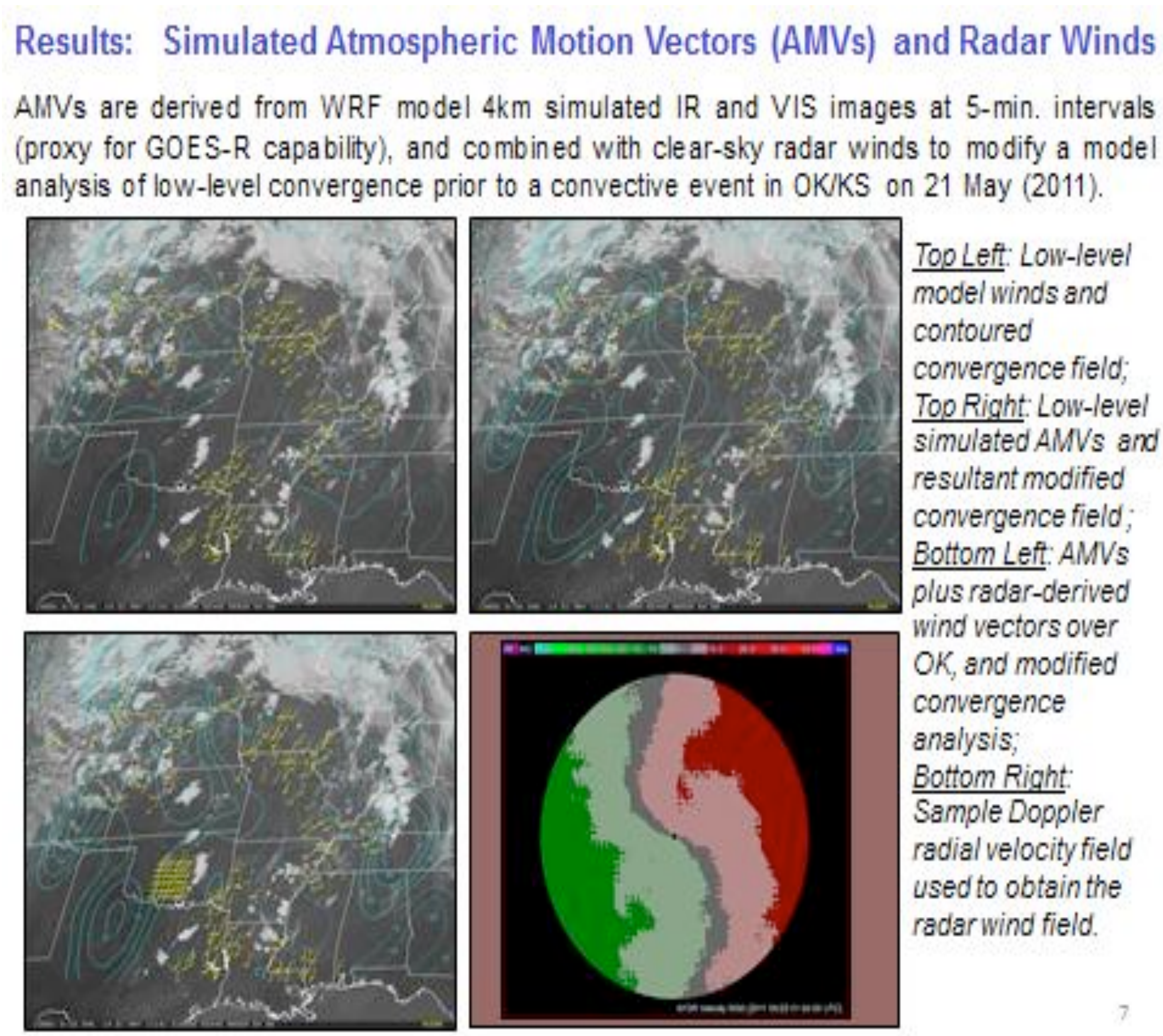

Figure 55. Simulated GOES-R ABI AMVs plus radar winds for pre-convective case study

8.8 Ensemble Simulation of GOES-R Proxy Radiance Data from CONUS Storm-Scale Ensemble Forecasts, Product Demonstration and Assessment at the Hazardous Weather Testbed GOES-R Proving Ground

CIMSS Project Lead: Jason Otkin
CIMSS Support Scientists: Rebecca Cintineo and Lee Cronce
NOAA Collaborators: Steve Weiss (Storm Prediction Center), Fuzhong Weng (NOAA STAR), Jack Kain (National Severe Storms Laboratory), and David Turner (National Severe Storms Laboratory)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

- Outreach and Education

Project Overview

As part of the NOAA Hazardous Weather Testbed (HWT) Spring Experiment, the Center for the Analysis and Prediction of Storms (CAPS) at the University of Oklahoma has produced high-resolution ensemble model forecasts in real-time over the CONUS since 2007. By utilizing national supercomputing resources, sophisticated forward radiative transfer models were used to generate synthetic infrared brightness temperatures at hourly intervals for several ensemble members during the 2012 and 2013 HWT Spring Experiments. Since the ensemble members employed different cloud microphysical and planetary boundary layer (PBL) parameterization schemes, an evaluation of the radiative transfer model and parameterization schemes was also possible. The synthetic satellite imagery was made available to the HWT as part of the CIMSS GOES-R Proving Ground activities. The project will help familiarize operational forecasters, numerical modelers and physical scientists with the capabilities of GOES-R.

Summary of Accomplishments and Findings

During the first year of this 3-year project, a processing system used to generate synthetic GOES-R, GOES-13, and GOES-15 infrared brightness temperatures was written for use on the 'kraken' and 'darter' supercomputers at the National Institute for Computational Sciences (NICS) at the University of Tennessee. This system was subsequently used to generate synthetic satellite data for 20 CAPS ensemble members each day during the 2012 and 2013 HWT Spring Experiments. Participants at the HWT could view synthetic GOES-13 10.7 μm imagery for a subset of the CAPS ensemble members via the CAPS ensemble model Web page (http://www.caps.ou.edu/%7Efkong/sub_atm/spring12.html). Feedback from the participants was generally positive. For instance, many people stated that the synthetic satellite imagery allowed them to efficiently examine the evolution of the forecast cloud field and to determine how much the model differed from reality at later forecast times through comparisons with observed satellite imagery. Examples demonstrating how HWT participants used the synthetic satellite imagery to create and modify their convective forecasts are shown in Bikos et al. (2012).

Figure 56 shows a representative example of synthetic GOES-13 10.7 μm imagery from four of the CAPS ensemble members at 22 UTC on 22 May 2012. The ensemble members had identical configurations except for using different cloud parameterization schemes. Inspection of the synthetic imagery shows that the deep convection across the central U.S. was very sensitive to the assumptions made by each microphysics scheme.

Synthetic GOES-13 infrared brightness temperatures generated during the 2012 HWT were compared to real satellite observations to assess the ability of various microphysics and PBL parameterization schemes in the WRF model to accurately simulate the spatial and temporal characteristics of the cloud field. Four PBL schemes and five double-moment microphysics schemes predicting both the number concentration and mixing ratio for at least one cloud species were evaluated during this study. Large differences were found in the simulated cloud cover, especially in the upper troposphere, when using different microphysics schemes. The results revealed that the Morrison and Milbrandt-Yau microphysics schemes generate too many upper level clouds, whereas the WDM6 scheme consistently did not produce enough clouds. Unlike these schemes, the widely used Thompson scheme did not have a consistent bias towards under- or over-predicting the cloud cover extent, and thus, was the most accurate microphysics scheme evaluated during this study. The differences resulting from varying the PBL schemes were not as dramatic as those obtained when varying the microphysics schemes and the results are less consistent among the evaluation methods used, making it difficult to determine which scheme performs best for the springtime in the U.S., especially in situations with deep convection.

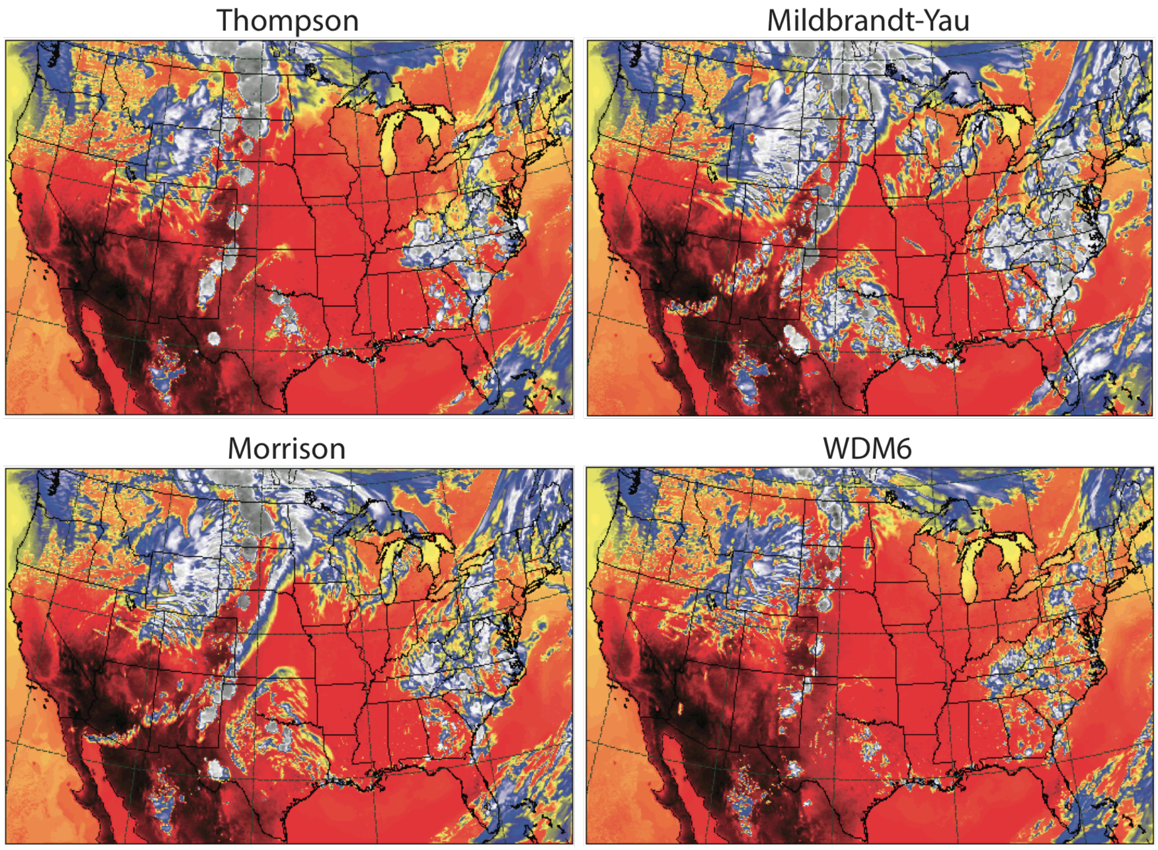

Figure 56. Simulated GOES-13 10.7 µm brightness temperatures (K) valid at 2200 UTC on 22 May 2012 for four of the CAPS ensemble members differing only their use of microphysics parameterization scheme.

A manuscript describing results from this study has been accepted for publication in *Monthly Weather Review.*

Publications, Reports, Presentations

Bikos, D., D. T. Lindsey, J. A. Otkin, J. Sieglaff, L. Grasso, C. Siewart, J. Correia, M. Coniglio, R. Rabin, J. Kain, and S. Dembek, 2012: Synthetic satellite imagery for real-time high resolution model evaluation. *Wea. Forecasting*, **27**, 784-795.

Cintineo, R., J. A. Otkin, F. Kong, and M. Xue, 2013: Evaluating the accuracy of planetary boundary layer and cloud microphysical parameterization schemes in a convection-permitting ensemble using synthetic GOES-13 satellite observations. Conditionally accepted for publication in *Mon. Wea. Rev.*

8.9 GOES-R Education Proving Ground and Super Rapid Scan Animations for Science on a Sphere

<u>CIMSS Project Leads</u>: Margaret Mooney and Steve Ackerman
<u>CIMSS Support Scientists</u>: Rick Kohrs and Mike Foster
<u>NOAA Collaborators</u>: Nina Jackson, NESDIS Education, Tim Schmit, STAR/ASBP and Steve Goodman NESDIS/GOES-R Program Office
<u>NOAA Strategic Goals Addressed</u>:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Outreach and Education

Project Overview

The need for teacher training around the topic of satellite meteorology is stronger than ever as we approach the launch of the GOES-R satellite. To address this need, significant updates were proposed and implemented to the CIMSS *Satellite Meteorology for Grades 7-12* on-line resource (http://cimss.ssec.wisc.edu/satmet/), including a new module on next generation satellites. Since completion in 2011, CIMSS has been promoting and distributing the revised resource at annual meetings of the American Meteorological Society (AMS), summer meetings of the Federation of Earth Science Information Partners (ESIP) and annual Satellite Educators Conferences.

CIMSS also planned for an **Education Proving Ground** featuring the design and development of activities for G7-12 teachers and students in preparation for the launch of GOES-R. Our eventual goal is to have scientists from CIMSS work with students virtually during post-launch GOES checkout activities. A key element of this effort will be sustained interaction between CIMSS EPO staff and a core group of committed educators recruited specifically to collect feedback for iterative improvements to the classroom activities prior to launch. The Education Proving Ground will rely on close coordination with CIMSS/ASPB scientists who check data quality following current GOES satellite launches. In this way, teachers will be ready to run similar activities with their students following the 2015 GOES-R launch and be ready for the new types of satellite imagery and products which will be available in the upcoming GOES-R era.

Informal education efforts related to this initiative were added in 2012 and involve animations of GOES-14 Super Rapid Scan 0.63 μm visible channel images for display on NOAA's Science on a Sphere (SOS) exhibits. The first of these animations, developed at CIMSS/SSEC, debuted at the 2013 annual American Meteorological Society (AMS) conference in Austin Texas and featured Hurricane Sandy. GOES-R Global Lightning Mapper demonstrations are being prepared for the for the 2014 AMS meeting in Atlanta, using data from the North Alabama Lightning Mapping Array (NALMA). All SOS data sets will be made available to other institutes through an existing SOS listserve and the CIMSS EarthNow Blog. (http://sphere.ssec.wisc.edu/)

The intended outcomes of this project are:

1) Awareness of NOAA's contributions to successive advances in remote sensing applications,
2) Increased utilization of satellite data in science classrooms,
3) Improvements in science literacy, and
4) An effective transfer of GOES-R satellite products to the educational community.

Summary of Accomplishments and Findings

Content updates to the CIMSS *Satellite Meteorology for Grades 7-12* on-line resource (http://cimss.ssec.wisc.edu/satmet/) included revisions based on feedback acquired from past users, adding an overview on the 2005 Hurricane Season and remote sensing aspects of the 2010 Deepwater Disaster. We also developed a new module on next-generation satellites featuring the Suomi NPP Satellite, JPSS and GOES-R. These updates were completed in time for the 25th Satellite Educators Conference in August 2012 where new content was presented by project partner Paul Ruscher and CD's distributed to educators. Ruscher also began recruiting teachers to the Education Proving Ground at the 2012 conference. Concomitantly, Margaret Mooney recruited participants from the 2012 ESIP Teacher Workshop in Madison Wisconsin.

A total of six middle and high school teachers will participate in the GOES-R Education Proving Ground over the 2013-2014 school year. Two Wisconsin teachers were selected in the spring of 2013. Two educators from New Jersey were recruited at the 2013 Satellite Educators Conference. Two others are pending. The goal is to have some or all of these teachers present their lesson plans at the 2014 Satellite Educators Conference, scheduled to take place in Madison at CIMSS.

A GOES-14 Super Rapid Scan (1-minute interval) picture-in-a-picture (pip) animation was developed and displayed for NOAA's Science on a Sphere (SOS) exhibit at the 2013 annual American Meteorological Society (AMS) conference featuring detailed temporal and structural cloud features associated with Hurricane Sandy. GOES-14 remained in SRSO-R mode to monitor Sandy and spectacular 1-minute imagery was captured. Similar pips demonstrating GOES-R Global Lightning Mapper are being prepared for the 2014 AMS meeting in Atlanta using data from the North Alabama Lightning Mapping Array (NALMA). All SOS data sets will be made available to other institutes through an existing SOS listserve and the CIMSS EarthNow Blog (http://sphere.ssec.wisc.edu/).

Publications, Reports, Presentations

Mooney, Margaret; Ackerman, S.; Jackson, N.; Ruscher, P. and Rowley, P. Satellite meteorology resources and the GOES-R Education Proving Ground. Annual Symposium on Future Operational Environmental Satellite Systems, 9th, Austin, TX, 6-10 January 2013.

Mooney, Margaret; Ackerman, S.; Jackson, N. L. and Whittaker, T. Infusing satellite data into earth science education with SAGE, ESIP and SNAPP. Symposium on Education, 20th, Seattle, WA, 23-27 January 2011. American Meteorological Society (AMS), Boston, MA, 2011.

Figure 57. GOES-R content from the CIMSS Satellite Meteorology course

8.10 Improved Understanding and Diagnosis of Tropical Cyclone Structure and Structure Changes

CIMSS Project Lead: Christopher M. Rozoff

NOAA Collaborators: John Knaff (NESDIS/StAR), Mark DeMaria (NESDIS/StAR), James P. Kossin (National Climatic Data Center), Chris Landsea (NHC)

NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Protect, restore and manage the use of coastal and ocean resources through an ecosystem approach to management
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

This May 2011-May 2014 project is supported by the GOES-R Risk Reduction program.

Improving tropical cyclone (TC) intensity forecasts remains a primary goal of TC research. TC structure change is another challenging forecast problem requiring further examination since structure changes relate to the area of damaging winds and the extent of the storm surge associated with a TC landfall. The products of GOES-R offer significant potential in the diagnosis of important features related to structural evolution.

To improve our understanding and prediction of TC structure change, we are carrying out a multi-faceted effort between NOAA and UW-Madison/CIMSS. The NOAA Project Leads are using GOES-R advanced baseline (ABI) and GOES lightning mapper (GLM) proxy datasets to develop algorithms to improve estimates of TC location, determine TC size and radius of maximum winds, and better understand the role of total precipitable water on TC size. The CIMSS project component is employing proxy ABI data and other datasets to improve the diagnosis and prediction of TC structural changes. The project groups are working together to develop a statistical-dynamical model that incorporates the new structure-related ABI and GLM forecast products developed here.

Summary of Accomplishments and Findings

The following milestones have been achieved in this project:

- WRF simulations of storm size evolution
  We carried out an idealized, high-resolution WRF simulation of a TC on the β plane in order to study the relationships between structure change and latent heating. Proxy ABI data were generated from this model output and analyzed as well. One significant finding was that secondary eyewall formation (SEF) is predominantly an adjustment process to rainband latent heating (Rozoff et al. 2012) [the fourth most read article online of all the *J. Atmos. Sci.* articles in a 12-month period following publication]. This paper also sheds light into TC size change processes as well. General size evolution is related to the distribution of rainband latent heating and the associated convergence of absolute angular momentum.
- A climatology of TC eyewall replacement cycles
  Leveraged with a NOAA JHT grant, we used low-level aircraft reconnaissance data to document the climatology of structural changes associated with eyewall replacement cycles in Atlantic Hurricanes (Sitkowski et al. 2012).

The following milestones are in progress:

- A climatology of TC size change
  A retrospective analysis of TC size change in the Atlantic and East Pacific Ocean basins is being created using passive microwave imagery (MI) from low-earth orbiting satellites. The 19, 37, and 85-GHz channels are being used to exploit the different resolutions and capabilities of each sensor. We are fusing this data with aircraft reconnaissance data and various environmental predictors to empirically estimate storm size metrics from satellite imagery. This work will be described in Rozoff and Knaff (2013).
- Development of an empirical-dynamical model for storm size evolution.

CIMSS is assisting CIRA in developing an empirical-dynamical model that predicts size change. It is based on a parametric “double Rankine vortex” model that incorporates various environmental and storm-structure predictors to provide 120-h forecasts of the radius of maximum wind and the outermost radial extent of the 34-, 50-, and 64-kt winds in the four geographical quadrants of TCs. Models are being developed for both the Atlantic and East Pacific Ocean basins. CIMSS input will include the provision of various satellite-based predictors, including structural predictors obtained from infrared imagery and also MI.

Publications, Reports, Presentations

Rozoff, C. M., and J. Knaff, 2013: A passive-microwave imagery-based climatology of tropical cyclone size in the Atlantic and Eastern Pacific Oceans. *Mon. Wea. Rev.*, in preparation.

Sitkowski, M., J. P. Kossin, C. M. Rozoff, and J. Knaff, 2012: Hurricane eyewall replacement cycles and the relict inner eyewall circulation. *Mon. Wea. Rev.*, **140**, 4035-4045.

Rozoff, C. M., D. S. Nolan, J. P. Kossin, F. Zhang, and J. Fang, 2012: The roles of the expanding wind field and inertial stability in tropical cyclone secondary eyewall formation. *J. Atmos. Sci.*, **69**, 2621-2643.

8.11 Continued Development of the GOES-R AWG Fog/Low Cloud Products

CIMSS Project Lead: Corey Calvert
CIMSS Support Scientists: Chad Gravelle and Scott Lindstrom
NOAA Collaborator: Michael Pavolonis (NOAA/NESDIS/STAR)
NOAA Strategic Goals Addressed:

- Serve society’s needs for weather and water information
- Support the nation’s commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

Low ceiling and visibility is a weather hazard that nearly every forecaster, in nearly every National Weather Service (NWS) Weather Forecast Office (WFO), must regularly address. In addition, national forecast centers such as the Aviation Weather Center (AWC), Alaska Aviation Weather Unit (AAWU), and the Ocean Prediction Center (OPC) are responsible for issuing low ceiling and visibility related products. As such, reliable methods for detecting and characterizing hazardous low clouds are needed. Traditionally, hazardous areas of Fog/Low Stratus (FLS) are identified using a simple stand-alone satellite product that is constructed by subtracting the 3.9 and 11 μm brightness temperatures. However, the 3.9-11 μm brightness temperature difference (BTD) has several major limitations. Back in 2008, in an effort to address the limitations of the 3.9-11 μm BTD, the GOES-R Algorithm Working Group (AWG) started developing an approach that fuses satellite, Numerical Weather Prediction (NWP) model, Sea Surface Temperature (SST) analyses, and other data sets (e.g., digital surface elevation maps, surface emissivity maps, and surface type maps) using a naïve Bayes classifier to determine the probability that Marginal Visual Flight Rules (MVFR), Instrument Flight Rules (IFR), and Low Instrument Flight Rules (LIFR) conditions are present at the resolution of the satellite data. MVFR/IFR/LIFR conditions are characterized by a cloud ceiling below 3000/1000/500 ft and/or a surface visibility less than 5/3/1 mile(s) respectively. In addition to the probability-based products, the GOES-R FLS algorithm produces an estimate of the FLS thickness (cloud top height minus cloud base height). A relationship was also found that allows the cloud thickness product to be used to estimate the time it will take radiation fog to dissipate.

Along with algorithm development, a comprehensive training module was also created to remotely train forecasters and other users on how to correctly interpret the GOES-R FLS products. Using this training module we formally introduced the GOES-R FLS products to the NWS, AWC, AAWU and OPC using Advanced Weather Interactive Processing System (AWIPS), NAWIPS and AWIPS2 to visualize the products. Through their evaluation and feedback we continue to improve the GOES-R FLS products so they can eventually replace the traditionally-used 3.9-11 μm BTD. This project will ensure the readiness of the fog/low cloud algorithm for operational implementation upon the deployment of GOES-R.

Summary of Accomplishments and Findings

The GOES-R fog/low cloud algorithm is designed to quantitatively identify clouds that produce MVFR, IFR and LIFR conditions. The fog detection algorithm combines textural and spectral information from the satellite, model RH data, the difference between the cloud radiative temperature and modeled surface temperature and other ancillary data sets (e.g., global SST analysis) using a naïve Bayes classifier to determine a probability that each aviation-based visual flight rule category is present. At night, the algorithm utilizes modeled RH data along with the 3.9 and 11 μm channels. During the day modeled RH data along with the 0.65, 3.9, and 11 μm channels are used. LUT's were created using a 3.9 μm pseudo-emissivity (night), 3.9 μm reflectance (day), a 3x3 pixel 0.65 μm reflectance spatial uniformity metric (day), the difference between the cloud radiative temperature and surface temperature (both day and night), and modeled RH (both day and night) from both fog and non-fog water clouds determined by surface observations and the GOES-R cloud type algorithm. Information obtained from the LUT's is combined using the naïve Bayesian method to produce a probability that MVFR/IFR/LIFR conditions are present for any given satellite pixel. The fog/low cloud depth is calculated for each pixel flagged by the detection algorithm (excluding pixels containing ice or overlaying clouds) based on a linear relationship between the 3.9 μm pseudo-emissivity (night) and LWP (day). Examples of the final output determined by the FLS algorithm are shown in the figure below. Evaluation of the GOES-R FLS products along with the traditional 3.9-11 μm BTD product using 12 days of data (one day for each month of the year), showed that the GOES-R FLS products were nearly twice as skillful at detecting fog/low stratus clouds than the 3.9-11 μm BTD.

A linear relationship between the last nighttime fog/low stratus thickness estimation and the dissipation time for radiation fog events was also found. This relationship gives forecasters the estimated amount of time after sunrise that radiation fog will take to clear. This relationship only works for radiation fog events because different processes can influence other types of fog (e.g., advection fog) and make estimating dissipation time much more complicated. Tests performed on numerous radiation fog scenes have verified this relationship and have proven it to be accurate with only a small amount of error (usually much less than one hour).

Along with developing the GOES-R FLS products we are also responsible for training users how to properly interpret the products. We determined the best way to train a large amount of forecasters was to create a comprehensive training module. One important aspect of the training module was to use region-specific examples so forecasters working in different parts of the country would see how the products look on real cases pertinent to their geography. This was

relevant because forecasters are more familiar looking for and identifying certain FLS events common to their specific forecast area and are therefore more comfortable seeing the new products on those specific types of events. The training module was created as a PowerPoint presentation and also converted into a VISIT training module. The VISIT training module is available at:
http://rammb.cira.colostate.edu/training/visit/training_sessions/forecaster_training_for_the_goes-r_fog_low_stratus_products/
In the interest of keeping examples current, a running blog is also kept updated (usually several new entries per week) by Scott Lindstrom here at UW-Madison/CIMSS. This blog focuses on both common and uncommon FLS events from different geographic areas and shows in detail how the GOES-R FLS products can be used to identify hazardous areas of fog/low stratus in each. This blog can be found at: http://fusedfog.ssec.wisc.edu/.

At least 24 WFO's and 3 National Centres participated in various live GOES-R AWG FLS training sessions since September 1, 2012. After training, numerous forecast offices in the NWS Alaska, Eastern, Central, and Western Regions started formally evaluating the GOES-R AWG FLS products. The first round of formal feedback, collected in the form of questionnaires and surveys, indicated the vast majority of forecasters thought the products were very useful. One statistic that proves that forecasters are using the products is the number of local area forecast discussions (AFDs) where the GOES-R FLS products were mentioned. Since March 2012, the GOES-R FLS products have been cited in more than 75 AFDs. This number is increasing weekly as more forecasters are getting comfortable with the products and use them in their daily routine.

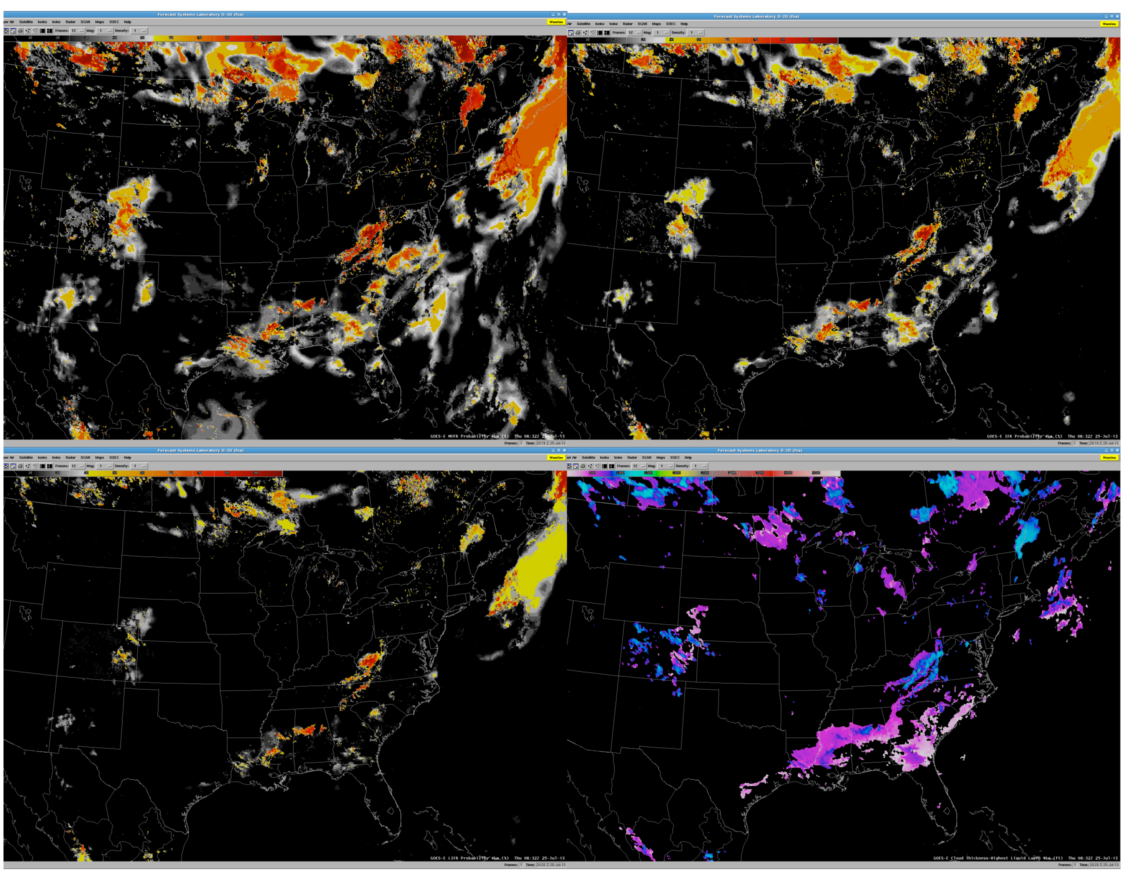

Figure 58. Example output from the GOES-R fog/low cloud algorithm from July 25, 2013 at 08:32 UTC. The top, left panel is the probability that MVFR conditions are present. The top, right panel is the probability that IFR conditions are present. The bottom, left panel is the probability that LIFR

conditions are present. The bottom, right panel is the estimated thickness of the highest liquid water cloud layer.

Publications, Reports, Presentations

Calvert, C. and M. Pavolonis. The Introduction and Evaluation of a Prototype GOES-R Fog/Low Stratus Thickness algorithm Using SEVIRI, GOES and SODAR Data. AMS Annual Meeting (89th): Fifth Annual Symposium on Future Operational Environmental Satellite Systems – NPOESS and GOES-R. Phoenix, AZ, January 2009.

Calvert, C. and M. Pavolonis. The GOES-R Low Cloud/Fog Algorithm: Description and Evaluation. GOES-R AWG & Risk Reduction Review Meeting. Alephi, MD.

Pavolonis, M.J. and C. Calvert: GOES-R Fog and Low Cloud Detection Algorithm Theoretical Basis Document (ATBD), Final Draft (100%).

The GOES-R Fog/Low Cloud Products, M. Pavolonis and C. Calvert, AWG Annual Meeting. Madison, WI, June 2010 – Oral presentation.

An overview of the GOES-R Fog/Low Cloud Products, M. Pavolonis and C. Calvert, OCONUS GOES-R Proving Ground Meeting. Honolulu, HI, July 2010 – Oral presentation.

A Quantitative Fog/Low Stratus (FLS) Detection Algorithm for GOES-R. C. Calvert and M. Pavolonis, AMS Annual Meeting. New Orleans, LA, January 2012.

New Quantitative Volcanic Cloud and Fog Products for GOES-R. M. Pavolonis and C. Calvert, AMS Annual Meeting. New Orleans, LA, January 2012. – Oral presentation.

An Overview of the GOES-R Fog/Low Stratus Algorithm. C. Calvert and M. Pavolonis, National Weather Association Annual Meeting. Madison, WI, October 2012 – Oral presentation.

GOES-R Fog/Low Stratus Forecaster Feedback. C. Gravelle, M. Pavolonis and C. Calvert, National Weather Association Annual Meeting. Madison, WI, October 2012.

Results from the Central Region Evaluation of the GOES-R Fog/Low Stratus Products. C Gravelle, M. Pavolonis and C. Calvert, 2nd NWS Eastern Region Virtual Satellite Workshop. February 2012.

9 CIMSS Participation in the Development of GOES-R Proving Ground

CIMSS Project Lead: Wayne Feltz
CIMSS Support Scientists: Scott Bachmeier, Scott Lindstrom, Lee Cronce, and Justin Sieglaff
NOAA Collaborators: Tim Schmit (ASPB/NESDIS/STAR), Gary Wade (ASPB/NESDIS/STAR)
NOAA Strategic Goals Addressed:

- Serve society’s needs for weather and water information
- Support the nation’s commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Outreach and Education

Project Overview

A proving ground provides resources for testing and validating ideas, technologies, and products before they are integrated into operational use. Implementation of a National Weather Service (NWS) proving ground for Geostationary Operational Environmental Satellite (GOES)-R ensures that all changes, either technological or procedural, undergo rigorous integrated testing before implementation.

This proposal from the Cooperative Institute for Meteorological Satellite Studies (CIMSS) is to support the GOES-R Proving Ground activities began in 2008 and will continue until GOES-R launch. The proving ground concept allows developers at CIMSS and other research centers to be involved at an early stage in product development with forecasters, providing the opportunity for interaction between developers and users. GOES-R Proving Ground funding will support personnel, including satellite applications experts and computer and technical support at CIMSS, to work directly with NWS forecast offices and NOAA National Centers.

The GOES-R Satellite Proving Ground includes two levels of interaction, national testbeds/PG demonstrations and regional/local collaborations. The first level of interaction will include supporting multiple NOAA testbeds (http://www.esrl.noaa.gov/research/uswrp/testbeds/) and/or Proving Ground demonstrations including the Hazardous Weather Testbed at the National Weather Center, the National Hurricane Center (NHC) PG demonstration, the Aviation Weather Testbed at the Aviation Weather Center (AWC), the NWS Training Center Testbed, the High Latitude PG demonstration at the Alaska Aviation Weather Unit, Satellite Applications Branch (SAB)/Ocean Prediction Center (OPC)/Hydrometeorological Prediction Center (HPC) PG demonstration, and Pacific Region PG demonstration. For the local level, CIMSS will build on close relationships already established with the NWS Forecast Offices at Milwaukee/Sullivan, Wisconsin. CIMSS interacts with over 50 NWS forecast offices in a limited capacity

In the GOES-R Proving Ground, developers and forecasters will test, apply, and evaluate GOES-R proxy algorithms for new GOES-R satellite data and products using proxy and simulated datasets, including GOES, MODIS/VIIRS, SEVIRI, and computer simulated products. These teams will test and validate the applications of these products in an operational setting.

Summary of Accomplishments and Findings

The primary focus has been to test, apply, and improve select GOES-R satellite baseline, future capability, and risk reduction imagery/products in support of National Centers and local NWS offices. CIMSS participated in a March 2012 GOES-R Proving Ground review meeting in Kansas City, Kansas and regular GOES-R Proving Ground coordination/reporting teleconferences. GOES-R PG oral and poster presentations occurred at various conferences is 2012-2013 including the American Meteorological Society (AMS) Conference, the National Weather Association (NWA) Conference, the 2012 AMS Severe Local Storms conference, and the EUMETSAT Annual conference in Sopot, Poland. Internet Web site access to GOES-R Proving Ground activities is hosted at: http://cimss.ssec.wisc.edu/goes_r/proving-ground.html.

Test and Apply Algorithms for Expected GOES-R Satellite Data Imagery/Products in Support of National NOAA Testbeds/PG Demonstrations

The following Proving Ground activities occurred in 1 April 2012 – 30 March 2013 funding cycle where several GOE-R proxy decision support products developed at CIMSS were demonstrated with operational forecasters to obtain feedback:

- Hazardous Weather Testbed (HWT) Spring Experiment (7 May – 15 June). Participants included 28 forecasters and 16 visiting scientists;
- National Hurricane Center (NHC) Tropical Cyclone Demonstration (1 Aug. – 30 Nov.)

Participants included forecasters from NHC;

- Aviation Weather Center (AWC) Summer Experiment (4 June – 15 June). Participants included AWC forecasters and FAA representatives;
- HPC/ OPC/ TAFB/ and SAB demonstrations (ongoing: focus on precipitation and ocean applications);
- High Latitude and Arctic Testbed (ongoing: focus on snow/ cloud/ volcanic ash/ and aviation applications). Participants include NWS Alaska Region;
- Air Quality (ongoing: focus on aerosol detection); and
- Pacific Region OCONUS Demonstration (ongoing: focus on tropical cyclones/ heavy rainfall/ and aviation applications). Participants include NWS forecasters and scientists from the University of Hawaii.

UW-Madison/CIMSS scientists were engaged with the demonstrations listed above by providing the following GOES-R Baseline, Future Capability, or Risk Reduction decision support proxy data. Product assessment highlights for eight of the UW-Madison/CIMSS decision support products are listed below as reported in the GOES-R PG 2012 Annual report and HWT/AWC/NHC Testbed final evaluation reports.

Publications, Reports, Presentations

Bedka, Kristopher M.; Dworak, Richard; Brunner, Jason and Feltz, Wayne. Validation of satellite-based objective overshooting cloud-top detection methods using CloudSat profiling radar observations. *Journal of Applied Meteorology and Climatology*, **51**, Issue 10, 2012, pp.1811-1822.

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Dworak, Richard; Bedka, Kristopher; Brunner, Jason and Feltz, Wayne. Comparison between GOES-12 overshooting-top detections, WSR-88D radar reflectivity, and severe storm reports. *Weather and Forecasting*, **27**, Issue 3, 2012, pp.684–699.

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Lakshamanan, Valliappa; Rabin, Robert; Otkin, Jason; Kain, John S. and Dembek, Scott. Visualizing Model Data Using a Fast Approximation of a Radiative Transfer Model. *Journal of Atmospheric and Oceanic Technology*, **29**, Issue 5, 2012, pp.745–754.

Lindsey, Daniel T.; Schmit, Timothy J.; MacKenzie, Wayne M. Jr.; Jewett, Christopher P.; Gunshor, Mat M. and Grasso, Louie. 10.35 micron: Atmospheric window on the GOES-R Advanced Baseline imager with less moisture attenuation. *Journal of Applied Remote Sensing*, **6**, 2012, doi:10.1117/1.JRS.6.063598.

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Monette, Sarah A., Christopher S. Velden, Kyle S. Griffin, Christopher M. Rozoff, 2012: Examining Trends in Satellite-Detected Tropical Overshooting Tops as a Potential Predictor of Tropical Cyclone Rapid Intensification. *J. Appl. Meteor. Climatol.*, **51**, 1917–1930. doi: http://dx.doi.org/10.1175/JAMC-D-11-0230.1

Schmit, Tim. The ABI on GOES-R. National Weather Association Newsletter, 2012, pp.4.

Identification of Convectively-Induced Aircraft Turbulence using Satellite Data, Sarah A. Monette, Kristopher M. Bedka, and Wayne F. Feltz. American Meteorological Society Annual Meeting, Austin, TX. Jan 6-10, 2013.

Total Lightning in a Multi-sensor Approach to the Detection and Forecasting of Convectively Induced Turbulence, Ryan Rogers, Larry Carey, Kris Bedka, Cecilia Fleeger, Wayne Feltz, Sarah Monette. American Meteorological Society Annual Meeting, Austin, TX. Jan 6-10, 2013.

The GOES Objective Overshooting Top Signature Detection Product: Algorithm Description, Validation, and Applications, Kristopher Bedka, Richard Dworak, Lee Cronce, and Wayne Feltz. 2nd National Weather Service Eastern Region Virtual Satellite Workshop, February 26, 2013.

Total Lightning in a Multi-sensor Approach to the Detection and Forecasting of Convectively Induced Turbulence, Ryan Rogers, Larry Carey, Kris Bedka, Cecilia Fleeger, Wayne Feltz, Sarah Monette. NOAA Satellite Science Week Virtual Meeting, March 18-22, 2013.

Analysis of the Co-Evolution of Total Lightning, Ground-Based Radar-Derived Fields, and GOES-14 1-Minute Super Rapid Scan Satellite Observations of Deep Convective Cloud Tops, Kristopher Bedka, Cecilia Fleeger, Ryan Rogers, Larry Carey, Wayne Feltz, and Jan Kanak. NOAA Satellite Science Week Virtual Meeting, March 18-22, 2013.

10 X/L-Band Polar Orbiting Satellite Direct Broadcast Reception Station and Automated Processing System for the NWS, Hawaii

CIMSS Project Lead: Liam Gumley
CIMSS Support Scientists: Kathy Strabala, Jordan Gerth
NOAA Collaborators: Mitch Goldberg (JPSS), Bill Ward (NWS)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

SSEC leveraged it's experience with the CSPP and IMAPP projects, and with operating direct broadcast ground stations, to manage the installation of a satellite data reception system for the National Weather Service in Honolulu HI to enable real-time acquisition and processing of data from polar orbiting satellites including:

- JPSS Suomi NPP,
- NASA Terra and Aqua,
- NOAA POES,

- EUMETSAT Metop, and
- CMA FY-3.

The system includes a 2.4 meter diameter X/L-band ground station for satellite data acquisition; an automated data processing system for creating a diverse array of satellite products; and an interface to the National Weather Service Advanced Weather Interactive Processing System (AWIPS) for real-time product display and analysis. SSEC provided project management for pre-installation planning, installation support, system setup and testing, end user training, and ongoing software support for product generation. The project duration is 3 years.

Summary of Accomplishments and Findings

Satellite imagery from the system is now used routinely in AWIPS by the NWS Forecast Office in Honolulu, HI. For example, during the approach of Hurricane Flossie in July 2013, VIIRS DNB imagery was used by the NWS to change the forecast track because it allowed better definition of the eye region of the storm. The forecast discussion is included below:

TROPICAL STORM FLOSSIE DISCUSSION NUMBER 19
NWS CENTRAL PACIFIC HURRICANE CENTER HONOLULU HI EP062013
500 AM HST MON JUL 29 2013
THE CENTER OF FLOSSIE WAS HIDDEN BY HIGH CLOUDS MOST OF THE NIGHT BEFORE VIRS NIGHTTIME VISUAL SATELLITE IMAGERY REVEALED AN EXPOSED LOW LEVEL CIRCULATION CENTER FARTHER NORTH THAN EXPECTED. WE RE-BESTED THE 0600 UTC POSITION BASED ON THE VISIBLE DATA. SUBJECTIVE DVORAK ANALYSES CONTINUED SHOW CURRENT INTENSITIES OF 3.0 BUT SATELLITE LOOPS SUGGEST A RAPID WEAKENING TREND WITH THE LOW LEVEL CENTER PULLING AWAY FROM A SMALL AREA OF CONVECTION SOUTHEAST OF THE CENTER. IT IS LIKELY THAT CONTINUED NORTHWEST SHEAR WILL MAINTAIN THIS WEAKENING TREND.
THE TRACK HAS BEEN SHIFTED NORTH TO REFLECT THE RE-LOCATED CENTER. THE TRACK GUIDANCE SHIFTED FOLLOWING THE TRACK CHANGE AND WAS CONSISTENT WITH A NEW TRACK FARTHER TO THE NORTH. THE TRACK NOW SHOWS FLOSSIE PASSING OVER MAUI TODAY...OVER OAHU TONIGHT...THEN PASSING SOUTH OF KAUAI EARLY TUESDAY MORNING. WE EXPECT FLOSSIE TO WEAKEN STEADILY AS IT TRACKS WEST NORTHWEST AND DISSIPATE WITHIN 96 HOURS.

The complete hardware and software system was installed in Honolulu on August 8, 2012. The satellite data acquisition system includes a state-of-the-art antenna positioner, 2.4-meter diameter reflector, dual-band feed, X and L-band receivers, and an antenna control and data acquisition computer server. Product generation is accomplished by a separate server collocated with the antenna control server. SSEC managed the setup and installation of the product generation software on the data processing server, and it is currently creating real-time products from Suomi NPP VIIRS, CrIS, ATMS, and Terra/Aqua MODIS. The system includes sufficient disk space to maintain a 14-day rolling archive of satellite data products and images. Real-time processing of satellite data products is accomplished by the Direct Broadcast Processing System (DBPS) software package developed at SSEC.

The processing system includes automated software to convert selected output products into the Network Common Data Format (netCDF) required for display in the Advanced Weather Interactive Processing System (AWIPS). Once the files are converted to the appropriate netCDF format and naming convention, the files are compressed and transferred to the NWS Office using the Unidata Local Data Manager (LDM). On the NWS local data ingest side, the files are unpacked on arrival and stored in the appropriate local directory structure.

Training was conducted at the customer location (University of Hawaii) following system installation on both system operation and maintenance, and derived product applications. The training consisted of the following modules:

- Antenna and acquisition system operations and maintenance (presented by the vendor),
- Processing system operation and maintenance (presented by SSEC), and
- Product applications (presented by SSEC).

Further in-depth training will be conducted on-site in August 2013.

Figure 59. 2.4-meter X/L-band antenna

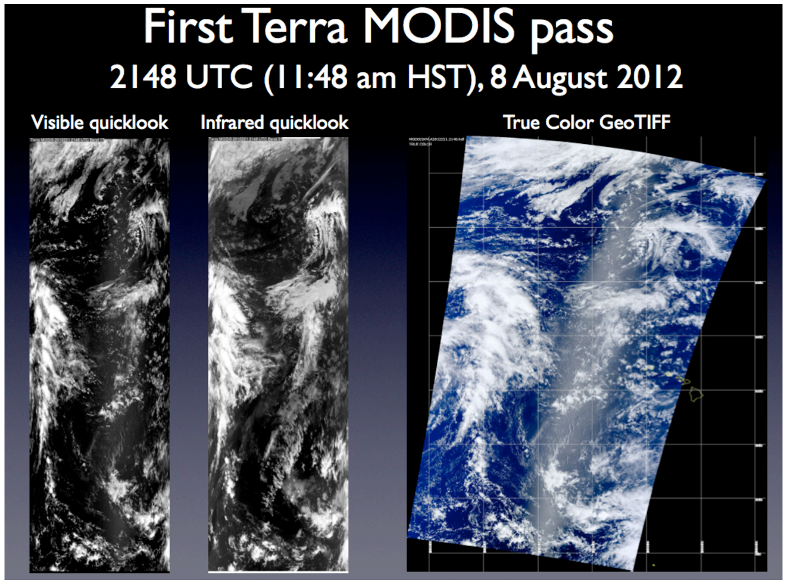


Figure 60. First imagery acquired by the 2.4-meter antenna

11 CIMSS High Impact Weather Studies with GOES-R and Advanced IR Sounders

CIMSS Project Lead: Jun Li
CIMSS Support Scientists: Jinlong Li, Pei Wang, Kevin Baggett
NOAA Collaborator: Tim Schmit, NESDIS/STAR
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

This project started in 2009 is for CIMSS scientists to study the use of the combined the advanced imaging products from the next generation Geostationary Operational Environmental Satellite (GOES-R) and the advanced infrared (IR) sounder data from polar-orbiting satellites for high impact weather warning, nowcasting and short range forecast applications. Severe weather warning, monitoring and forecasting requires nearly continuous monitoring of the vertical temperature and moisture structure of the atmosphere on various spatial scales, the value of combining high spatial and temporal resolution GOES-R Advanced Baseline Imager (ABI) and the advanced IR sounder observations for high impact weather (convective storms, tropical cyclones, etc.) warning, nowcasting and short-range forecasting are studied and demonstrated using the Atmospheric InfraRed Sounder (AIRS), Cross-track Infrared Sounder (CrIS), Moderate Resolution Imaging Spectroradiometer (MODIS), and the current GOES Sounder observations.

Summary of Accomplishments and Findings

CIMSS sounding team have developed a demonstration system – Satellite Data Assimilation for sTorm forecasts (SDAT) which comprises of data ingesting, assimilation and forecasting. SDAT is built upon the combination of Weather Research Forecast (WRF) and the community Gridpoint Statistical Interpolation (GSI) system, and is able to assimilate both the GOES-R products (such as legacy soundings, total precipitable water, AMVs, and water vapor channel radiances) and the JPSS sounder data (CrIMSS soundings or radiances). SDAT has been used for hurricane Sandy forecast experiments at STAR super computer S4 (satellite simulations and data assimilation studies) physically located at SSEC. By assimilating GOES-R moisture information (using MODIS as proxy) and NPP CrIMSS sounding products in hurricane Sandy forecast experiments with SDAT, better forecasts (both track and intensity) than the operational models (GFS and HWRF) are obtained, which demonstrates the importance of combined GOES-R and JPSS measurements for hurricane forecasts. Accomplishments and findings are below:

(a) Design and develop a demonstration system for tropical cyclone forecasts with combined GOES-R water vapor and JPSS sounder data. Observations of atmospheric temperature and moisture information in the environment region are very important to the prediction of the genesis, intensification, motion, rainfall potential, and landfall impacts of TCs such as Sandy (2012) through numerical weather prediction (NWP) models. In order to enhance the application of GOES-R water vapor measurements, a near real time demonstration system is being developed for assimilating combined GOES-R water vapor and JPSS sounder data for tropical cyclone (TC) forecasts. The system is at the current available infrastructure (STAR super computer S4) at SSEC. Figure 61 is the flowchart of GOES-R/JPSS assimilation system for TC forecast.

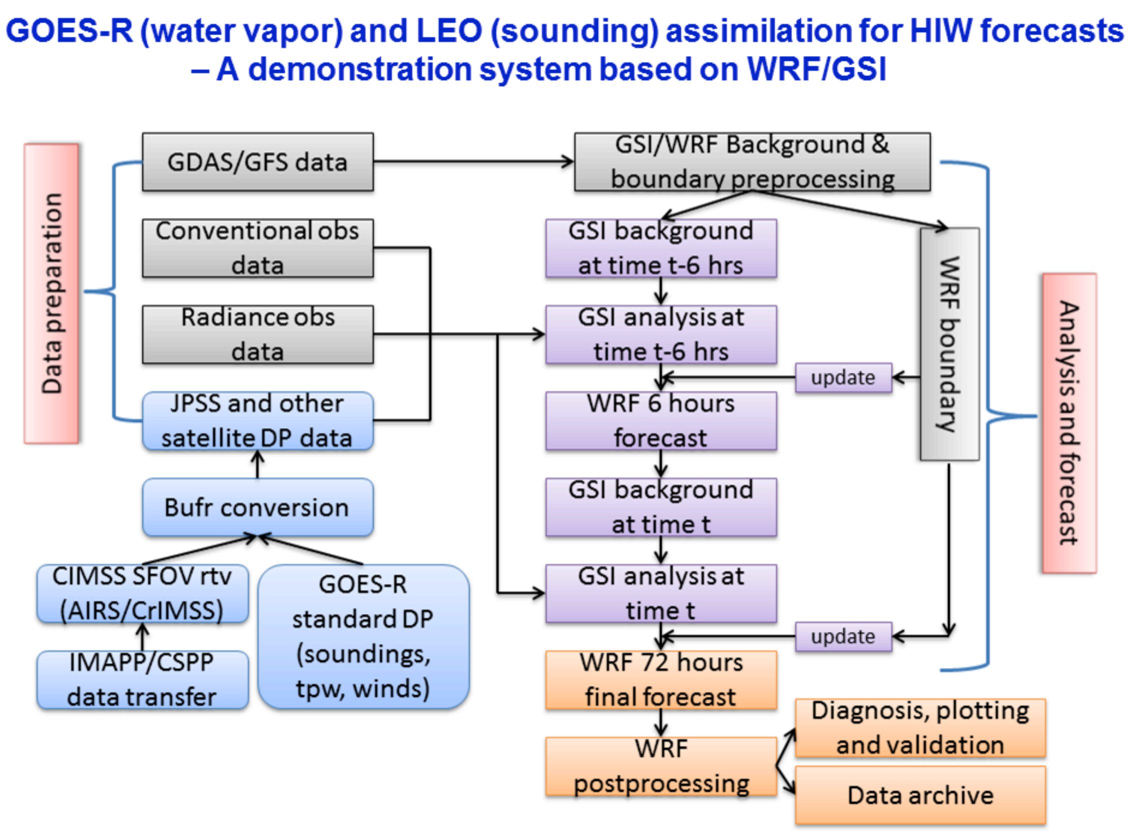


Figure 61. Flowchart of GOES-R (legacy soundings, tpw, winds) and JPSS sounding assimilation system for tropical cyclone forecasts.

The near real time data assimilation system (SDAT) mainly consists of three major parts. The first part is the data preparation, the second part is the data assimilation and the third part is forecasting. The latest community Gridpoint Statistical Interpolation (GSI) system and Weather Research Forecast (WRF) model is the core of our assimilation and forecast system. The NOAA National Centers for Environment Prediction (NCEP) global forecast system (GFS) output are used as GSI/WRF background and boundary input information. All conventional observations and satellite radiances data (GOES-R and JPSS) can also be obtained from NOAA/NCEP real time forecast system. In addition to the regular data from NCEP, some specific satellite derived products can be processed at CIMSS for assimilation. We have developed the capability to ingest GOES-R derived products (e.g., TPW – total precipitable water, layer PW and winds) into bufr file for assimilation application. GSI/WRF is designed to assimilate data every 6 hours (can be assimilated more frequently if computer resource allows) followed by 72-hour forecasts.

(b) Multiple LEO satellite water vapor measurements used for GOES-R WV proxy in assimilation experiments. Ideally, GOES Sounder should be used as proxy for GOES-R in high impact weather studies, however, since GOES Sounder has limited spatial coverage, we use water vapor measurements from multiple LEO (polar-orbiting) satellites to emulate the GOES-R water vapor measurements (total precipitable water in this study). TPW measurements from Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) are used to demonstrate the impact of GOES-R water vapor measurements on tropical cyclone analysis and forecasts. Figure 62 shows Typhoon Sinlaku sea level pressure (SLP) analysis for September 8 - 13, 2008 from control and TPW (MODIS and AMSR-E) assimilation, along with the observations. The control run assimilates radiosondes, satellite AMVs, QuickSCAT winds, COSMIC GPS-RO, ship and land surface observations. The water vapor measurements (TPW) provide a much better analysis for intensity than the control run.

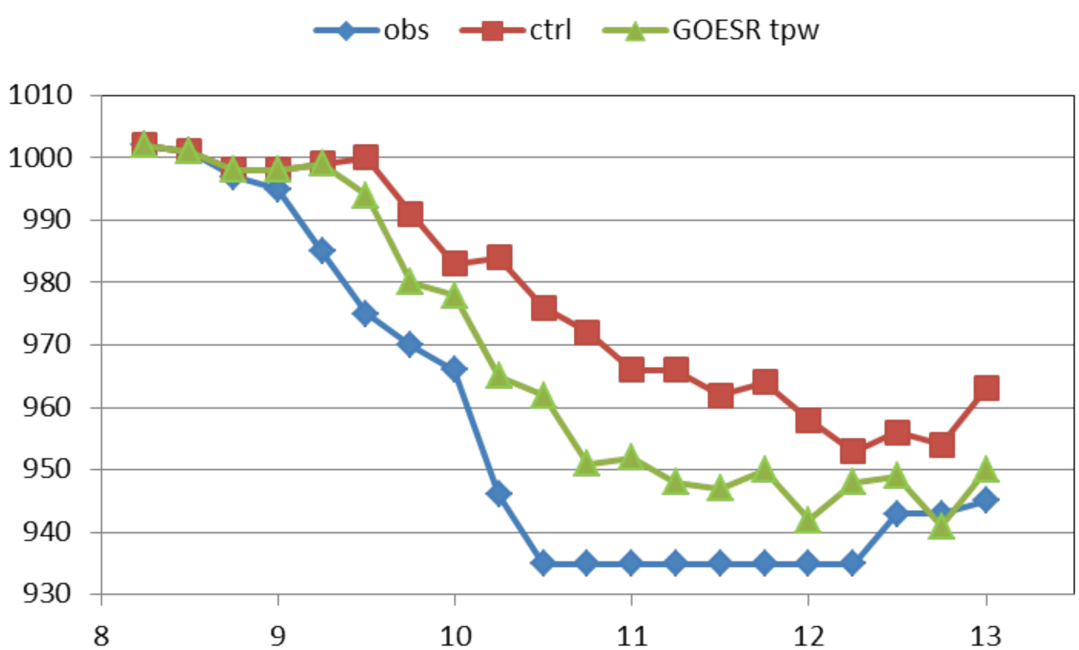


Figure 62. Typhoon Sinlaku sea level pressure analysis for September 8-13, 2008 from control and TPW assimilation along with the observations.

The TPW assimilation for hurricane Sandy (2012) forecast experiments are also conducted, three types of data are used in the experiments: (a) GTS - data obtained through WMO's global telecommunication system, GTS contains all the conventional data and other related data, (b) TPW over ocean from MODIS onboard Terra/Aqua – TPW derived with GOES-R legacy atmospheric profile (LAP) algorithm), and (c) GOES Sounder TPW – TPW derived from GOES-13 and GOES-15 Sounders with GOES-R LAP algorithm. In order to investigate the impact of using moisture data for Sandy forecasts, GTS+TPW data are used in the experiments. The experimental forecasts are converted to GOES-13 Imager 11 μm brightness temperatures (BTs) and verified with GOES-13 BT measurements. It is found that mesoscale feature forecasts with moisture observations assimilated are improved.

In summary, the results are encouraging and suggest a positive impact of GOES-R water vapor information for forecasting hurricane tracks and intensity. This progress has been reported in NOAA/NESDIS's Joint Center for Satellite Data Assimilation (JCSDA) newsletter (March 2012), see the following link for the newsletter: (http://www.jcsda.noaa.gov/documents/newsletters/201203JCSDAQuarterly.pdf).

Publications, Reports, Presentations

Li, J., P. Wang, T. Schmit, C. Velden, and Jinlong Li, 2013: Improving tropical cyclone forecasts with advanced sounding measurements from satellites, IOAS/TROPICALSYMP, AMS 93rd Annual Meeting, 06 – 10 Jan 2013, Austin, TX.

Li, J., T. Schmit, P. Wang, C. Velden, Jinlong Li, Z. Li, and W. Bai, 2013: Improving tropical cyclone forecasts in regional NWP with GOES-R water vapor and JPSS sounder measurements, JCSDA Session at the 93rd AMS Annual Meeting 06 – 10 Jan 2013, Austin, TX.

Wang, P., J. Li, T. Schmit, J. Li, Z. Li, and W. Bai, 2013: Improve tropical cyclone forecasts with hyperspectral infrared sounder data, AMS 93rd Annual Meeting, 06 – 10 Jan 2013, Austin, TX.

Li, J., 2012: Assimilation of satellite data in regional NWP - progress and challenges, invited talk at the NSF sponsored Earth Cube Workshop – Shaping the Development of EarthCube to Enable Advances in Data Assimilation and Ensemble Prediction, 17 – 18 December 2012, Boulder, Colorado.

Zheng, J., J. Li, Jinlong Li, and T. J. Schmit, 2012: Assimilating AIRS Soundings with WRF/3DVAR for Hurricane Forecast Improvement. *Advances in Atmospheric Sciences* (submitted).

Li, Jun; C.-Y. Liu, P. Zhang, and T. J. Schmit, 2012: Applications of full spatial resolution space-based advanced infrared soundings in the preconvection environment. *Weather and Forecasting*, **27**, 515 - 524.

Kwon, Eun-Han; Jun Li, Jinlong Li; B. J. Sohn, and E. Weisz, 2012: Use of total precipitable water classification of a priori error and quality control in atmospheric temperature and water vapor sounding retrieval. *Advances in Atmospheric Sciences*, **29**, 263 - 273.

Yao, Z., Jun Li, and Jinlong Li, 2012: Sunglint impact on atmospheric soundings from hyperspectral resolution infrared radiances. *Advances in Atmospheric Sciences*, **29**, 455 - 463.

Li, Z., J. Li, Y. Li, T. Schmit, L. Zhou and M. D. Goldberg, 2013: Determining Infrared Land Surface Emissivity Diurnal Variation from Satellites, 93rd AMS Annual Meeting, 9 – 13 January 2013, Austin, TX.

Lee, Yong-Keun, Zhenglong Li, Jun Li, and Timothy J. Schmit, 2013: Evaluation of the GOES-R ABI LAP retrieval algorithm using the current GOES sounder. *Journal of Applied Meteorology and Climate* (conditionally accepted).

Li, Z., J. Li, Y. Li, Y. Zhang, T. J. Schmit, L. Zhou, M. Goldberg, and W. Paul Menzel, 2012: Determining Diurnal Variations of Land Surface Emissivity from Geostationary Satellites. *Journal of Geophysical Research – Atmospheres*, **117**, D23302.

12 Investigations in Support of the GOES-R Program Office

CIMSS Project Lead: Paul Menzel
NOAA Collaborator: Steve Goodman
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Outreach and Education

Summary of Accomplishments and Findings

Satellite Task Force (SATTF) Report to the NOAA SAB

The SATTF report to the NOAA Science Advisory Board was presented on 14 November 2012 and accepted after minor modification. NESDIS is working on some of the recommendations (see last progress report). The summary conclusions of the SATTF were:

> NOAA has established a basis and starting point for assessing and replanning its satellite system architecture. NOAA is faced with a demanding and evolving set of challenges, and addressing those challenges will take time. Given the current planning for GOES and JPSS it may take up to a decade to establish an alternate, less costly satellite system architecture. Nonetheless, there are actions that can be taken in the near term. The recommendations provided as a result of the SATTF review of NESDIS replanning should assist in addressing today's challenges and strengthen the existing foundation. A desired outcome is to provide NOAA and the nation the means to address the core requirements of the user community, meet national policy guidance, continue to leverage the international satellite enterprise through partnerships and reduce risk with the ultimate result being a way forward for "a more affordable, flexible and robust satellite and services architecture."

Updated Version of AppMetSat

"Remote Sensing Applications with Meteorological Satellites" was updated in November 2012 and posted at ftp:\\ftp.ssec.wisc.edu/pub/menzel/AppMetSat12.pdf.

Participation in NOAA Satellite Science Week

From 18 to 21 March 2013 P. Menzel attended the virtual NOAA Satellite Science Week (organized with the help of COMET technical staff) and participated in the Independent Advisory Committee discussions. Several comments / recommendations were offered.

Remote Sensing Bootcamp

From 25 to 29 March 2013 and again from 8 to 12 July 2013, as part of the two week Remote Sensing Bootcamps, P. Menzel gave lectures on Applications with MODIS, VIIRS, CrIS, and ATMS. The agenda for the first week of each bootcamp was as follows:

> *Monday Lecture 9 – 11 am and Lab 1 – 4 pm*
> Satellite orbits, Planck function, Radiation, BTs in mixels, Intro to HYDRA,
> Reflected solar and thermal emission, 4 versus 11 um BTs
> *Tuesday Lecture 9 – 11 am and Lab 1 – 4 pm*
> RTE, land-ocean-atmosphere spectral signatures in MODIS & VIIRS
> *Wednesday Lecture 9 – 11 am and Lab 1 – 4 pm*
> Hyperspectral infrared spectra, Microwave sounding,
> VIIRS, CrIS, & ATMS split window estimates of low level moisture.
> *Thursday Lab 1- 4 pm*
> Group projects on winter storm over the Great Lakes, USA
> *Friday Lecture 9 – 11 am*
> Group presentations, Summary Lecture, Quiz.

10 to 15 students participated and prepared presentations. A summary quiz verified that most of the material had been learned.

Collaborations with EUMETSAT

P. Menzel co-chaired a Meteosat-Third Generation (MTG) Infrared Radiation Sounder (IRS) Workshop on Nowcasting Applications. A key objective is to get the nowcasting community interested in the potential of hourly hyperspectral sounder observations. Ideally this would involve direct use of the observations, but, in this modern area of informatics, smart ways of combining the MTG-IRS information stream with other information streams will also be studied. An organizing meeting was held in Rome 30-31 May and the workshop was held in Darmstadt 25-26 July. More than forty forecasters from the European Union gave presentations on current nowcasting practices and hopes for improvement from Meteosat Third Generation –Infrared Sounder. CIMSS (N. Smith, R. Petersen, P. Antonelli, and P. Menzel) gave presentations on the information content from infrared high spectral resolution measurements, nearcasting the pre-convective environment with current geo-sounders, and applications with time sequences of polar orbiting sounders. Working Groups discussed the anticipated nowcasting practices in 2020 and recommended training programs to prepare to utilization of MTG-IRS.

13 CIMSS Studies on Advanced Geostationary IR Sounder with OSSE

CIMSS Project Lead: Jun Li
CIMSS Support Scientists: Zhenglong Li, Jason Otkin, and Agnes Lim
NOAA Collaborators: Tim Schmit (STAR), Robert Atlas (AOML), and Sean Casey (JCSDA)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation

Project Overview

This project started in 2012 is for the University of Wisconsin-Madison (UW-Madison) Cooperative Institute for Meteorological Satellite Studies (CIMSS) to study the unique value of a geostationary advanced infrared (IR) sounder for severe weather warning and short-range forecasting, and to develop methodologies for simulating the geostationary advanced IR sounder data from nature runs for OSSE (Observing System Simulation Experiments), through collaboration with AOML and JCSDA.

Summary of Accomplishments and Findings

As part of the OSSE project, CIMSS is responsible for generating the simulated radiance/brightness temperature (Tb) from future instruments. As a representative of future instrument, an AIRS onboard geostationary satellite is assumed and used. The following summarizes the accomplishments and findings.

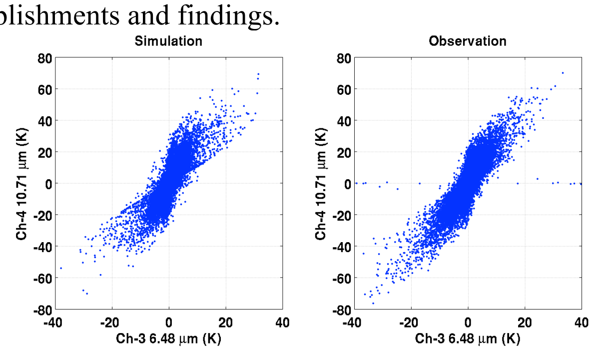


Figure 63. The temporal variation of GOES-12 Imager channel 3 and 4 from the simulation (left) and the observation (right).

(a) *Software in Fortran 90 has been developed to simulate AIRS Tb (brightness temperature) spectrum in geostationary orbit.* The software has been applied to the WRF nature run (regional OSSE) and the ECMWF nature run (global OSSE). The simulation is generated using SARTA V1.07 (Strow et al. 2003) plus the cloudy model (Wei et al. 2004).The simulated Geo AIRS Tb has been validated with GOES Imager radiance measurements. Figure 64 shows that the simulated AIRS radiances from natural run capture the real temporal variations reasonably well.

(b) *Software in Fortran 90 has been developed to convert the simulated radiances to bufr files, and the simulated radiances can be directly digested by GSI for assimilation in OSSE*. The bufr files have been delivered to AOML and JCSDA for testing in global OSSE.

(c) *Based on the feedbacks from AOML and JCSDA, the following problems have been identified and fixed*:

- The most out 10 row/columns in the WRF nature run, which are affected by boundary conditions, show problematic simulations, and are therefore removed. Figure 64(b) show reduced coverage due to boundary removed.
- Cloudy radiances are found to have negative impacts on the assimilation; many cloudy radiances are assimilated as mistakenly identified as clear. We have removed cloudy pixels and re-generated bufr files which contain clear sky pixels only. See Figure 64(c).
- To further increase the usage of simulated AIRS radiances, clear channels in cloudy pixels are retained in the bufr files. Figure 65 show how clouds affect spatial coverage

for different channels. For channels peaking near the surface, like 11.11 μm, most of radiances are affected by clouds. But for channel peaking high, most of the observations are not affected by clouds. CIMSS has developed a technique to identify clear channels, and is currently working on generating bufr files of all AIRS radiances that are not affected by clouds using the WRF nature run.

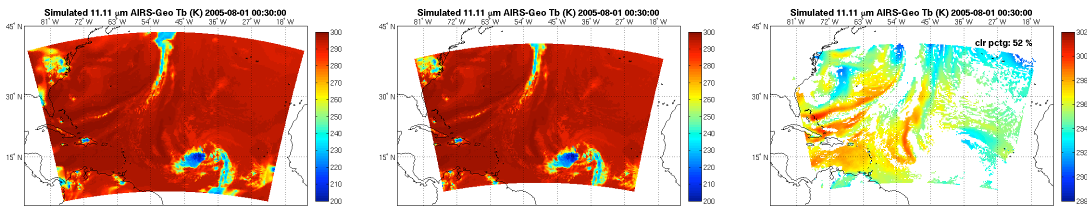


Figure 64. (left) Original simulated AIRS brightness temperature at 11.11 μm using WRF nature run, (middle) after removing boundary and (right) after removing clouds.

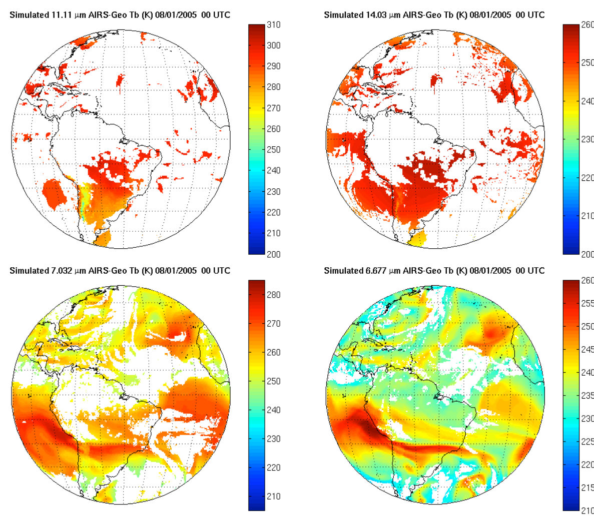


Figure 65. Simulated AIRS clear channel radiances of (upper left) 11.11 μm, (upper right) 14.03 μm, (lower left) 7.032 μm, and (lower right) 6.677 μm.

Publications, Reports, Presentations

Li, J., 2012: Assimilation of satellite data in regional NWP - progress and challenges", invited talk at the NSF sponsored Earth Cube Workshop – Shaping the Development of EarthCube to Enable Advances in Data Assimilation and Ensemble Prediction, 17 – 18 December 2012, Boulder, Colorado.

Li, J., T. J. Schmit , R. Atlas, R. Heymann, Z. Li, J. Otkin , W. Bai, T. Schaack, and B. Pierce, 2012: GEO advanced IR radiance simulation and validation for R-OSSE, presentation at AGU Fall Meeting, San Francisco, CA, 03 – 07 December 2012.

14 GOES-R Calibration/Validation Field Campaign Support

CIMSS Project Lead: Wayne Feltz
CIMSS Support Scientists: Lee Cronce, Todd Schaak, Allen Lenzen, and Erik Olson
NOAA Collaborators: Brad Pierce (ASPB/NESDIS/STAR), Andrew Heidinger (ASPB/NESDIS/STAR), and Shobha Kondragunta (NESDIS/STAR)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes:

- Satellite Sensors and Techniques

Project Overview

This current 2-year research task supports ground-based field experiment validation for GOES-R Cloud, Aerosol, Land and Sounding AWG team algorithm requirements and addresses the need for more extensive calibration and validation was just highlighted in GOES-R Algorithm Development Board's baseline and option 2 response documents under Finding #1: "Insufficient Validation : Reporting of measurement validation lacked completeness and was rarely independent." The proposal builds on the Ground-based Atmospheric Monitoring Instrument Suite (GAMIS) instrumentation currently operating at University of Wisconsin's Space Science and Engineering Building which offers an impressive set of remote sensing capabilities. We propose here to leverage GAMIS instrumentation by adding a CIMEL sun photometer to provide an Aerosol Robotic Network (AERONET) suite of capabilities and a GPS-MET receiver to provide integrated precipitable water information. The addition of these instruments will complement the SSEC rooftop instrument suite and will provide a continuous aerosol and water vapor monitoring capability. In addition, we propose to deploy a high-spectral resolution LIDAR (HSRL) and a high-spectral resolution measurement of solar irradiance from the CU/LASP (SSFR) during the NSF sponsored DC3 field campaign in spring 2012. This suite of ground-based instruments will provide state-of-the-art validation opportunities for GOES-R Aerosol, Cloud, Surface Radiation and Sounding algorithms applied to GOES-13 and MODIS.

Summary of Accomplishments and Findings

This proposal focuses on validation of GOES-R Advanced Baseline Imager (ABI) aerosol, cloud, land and sounding retrievals using surface and airborne measurements during NSF and NASA sponsored field campaigns scheduled during 2012. The airborne and surface validation tools and procedures developed under this proposal will provide the foundation for post-launch ABI validation activities in 2015.

Task 1: Ground-Based Measurements for GOES-R Aerosol, Cloud, Surface Radiation and Total Precipitable Water Validation

During the first year of this project we have added a CIMEL sun photometer to the UW-Madison SSEC roof-top instrumentation suite and become a member of the Aerosol Robotic Network (AERONET) federation. The CIMEL Sunphotometer is installed on the roof of the Engineering Research Building on the University of Wisconsin-Madison campus on November 01, 2012. The instrument is approximately 55 m off the surface. The instrument was leveled and aligned and the "AUTORUN" feature was started. Data were collected manually during the first 2 weeks of November and transferred manually to the Aeronet group using the K7 file transfer Web page. Automatic data collection began on November 26, 2012.

We also deployed a high-spectral resolution LIDAR (HSRL) to Norman, OK from May 10-July 10, 2012 for ground-based lidar measurements during the NSF Deep Convective Clouds and Chemistry (DC3) mission and a high-spectral resolution Solar Spectral Flux Radiometer (SSFR) measurement of solar irradiance was deployed at Boulder, CO through a sub-contract award to CU/LASP.

Task 2: Validation of GOES-R Aerosol and Cloud Retrievals during the 2012 TORERO and DC3 Field Campaigns

The first field campaign was the National Science Foundation (NSF) sponsored "Tropical Ocean TRoposphere Exchange of Reactive Halogen Species and Oxygenated VOC" (TORERO) mission which sampled the Equatorial Pacific during January- February 2012. The second campaign was the joint NSF and NASA Deep Convective Clouds & Chemistry Experiment (DC3) campaign which sampled the central US campaign during May-June, 2012.

We participated in daily flight planning activities during both TORERO and DC3 by providing daily Real-time Air Quality Modeling System (RAQMS) Forecasting and AVHRR Pathfinders Atmospheres - Extended (PATMOS-X) cloud retrievals during both TORERO and DC3 missions. Active participation in the flight planning discussions and in-field analysis provides invaluable context for the airborne measurements and helps establish a meaningful collaboration between the GOES-R satellite community and airborne communities. Through collaboration with the TORERO and DC3 mission scientists as well as individual instrument PIs we had access to preliminary airborne measurements for quick look comparisons. The airborne measurements include: direct measurements of aerosol and cloud extinction from High Spectral Resolution Lidar (HSRL) (Eloranta, 2005) during TORERO and Differential Absorption Lidar-High Spectral Resolution Lidar (DIAL-HSRL) (Hair et al., 2008) during DC3. Airborne hyperspectral cloud retrievals from the Solar Spectral Flux Radiometer (SSFR) (Pilewskie et al., 2003) and its follow-on the HIAPER Airborne Radiation Package (HARP) during TORERO and DC3; and Microwave Temperature Profiler (MTP) (Denning et al., 1989) retrievals during TORERO. We will use finalized airborne measurements for post mission validation activities during year 2 of this effort.

Figure 66 summarizes the airborne sampling by the NSF GV aircraft during TORERO and the combined NSF GV and NASA DC8 sampling during DC3. During TORERO the GV flew primarily out of Costa Rica and sampled outflow from maritime deep convection with additional survey flights along the South American Coast. Very little aerosol was observed during TORERO so our validation efforts will focus on cloud and temperature retrievals. During DC3 the GV and DC8 flew coordinated flights that targeted continental deep convection with the DC8 sampling low-level inflow and the GV sampling upper level outflow. Both aircraft sampled heavy aerosol loading due to extensive biomass burning that occurred over the western US and northern Mexico during DC3 so our validation efforts will focus on cloud, aerosol, and temperature retrievals.

The University of Colorado LASP Solar Spectral Flux Radiometer (SSFR) group (Sebastian Schmidt, Lead) deployed the SSFR at Boulder, CO during DC3. SSFR provides multi-spectral retrievals of cloud optical thickness, effective radius, liquid/ice water path, as well as aerosol single scattering albedo and asymmetry parameter (with HSRL). The instrument is calibrated using a NIST-traceable lamp and has a radiometric accuracy of 3-5% and a precision of 0.5%. GOES PATMOS-X cloud microphysical retrieval validation studies using the Boulder SSFR measurements allow us to demonstrate the use of SSFR measurements for GOES-R ABI cloud validation. Cloud optical thickness and effective radius is derived from zenith-viewing spectral transmitted radiance using the spectral slope of the transmitted radiance between 1565 nm and 1634 nm, normalized to its value at 1565 nm and the transmittance at 515 nm (McBride et al., 2011). Normalizing the near-infrared transmittance by its value at 1565 nm before calculating the spectral slope reduces the dependence of the retrieval on spectrally correlated errors, such as radiometric uncertainty.

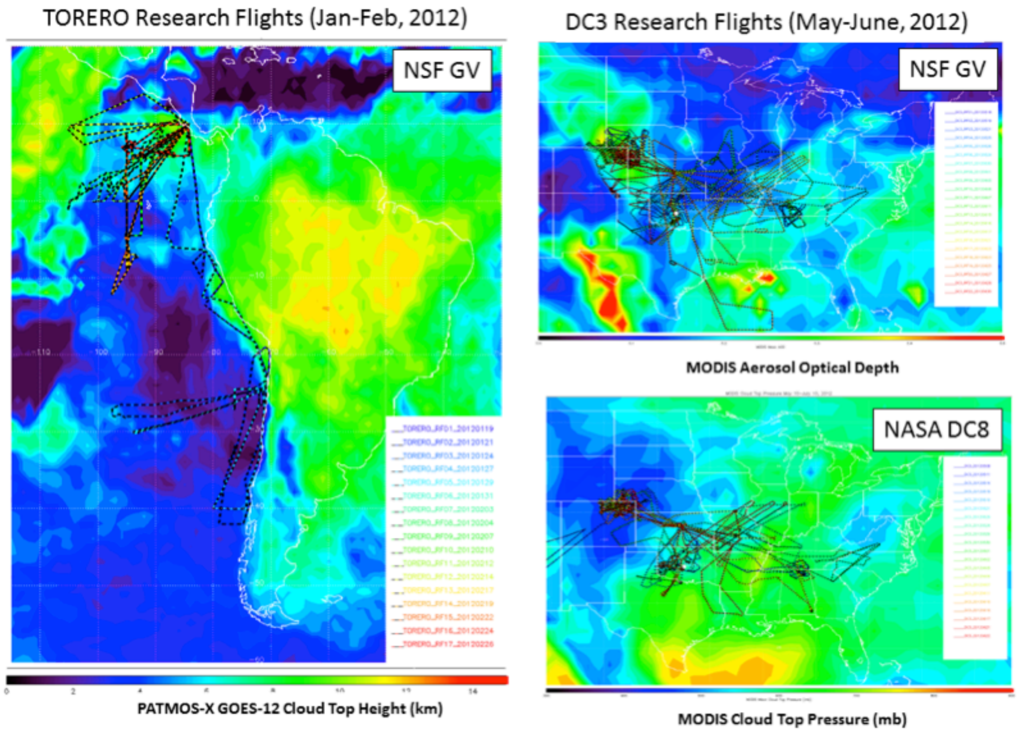


Figure 66. NSF GV and NASA DC8 flight tracks during TORERO (left) and DC3 (right) field campaigns. Mean January - February, 2012 PATMOS-X GOES-12 Cloud Top Height (km) retrievals are shown in the left panel. Mean May-June 2012 MODIS AOD and CTP (mb) are shown.

15 SSEC/CIMSS Cloud Research in Support of the Suomi NPP and JPSS Programs

15.1 VIIRS Cloud mask Validation and Tool Development

CIMSS Project Lead: Denis Botambekov
CIMSS Support Scientists: Rich Frey, Christine Molling
NOAA Collaborator: Andrew Heidinger NOAA/STAR/NESDIS
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

This project supports the JPSS VIIRS Cloud Mask Cal/Val Team for 1 year. The goal of this effort is to use our previously developed tools and tune the cloud mask. NPP/VIIRS was launch in November 2011. This work is coordinated with other member at other institutes.

We intend to leverage our efforts within the existing NPP PEATE located at the University of Wisconsin. Through this project, we intend to continue to interact with our NGST colleagues (Keith Hutchison and Eric Wong) and the Air Force Weather Agency (AFWA) in Omaha, Nebraska (Tom Kopp). This project will also aim to discover bugs and potential fixes in the VIIRS Cloud Mask (VCM).

Task List

- *Validation Tool Development*
  The cloud mask team is developing the tools to provide global validation of the VCM results. These tools complement the more detail tools developed for small individual granules.
- *NOAA/NASA Cloud Mask Comparison*
  The cloud mask team at CIMSS has developed tools to compare the cloud masks it develops for NASA and NOAA. These are run at SSEC in Madison, Wisconsin (UW-Madison). They are designed to develop and analyze match-ups between the VCM, the MODIS cloud mask, and potentially other cloud mask algorithms.
- *NOAA Match-ups with CALIOP*
  CIMSS has also developed tools to compare CALIPSO LIDAR cloud detection results. This tool now runs at SSEC. The tool is actually designed to analyze match-ups between CALIOP and any available cloud mask and can be used to identify large scale errors and can tie them to specific cloud characteristics (i.e., cloud height and emissivity).

Summary of Accomplishments and Findings

Developed tools are used to plot global composites of VCM (Figure 67), validate them with the other cloud mask algorithm products (NOAA PATMOS-x, MODIS C5 and C6, etc.), analyze the quality of the clear radiances, and compare the performance of the VCM over all regions. We use these tools to identify large scale errors and differences between the VIIRS and MODIS cloud masks. These tools are capable of processing large amounts of data. We operate these tools periodically to track the performance changes of the VCM as it is tuned and refined.

Developed CALIPSO – VIIRS match-ups collocation tools are used to generate many days of results and to also track changes in performance as the VCM is tuned. The tools allow making a statistical comparison with the other cloud mask products (Table 2).

The new thresholds for existing VCM tests (M1, M5, M7 Reflectance test, etc.) were found by using our global validation tools, which led to improvement of the performance of these tests and the algorithm in general. This work is done in a close collaboration with the other members of VCM Cal/Val team.

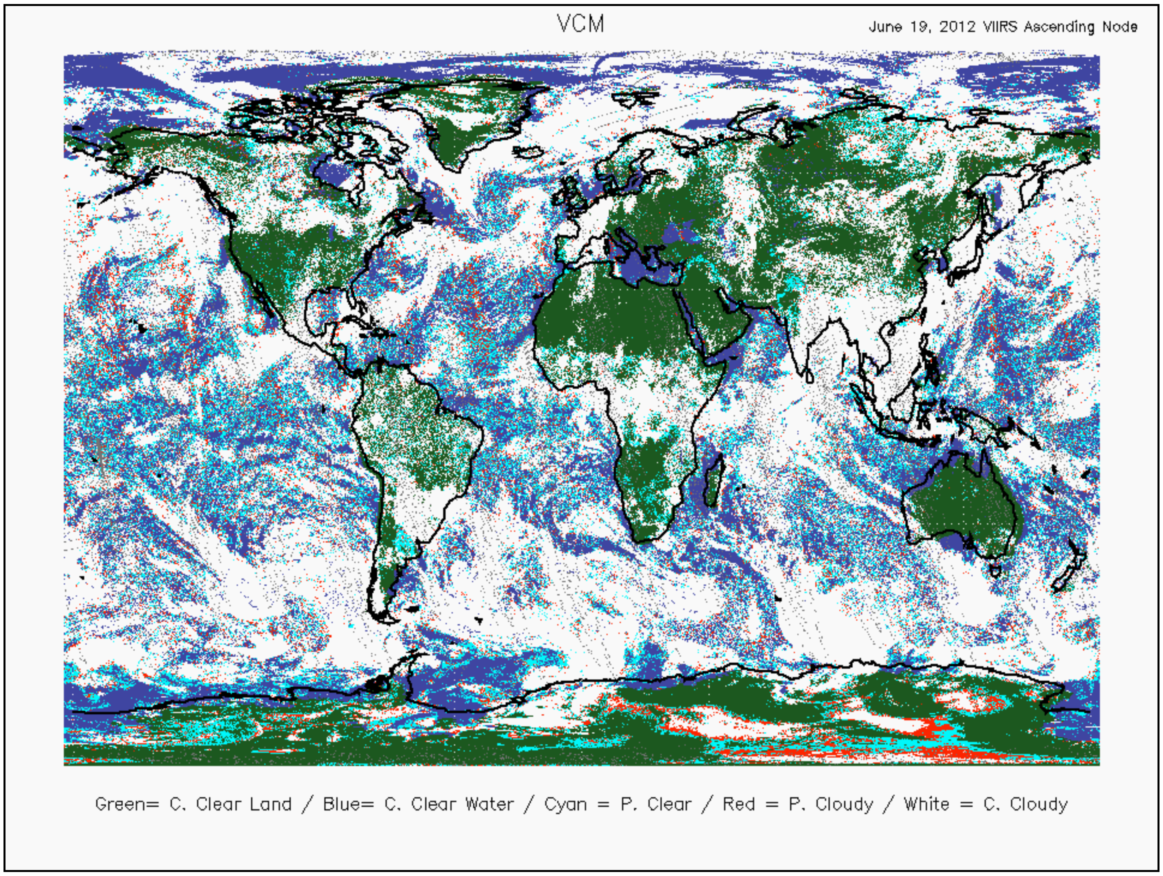


Figure 67. VCM performance on June 19, 2012 ascending node (day time)

Table 2. Statistical Cloud Mask Algorithms comparison, based on CALIPSO – VIIRS/AQUA-MODIS collocation data from 11/10/2012 and 11/29/2012 over whole globe day and night.

Cloud Mask Algorithm	Sample Size	Cloud fraction				Probability of		
		Active	Passive	Pr. Clear	Pr. Cloudy	Detection	False D.	Leakage
VCM	582257	0.733	0.655	0.073	0.030	0.878	0.022	0.100
NOAA PATMOS-x VIIRS	582257	0.733	0.705	0.054	0.056	0.921	0.027	0.051
NOAA PATMOS-x MODIS	425370	0.749	0.712	0.066	0.059	0.937	0.013	0.050
MODIS C6	425370	0.749	0.733	0.056	0.048	0.930	0.027	0.043

Publications, Reports, Presentations

The VIIRS Cloud Mask: Progress in the First Year of S-NPP Towards a Common Cloud Detection Scheme. Submitted to *Journal of Geophysical Research – Atmospheres* on 06/28/2013.

15.2 VIIRS Cloud Mask Tuning and Software Support

CIMSS Project Lead: Rich Frey
CIMSS Support Scientist: Denis Botambekov
NOAA Collaborator: Andrew Heidinger NOAA/STAR/NESDIS
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

This project supports the JPSS VIIRS Cloud Mask Cal/Val Team. The goal of this year's effort is to use our previously developed tools and tune the cloud mask. NPP/VIIRS was launched in November 2011. Our plan is to tune the VIIRS Cloud Mask (VCM) during in the spring of 2012. This work is coordinated with other member at other institutes. We intend to leverage our efforts within the existing NPP PEATE located at the University of Wisconsin. Through this project, we intend to continue to interact with our NGST colleagues (Keith Hutchison and Eric Wong) and the Air Force Weather Agency (AFWA) in Omaha, Nebraska (Tom Kopp). This project will also aim to discover bugs and potential fixes in the VCM.

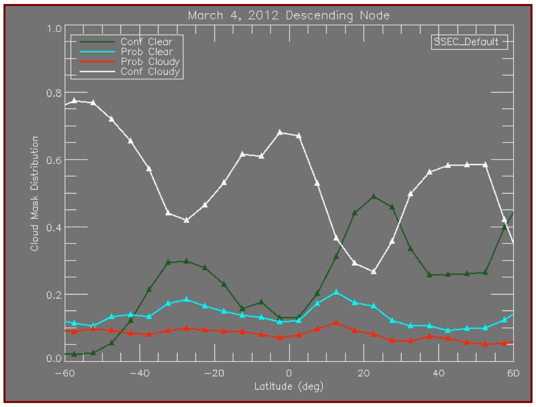
Summary of Accomplishments and Findings

Initial VCM cloud test threshold tuning was completed in April, 2012 and the new thresholds implemented on May 1, 2012. Pre-launch values were updated to optimize cloudy vs. clear-sky discrimination using input VIIRS calibrated reflectance and infrared brightness temperatures measured from space. Figure 68 shows zonal distributions of the four VCM output clear-sky confidence categories using pre- and post-launch thresholds. As clear vs. cloudy thresholds were adjusted to match measured on-orbit values, the numbers of probably clear and probably cloudy results declined as expected.

Additional M1 (0.412 micron) and M5 (0.672 micron) reflectance thresholds were developed for background top of canopy NDVIs of 0.0-0.3. Many semi or seasonally arid regions are not identified as "deserts" in the static ancillary surface type data; hence, either M1 (normally used as a daytime desert test) or M5 tests are used in these cases, determined by a threshold NDVI of 0.2. The thresholds are functions of NDVI and scattering angle.

Scattering angle dependent M7 (0.865 micron) cloud test thresholds were developed for daytime water surfaces, replacing the original static values. While the new thresholds are very effective for most ocean areas, problems have been identified for regions impacted by sun-glint. Thresholds tor these areas will be re-derived.

The nighttime land M12-M16 (3.7-12.0 micron) brightness temperature difference (BTD) and nighttime ocean M15-M12 (10.8-3.7 micron) BTD test thresholds were further optimized after the initial tuning. The M12-M16 test was significantly over-clouding in some tropical areas and the M15-M12 was tuned to detect more ocean stratus clouds.



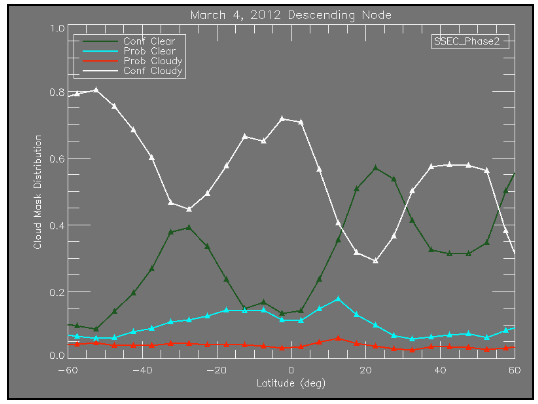


Figure 68. Zonal distribution (percent) of VCM output clear-sky confidence categories for March 4, 2012 using pre-launch (left) and post-launch (right) cloud test thresholds. Confident clear and confident cloudy categories (green, white) show an increase while probably clear and probably cloudy results (cyan, red) show declines as thresholds were adjusted to on-orbit measured visible/NIR reflectances and IR brightness temperatures.

15.3 VIIRS Cloud Mask Validation using Surface Sites

CIMSS Project Lead: Christine Molling
CIMSS Support Scientist: Lisha Roubert
NOAA Collaborator: Andrew Heidinger (NESDIS/STAR/ASPB)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

VIIRS Cloud Mask Validation using SURFRAD Sites is part of SSEC/CIMSS Cloud Research in Support of the SuomiNPP and JPSS Programs. The cloud mask validation portion of the project has been built in parallel with work validating could masks for AVHRR on POES and GOES Imager. This project seeks to validate the VIIRS Cloud Mask (VCM) by using data from seven instrumented ground sites in the continental United States in the Surface Radiation (SURFRAD) network. Simultaneously, the VCM is also being compared to the PATMOS-x-based AVHRR Cloud Mask adapted for VIIRS (the PCM for AVHRR is the official NOAA AVHRR cloud mask algorithm) at those same sites, in order to quantify the performance of the VCM with respect to that of the PCM. A high quality VCM will allow a continuation of the calibrated PCM that runs back to TIROS-N in 1978, allowing AVHRR-based climate studies to continue into the VIIRS era. This project is currently in its second year.

Task List

- *Validation Tool Development*
  This task will modify a SURFRAD tool developed for the GOES-R AWG program for use with VIIRS data.

- *Routine Cloud Mask Monitoring*
  This task will create scripts to daily download VIIRS data over CONUS and run a cloud products algorithm using the VIIRS channel data and VCM. It will also create a tool to compute statistics related to the accuracy of the cloud mask by comparing results among several different cloud and radiometric variables and data from SURFRAD station measurements. Statistics computed from this tool and results from the Validation Tool will be run on a weekly basis and posted on a Web site.
- *Extension to Cloud Optical Properties*
  This task will create a tool to compare VIIRS-based cloud optical depth and cloud transmission to SURFRAD-based atmospheric transmission. Statistics will be computed and posted on a weekly basis on the Web site mentioned above.

Summary of Accomplishments and Findings

Task 1: Validation Tool Development

A tool to compare GOES Imager-based cloud mask with SURFRAD data was modified to work with VIIRS VCM and PCM using satellite vs. SURFRAD surface skin temperature to determine whether scene is cloudy or not.

Task 2: Routine Cloud Mask Monitoring

Tool was configured to run on a weekly basis with results posted to a Web site. See the link to the VIIRS page on http://cimss.ssec.wisc.edu/clavr/surfrad/practice.html. Tool was also used to evaluate cloud mask with and without snow during Nov 2012 (Figure 69, Table 3). Early indications are that snow cover does affect the quality of the cloud mask, although this analysis needs to be repeated on more data after the VCM algorithm updates in Spring, 2013.

Task 3: Extension to Cloud Optical Properties

A tool is in progress that compares cloud transmission from satellite to total atmospheric (clear sky + cloud) transmission. This is not yet posted on the Web site.

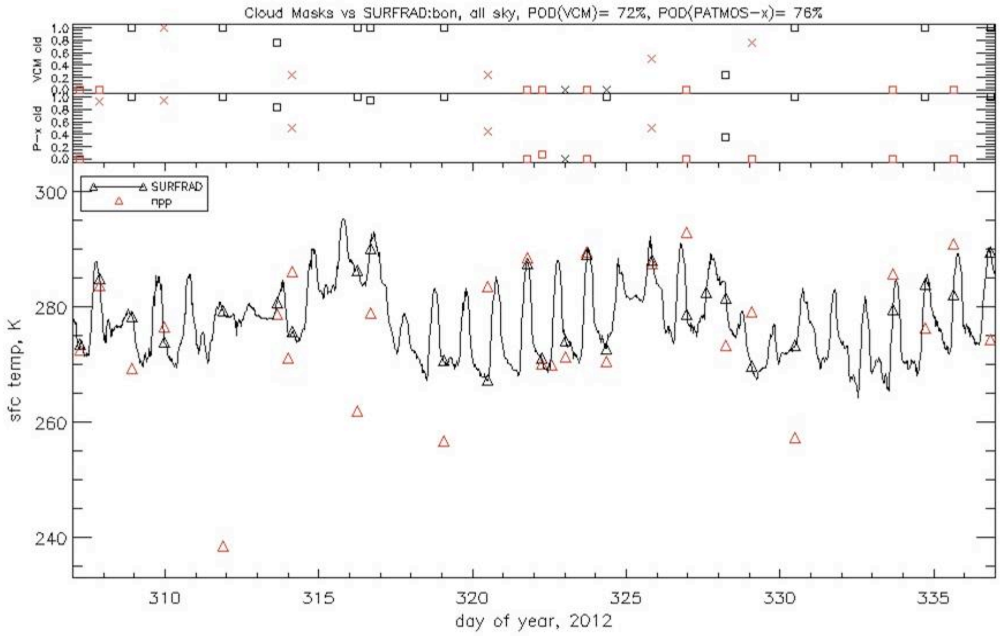


Figure 69. VIIRS Cloud Mask (VCM) and PATMOS-x Cloud Mask (PCM) evaluation for November 2 through Dec 1, 2012 at one SURFRAD site: Bondville, IL. The top axis shows the accuracy of the VIIRS cloud mask. Red squares indicate that the VCM and the difference between skin temperatures agree that the sky is clear. Black squares indicate that they agree that the sky is cloudy. Red X's indicate that the skin temperature says it is clear, but the cloud mask says it is cloudy. Black X's indicate that the skin temperature says it is cloudy, but the cloud mask says it is clear. The second cloud axis shows the accuracy of the PATMOS-x cloud mask. The symbology is the same as the top axis. The bottom axis compares the SURFRAD site surface temperature (black line with a black triangle at each satellite image time) with the surface temperature derived from NPP's VIIRS instrument (red triangle) by way of PATMOS-x. The PODs in the title are each cloud mask's probability of correct detection of clear/cloudy sky condition (compared to the skin temperature difference) for all satellite observations in the plot.

Table 3. Evaluation of VCM and PCM during Nov 2 through Dec 1, 2012 for seven SURFRAD sites for all surface conditions and those conditions without snow cover.

Location	VCM POD % (with snow)	VCM POD % (without snow)	PCM POD % (with snow)	PCM POD % (without snow)	N with snow	N without snow
BON	72	70	76	75	25	24
DRA	77	77	77	77	22	22
FPK	75	66	79	100	24	3
GWN	88	88	82	82	17	17
PSU	81	81	87	81	15	11
SXF	54	52	63	64	22	17
TBL	80	70	85	80	20	10

15.4 SSEC/CIMSS Cloud Research in Support of the SuomiNPP and JPSS Programs – Cloud Algorithm

CIMSS Project Lead: Andi Walther
CIMSS Support Scientists: Denis Botambekov, Mike Foster
NOAA Collaborator: Andrew Heidinger, NOAA/STAR
NOAA Strategic Goals Addressed:

- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) was designed to provide risk reduction and smooth transition to the future operational Joint Polar Satellite System (JPSS). NPP was successfully launched on October 28, 2011, and placed into a 1330 sun-synchronous orbit at 834 km altitude. The sensor of interest to this research is the Visible/Infrared Imager/Radiometer Suite (VIIRS), representing the successor optical-spectrum radiometer to the Advanced Very High Resolution Radiometers (AVHRR). This project supported the Suomi NPP and JPSS program team with the evaluation of the VIIRS cloud optical properties (COP) algorithm and it's possible improvements.

Summary of Accomplishments and Findings

The output of COP algorithm consists on Cloud Optical Thickness (COT) and Effective Particle Size (EPS) and corresponding quality products. Firstly, we focused on the analysis of the quality flags of COP. It was found that several quality flag definitions were in accurate and confusing.

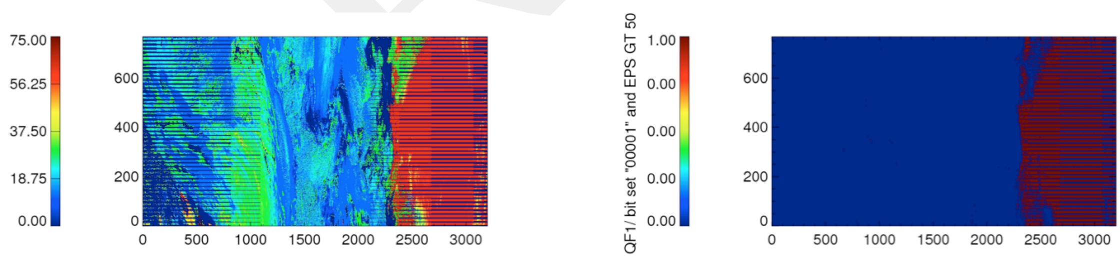


Figure 70. Example of a QF issue in Suomi NPP COP QF product. Left image shows EPS scene from 4 March 2012. The left side shows the corresponding 5th bit of COP quality flag.

Figure 70 shows an example of a detected quality flag error. There are EPS values bigger than 50 if all QF1/B3-4 are set to "0". This issue was corrected in the next operational retrieval update in September 2012.

Analysis of COT and EPS output provided statistics with very low success rate in comparison to other group's algorithms. As an example, the successful retrieval ratio lies only at 58% out of all cloudy pixels, which is much lower than more than 96% success rate of the AWG algorithm. Our analysis helped the JPSS team to improve their output in a second release, although their algorithm still suffers from many issues.

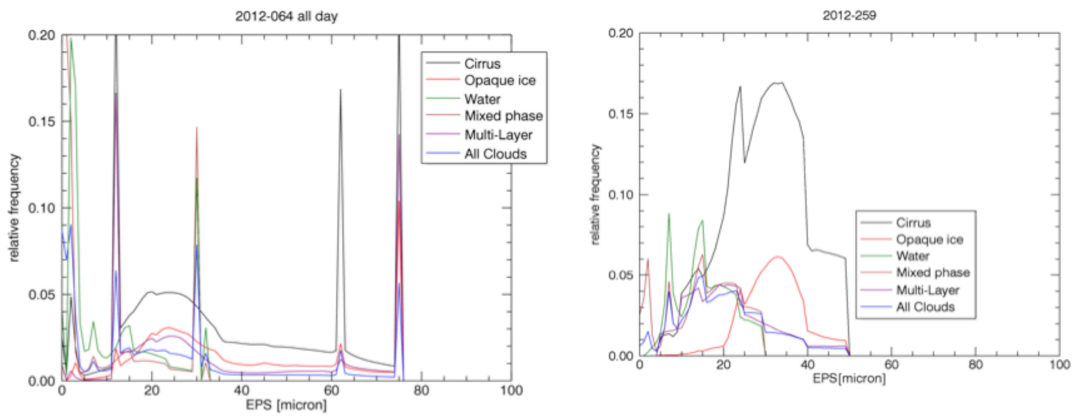


Figure 71. Histogram of EPS from first release (left) and second release (right)

Figure 71 shows the strong peaks in the histogram of EPS as a function of cloud type. The second release avoids the preference to one value for every cloud type, but still shows artificial and unrealistic distribution of EPS.

A detailed report (Heidinger et al, 2013) provides a detailed analysis of all cloud retrieval assessment efforts.

Publications, Reports, Presentations

Heidinger, A., R. Holz, A. Walther, D. Botambekov, S. Miller, C. Seaman, Y. Noh and Q.Zhang,2013: JPSS Cloud Algorithm Assessment Report, Prepared by the JPSS Cloud Cal/Val Team for the JPSS project, October 2012

15.5 VIIRS Cloud Type Algorithm and Delivery to NESDIS Operations

CIMSS Project Lead: Corey Calvert
CIMSS Support Scientist: Justin Sieglaff
NOAA Collaborator: Michael Pavolonis (NOAA/NESDIS/STAR)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

Clouds play a critical role in Earth's climate system so cloud detection is very important. Polar-orbiting satellites orbit the Earth several times per day and are able to view the entire earth, making them ideal platforms for determining global cloud coverage. Along with accurately detecting where clouds are located it is also important to accurately differentiate between different types of clouds. A cloud type algorithm was developed for the Visible Infrared Imaging Radiometer Suite (VIIRS) on board the Suomi-NPP polar-orbiting satellite. The algorithm separates clouds into the following five categories: warm liquid water, mixed phase, opaque ice (deep convection), non-opaque ice (cirrus) and cloud overlap (multiple cloud layers). Because the algorithm was developed before VIIRS was launched, certain thresholds and threshold functions were based on the modeling of single-layer water and ice clouds. Starting in 2012, we proposed to evaluate the VIIRS cloud type algorithm, which is built into the VIIRS cloud mask, and make any necessary modifications to improve the overall performance. This project will ensure that the cloud type algorithm performs accurately throughout the lifetime of the VIIRS instrument and will be ready for delivery to NESDIS operations.

Summary of Accomplishments and Findings

The initial evaluation of the VIIRS cloud type algorithm involved validating the ability to differentiate between water and ice phases. Cloud pixels identified by the algorithm as liquid water or mixed phase were classified as water phase and pixels identified as opaque ice, non-opaque ice or overlap were classified as ice phase. The VIIRS cloud phase product was evaluated globally using collocated 5 km resolution Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) matchup files from May 10, 2012. The space-borne lidar is highly accurate when determining the phase of clouds and can therefore be relied upon to accurately validate the VIIRS cloud type algorithm. Validation was performed when both CALIOP and VIIRS detected either a water or ice cloud. Any collocated pixel determined to be clear sky by either sensor was not used in the validation process.

Initial validation results indicate the VIIRS cloud phase product determined the same phase as CALIOP for about 80% of the pixels validated. After further investigation it was found that a large majority of VIIRS pixels that did not match the CALIOP cloud phase distinction occurred because the VIIRS cloud type algorithm returned a water phase category when the CALIOP algorithm returned ice phase. Looking at a sample granule it appeared that several glaciated convective clouds were being misclassified as mixed phase (generally classified as water phase for this validation) instead of ice phase. The top panel in the figure below shows a VIIRS false color image where bare land appears green, ice clouds look bright pink and water clouds are yellowish in color. Focusing around southwest Texas/northern Mexico there are several convective clouds that appear bright pink on the false color image. These are opaque ice clouds at the top of growing thunderstorms. However, the bottom left panel of the figure below shows the VIIRS cloud type algorithm erroneously classified these clouds as mixed phase (green) instead of opaque ice (yellow).

Among others, the VIIRS cloud type algorithm uses a test based on the relationship between the 11μm brightness temperature and the 8.5μm – 11μm brightness temperature difference (BTD) to differentiate between ice and water clouds. This test, called the infrared cloud phase discrimination test, was determined to be the source of the majority of misclassified VIIRS pixels. When this test is applied, a threshold function is used to differentiate water clouds from ice clouds. However, the original threshold function was not calculated using VIIRS data because the instrument was not launched until after the algorithm was developed. Instead, the threshold function was initially chosen based on the modeling of single-layer water and ice clouds (Pavolonis et al., 2005). Now that VIIRS data is available, a new threshold function was calculated to improve the performance of the infrared cloud phase discrimination test, and therefore, the overall performance of the VIIRS cloud type algorithm. The bottom right panel in the figure below shows the VIIRS cloud type algorithm applied using the newly calculated threshold function. Note that the convective cloud tops in southwest Texas/northern Mexico are now correctly identified as opaque ice clouds instead of mixed phase. Early validation results are encouraging, but further evaluation and modifications are likely necessary to ensure the VIIRS cloud type algorithm performs dependably at a high level.

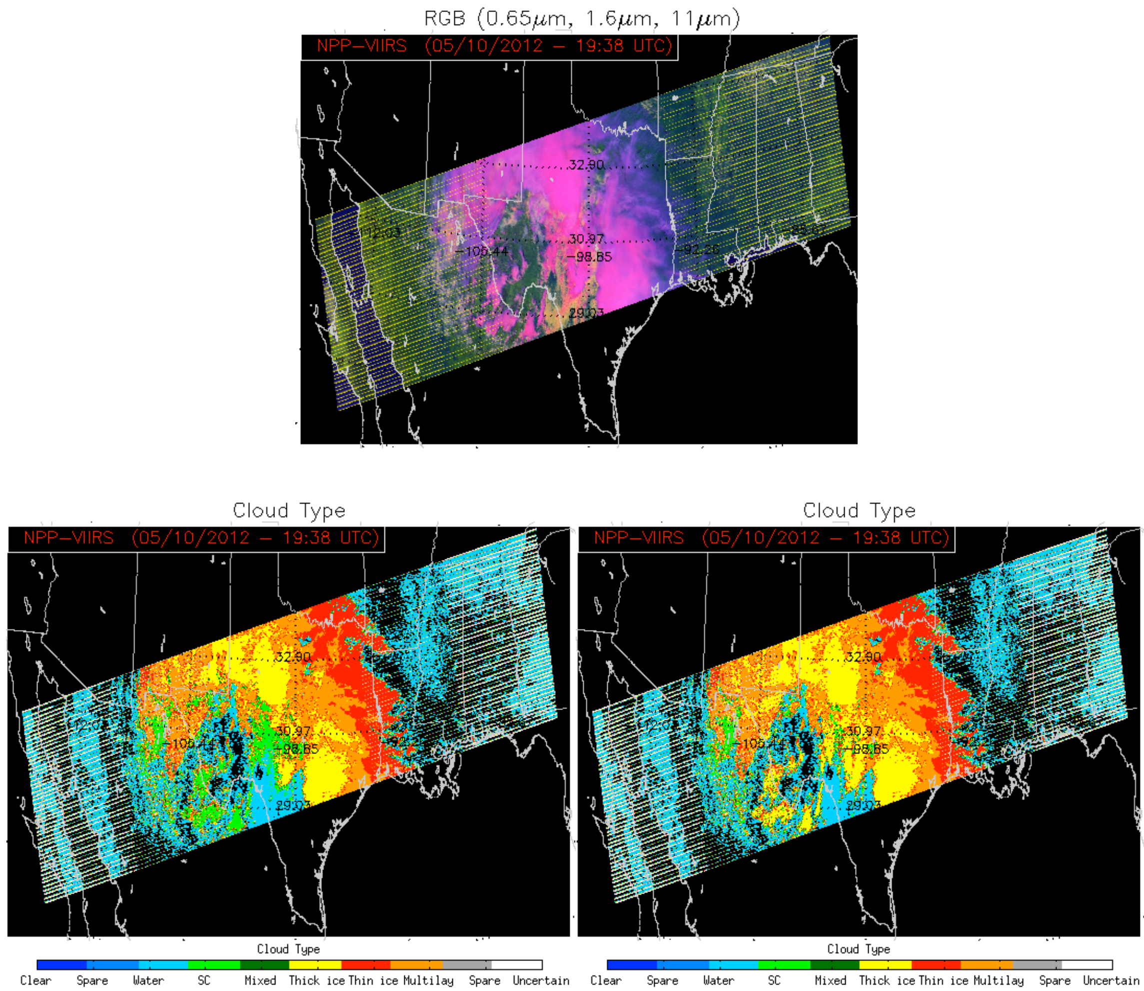


Figure 72. A daytime VIIRS scene over Texas on May 10, 2012 at 1938Z. The top panel is a false color image where ice clouds appear pink and water clouds appear yellowish. The bottom left panel is the VIIRS cloud type product with the original infrared cloud phase discrimination threshold function. The bottom right panel is the VIIRS cloud type product with the updated threshold function.

References

Pavolonis, Michael J., Andrew K. Heidinger, Taneil Uttal, 2005: Daytime Global Cloud Typing from AVHRR and VIIRS: Algorithm Description, Validation, and Comparisons. *J. Appl. Meteor.*, **44**, 804–826.

15.6 VIIRS Cloud Team Computing Equipment Support

CIMSS Project Lead: Michael J. Foster
NOAA Collaborator: Andrew Heidinger
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications

- Satellite Sensors and Techniques

Project Overview

The goal of this project is to provide computing support for the Cal/Val and analysis tasks of the VIIRS Cloud Team. The processing- and storage- intensive nature of these tasks caused us to seek a distributed processing solution. We intend to leverage the current computing resources at the University of Wisconsin to maximize processing and storage for each dollar spent. This is the first year of this project.

Summary of Accomplishments and Findings

The University of Wisconsin – Madison Space Science and Engineering Center (SSEC) offers computing resources with which to process the proposed Cal/Val. Those resources include a server cluster with a multi-node storage array. To support the computing needs of the VIIRS cloud team and to leverage available resources two Dell PowerEdge R720 Servers were purchased as part of the infrastructure of a larger Science computing cluster (described below).

182 TB lustre storage system
437 TB lustre storage system
240 amd cores (2.7 GB ram/core)
64 intel cores (4 GB ram/core)

Infiniband network
Two core FDR10 (40 Gbit/sec) 36 port switches
Three SDR (8 Gbit/sec) and two DDR (16 Gbit/sec) edge switches
Mix of SDR, DDR, QDR, and FDR10 network cards for all of the servers

Additional services provided by the SSEC Technical Computing division include:

- Nightly backups of servers;
- Mirrored and backed up versioning systems, including CVS and SVN, for storing programs, source code, etc.;
- Archiving to tape for larger data sets;
- Assistance compiling, linking scientific software; and
- Support scheduling cluster processing including scripts, technical support, and analysis for your scripts / cluster programs.

The servers were successfully integrated into the cluster processing nodes, and several scripts were written to facilitate distributed processing of VIIRS data on the cluster. The generation of cloud products has successfully been processed on the ZARA cluster for month-long periods of VIIRS measurements. These products have been integral parts of the VIIRS Cloud Team Cal/Val efforts. Figure 73 shows an example of one the products generated on the cluster from VIIRS.

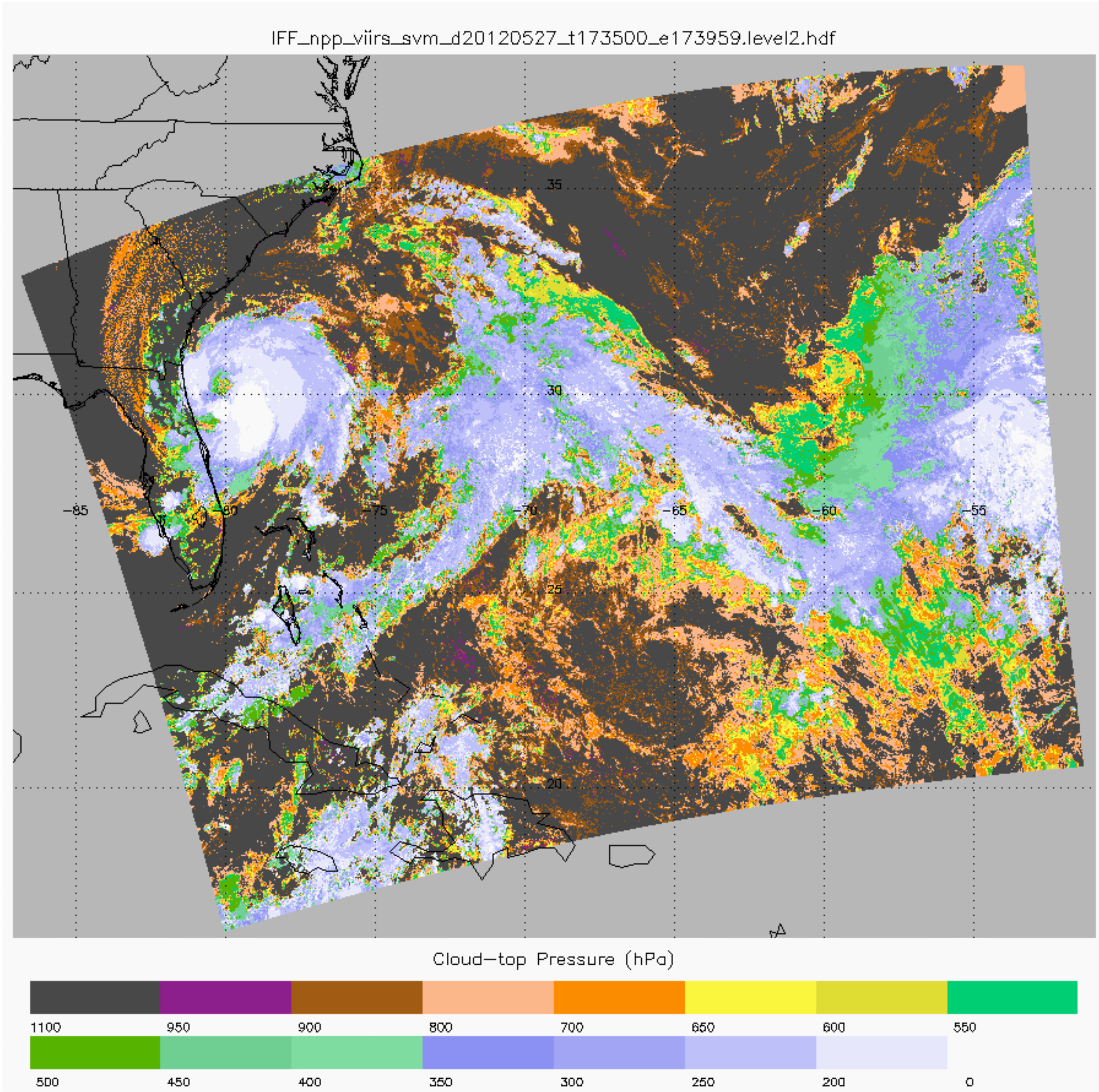


Figure 73. Image of AWG Cloud Height Algorithm (ACHA) cloud-top pressure product processed on the ZARA cluster from VIIRS measurements.

15.7 NPP-VIIRS Cloud Property EDR Validation Activities

CIMSS Project Lead: Bryan A. Baum
NOAA Collaborator: Andrew Heidinger, NOAA/NESDIS/STAR
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

The goal is to provide an assessment of the VIIRS cloud top property EDRs from the first year of operation, with an initial emphasis on finding artifacts and determining the behavior of the cloud top pressure data obtained from the relatively immature set of algorithms adopted in the JPSS framework.

Summary of Accomplishments and Findings

To summarize the analysis we performed to evaluate the VIIRS EDR (aggregated on a 5-km spatial scale) cloud-top pressures (CTP): *the VIIRS EDRs contain (a) serious artifacts and (b) suffer from implementation issues*. Furthermore the CTP product can only be interpreted correctly through use of the appropriate overall quality flag, something that most users do not take the time to understand adequately. More details on these issues are in the Heidinger et al. (2013) cloud EDR cal/val evaluation report (reference below).

There are no global monthly gridded products provided for VIIRS. To provide a consistent way to filter the cloud products similarly for different sensors, we developed a new approach for our gridded CTP assessment activities. The goal is to develop a method with which any geo-referenced parameter, at any level of processing (L1B/L2), can be projected from its non-uniform instrument domain to a uniform space-time domain. As such, the gridded output is tailored to specific research needs but is created for a user-defined (not product-defined) length of time, from any suite of instruments relevant to the study. Our approach is called the space-time gridding (STG) method and is documented in Smith et al. (2013; reference below). The STG approach results in a daily gridded product at a user-selected spatial resolution (i.e., the space element). A longer–term product is developed in a subsequent step from the daily maps (i.e., the time element).

To make sense of the VIIRS cloud property EDRs, it was necessary to filter the parameters by using the CTP quality flag called "Overall Quality." The investigation into the quality flags was needlessly complicated by the difficulty in finding the appropriate documentation. The document, 474-00083_OAD-VIIRS-CTP-EDR-SW_RevA_20120127.pdf, is what a general user would expect to provide information relevant to the EDR, but in fact there is no description of EDR quality flags. The EDR quality flag is defined only in 474-0001-04-02_Rev-Baseline.pdf. In fact, one has to get to page 309 of 329 total pages (although when you pull it up, it's on page number 288 according to the internal numbering) to actually find the overall quality flag. This is going to be problematic for most users, and in fact, it took us considerable time to track this down. The documentation for the EDR indicates that the overall quality flag is available only for the "Average Cloud Top Pressure" variable, so this parameter is what is analyzed for global data recorded on May 1, 2012. The overall quality flag provides four quartiles. If the EDR CTP product is filtered using this quality flag and results are kept for which at least 50% of the retrievals are valid, we arrive at the results shown in Figure 74 for May 1, 2012. In the daytime (upper panel) results, note that there are systematic gaps, primarily in the Northern Hemisphere. These gaps might be expected over ocean since these gaps are caused by the potential presence of sun glint. However, it seems that the angular calculation for sun glint potential is also being applied over land, with a subsequent downgrading of the overall quality assessment. The sunglint issue over land has now been resolved.

As another way of assessing the VIIRS cloud-top pressure (CTP) EDR, we performed a comparison with MODIS CTP products derived using the upcoming Collection 6 software. For the high cloud comparisons of global cloud top pressure shown in Figure 75, the results for the month of September 2012 are aggregated and presented on a 1˚x1˚ grid. The data are filtered as follows: (a) CTP $\leq$ 440 hPa and (b) the viewing zenith angle $\leq 32^\circ$. As such, the results are for high-level clouds only. To be clear, our evaluation is based on the MODIS Collection – 6 5 – km CTP results provided by the Atmosphere PEATE and the VIIRS EDRs at 5 – km resolution. The (MODIS-VIIRS) CTH difference plot indicates that in general, daytime MODIS cloud top pressures are about 50 - 100 hPa lower (clouds are higher) than those from VIIRS, with even larger differences in the nighttime comparison. Note that VIIRS has different algorithms for nighttime and daytime ice cloud retrievals. At the level of ice clouds in the troposphere, a rule of thumb is that 1 km $\sim$ 50 hPa. Thus there is a bias of 1–3 km in high-level cloud heights between MODIS and VIIRS, with VIIRS CTH generally lower than MODIS. This is not always the case, however. For example, in the daytime comparison over the Himalayas and the Tibetan Plateau, the opposite is true – MODIS CTP values are higher than VIIRS (i.e., clouds are lower). This raises a red flag because cloud retrievals are tricky over high elevation terrain, and the VIIRS EDR algorithms have not been through a rigorous evaluation.

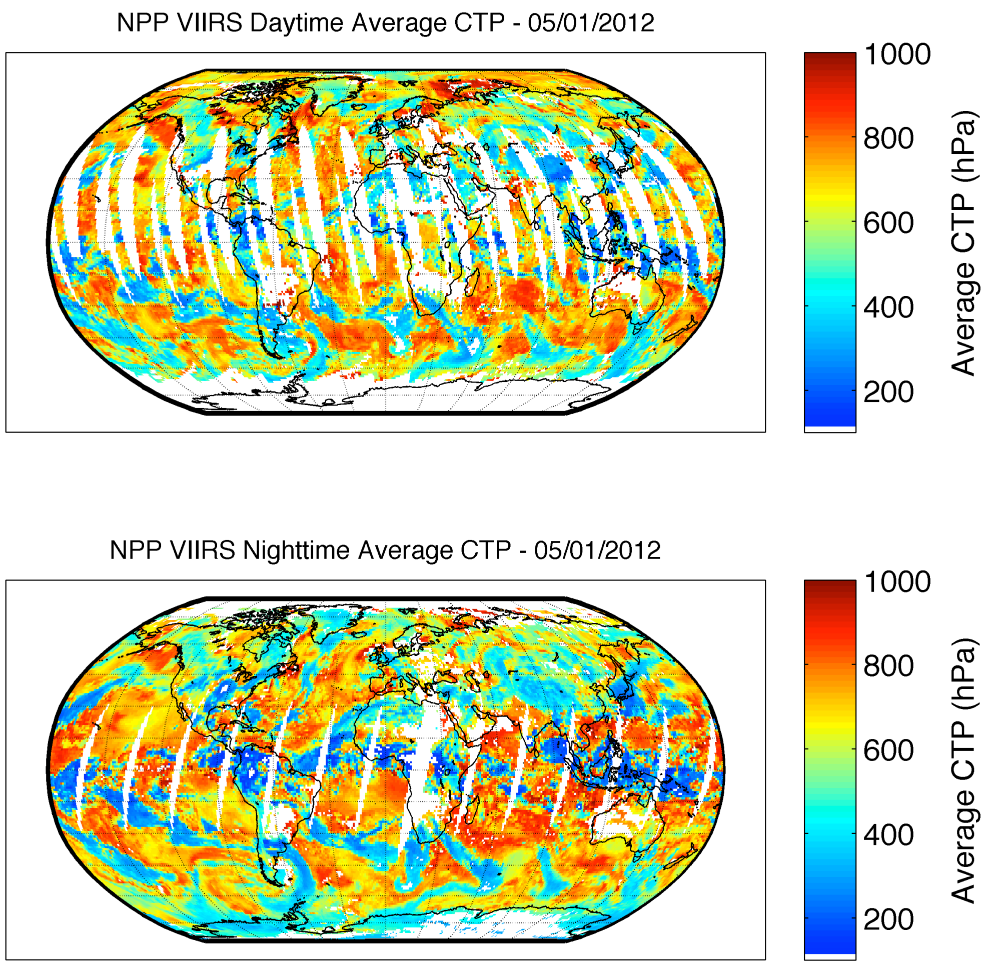


Figure 74. After filtering by the "overall quality" flag, the daytime (top panel) and nighttime (lower panel) cloud top pressure (in hPa) is shown on a 1° equal-angle grid for the VIIRS EDR product from May 1, 2012. Artifacts in the data product are removed by using the overall quality flag, but a user may not know to apply this when analyzing the product. Also note that in the Northern Hemisphere, the sun glint regions over ocean receive further reduction in quality, and it appears that the reduction in quality for potential sun glint is applied over land, too. This was noted and fixed in the VIIRS cloud product stream.

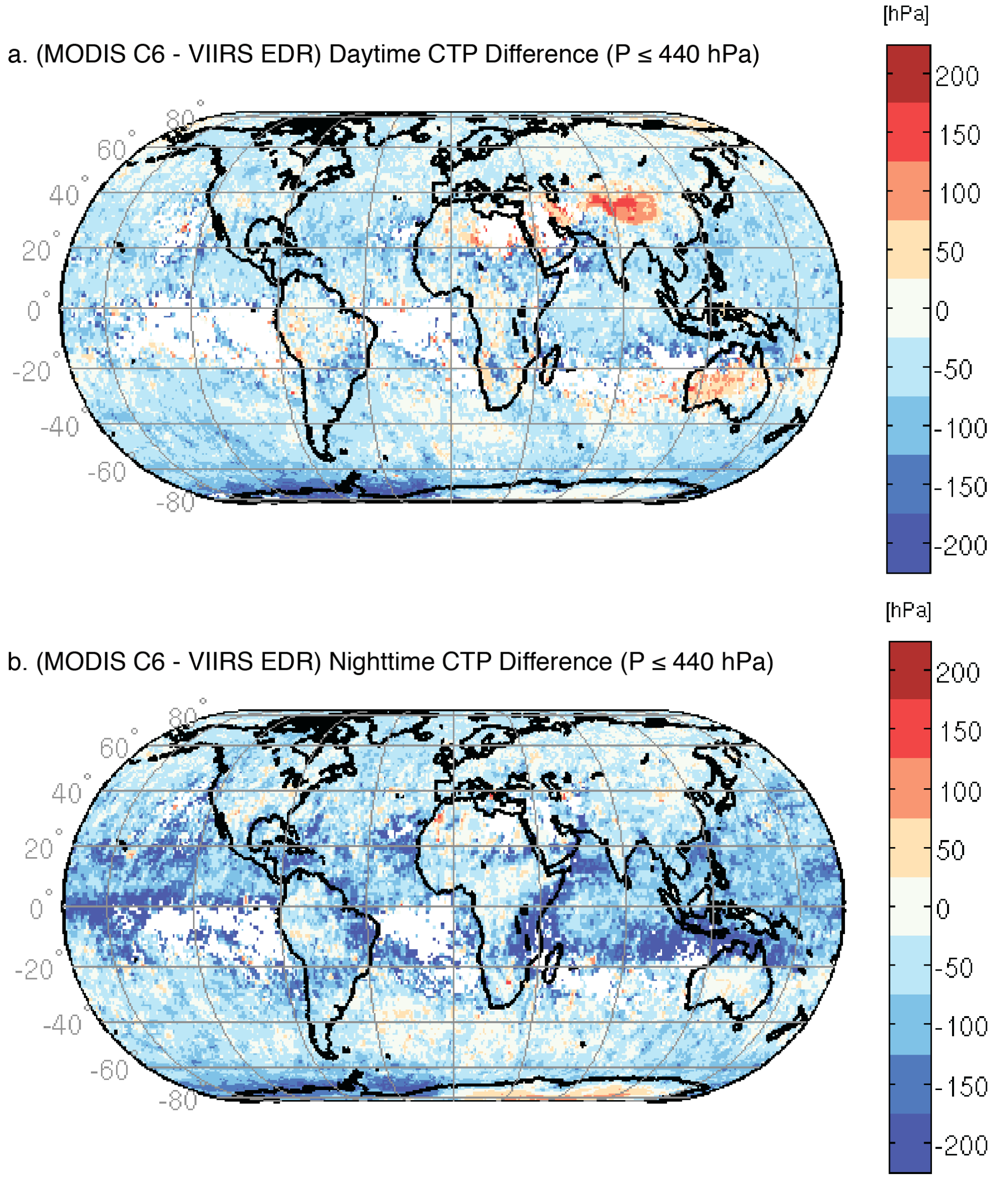


Figure 75. Results for high-altitude cloud top pressures (CTP ≤ 440 hPa) differences between MYD06 Collection – 6 5 km CTP and VIIRS 5 km EDR CTP for the full month of September 2012. Cloud top pressure (in hPa) is presented on a 1° equal-angle grid for the (MODIS–VIIRS) differences for (a) daytime and (b) nighttime.

Publications, Reports, Presentations

Heidinger, A., R. Holz, B. A. Baum, A. Walther, D. Botambekov, S. Miller, C. Seaman, Y-J. Noh, and Q. Zhang, 2013: JPSS Cloud Algorithm Assessment Report, prepared by the JPSS Cloud Cal/Val team for the JPSS project.

Smith, N., W. P. Menzel, E. Weisz, A. Heidinger, and B. A. Baum, 2013: A uniform space-time grid for comparison of global satellite cloud products: Characterization and sensitivity studies. *J. Appl. Meteor. Clim.*, **52**, 255-268.

15.8 CrIS/VIIRS Cloud Height Comparison

CIMSS Project Lead: Eva Borbas
CIMSS Support Scientists: Nadia Smith, Paul Menzel
NOAA Collaborator: Andrew Heidinger
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

To supplement VIIRS cloud heights, the NPP CrIS hyperspectral IR sensor is being used to generate accurate cloud heights for cirrus clouds at a lower spatial resolution. CIMSS has developed a regression approach (called the Dual-Regression method, Smith et al., 2011) to estimate cloud heights from CrIS that we will implement to validate the VIIRS cloud height performance in the presence of optically thin cloud. This data set is important because it also serves as a backup to CALIPSO, should CALIPSO fail.

Proposed work includes:(1) adapting the 4-layer Lapse Rate (4LR) algorithm for use of combined CrIS and VIIRS data in night-time cloud situations, package VIIRS+CrIS algorithm for transfer; prepare s/w for routine use. (2) performing and documenting regional and global tests of CTP with CrIS only (Smith et al., 2011), CrIS plus VIIRS using 4LR and the 3-band Merging Gradient (3MG) (Weisz et al., 2011) algorithms, and CALIOP and MOD06 as reference.

Summary of Accomplishments and Findings

VIIRS does not have any spectral bands located in H2O or CO2 absorption bands, which degrades its ability to determine semi-transparent cloud properties (including cloud top pressures/heights) compared to that of sensors including even a single absorption channel (Heidinger et al., 2010). In an effort to ensure continuity and consistency between historical cloud products and those provided from the SNPP sensors (and JPSS in the future), we are working to demonstrate a VIIRS plus CrIS cloud algorithm that can extend the AVHRR/HIRS and MODIS/AIRS cloud record.

Several techniques are being tested using a single granule of VIIRS and CrIS data from August 2012 over Korea for these initial studies. Figure 76 shows the VIIRS CTP as retrieved on the IDPS with the operational algorithm along with the results from the research algorithm using an optimal estimation approach; significant differences are seen in the high thin clouds, especially in some areas where operational VIIRS assigns high clouds to low altitudes. CrIS Dual Regression (DR) retrievals confirm the locations to be high clouds. The 4 layer lapse rate (4LR) results are also shown on the figure.

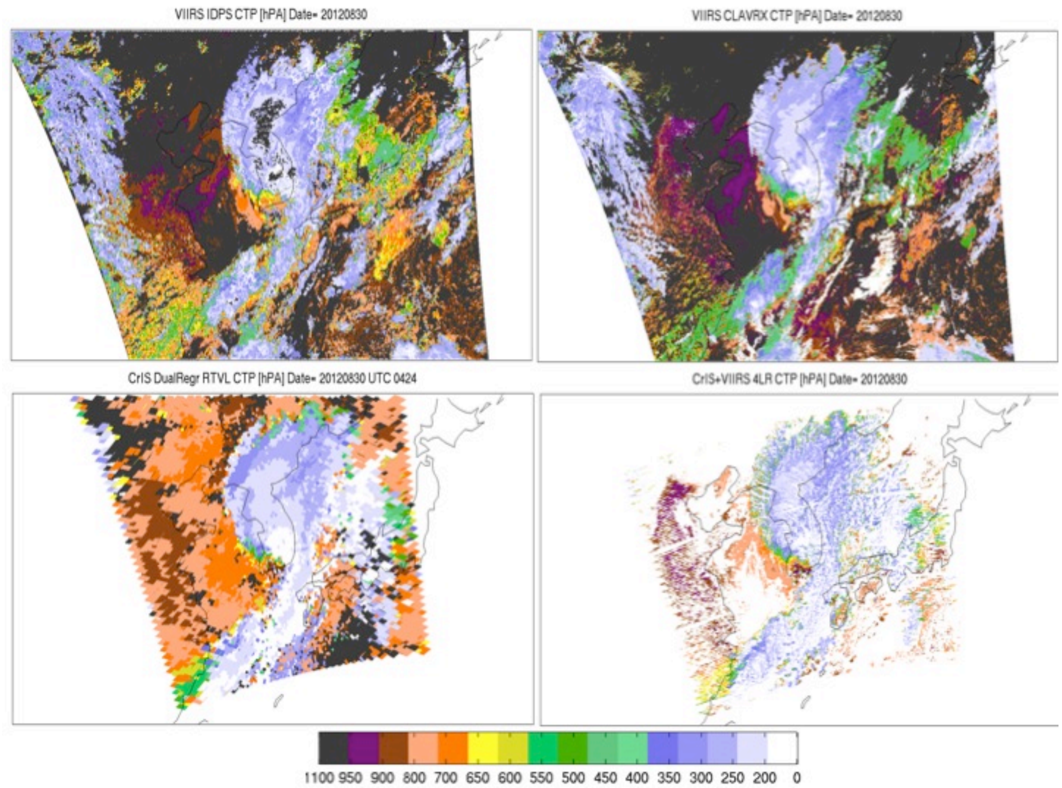


Figure 76. Cloud Top Pressure (hPa) comparison for August 30, 2012 UTC 0424 granule: (top left) the official NOAA VIIRS-only CTP EDR from the IDPS, (top right) the CLAVRX VIIRS-only CTP product, (bottom left) the UW Dual Regression CrIS-only CTP retrieval, and (bottom right) the 4-layer Lapse Rate (4LR) combined VIIRS and CrIS CTP retrieval.

A pseudo VIIRS channel at 13.3 microns statistically constructed from CrIS and VIIRS measurements is also being studied. The CrIS sensor high spectral resolution measurements in the 15 micron CO2 absorption bands are especially important for cloud property retrieval. Using the infrared spectral bands on VIIRS at 780 meter resolution and a convolution of the 15 micron spectral measurements on CrIS at 15 km resolution, statistical construction of a 13.3 micron channel at 780 meter resolution is accomplished via data fusion techniques (Cross et al., 2013). The VIIRS channels combined with the statistically constructed 13.3 micron channel are then used in a cloud top pressure algorithm that has been developed for the pending Advanced Baseline Imager to be launched in 2015 on GOES-R (Heidinger et al., 2011). Figure 77 shows cloud top pressures derived using VIIRS data with an optimal estimation approach that relies on the NCEP Global Data Assimilation System as a first guess. The difference of with and without the pseudo 13.3 micron data is shown on the right. In high thin cirrus west of North Korea, with the 13.3 micron data the optimal estimation gets the CTP at 250 hPa while without the 13.3 micron data it pins the clouds at the tropopause. In low clouds over the Pacific Ocean south of Japan, the 13.3 micron data helps the ABI algorithm left the clouds off the ocean surface, in better agreement with MODIS results (not shown).

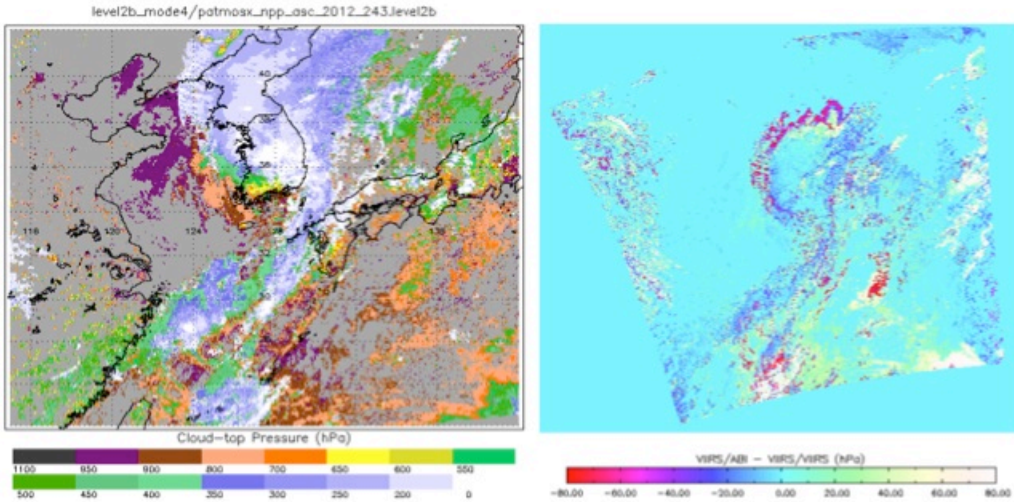


Figure 77. (left) 28 August 2012 cloud top pressures derived from VIIRS data without the 13.3 micron data using an optimal estimation approach that relies on the NCEP Global Data Assimilation System as a first guess. (right) Difference of CTPs with minus without 13.3 micron data.

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Smith, W.L., E. Weisz, S.V. Kireev, D.K. Zhou, Z. Li and E.E. Borbas, 2011: Dual- Regression Retrieval Algorithm For Real-time Processing of Satellite Ultraspectral Radiances, submitted to *JAMC*.

Weisz, E., W.P. Menzel, N. Smith, R. A. Frey, E.E. Borbas, and B. A. Baum, 2011: An Approach for Improving Cirrus Cloud Top Pressure/Height Estimation by Merging High-Spatial-Resolution Infrared-Window Imager Data with High-Spectral-Resolution Sounder Data, *J. Appl. Meteor. Climatol.*, **51**, 1477–1488. doi: http://dx.doi.org/10.1175/JAMC-D-11-0170.1

Heidinger, Andrew K, 2011: ABI Cloud Height Algorithm (ACHA) Algorithm Theoretical Basis Document (ATBD), GOES-R Program Office. (http://www.goes-r.gov/products/ATBDs/baseline/Cloud_CldHeight_v2.0_no_color.pdf)

Heidinger, A. K., M. J. Pavolonis, R. E. Holz, B. A. Baum, and S. Berthier, 2010: Using CALIPSO to explore the sensitivity to cirrus height in the infrared observations from NPOESS/VIIRS and GOES-R/ABI. *J. Geophys. Res.*, **115**.

Cross, J., I. Gladkova, M. Grossberg, and W. P. Menzel, 2013: Statistical Estimation of a 13.3 micron VIIRS Channel using Multisensor Data Fusion. Submitted to *Journal of Applied Remote Sensing*.

15.9 VIIRS Evaluation using Satellite Observations

CIMSS Project Lead: Robert Holz
CIMSS Support Scientists: Min Oo, Andi Walter
NOAA Collaborator: Andy Heidinger, NOAA
NOAA Strategic Goals Addressed:
- o Provide critical support for the NOAA missions

CIMSS Research Themes:
- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

This project supports the NPP-VIIRS cloud and aerosol evaluation as part of the Joint Polar Satellite System (JPPS). The VIIRS cloud algorithms where developed by Northrop Grumman Aerospace Systems (NGAS). Before launch, the performance of these algorithms (both aerosol and clouds) have not been well characterized due to a lack of pre-launch proxy data with only small (24 granule) proxy data set available for evaluation. The successful launch of Suomi NPP provides for the first time the ability to evaluate the NGAS algorithms using real observations. Using the extensive tools and processing capabilities developed as part our current support for JPSS, we provide satellite inter comparisons with VIIRS with a focus on NASA A-Train cloud products.

Summary of Accomplishments and Findings

We completed a significant milestone this year with the completion of the JPSS cloud assessment report which was delivered to the JPSS program in December of 2012. This project supported both the evaluation and report preparation. Our work has identified and corrected two issues during this first year. First, the team identified an error in the COP lookup table interpolation. Second, the team developed an improvement to the height assessment of low level clouds that will impact the accuracy performance. The second fix has not been implemented into the IDPS yet. The results for a 3 months of collocated CALIOP (lidar) and VIIRS cloud top heights are presented in Figure 78. Notice the significant over estimation of the cloud top height in regions of marine stratus. Our team has addressed this issue with more recent results having a significantly reduced bias.

Even with these improvements, the team has found major issues remain with the cloud products. Artifacts that remain in the products jeopardize their utility until solutions can be found and implemented. For these reasons, we do not feel these products are useable by NOAA customers at this time. The major issues that have been identified are:

- Low convergence rates for cloud retrievals. For example, roughly 60% of cloudy pixels have IP COP results classified as successful.
- Cloud top heights are severely underestimated in general for most transmissive high-level clouds (i.e., cirrus), especially in the Tropics, but can also exhibit a tendency for severe over-estimation at times when solutions appear to follow the Tropopause Level.
- The inference of cloud base height is challenging for a passive VIS/IR sensor such as VIIRS. The cloud base height product depends critically the performance of the CTH and cloud phase, among other things, as input. Comparisons with the active radar of CloudSat indicate that there is very limited accuracy obtained at this time. The product demonstrates less accuracy for thin cirrus than water cloud layers.
- For most of the first year, COP exhibited erroneous distributions of optical thickness and particle size due to problems associated with the look-up tables (LUTs). Earlier analyses led to an updated LUT being developed for IDPS.
- With the updated LUT that went into IDPS operations on 5 September, 2012, the COP does not return a valid result for about a third of the cloudy pixels, a much higher number than other operational algorithms.
- The accuracy specification is met for some of the COP parameters for some phases. The precision specification is generally not met.
- With the updated LUT that went into IDPS operations on 5 September, 2012, there are still indications of LUT-related issues. The COP comparisons relative to NOAA and NASA results indicate a large scan angle dependence that hints at continued flaws in the COP LUTs. Discontinuities in the distributions of the latest COP results also indicate remaining issues with the COP convergence method.

- The team has found difficulty in using the quality flags and has found them to be generally inadequate. The quality flags are designed for analysis to determine specification compliance. Their use by the community will be problematic. The team has made suggestions for additions to the COP quality flags to address these issues.
- Taken together, some issues such as QA flags could be resolved given sufficient resources. However, the COP and CTP/CTH/CTT algorithms suffer from a lack of operational maturity. The ADL may lack the necessary ancillary data sets required to help improve products over land surfaces.

We are currently working to address some of the issues with NGAS and continue provide recommendations to the JPSS project.

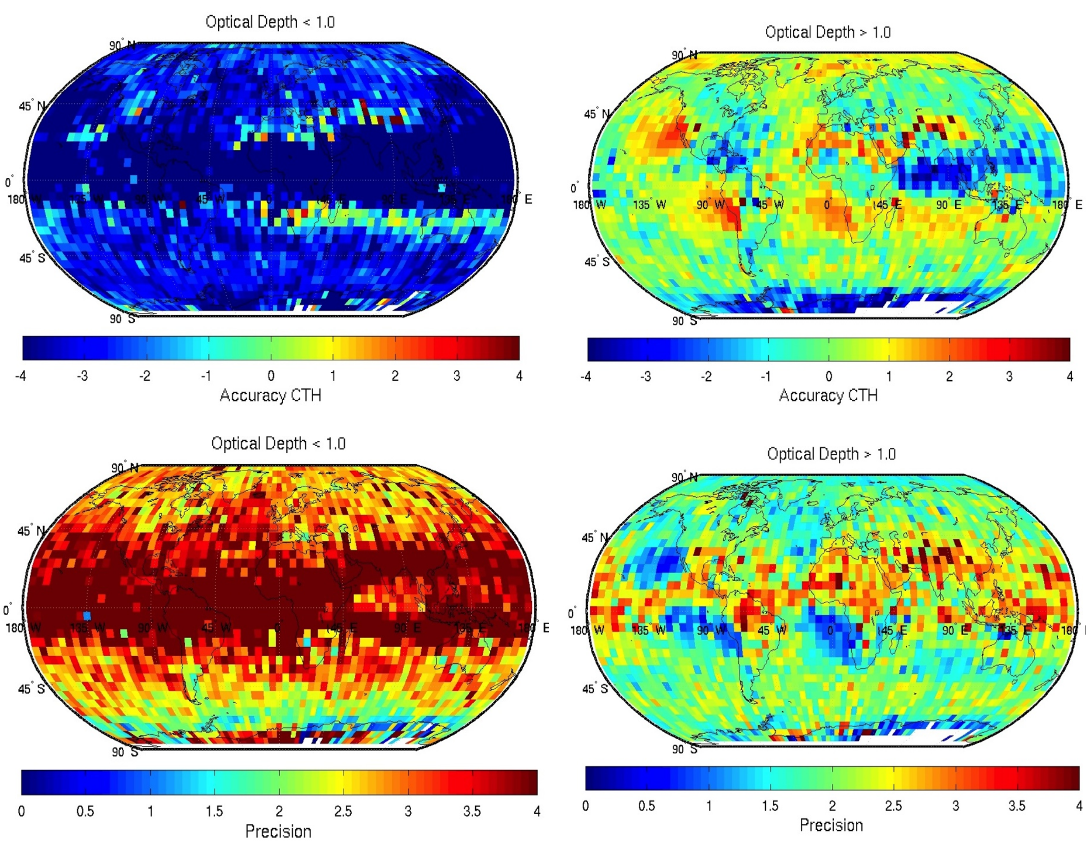

Figure 78. The global 5x5 deg gridded collocated differences between the lidar cloud top height (CALIOP) and the VIIRS IDPS cloud top. A negative difference occurs when VIIRS is lower then the lidar. The Accuracy (mean) is presented in the top images. The precision (STD) for ensemble of the fov within each grid box is presented in the bottom images.

15.10 VIIRS Cloud Product ADL Support

<u>CIMSS Project Lead</u>: Yue Li
<u>CIMSS Support Scientist</u>: Denis Botambekov
NOAA Collaborator: Andy Heidinger
<u>NOAA Strategic Goals Addressed</u>:

- Serve society's needs for weather and water information

- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

The Interface Data Processing Segment (IDPS) developed by Raytheon Intelligence and Information Systems currently processes satellite data received from the Joint Polar Satellite System (JPSS), the latest generation polar-orbiting environmental satellites. Calibration/validation of various retrieval algorithms and data produced from IDPS are vital for the success of the mission before official data release. Due to the difficulty of testing algorithm changes directly in IDPS, Algorithm Development Library (ADL) was developed to provide a platform for the scientific community to run and test IDPS algorithms. However, the sophisticated design of ADL framework and data preparation procedures, as well as demanding computing resources, make the installation and use of ADL to test algorithm changes very challenging. The major complications also include the lack of introductory level manuals and requirement of specific software environment. In collaboration with NOAA STAR AIT, we were finally able to conduct research with ADL by making significant efforts to set up and manipulate the ADL system.

The k ratio is a fundamental parameter in infrared cloud properties retrieval from satellite observations, which can be computed from emissivity profiles at two channels. In the current VIIRS ATBD, two infrared channels 8.5μm (M14) and 12μm (M16) are used in retrieving cloud top parameters, including cloud top temperature and optical properties. Cloud top height and pressure are subsequently derived by collocating with atmospheric profiles. Hence, the accuracy of cloud top property retrieval is heavily dependent on the k ratio relationship of these two IR bands. However, the relationship between the k ratio and effective particle size for ice crystals shows significant differences between that employed in VIIRS ATBD and from single scattering property computations. Moreover, in comparison to CALIPSO product, current nighttime VIIRS cloud top height indicates a negative bias, on average of 2km. There is a possibility that the negative bias is partially due to the incorrect k ratio relationship. Therefore, to explore the sensitivity of cloud top height to k ratio, ADL is set up to run test granules over nighttime on November 10, 2012. ADL is installed on a workstation held at SSEC, and then input, ancillary and auxiliary data are prepared for the selected day. Two sets of numerical experiments are carried out with ADL, using the original and updated k ratio relationships. The generated intermediate product (IP) from the original codes is denoted as baseline case, and output from ADL with modified k ratio is named as updated case.

The baseline output and difference between the two cases for a test VIIRS granule at 1551UTC is displayed in Figure 79. Generally, cloud top height increases in the updated case. The most significant increase occurs where the baseline cloud top is relatively low (less than 4km), probably suggesting overlapped clouds. This may be explained as in the baseline case, upper level ice clouds are not detected whereas they are detectable in the updated case. Scatter plots in Figure 80 demonstrate that after excluding overlapped clouds, the percentages of negative biases and significant positive biases are largely reduced, consistent with this speculation. Comparison with active lidar observations by CALISPO will be useful in verifying the results.

An examination of 24 nighttime granules between 1548UTC to 1622UTC on the same day shows an average increase of 1km in cloud top height in the updated case. Further validation is necessary with collocated in situ observation and satellite retrievals, such as CALIPSO, which shows superior capability in detecting upper level ice clouds and thin cirrus. Comparisons with retrievals from other existing algorithms are also options. This validation is in progress. Nevertheless, the current attempt to modify k ratio relationship and test run with ADL shows very promising results.

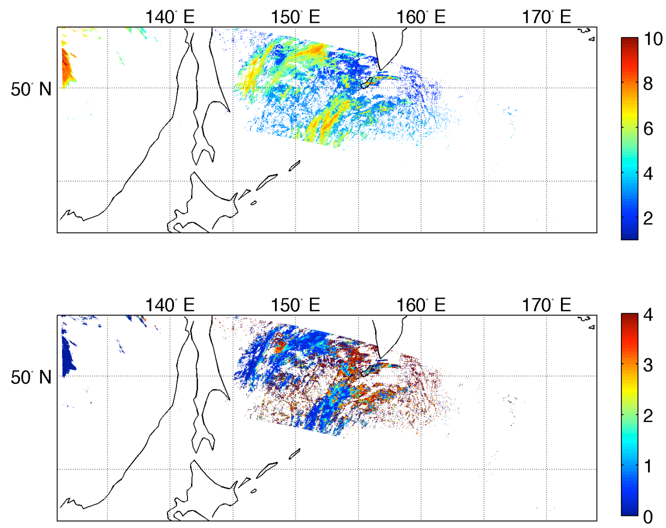

Figure 79. Cloud top height of a test granule at 1551 UTC on November 10, 2012 for the baseline case (upper) and difference between updated and baseline cases (bottom). Ice clouds, cirrus, and overlapped clouds are shown. Cloud mask, confidence and phase quality flags from VCM have been applied. Units are in km.

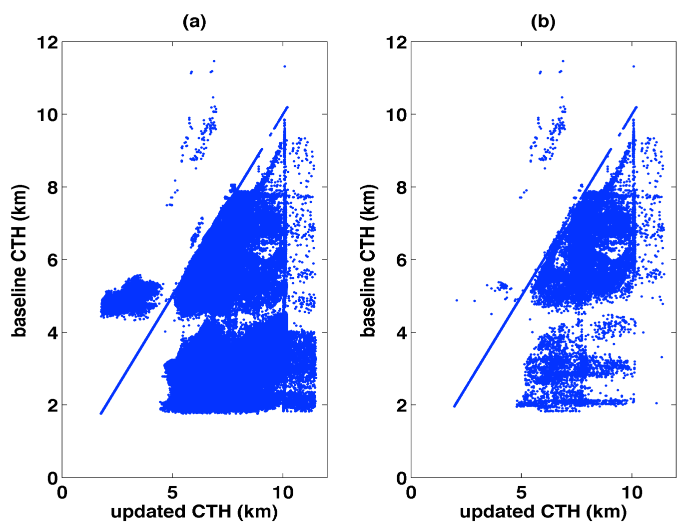

Figure 80. The same granule as in Fig. 1. Scatterplots of cloud top height between updated and baseline cases for (a) ice clouds, cirrus, and overlapped clouds, and (b) ice clouds and cirrus only. Units are in km.

15.11 McIDAS-V Support for SuomiNPP

CIMSS Project Leads: Tom Rink, Tommy Jasmin

NOAA Collaborators: Don Hilger (NESDIS/StAR Imagery Applications Team Lead), Michael Denning (NOAA Satellite Operations Facility, Suitland, MD)

NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond
- Protect, restore and manage the use of coastal and ocean resources through an ecosystem approach to management
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques
- Outreach and Education

Project Overview

The goal for this project is to leverage McIDAS-V's interactive display, user-defined computation via python and disparate data integration capabilities to visualize and interrogate SuomiNPP data products.

Summary of Accomplishments and Findings

Utilizing simulated data developed and distributed by a NOAA computing facility known as the Government Resource for Algorithm Verification, Independent Testing, and Evaluation (GRAVITE), CIMSS was able to add visualization and analysis capabilities to McIDAS-V for the Visible/ Infrared Imager Radiometer Suite (VIIRS), the Advanced Technology Microwave Sounder (ATMS), and the Cross-track Infrared Sounder (CrIS).

CIMSS was one of the first organizations worldwide to visualize and analyze both the simulated GRAVITE data, and the post-launch, live Suomi NPP data. McIDAS-V was employed to provide quality VIIRS imagery to the JPSS Imagery Team within the first two orbits of "first light" (Figure 81). CIMSS also provided critical pre-launch feedback to correct errors in the NPP data model, in the NPP product profiles, and in documentation. CIMSS played a vital role in a mutually beneficial feedback cycle among the various agencies supporting NPP pre-launch – a collaboration which has certainly been a key factor in this successful first JPSS mission.

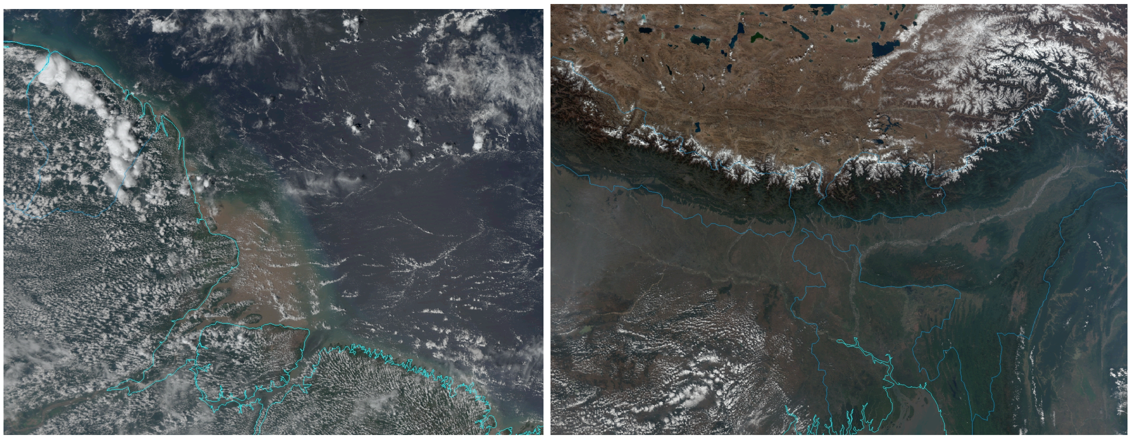

Figure 81. VIIRS imagery generated by McIDAS-V within 12 hours of "first light." Amazon River delta on the left, northern India on the right (Note Himalayan Mountains blocking dust and air pollution).

A new, stable version of McIDAS-V with support for Suomi NPP instrument SDRs: Visible/ Infrared Imager Radiometer Suite (VIIRS), the Advanced Technology Microwave Sounder (ATMS), and the Cross-track Infrared Sounder (CrIS), has been made available to the public. This release includes the external ancillary metadata files required for instrument calibration and quality control indication, and will be updated as necessary in future releases for changes in instrument characteristics. McIDAS-V can display, analyze and interrogate SDRs, available from the NOAA CLASS, UW-Madison PEATE, and IDPS from a simple set of user interface operations without any knowledge of the underlying storage formats. Users can graphically select an arbitrary subset spanning multiple contiguous files with the aggregation automatically done under-the-hood giving a single dataset view of the files. These capabilities are unique.

VIIRS RGB composites can be generated and a interactive python scripting tool provides use defined product creation (figure above). A re-gridding capability to handle visual artifacts displaying VIIRS, including bow-tie deletion, is also available as a plugin. Complete CrIS spectra can now be interrogated in the McIDAS-V Multi/Hyper-Spectral interface. See figures below.

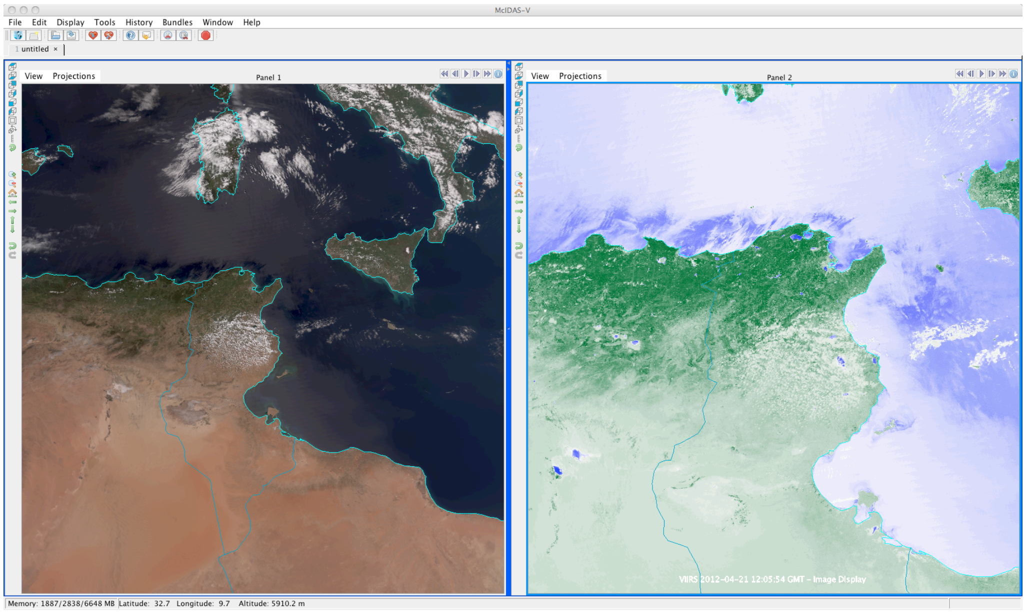

Figure 82. This image shows a simple formula and color enhancement applied to VIIRS granules to produce a Normalized Difference Vegetation Index (NDVI) on the right panel and M5,M4,M3 RGB on the left, over North Africa.

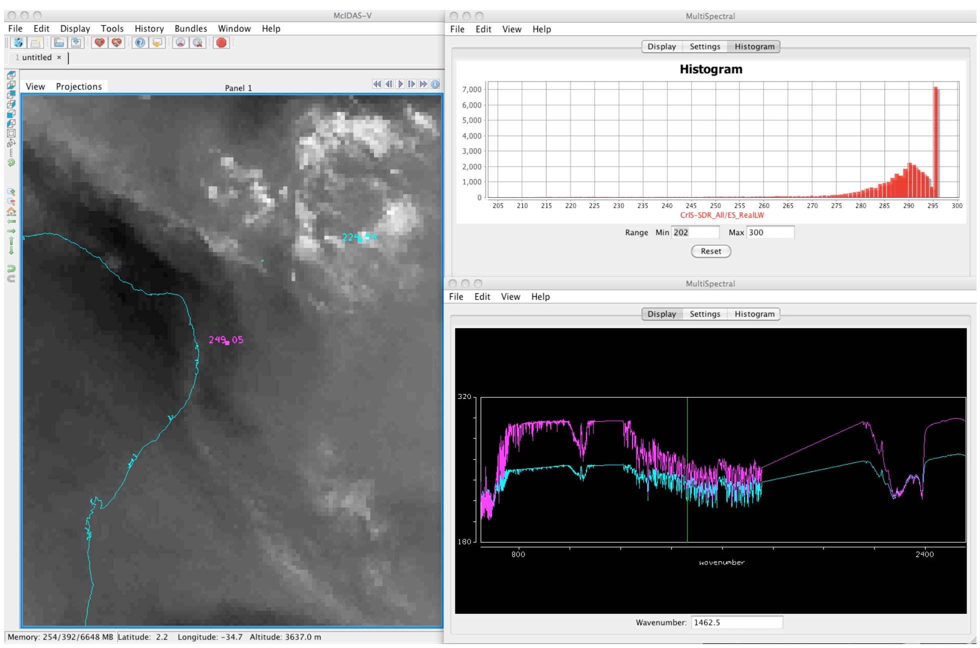

Figure 83. McIDAS-V provides a novel way to visualize and interrogate hyperspectral data. CrIS channels can be manipulated bi-directionally from both image and spectra display windows.

Progress has been made towards providing these various capabilities for the Imagery and higher level product EDRs.

The McIDAS-V bundle capability (saving state including data and operations) has been implemented for Suomi NPP data. This allows users to quickly restore a state of analysis, and to easily share it with colleagues via a single .mcvz file.

Publications, Reports, Presentations

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Straka III, William; Jasmin, T.; Rink, T.; Lindsey, D.; Hillger, D.; Miller, S., and Achtor, T.: McIDAS-V, Visualization and Data Analysis for Suomi National Polar-orbiting Partnership. 29th Conference on Environmental Information Processing Technologies, Austin, TX, 05-10 January 2013. American Meteorological Society, Boston, MA, 2012.

16 SSEC/CIMSS Research Tasks in Support of the SuomiNPP and JPSS Programs

The tasks included in section 16 address the goals and themes listed below.

NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications
- Outreach and Education

16.1 A Broad Scope of Calibration/Validation and Independent Verification and Validation Activities in Support of JPSS, with Emphasis on CrIS SDRs

CIMSS Project Leads: David Tobin and Henry Revercomb
CIMSS Support Scientists: Robert Knuteson, Joseph Taylor, Lori Borg, Dan DeSlover, Graeme Martin
NOAA Collaborator: Dr. Yong Han, NOAA/STAR

Project Overview

This is a project that began with support of the IPO office in the NPOESS program about 10 years ago. With the transition from NPOESS to the JPSS program this project became part of the JPSS SDR Cal/Val activities with STAR team leader Dr. Yong Han. Both pre-launch thermal vacuum and post-launch on-orbit data has been analyzed extensively to provide both the optimal calibration parameters and innovative techniques for the validation of the CrIS radiance channels. Our efforts are focused on the CrIS sensor design, calibration algorithms, and characterization of the resulting SDRs for weather and climate applications.

Summary of Accomplishments and Findings

The major focus of our recent efforts has been to perform our various post-launch Suomi-NPP CrIS SDR cal/val tasks. Example accomplishments from the previous reporting periods include in part:

1) Use of the UW/UMBC CCAST calibration software to demonstrate early performance,
2) Identification of a scan direction bias that was resolved by updating the FIR filter,
3) Evaluation of non-linearity correction parameters to minimized FOV-to-FOV radiometric differences,
4) Assessment and monitoring of FOV-to-FOV spectral calibration,
5) Inter-calibration of CrIS with Aqua AIRS and METOP-A IASI,
6) Inter-calibration of CrIS and VIIRS,
7) Analysis of spectral ringing artifacts and identification of the on-board numerical filter as the source of the majority of the ringing,
8) Establishment of a radiometric calibration uncertainty chain regarding nonlinearity corrections,
9) Estimates of the CrIS on-orbit radiometric uncertainty, and
10) Re-processing of the CrIS SDR mission data using refined calibration parameters.

The current status of the CrIS SDR radiometric assessment is captured partially in Figure 84 and Figure 85. Evaluation efforts to date show that the spectral and radiometric performance of CrIS is very good, yet with some remaining issues requiring further investigation. Figure 84 compares CrIS to AIRS and IASI-A sensors for simultaneous nadir overpasses. Agreement at the 0.2 K level is seen across most wavenumbers. Various issues due to CrIS, as well as AIRS and IASI, at lower levels are also evident in these comparisons and are the topics of various on-going investigations by the various sensor teams. Figure 85 shows the expected Radiometric Uncertainty (RU) of Suomi-NPP CrIS, which is better than 0.2K 3-sigma for a typical Earth view spectrum for all wavenumbers, with major uncertainty contributions from the ICT predicted radiance knowledge and radiometric nonlinearity. Spectral calibration contributions, including inter-FOV spectral calibration, are negligible to the RU. Not included in the RU estimate are component uncertainties due to two unresolved calibration artifacts including a spectral ringing (Gibbs effect) artifact that is largest at the spectral band edges, and small artifacts seen for cold scene temperatures in the shortwave band. Further diagnosis of these issues is underway, and their identification may have important ramifications for future testing of the JPSS-1 and JPSS-2 sensors and/or calibration algorithms.

These efforts have also been summarized in our monthly and quarterly project reports. Most recently, we have also contributed to three papers summarizing the radiometric calibration, spectral calibration, and noise performance of Suomi-NPP CrIS which have been submitted to the special issue of JGR-Atmospheres on the calibration/validation results from the Suomi-NPP satellite.

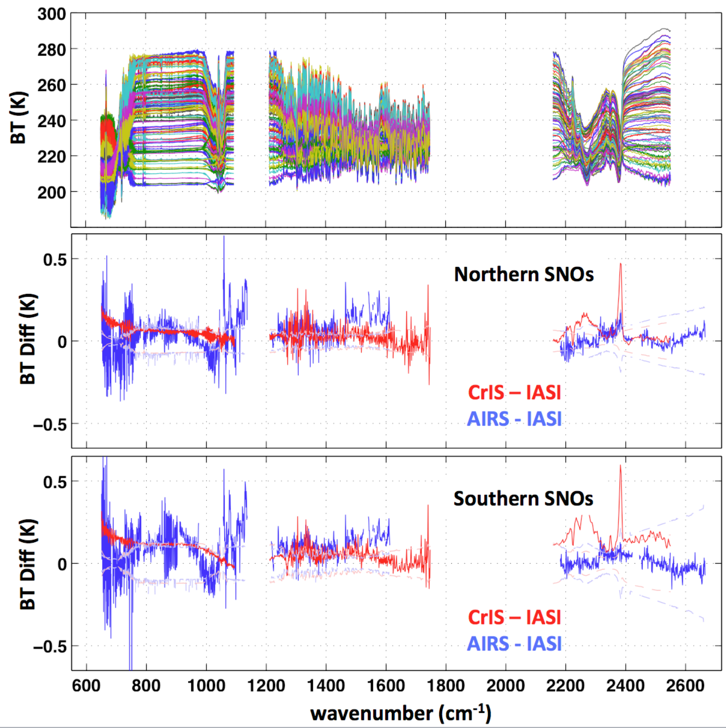

Figure 84. Summary of on-orbit comparison between CrIS brightness temperature spectra and both AIRS and IASI. All data from February-November 2012 that meets inter-comparison criteria (within 20 minutes, and 3° degrees viewing angle, with viewing angle <30° for AIRS and near nadir for IASI) is used. The dashed curves are error estimates indicating that most of these differences are significant. While these results will be the subject of detailed studies for considerable time, it is clear that the agreement is very good, especially between CrIS and IASI.

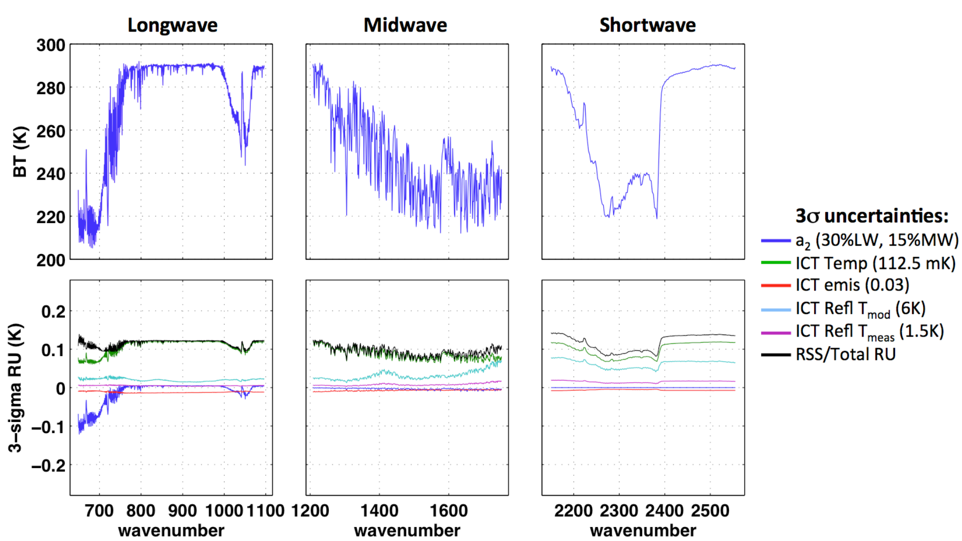

Figure 85. The Suomi-NPP CrIS Radiometric Uncertainty (RU) estimate for a typical Earth view spectrum, with component uncertainties from the nonlinearity corrections (a_2 uncertainty), ICT temperature uncertainty, ICT emissivity uncertainty, and ICT reflected temperature uncertainty. The RU is less than ~0.2 K for all wavenumbers and scene temperatures.

Publications, Reports, Presentations

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Tobin, D. C., H. E. Revercomb, J. K. Taylor, R. O. Knuteson, D. H. DeSlover, L. A. Borg, Cross-track Infrared Sounder (CrIS) Spectral Radiance Calibration and Evaluations, IRS 2012: Proceedings of the International Radiation Symposium, American Institute of Physics press, paper under review.

Revercomb, H., F. Best, R. Knuteson, D. Tobin, J. Taylor, J. Gero, Status of High Spectral Resolution IR for Advancing Atmospheric State Characterization and Climate Trend Benchmarking: A Period of Both Opportunity Realized and Squandered, IRS 2012: Proceedings of the International Radiation Symposium, American Institute of Physics press, paper under review.

Performance of CrIS on NPP, David Tobin, Hank Revercomb, Robert Knuteson, Dan DeSlover, Joe Taylor, Lori Borg, Fred Best, CALCON 2012, 27-30 August 2012, Logan, Utah. (presentation)

CrIS Calibration and Validation, Larrabee Strow, Howard Motteler, Paul Schou, Scott Hannon, David Tobin, CALCON 2012, 27-30 August 2012, Logan, Utah. (presentation)

UW CrIS SDR Status Report, talk presented at the Suomi-NPP SDR Provisional Product Review, NCWCP, College Park, MD, 23-24 October 2012.

The Cross-track Infrared Sounder (CrIS) on Suomi NPP: Expected Radiometric and Spectral Performance and Calibration/Validation Results: Part I, Henry E. Revercomb et al., paper number 8527-1 (Invited talk), SPIE 2012 Asia-Pacific Remote Sensing, 29 Oct- 1 Nov 2012, Kyoto, Japan.

The Cross-track Infrared Sounder (CrIS) on Suomi NPP: Expected Radiometric and Spectral Performance and Calibration/Validation Results: Part II, Daniel H. DeSlover et al., poster number 8527-51, SPIE 2012 Asia-Pacific Remote Sensing, 29 Oct- 1 Nov 2012, Kyoto, Japan.

Cross-track Infrared Sounder (CrIS) Spectral Radiance Calibration and Evaluations, David Tobin et al., poster # A33N-0352, AGU 2012 Fall Meeting, 3-7 December 2012, San Francisco, CA. (extended abstract)

Suomi NPP/JPSS Cross-track Infrared Sounder (CrIS): Radiometric and Spectral Performance, Hank Revercomb et al., Ninth Annual Symposium on Future Operational Environmental Satellite Systems, 93rd AMS Annual Meeting, 5-10 January 2013, Austin, TX. (extended abstract)

The Cross-track Infrared Sounder (CrIS) on Suomi NPP: Quality Assurance Study, Daniel DeSlover et al., poster number 299, Ninth Annual Symposium on Future Operational Environmental Satellite Systems, 93rd AMS Annual Meeting, 5-10 January 2013, Austin, TX. (extended abstract)

Suomi NPP/JPSS Cross-track Infrared Sounder (CrIS): Non-linearity Assessment and On-Orbit Monitoring, Robert Knuteson et al., poster number 301, Ninth Annual Symposium on Future Operational Environmental Satellite Systems, 93rd AMS Annual Meeting, 5-10 January 2013, Austin, TX. (extended abstract)

Suomi NPP/JPSS Cross-track Infrared Sounder (CrIS): Calibration Validation With The Aircraft Based Scanning High-resolution Interferometer Sounder (S-HIS), Joe K. Taylor et al., poster number 695, Ninth Annual Symposium on Future Operational Environmental Satellite Systems, 93rd AMS Annual Meeting, 5-10 January 2013, Austin, TX. (extended abstract)

Calibration/Validation of CrIS on Suomi-NPP: Intercalibration with AIRS, IASI, and VIIRS, David C. Tobin et al., poster number 700, Ninth Annual Symposium on Future Operational Environmental Satellite Systems, 93rd AMS Annual Meeting, 5-10 January 2013, Austin, TX. (extended abstract)

Results of calibration/validation efforts for the cross track Infrared Sounder on Suomi NPP, David Tobin et al., Third IASI Conference, 4-9 February 2013, Hyeres, France. (presentation)

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Cal/Val of CrIS on Suomi-NPP: Intercalibration with AIRS, IASI, and VIIRS, D. Tobin, Spring 2013 GSICS Quarterly Newsletter. http://www.star.nesdis.noaa.gov/smcd/GCC/newsletters.php

Tobin et al., Results of Calibration/Validation efforts for the Cross-track Infrared Sounder (CrIS) on Suomi-NPP, OSA/FTS Meeting, Arlington, VA, June 2013.

Tobin et al., Suomi-NPP, CrIS Radiometric Calibration Uncertainty, submitted to *JGR-Atmospheres*.

Han et al., Suomi NPP CrIS Measurements, Sensor Data Record Algorithm, Calibration and Validation Activities, and Record Data Quality, submitted to *JGR-Atmospheres*.

Strow et al., Spectral Calibration and Validation of CrIS Satellite Sounder, submitted to *JGR-Atmospheres*.

16.2 VIIRS SDR Calibration/Validation

CIMSS Project Lead: Christopher Moeller
CIMSS Support Scientist: Dan LaPorte
NOAA Collaborator: Changyong Cao, STAR

Project Overview

The S-NPP satellite was launched in fall 2011 with the VIIRS sensor becoming fully operational in January 2012. This task supports participation in VIIRS pre- and post-launch performance evaluation including:

1. SDR performance assessment including Cal/Val task network assignments supporting Beta, Provisional and Validated status assignment to the SDR product quality;
2. Identification of performance anomalies and development/implementation of mitigation strategies;
3. Spectral performance characterization and evolution (Govt Team POC). Support science community use of VIIRS relative spectral response functions;
4. Interaction with EDR teams to communicate SDR performance issues and support EDR impact assessments;
5. LUT updates in support of SDR production;
6. Membership on the VIIRS SDR team and associated activities; and
7. Preparation for JPSS-1 VIIRS Pre-Launch Test Program.

Summary of Accomplishments and Findings

- VIIRS-CrIS and VIIRS-IASI spectral radiance comparisons reveal excellent calibration performance for bands M13, M14, M15, M16, and I5 with differences < 0.1 K for typical scenes. Bands M12 and I4 show slightly larger biases at typical scenes. All bands exhibit larger biases at cold earth scenes but this performance appears to be within the pre-launch radiometric uncertainty requirements. The root cause of elevated cold scene bias continues under investigation.
- The 1+ year record of VIIRS-CrIS spectral radiance comparisons reveals excellent stability in M13, M15, M16, and I5 radiometric performance. Any long-term trends appear to be < 10mK/year.
- Ongoing RTA mirror throughput degradation has modulated the VisNIR and SWIR spectral response. Modulated RSR have been reviewed and approved for insertion into the IDPS operational SDR production.
- VIIRS on-orbit warmup/cooldown exercises consistently reveal a small radiometric response that suggests that some component(s) of VIIRS calibration is biased by operating the OBC at the nominal 292.5 K operational temperature. The systematic nature of this behavior suggests that it may be corrected by a change to the SDR algorithm process and/or LUTs.
- The VIIRS HAM RVS is well characterized as shown by < 0.1 K scan angle dependence in on-orbit instrument comparisons.
- VIIRS spectral out-of-band (OOB) influence is estimated at < 0.1K for TEB. This is within the pre-launch radiometric uncertainty requirement.
- Lessons learned from VIIRS Flight 1 spectral testing are being incorporated into JPSS-1 VIIRS spectral test program. GSE upgrades and procedures modifications have been completed; use of the NIST T-SIRCUS measurement equipment is also planned.

Publications, Reports, Presentations

Moeller, C., J. McIntire, T. Schwarting, D. Moyer, and J. Costa: Suomi NPP VIIRS Spectral Characterization: Understanding Multiple Releases. *SPIE Proc.* **8510**, 85101S, doi: 10.1117/12.980437 (2012).

Moeller, C.: Early NPP VIIRS SDR Performance: Univ. Wisconsin. Presentation at the NPP VIIRS SDR Product Review, April 5, 2012. Camp Springs, MD.

Moeller, C.: S-NPP VIIRS SDR Performance: Univ. Wisconsin. Presentation at the S-NPP SDR Product Review, October 23-24, 2012. College Park, MD.

Moeller, C., D. Tobin, N. Lei, J. McIntire, and T. Schwarting: SNPP VIIRS Spectral Status. Presentation at the SNPP VIIRS Calibration Workshop, January 22, 2013. Lanham, MD.

Moyer, D., C. Moeller, and F. De Luccia: VIIRS Thermal Emissive Bands On-orbit Calibration Coefficient Performance Using Vicarious Calibration Results:, *SPIE Proc.* **8866**. (2013).

Moeller C., D. Tobin, and G. Quinn: S-NPP VIIRS Thermal Band Spectral Radiance Performance Through 18 Months of Operation On-orbit, *SPIE Proc.* **8866** (2013).

16.3 CrIMSS Post Launch EDR Assessment

CIMSS Project Lead: Robert Knuteson
CIMSS Support Scientists: Michelle Feltz (AOS), Jacola Roman (AOS)
NOAA Collaborators: Chris Barnet, Tony Reale NOAA/STAR

Project Overview

This project started under the JPSS EDR Cal/Val team originally lead by Chris Barnet of NOAA STAR and now under the leadership of Tony Reale of NOAA STAR with continuous support for the past three years. The focus of this effort is to take advantage of state-of-the-art temperature and water vapor measurements for the validation of the NOAA sounding products produced from SDR data collected by the JPSS program. The initial studies were done with AIRS data (2002+) and with CrIS/ATMS data starting in 2012 on Suomi NPP. The goal is to transition successful methodologies into the NOAA Data Exploitation (NDE) system as appropriate. We proposed the use of collocated ARM Raman Lidar measurements as well as the ground-based GPS column water vapor measurements to assess the NPP water vapor sounding product, and the high quality COSMIC RO temperature profiles to assess the NPP temperature sounding product.

Summary of Accomplishments and Findings

Significant progress has been made on the use of GPS radio occultation (RO) measurements for the validation of hyperspectral IR sounder temperature products, in particular the CrIMSS AVTP product, a key parameter in the JPSS program. This work supported an undergraduate student in the publication of a paper on the detailed methodology of the validation matchup titled, "A Methodology for the Validation of Temperature Profiles from Hyperspectral Infrared Sounders Using GPS Radio Occultation: Experience with AIRS and COSMIC" by Michelle Feltz. The following figures are from that publication. This work is also referenced in two JGR publications in the 2013 JPSS Cal/Val special issue in Nalli et al., "Validation of Infrared Sounder Environmental Data Records: Application to the Cross-track Infrared Microwave Sounder Suite (CrIMSS)" and in Divakarla et al., "The CRIMSS EDR Algorithm: Characterization, Optimization And Validation". This temperature validation method has application to all sounders and has been applied to retrievals from AIRS on Aqua, IASI on MetOp, and CrIS on Suomi NPP. In addition to providing a common reference for the inter-comparison of temperature products from satellite sounders, the GPS RO has higher vertical resolution and higher absolute accuracy than the IR sounders but significantly poorer spatial coverage. This work is expected to lead to improvements in the bias and RMS of JPSS and other NOAA sounding product systems such as NUCAPS.

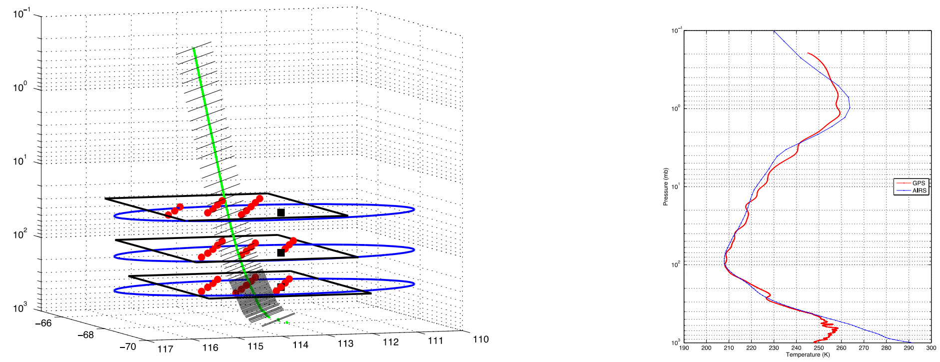

Figure 86. Illustration of the intersection of IR sounding retrieval levels and a coincident GPS RO profile.

Publications, Reports, Presentations

Feltz, M., R. Knuteson, D. Tobin, S. Ackerman, H. Revercomb, and A. Reale, 2012: Methodology for the Validation of Temperature Profile Environmental Data Records (EDRs) From the Cross-Track Infrared Microwave Sounding Suite (CrIMSS): Experience with GPS Radio Occultation From COSMIC, AMS Annual Meeting, New Orleans, LA, 22-26 January 2012. http://ams.confex.com/ams/92Annual/webprogram/Paper200494.html

Feltz, Michelle, R. O. Knuteson, H. Revercomb, D. Tobin, and S. Ackerman, 2013, Validation of Temperature Profile Environmental Data Records (EDRs) from the Cross-Track Infrared Microwave Sounding Suite (CrIMSS) Using COSMIC Dry Temperature Profiles, proceedings of the 2013 AMS Annual Meeting, Austin, TX. https://ams.confex.com/ams/93Annual/webprogram/Manuscript/Paper216036/MFeltz_AMS2013_Manuscript_28Jan2013.pdf

Knuteson, R., D. Tobin, A. Sorce, J. Roman, S. Ackerman, H. Revercomb, and D. D. Turner, 2012: Methodology for the Validation of Water Vapor Profile Environmental Data Records (EDRs) From the Cross-Track Infrared Microwave Sounding Suite (CrIMSS): Experience with the DOE ARM Water Vapor Raman Lidar, AMS Annual Meeting, New Orleans, LA, 22-26 January 2012. http://ams.confex.com/ams/92Annual/webprogram/Paper200492.html

Roman, Jacola A., Robert O. Knuteson, Steven A. Ackerman, David C. Tobin, Henry E. Revercomb, 2012: Assessment of Regional Global Climate Model Water Vapor Bias and Trends Using Precipitable Water Vapor (PWV) Observations from a Network of Global Positioning Satellite (GPS) Receivers in the U.S. Great Plains and Midwest. *J. Climate*, **25**, 5471–5493. doi: http://dx.doi.org/10.1175/JCLI-D-11-00570.1

Roman, Jacola; R. O. Knuteson; S. A. Ackerman; H. E. Revercomb; W. Smith; E. Weisz, 2012. Using Regional Validation from SuomiNet, AMSR-e, and NWP Re-analysis to Assess the Precipitable Water Vapor from AIRS and CrIS for Detecting Extreme Weather Events. Fall AGU 2012, San Francisco, CA.

16.4 CrIMSS EDR Cal/Val: ARM Site Support

CIMSS Project Lead: David Tobin
CIMSS Support Scientist: Lori Borg
NOAA Collaborators: Tony Reale, NOAA/STAR and Nicholas Nalli, NOAA Affiliate

Project Overview

The goal of this project is to provide for the critical validation of NPP CrIMSS atmospheric temperature and water vapor retrieved profiles. The assessment of soundings on the 1K/km level and the establishment of a long term set of well-characterized sounding products requires accurate and on-going validation data. The Atmospheric Radiation Measurement (ARM) program field sites provide such data. In this arrangement, radiosondes are launched from the ARM sites coincident with the satellite overpasses of the sites, and analysis is performed by UW-Madison personnel to compare the radiosonde and CrIMSS EDR products to assess the accuracy of the satellite products. Previously for AIRS and IASI, best estimates of the atmospheric state and surface properties at the satellite overpass times were produced via a similar collaborative effort between NASA and ARM. This work was a fundamental, integral, and cost-effective part of the EOS validation effort and provided critical accuracy assessments of the AIRS temperature and water vapor soundings. This effort is anticipated to be repeated throughout the NPP mission life into FY15.

Summary of Accomplishments and Findings

These efforts have included coordination of satellite overpass radiosonde launches, creation of ARM best estimate profiles, and validation analysis of the CrIMSS products.

Phase1 - Sondes

The initial "phase" of radiosonde launches was conducted between July 2012 and June 2013. In this effort sonde pairs were launched at NSA and SGP, with a goal of 90 sonde pairs at each site. The first sonde in the pair was launched 45 minutes prior to overpass and the second sonde in the pair was launched 5 minutes prior to overpass. At TWP-Manus, single sondes were launched 15 minutes prior to overpass, with a goal of 90 sondes. In total, 90 sonde pairs were completed at NSA, 89 sonde pairs at SGP, and 94 single sondes at TWP-Manus. While, the sondes were completed in early December at NSA and in early January at SGP, the TWP launches were not completed until early June 2013. The TWP launches were put on hold pending resolution of a contract issue over the period of performance (POP), which ended on January 14, 2013. The POP was extended and launches resumed at the TWP site on March 15, 2013 and completed June 03, 2013.

Phase1 - ARM Best Estimate (BE) Sonde Product

The ARMBE product version v0p1 for sondes launched during Phase 1 was delivered in May 2013 and made available on the UW-Madison/SSEC ftp site:
ftp://ftp.ssec.wisc.edu/pub/crimss_edr_calval/
Detailed information on what is contained in the v0p1 best estimate sonde product can be found in the README.txt file located on the ftp site, but is included at the end of this report for completeness. An overview of the v0p1 ARMBE product was given to the EDR team at the bi-weekly EDR telecon (20130507). This presentation also included comparisons between the ARM BE v0p1 product and the CrIMSS retrievals and GDAS mode fields. Overall, the ARM BE product agrees well with the GDAS but differs significantly with the CrIMSS product especially near the surface. However, it should be noted that this analysis uses the only available CrIMSS EDRs for this time period (MX Version 5.3 - 6.5) which is a microwave only product. The official analysis will require comparison with the CrIMSS EDR IPs, which are currently not available with the latest MX version but are being generated by the CrIMSS Cal/Val team.

Phase2 - Sondes

Efforts included further coordination with ARM and NOAA regarding the NPP dedicated overpass sonde efforts. Phase2 of the sonde launch effort began in June 2013 at the NSA, SGP, and TWP ARM sites. Initially the strategy for Phase2 of the sonde launches was similar to that of Phase1, with 90 sonde pairs scheduled at each of the NSA and SGP sites (45 and 5 minutes prior to overpass) and 90 single sondes scheduled at TWP (15 minutes prior to overpass). In early July 2013, it was decided to alter the remaining Phase2 sonde schedule. This new schedule would spread the sondes out over a longer period, resulting in 7-8 sonde or sonde pair launches per month per site. The dual sondes at NSA would alternate with single sondes effectively saving approximately 25% of the remaining NSA sondes for the future Phase3 sonde effort. At the same time, it was determined that there were significant differences in the ascent rates of the sondes between the sites and that ARM would like to change these ascent rates such that they are within the recommended 5-5.5 m/s regime recommended by Vaisala. On July 16, 2013 the sonde launches for this effort were ceased until the changes in ascent rates could be made by ARM. This new schedule includes different sonde launch times for each of the three sites; alternating sonde pairs and single sondes at NSA, sonde pairs at SGP, and single sondes at TWP. These sondes will be spread out with 7-8 sonde pairs or single sondes per month through the end of May 2014. The new ascent rates will be taken into account such that the sonde launch times will put the sondes at approximately the same place in the atmosphere (~675hPa) at each of the sites at the overpass times. Phase 2 sonde launches began last week.

Future Efforts

Future efforts under this project include: 1) continuing coordination of the sonde launch schedule and logistics with the ARM personnel, including distribution of new Phase2 sonde launch schedule after ARM brings ascent rates into agreement with Vaisala recommendation, 2) Refinement of the best estimate products for the Phase1 launches using more frequent information on the time change of the atmospheric state to interpolate between the two dedicated radiosondes and inclusion of cloud and surface characterization data, and 3) Evaluation of the CrIMSS EDRs/IPs via comparisons with the ARM best estimate products, and/or evaluation of other retrieval products (e.g., NUCAPS, UW Dual Regression).

Publications, Reports, Presentations

We have provided quarterly progress reports for this project and given status reports at regularly scheduled CrIMSS EDR telecons. Publications and/or conference presentations are on hold pending availability of microwave+infrared CrIMSS EDR/IPs for the ARM site radiosonde launch times.

16.5 NPP-VIIRS Aerosol IP/EDR Evaluation

CIMSS Project Lead: Robert Holz
CIMSS Support Scientist: Min Oo
NOAA Collaborator: Istvan Laszlo, NOAA
NOAA Strategic Goals Addressed:

- Provide critical support for the NOAA missions

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

The validation of the VIIRS aerosol products began on 2 May 2012, about six months after the launch of Suomi-NPP. The six-month delay allowed the primary input parameters used by the aerosol algorithm spectral reflectance (SDRs) and cloud mask products (VCM) be characterize and refined. We are currently validating the VIIRS EDRs using the MODIS aerosol product, using these filtering criteria:

- VIIRS and MODIS retrievals are collocated within 5 minutes of observation time; match-ups are found for days of year 123, 126, 128, 131, 134, 136, 137, 139, 142, 144, 147, 150, 152 and 153 within May 2 – June 2, 2012;
- MODIS AOT over Land and Ocean are filtered with MODIS cloud mask QA (Best) to select data with Cloud Fraction 0 to 30%;
- MODIS AOT is filtered with the MODIS Quality Assurance to select collocations only with the quality mix recommended by the MODIS aerosol team; and
- The collocation seeks high quality VIIRS's nearest neighbor AOT that falls within the MODIS L2 10km product footprint.

Summary of Accomplishments and Findings

Product evaluation began with data collected on 2 May 2012 to Jun 2 are shown in `Figure 87`.

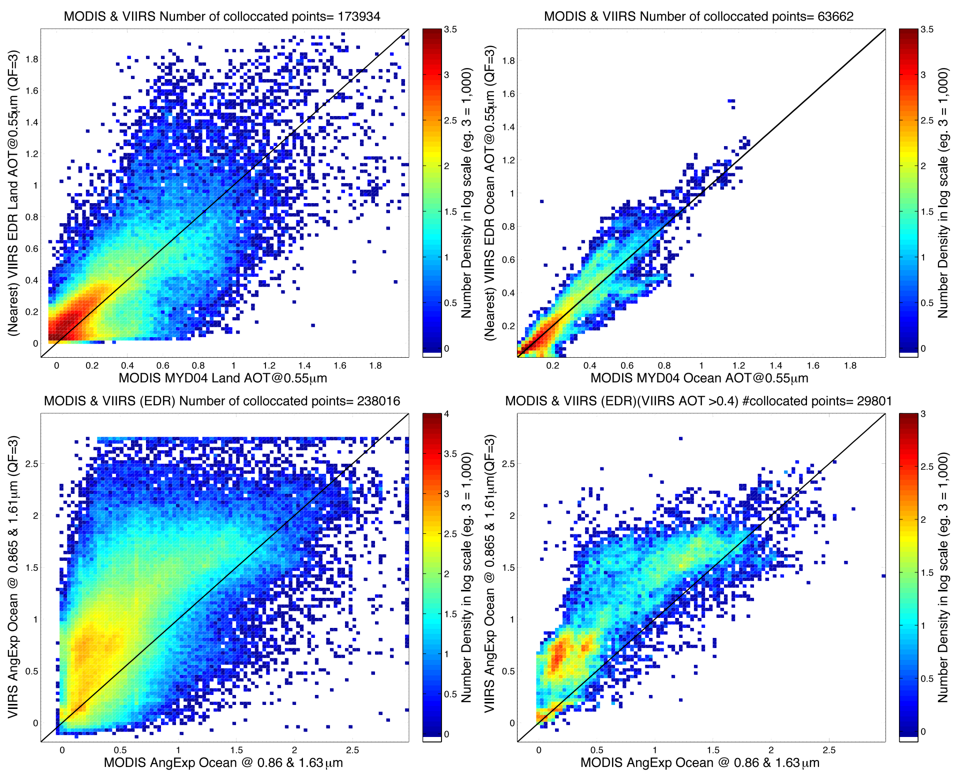

Figure 87. Density scatterplots of collocated VIIRS and MODIS AOT at 0.55 µm (top) and 0.865 µm/1.61 µm Ångström exponent (bottom). Left panel AOT for land and right panel AOT for ocean. Right panel Ångström exponent for AOT 550 nm greater than 0.40. Left panel Ångström exponent for all AOT.

In the Beta period, certain specific issues were identified such as the AOT product over land was biased high against Aqua MODIS AOT, and the over land Ångström exponent demonstrated little skill (not shown in this report). The high bias in AOT was traced to assumptions of surface reflectance ratios.

17 CIMSS Participation in the JPSS Algorithm Community Risk Reduction Program for 2012

17.1 NOAA Algorithm Continuity – Ice surface Temperature, Concentration, and Characterization

CIMSS Project Lead: Yinghui Liu
CIMSS Support Scientist: Xuanji Wang
NOAA Collaborator: Jeffrey R. Key, NOAA/NESDIS
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

The goal of this task is to modify the ice surface temperature (IST), ice concentration, and ice age/thickness (or "characterization"; Wang et al., 2010) algorithms that CIMSS developed for the GOES-R Advanced Baseline Imager (ABI) so that they can be applied to data from the NPP Visible Infrared Imager Radiometer Suite (VIIRS). These and other state-of-the-art products have been developed for the ABI instrument but, due to budgetary considerations, will not initially be generated for GOES-R.

Using these algorithms to generate VIIRS products will bring continuity to the NOAA product suite over time. Equally importantly, the current VIIRS products may not meet the needs of users, so these NOAA-unique products will provide alternatives to the industry-developed VIIRS products. The algorithms are mature and have been extensively tested on Moderate Resolution Imaging Spectrometer (MODIS) and other satellite data, and have been shown to meet the GOES-R requirements for accuracy and precision.

Summary of Accomplishments and Findings

GOES-R algorithms of ice surface temperature, concentration, and characterization have been modified to run using VIIRS data. Differences between ABI and VIIRS were taken into account, particularly the number and characteristics of the spectral bands. This modified algorithm has been applied to the NPP VIIRS SDRs to routinely generated ice surface temperature, concentration, and characterization near real-time. These products are generated daily near real time, and they are plotted and shown on a Web page maintained at CIMSS. All the retrieved products are archived. Examples of these retrieved products are shown in Figure 88, and Figure 89.

The process of integrating the algorithms into the GOES-R Algorithm Integration Team's "Framework" has begun. Documents, such as the Algorithm Theoretical Basis Documents (ATBD) that were written for ABI, will be modified accordingly. A number of design reviews are required for this project. The investigators prepared and passed the Critical Design Review (CDR) in April 2013.

Collocation, and statistical analysis of these retrieved products with in situ observations, and products from other satellites including MODIS, SSM/I are ongoing, which will allow routine evaluation of these retrieved products. The modified algorithm will be further improved based on these evaluations.

Publications, Reports, Presentations

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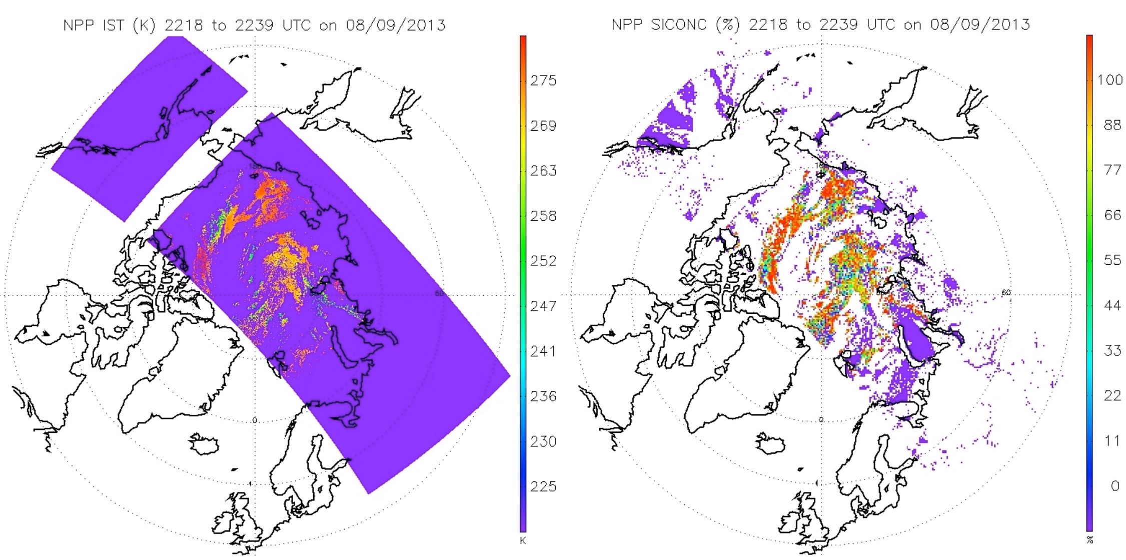

Figure 88. Retrieved ice surface temperature (left) and concentration (right) from NPP VIIRS SDR on August 9, 2013.

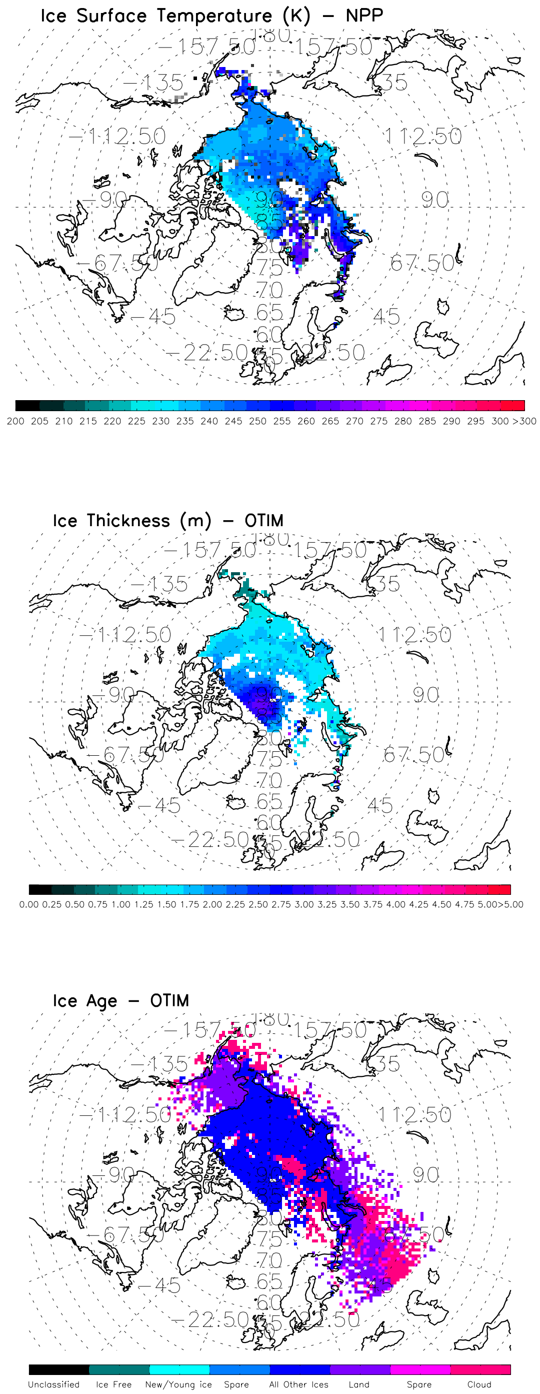

Figure 89. Sea ice surface temperature (top), OTIM retrieved sea ice thickness (middle) and age (bottom) with VIIRS data for the date of March 4, 2012 under clear-sky condition.

17.2 Transition of GOES-R AWG Cloud Algorithms to VIIRS/JPSS

CIMSS Project Lead: Andi Walther
CIMSS Support Scientists: Denis Botambekov, William Straka

NOAA Collaborator: Andrew Heidinger, NESDIS/STAR
NOAA Strategic Goals Addressed:

- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

This ongoing project involves the implementation of the CIMSS GOES-R AWG Cloud Algorithms to the data from the Suomi-NPP Visible Infrared Imaging Radiometer Suite (VIIRS). Specifically, this project covers the implementation of the ABI cloud mask (ACM), the ABI Cloud Height Algorithm (ACHA) and the Daytime Cloud Optical and Microphysical Properties (DCOMP) Algorithm. Implementation support is also provided for the Nighttime Cloud Optical and Microphysical Properties (NCOMP) Algorithm. In all, this project covers the generation on VIIRS of the following cloud products: clear-sky mask, top height, temperature and pressure, optical depth, particle size, water/ice path and base height. The motivation for this project is the demonstration of efficient processing of VIIRS data with NOAA and the generation of a set of products from VIIRS that is physically consistent with those from GOES-R.

Summary of Accomplishments and Findings

In the first year of this project, all GOES-R ABI algorithms were implemented in PATMOS-X and also in the existing NOAA algorithm framework GEOCAT.
For the GOES-R ABI Cloud Mask (ACM) we implemented beside the official binary clear-sky mask (clear or cloudy) an additional 4-level mask as an intermediate product (clear, probably clear, probably cloudy and cloudy). The ACM uses 9 spectral bands. Its cloud detection is based on spectral, spatial and temporal signatures. Most thresholds were derived from analysis of space-borne Lidar and current geostationary imager data.

The ABI Cloud Height Algorithm (ACHA) is an infrared-only retrieval that uses an analytical forward model in an optimal estimation framework to estimate cloud temperature, emissivity and β (an IR microphysical parameter). Cloud height and pressure are derived from the temperature and knowledge of the atmospheric profiles from the NWP ancillary data. For JPSS, ACHA is also required to estimate the cloud-base height and the development of this technique is included in this project. VIIRS does not offer the same set of IR channels as offered by the GOES-R ABI. In the ABI version of ACHA, the 11, 12 and 13.3 μm channels are used. On VIIRS, only the 8.5, 11 and 12 μm channels are available (Heidinger et al., 2010). ACHA uses scattering models of each channel within its forward model. Using the same methods employed on the ABI, the VIIRS channels will be incorporated.

One other crucial component is the daytime cloud optical and microphysical properties (DCOMP) algorithm, which generates estimates of cloud optical thickness, cloud effective radius and ice/water path during daylight conditions [Walther and Heidinger, 2012]. Figure 90 shows an example for the VIIRS/NPP retrieval output of DCOMP for Cloud Optical Thickness.

We could successfully evaluate all products against suitable validation test data.

VIIRS/NPP as a sun-synchrony polar-orbiting sensor requires special focus on Arctic Regions. We started a next project phase, which focus on further developments of specific retrieval modules for Polar region and snow surfaces and also completing the validation efforts.

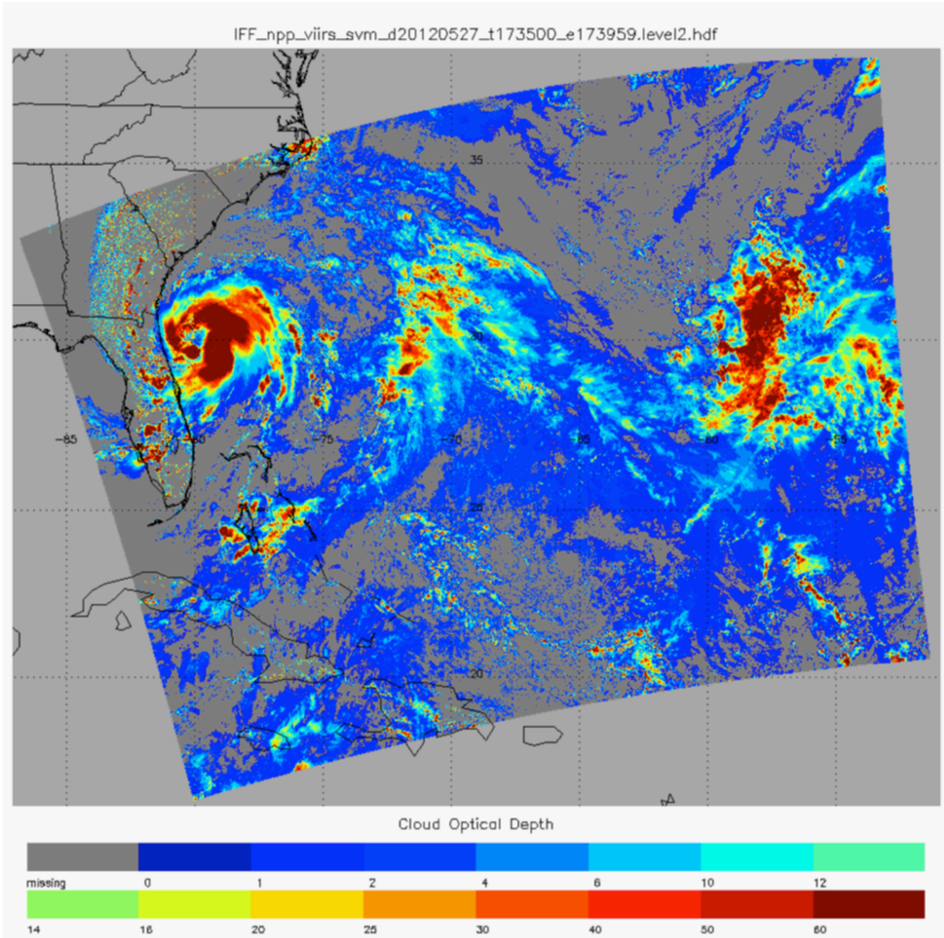

Figure 90. Cloud Optical Thickness from VIIRS/NPP on May 27 2012 17:35 UTC

Publications, Reports, Presentations

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Walther, A., A. Heidinger, W.Straka, 2011: ABI algorithm theoretical basis document for DCOMP., version 2.0 NOAA/NESDIS, 61pp. [Available online at http://www.goes-r.gov/products/ATBDs/baseline/Cloud_DCOMP_v2.0_no_color.pdf]

Walther, A. and A. Heidinger (2012): Implementation of the Daytime Cloud Optical and Microphysical Properties Algorithm in PATMOS-x. *JAMC*, **51**, Issue 7, 2012, 1371–1390.

17.3 JPSS Algorithm Integration Team

<u>CIMSS Project Lead</u>: R.K.Garcia
<u>CIMSS Support Scientists</u>: G.D.Martin, E.N.Schiffer, W.C.Straka III
<u>NOAA Collaborator</u>: W.Wolf
<u>NOAA Strategic Goals Addressed</u>:

- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

The JPSS AIT-MW supports the NOAA JPSS AIT toward the goal of implementing pseudo-operational product generation, validation, and visualization capabilities for SNPP and follow-on polar satellites.

Algorithms will be principally derived from GOES-R algorithm implementations, with necessary updates and modifications for multi-satellite use. AIT-MW will principally be supporting algorithms originating at UW-Madison/CIMSS, for instance cloud algorithms. This includes technical, implementation, and portability/compatibility concerns for several target systems. It also includes management of testing, delivery, and acceptance processes.

For GOES-R, AIT-MW has provided generalized technical expertise in making CIMSS algorithms ready for integration to the GOES-R pseudo-operational framework. The end result of that effort is the delivery of reference datasets and reference software implementations for use by the operational integration vendor, as well as algorithm theory and validation documentation.

For JPSS, efforts will be focused on risk-reduction for NPP/JPSS, i.e., validating for NPP a subset of product algorithms researched for and initially applied to GOES-R.

Summary of Accomplishments and Findings

Development work toward applying the GOES-R algorithms to VIIRS will not start until after the Critical Design Review of the algorithms, which has not happened as of July 2013.

Some preparatory work has been done under other project funds. For example, the VIIRS Polar Winds project has updated and ported several algorithms into the AIT Framework with minimal effort. These include the CLAVR-x Cloud Type, which acts as a proxy for the Cloud Type algorithm, the ABI Cloud Height and Bayesian Cloud Mask algorithms..

Additionally, GEOCAT has been modified to read in a subset of the VIIRS Moderate Resolution Band (“M-Band”) SDR and geolocation data, as well as be able to calculate the clear sky radiance values using both the PFAAST and CRTM models. Currently a refactoring is in progress that will allow processing of the remaining VIIRS M-band channels, as well as allow better code-sharing and collaboration among different research and pseudo-operational processing frameworks.

It is expected that beginning in Fall 2013, algorithm improvements and refactoring in support of JPSS will begin in earnest. The first algorithms that are expected to go into the AIT Framework are the cloud algorithms, with other algorithms afterward. Some modifications to the existing algorithms will be needed due to sensor differences between the Advanced Baseline Imager and VIIRS. While the GOES-R volcanic ash and cloud type algorithms can be applied (with some minimal modification) to VIIRS without a number of channels unique to ABI, the product accuracy (especially ash cloud heights and multilayered cloud detection) will be impacted. We anticipate exploration of combining CrIS and VIIRS measurements to prevent a loss in product accuracy. Where possibly, functionality shared across algorithms will be developed as common utilities, e.g., bow-tie deletion. The GOES-R-like JPSS cloud phase and volcanic ash products will also be validated using the methods developed in preparation for GOES-R.

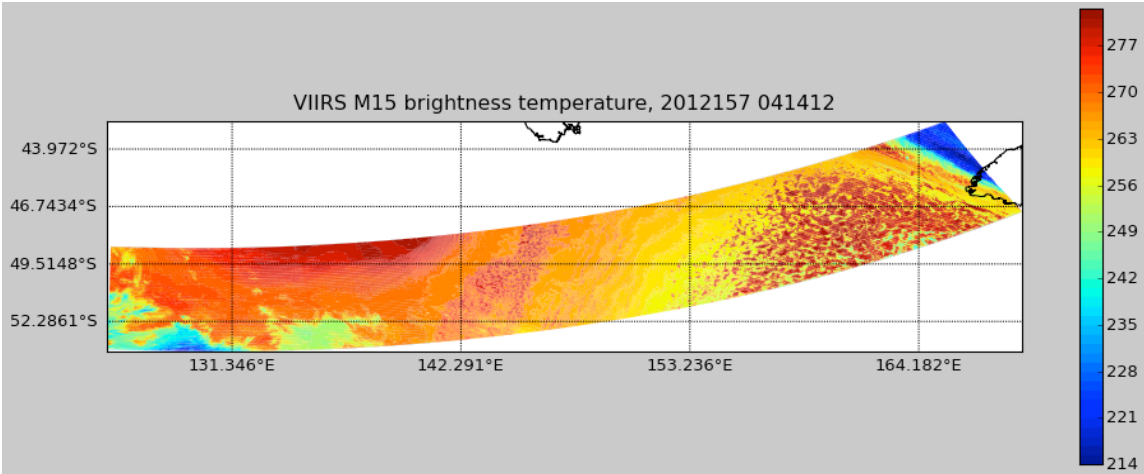

Figure 91. VIIRS Level 1 output from Geocat.

18 Hyperspectral Retrievals from Polar-Orbiting Sounders for Use in NWS Alaska Region Forecasting Applications

CIMSS Project Lead: Elisabeth Weisz
CIMSS Support Scientists: William L. Smith Sr., Nadia Smith
NOAA Collaborator: Mitchell Goldberg (NOAA/NESDIS/STAR)

NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications
- Outreach and Education

Project Overview

Accurate retrievals from hyperspectral sounder radiance measurements under both clear and cloudy sky conditions are valuable sources of mesoscale information and have the potential to greatly enhance regional weather prediction capabilities. To encourage the operational use of hyperspectral retrieval data in NWS (National Weather Service) forecasting offices, retrieval products from AIRS (Atmospheric Infrared Sounder), IASI (Infrared Atmospheric Sounding Interferometer) and CrIS (Cross-Track Infrared Sounder) are prepared for near real-time viewing and analysis in close collaboration with Alaska Region researchers and forecasters. This is the second year of a three-year JPSS (Joint Polar Satellite System) PGRR (Proving Ground and Risk Reduction) project, previously titled "Atmospheric Soundings from Suomi NPP/Aqua and Metop-A/Metop-B Sounding Pairs."

Summary of Accomplishments and Findings

With a fast, multi-instrument sounding retrieval algorithm now available (the dual-regression retrieval algorithm has been released in November 2012 under the Community Satellite Processing Package) real-time information from multiple sounders can be examined for the first time. It is anticipated that this newly available information source, if used together with traditional NWP data sources (e.g., broad-band imager data), will help forecasters to prepare more timely and accurate forecasts and severe weather warnings. Thus, the complementary use of hyper-spectral retrieval data with imagery and products from broadband instruments has been explored. An example of the type of quantitative information contributed by a sounder is given in Figure 92 showing a low-pressure system over the Gulf of Alaska on 26 September 2012. The Suomi-NPP VIIRS (Visible Infrared Imaging Radiometer Suite) infrared band image shows great spatial detail of the cloud features of the rapidly intensifying cyclone and provides some differentiation between optically thick and thin clouds. Although at lower spatial resolution the same spatial features are retrieved from CrIS sounding measurements, but this time they have quantitative values describing cloud altitude, cloud optical thickness and humidity.

In high latitudes, such as the Alaskan region, overpasses by the polar-orbiting satellites (Aqua, Suomi-NPP, Metop-A and Metop-B) are frequent enough to provide sufficient temporal and spatial coverage to allow the study of atmospheric dynamics. Figure 93 depicts IASI, CrIS and AIRS brightness temperatures as well as the change per hour in cloud top pressure retrieved. In particular, before and during storm systems the atmospheric situation changes very quickly. From studying and analyzing Alaskan region and CONUS (e.g., Moore, OK tornado) weather systems we find that the change in stability (e.g., lifted index) and clouds (in altitude, thickness, temperature) can be detected and accurate atmospheric profile tendencies can be derived from subsequent orbits. It is expected that this information on pre-convective instability, moisture transport and atmospheric motion from hyper-spectral measurements will lead to more reliable and accurate forecasts.

One of the main tasks of this project is to incorporate hyperspectral retrieval products into the NWS Alaska forecast system through AWIPS (Advanced Weather Interactive Processing System). Selected retrieval parameters (cloud top pressure, cloud optical depth, temperature and humidity at selected pressure levels, lifted index) have been converted to gridded NetCDF-3 files apt for display and analysis in AWIPS and a software package will be delivered to UAF this year.

Publications, Reports, Presentations

Smith, W. L., E. Weisz, S. Kirev, A. Larar, and H. Revercomb, Weather and Climate Applications of Ultraspectral IR Radiance Measurements. Presentation at the International Radiation Symposium (IRS), 6-10 August 2012, Berlin, Germany.

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Smith, W. L., E. Weisz, H. Revercomb, and A. Larar, Atmospheric Dynamics From Suomi NPP/Aqua and Metop-A/Metop-B Sounding Pairs. Presentation at the EUMETSAT Meteorological Satellite Conference, 3-7 September 2012, Sopot, Poland.

Weisz, E., W. L. Smith, N. Smith, Kathy Strabala, et al. (2012), Atmospheric Profile and Cloud Parameter Retrievals from Hyperspectral Infrared Radiances. Presentation at the CIMSS Science Symposium, 12 December 2012, Madison, WI, USA.

Smith, W. L., E. Weisz, N. Smith, JPSS PG Alaska AIRS, IASI and CrIS Retrievals, Presentation at the NWS Fairbanks, 27-28 February 2013, Fairbanks, Alaska.

Smith, W. L., E. Weisz, N. Smith, H. Revercomb, Forecasting Hurricane Intensity and Severe Convective Storms Satellite Sounding Pairs, presented at the NOAA 2013 Satellite Conference, 8-12 April 2013, College Park, MD.

Weisz, E., W. L. Smith, N. Smith, Community Satellite Processing Package (CSPP) Cross-track Infrared Sounder (CrIS) Dual- Regression Retrievals and Applications, presented at the NOAA 2013 Satellite Conference, 8-12 April 2013, College Park, MD.

Smith, N., E. Weisz, W. L. Smith, A Fresh Look at Hyperspectral Sounders: How 3-D Quantitative Information About the Atmosphere Can Enhance Real-Time Applications and Decision Making, presented at the CSPP/IMAPP Users' Group Meeting, 21-23 May 2013, Madison, WI.

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Weisz, E., W. L. Smith, N. Smith, JPSS PG Hyperspectral Sounder Retrieval Applications. JPSS Science Seminar (presented remotely from CIMSS, Madison, WI), 22 July 2013, Lanham, MD.

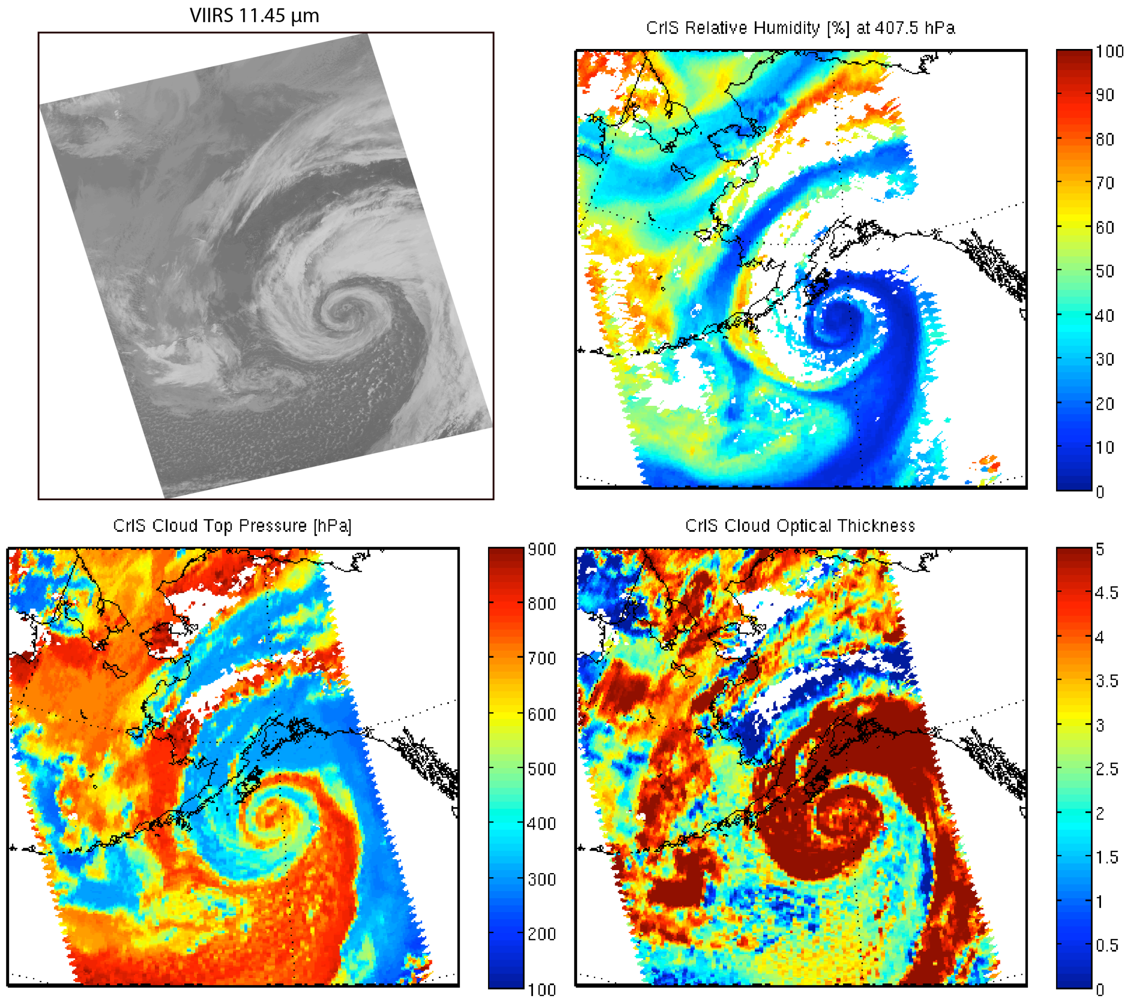

Figure 92. VIIRS 11 µm (I5) band, CrIS retrievals of relative humidity (at 400 hPa), cloud top pressure and cloud optical thickness for 26 Sept 2012.

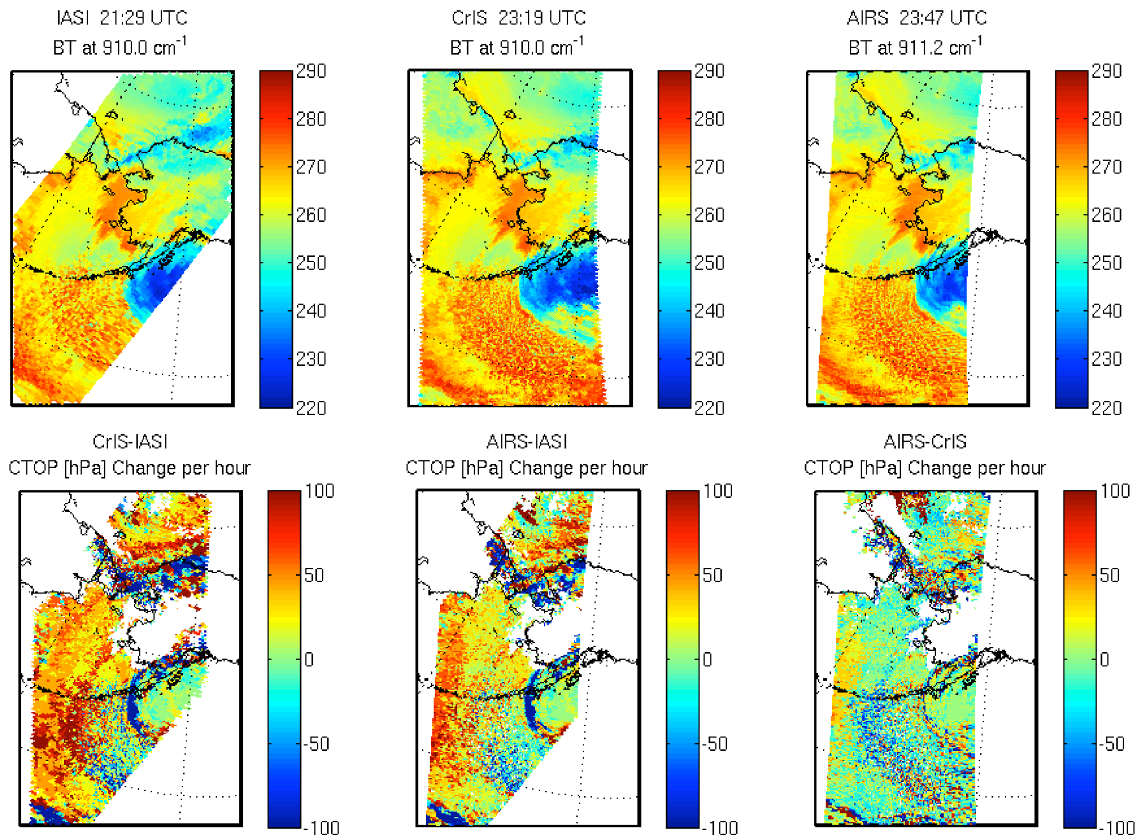

Figure 93. Top: Brightness temperature at 910 cm^{-1} (11 μm) window channels for IASI (Metop-A), CrIS and AIRS. Bottom: The change per hour in cloud top pressure (CTOP) between CrIS and IASI, AIRS and IASI, and AIRS and CrIS. For 01 Nov 2012.

19 CIMSS Participation in the JPSS Risk Reduction Program for 2012

19.1 Near Real-time Assimilation System Development for Improving Tropical Cyclone Forecasts with NPP/JPSS Sounder Measurements

CIMSS Project Lead: Jun Li
CIMSS Support Scientists: Jinlong Li, Pei Wang, Bill Bellon
NOAA Collaborators: Tim Schmit (NESDIS/STAR), Mark DeMaria (NESDIS/STAR), John L. Beven (NWS/NHC)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation

Project Overview

This task is part of CIMSS JPSS Risk Reduction project; the goal is to use the NPP/JPSS sounding measurements for improving the prediction of tropical cyclone (TC) genesis and evolution. The work will use the regional numerical weather prediction (NWP) models (WRF -

Weather Research and Forecasting, and HWRF – Hurricane WRF) and the advanced data assimilation methodologies (GSI, 3DVAR and 4DVAR). CIMSS scientists will develop a near real time assimilation system (SDAT – Satellite sounder data assimilation for TC forecasts) based on the combination of GSI and WRF and use NPP/JPSS sounding measurements from Community Satellite Processing Package (CSPP) or NOAA data ports (IDPS and NDE), to serve as an application demonstration system on the utilization of JPSS sounding measurements for TC forecasting.

Summary of Accomplishments and Findings

In order to study the use of satellite sounder data in a more realistic operational environment, CIMSS scientists have implemented the NCEP operational community Gridpoint Statistical Interpolation (GSI) for regional WRF (Weather Research and Forecasting – WRF-ARW 3.2.1) model. The GSI system was initially developed by NOAA/NCEP/EMC as a next generation global/regional analysis system, and now it is the operational grid-space regional analysis system at NOAA/NCEP. With GSI implemented into WRF, we have the flexibility on assimilating various satellite data in a realistic operational environment, thus it makes the research results more convincible for transition to the operation. Based on WRF/GSI, CIMSS scientists are also developing the satellite Sounder Data Assimilation for TC forecasts – SDAT, SDAT comprises of data ingesting and processing, data assimilation, forecasting and forecast analysis.

We have conducted the NPP sounder assimilation for hurricane Sandy (2012) forecast experiments, three types of data are used in the experiments: (a) GTS - data obtained through WMO's global telecommunication system, GTS contains all the conventional data and other related data, (b) AIRS – AIRS single field-of-view (SFOV) soundings developed at CIMSS and obtained from IMAPP (International MODIS and AIRS Processing Package), and (c) CrIMSS - CrIMSS sounding EDR from JPSS Cal/Val team.

The forecast experiments are conducted in WRF/GSI with 12 km spatial resolution, in order to investigate the impact of using satellite sounder data for Sandy forecasts, GTS+AIRS+CrIMSS data are used in the experiments. Data are assimilated every 6 hours followed by 72 hour forecasts. The assimilation window is +/- 1 hour. The experimental forecasts are compared with the operational regional HWRF and global GFS. Figure 94 shows the Sandy track root mean square error (RMSE) from CIMSS experimental forecasts with GTS, AIRS and CrIMSS data assimilated, the operational regional HWRF forecasts and the operational global GFS forecasts (AVNO). Forecasts start from 12 UTC 25 Oct and valid 18 UTC 30 Oct 2012.

Both CIMSS experimental and operational GFS track forecasts are good during that time period, GFS (AVNO) is good at the beginning time, but from at 18UTC 26 October, the track error becomes large. Figure 95 is the same as Figure 94 but for central sea level pressure (SLP) RMSE (hPa). In general, when satellite sounder data are assimilated, the SLP forecasts have been improved compared with the two operational models (GFS and HWRF). It should be noted that the SLP of AVNO is always weak when compared with best track from National Hurricane Center (NHC), and it is difficult to become strong according to SLP, but HWRF and CIMSS results are good at intensity forecasts during that time period. That means regional NWP has the advantage on intensify forecasts.

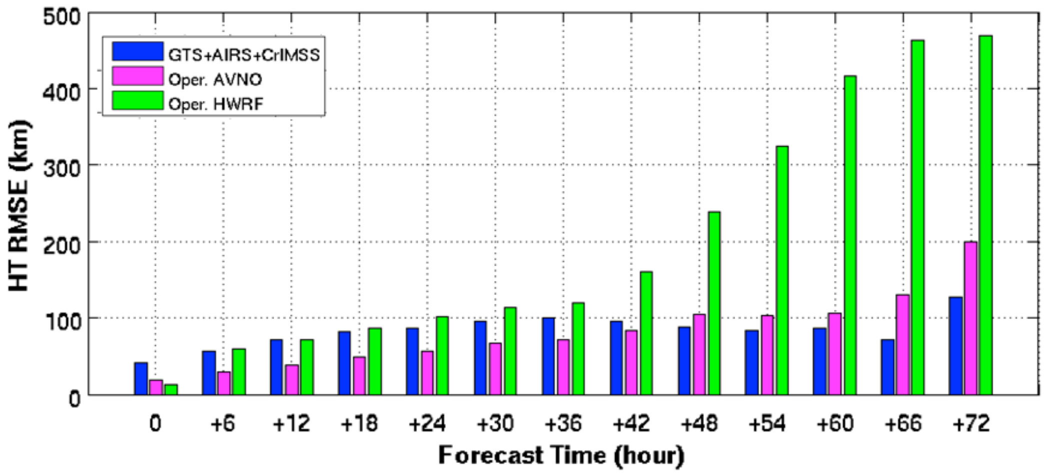

Figure 94. Sandy track forecast RMSE (km) from CIMSS experimental forecasts with GTS, AIRS, and CrIMSS data assimilated, the operational regional HWRF, and the operational global GFS forecasts (AVNO). Forecasts start from 12 UTC 25 Oct and valid 18 UTC 30 Oct 2012.

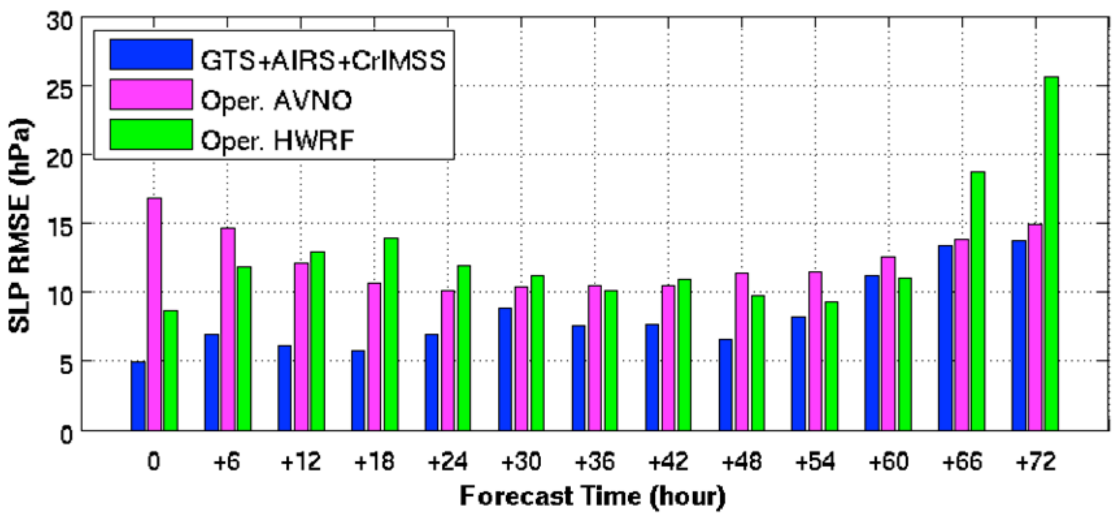

Figure 95. Sandy SLP RMSE (hPa) from CIMSS experimental forecasts with GTS, AIRS, and CrIMSS data assimilated, the operational HWRF, and the operational global GFS forecasts (AVNO). Forecasts start from 12 UTC 25 Oct and valid 18 UTC 30 Oct 2012.

As a forecast comparison example, Figure 96 shows the 72 hour track forecasts start from 18 UTC on 27 October 2012 from CIMSS experimental, operational HWRF and operational GFS.

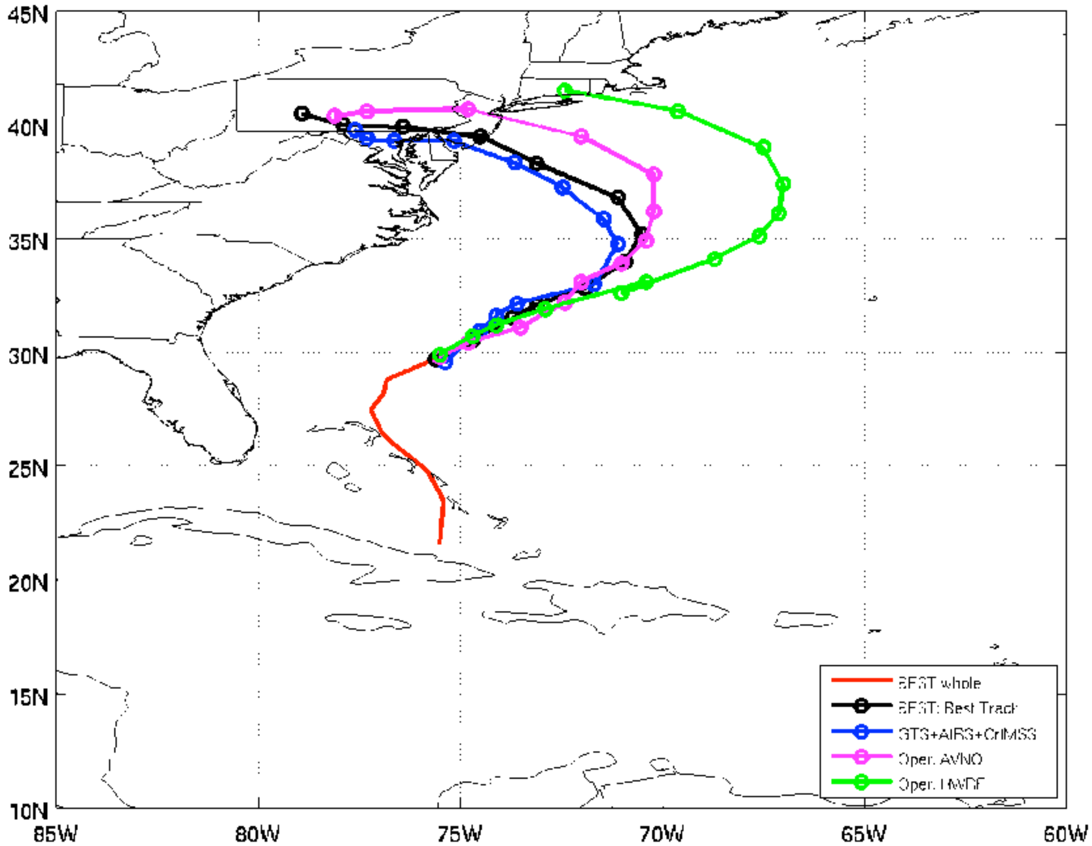

Figure 96. 72 hour forecasts start from 18 UTC 27 October 2012 from CIMSS experimental (blue), Operational (HWRF (green), and operational GFS (pink) along with the observation (black).

Publications, Reports, Presentations

Li, J., P. Wang, T. Schmit, C. Velden, and Jinlong Li, 2013: Improving tropical cyclone forecasts with advanced sounding measurements from satellites, IOAS/TROPICALSYMP, AMS 93rd Annual Meeting, 06 – 10 Jan 2013, Austin, TX.

Li, J., T. Schmit, P. Wang, C. Velden, Jinlong Li, Z. Li, and W. Bai, 2013: Improving tropical cyclone forecasts in regional NWP with GOES-R water vapor and JPSS sounder measurements, JCSDA Session at the 93rd AMS Annual Meeting 06 – 10 Jan 2013, Austin, TX.

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Zheng, J., J. Li, Jinlong Li, and T. J. Schmit, 2012: Assimilating AIRS Soundings with WRF/3DVAR for Hurricane Forecast Improvement, *Journal of Applied Meteorology and Climate* (submitted).

Li, J., 2012: Assimilation of satellite data in regional NWP - progress and challenges", invited talk at the NSF sponsored Earth Cube Workshop – Shaping the Development of EarthCube to Enable Advances in Data Assimilation and Ensemble Prediction, 17 – 18 December 2012, Boulder, Colorado.

19.2 Application of JPSS Imagers and Sounders to Tropical Cyclone Track and Intensity Forecasting

CIMSS Project Lead: Chris Velden
CIMSS Support Scientist: Derrick Herndon
NOAA Collaborator: Mark DeMaria

NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The time scale of tropical cyclone (TC) track and intensity changes is on the order of 12 hours, which makes JPSS instruments well suited for the analysis of these parameters. An application of JPSS data is being developed that uses thermal channels and radiance data from ATMS in the near storm environment to estimate TC intensity. This new information is being incorporated into existing intensity estimation techniques previously developed at CIMSS that already employ similar radiance data from AMSU and SSMIS. Once the ATMS algorithm is mature, the products will be made available through the JPSS Proving Ground to operational forecasters at the National Hurricane Center (NHC) and Joint Typhoon Warning Center (JTWC) for evaluation and feedback. If the evaluation is positive, the products can be transitioned to NHC and JTWC operations.

Summary of Accomplishments and Findings

Work so far has focused on data collection and algorithm development using AMSU data in preparation for the ATMS data, obtaining preliminary ATMS passes from the 2012 season, evaluating differences between AMSU and ATMS temperature anomalies, development of the first version of the intensity estimation algorithm using the ATMS microwave radiances, and beginning to adjust the CIMSS intensity estimation algorithm based on initial findings.

Brightness temperature (Tb) anomaly cross sections and the resulting Tb anomaly estimates for ATMS channels 7-9 can now be produced. The figure below shows example cross sections for Super Typhoon Jelewat (18W). The top image on September 25th represents a near ideal scan geometry with the center of the TC near nadir. Ideally, data matches would be limited to cases where aircraft ground truth data is available. However a lack of strong storms (CAT 4 and 5) in the Atlantic in 2012 required looking outside of this basin for cases that represent the upper bounds of the intensity scale. The Tb anomaly with STY Jelewat for the 17 UTC overpass on the 25^{th} yielded an anomaly of 7.9 K. This represents one of the largest Tb anomalies observed by a microwave sounder in a TC (SSMIS has observed similar magnitudes for storms with large eyes). The CIMSS AMSU algorithm only yielded an anomaly of 5.5 K three hours later. Jelewat was estimated to have an observed surface pressure anomaly of 88 hPa while the CIMSS intensity algorithm based on predicted values estimates a pressure anomaly of 99 hPa. Currently, the intensity algorithm is being refined and tested on independent cases.

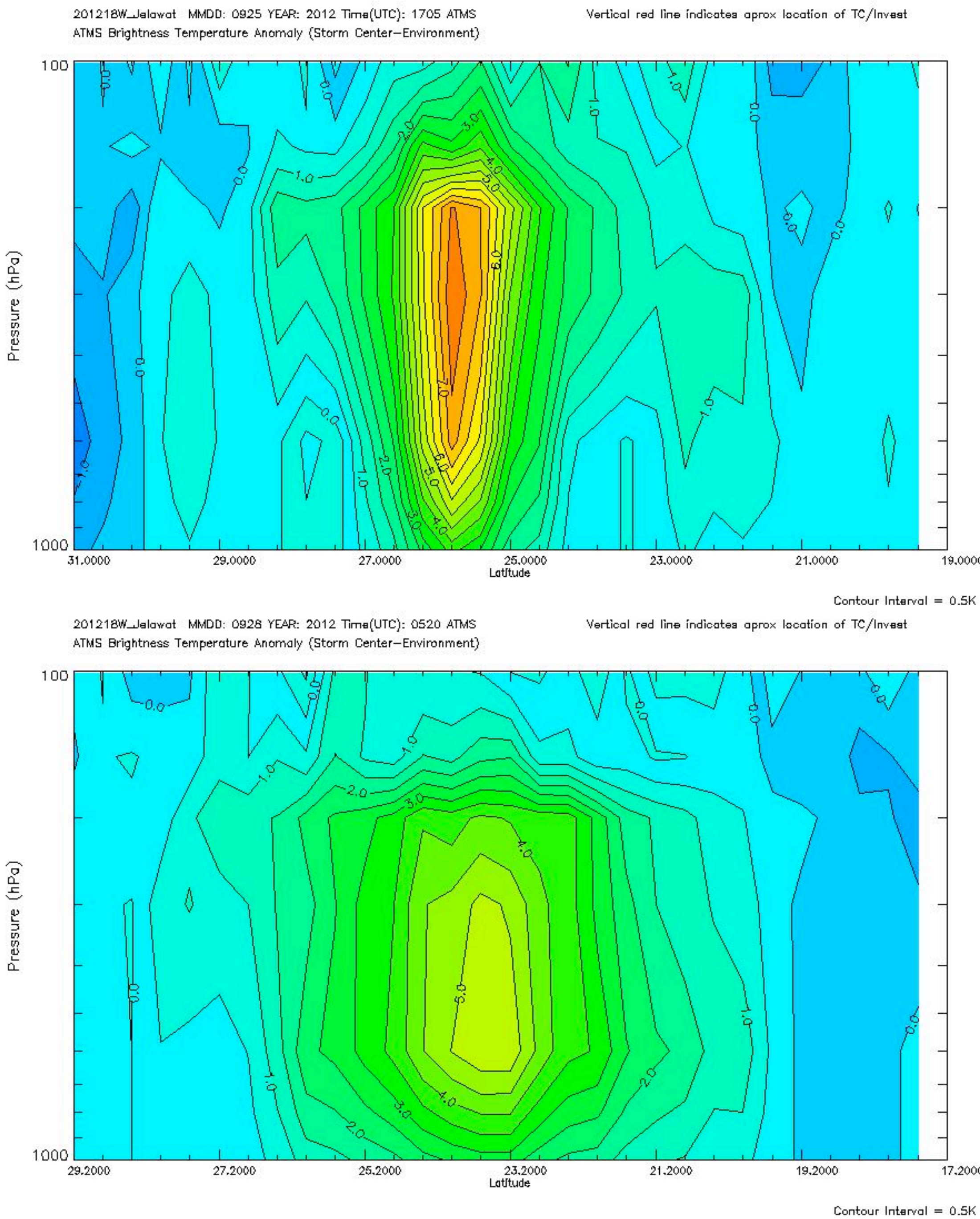

Figure 97. ATMS brightness temperature anomaly cross section for Super Typhoon Jelewat on September 25, 2012 (top) and September 28, 2012 (bottom). By the 28th, the Tb anomaly is reduced in magnitude while also expanding horizontally as the system underwent weakening.

19.3 Advancing Nighttime VIIRS Cloud Products with the Day/Night Band

CIMSS Project Lead: Andi Walther
CIMSS Support Scientist: Denis Botambekov
NOAA Collaborator: Andrew Heidinger

NOAA Strategic Goals Addressed:

- Understand climate variability and change to enhance society's ability to plan and respond

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

This ongoing 3-years project aims to use moonlight visible reflectance derived from measurements by the VIIRS Day/Night Band to improve cloud property and cloud mask retrievals during nighttime. The new algorithms are being developed as a part of an existing cloud processing system: CLouds from AVhrR-eXtended (CLAVR-x).

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) was designed to provide risk reduction and smooth transition to the future operational Joint Polar Satellite System (JPSS). NPP was successfully launched on October 28, 2011, and placed into a 1330 sun-synchronous orbit at 834 km altitude. The sensor of interest to this research is the Visible/Infrared Imager/Radiometer Suite (VIIRS), representing the successor optical-spectrum radiometer to the Advanced Very High Resolution Radiometers (AVHRR). The VIIRS "Day/Night Band" (DNB) is a sensor capable of measuring extremely low levels visible-band light down to the levels of moonlight reflectance with notable improvements to its predecessor in terms of calibration, radiometric and spatial resolution.

One component of the current CLAVR-x cloud retrieval scheme at CIMSS is the daytime cloud optical and microphysical properties (DCOMP) algorithm, which generates estimates of cloud optical thickness, cloud effective radius and ice/water path during daylight conditions [Walther and Heidinger, 2012].

This project involves a feasibility study if DCOMP is extendable to nighttime products by moonlight reflectance measurements. We will add a nighttime component to DCOMP by help of a lunar spectral irradiance model developed by Miller and Turner (2009).

Summary of Accomplishments and Findings

The lunar reflectance retrieval developed by Steven Miller of CIRA could be implemented in CLAVR-x framework. Solar to lunar reflection comparisons in clear-sky cases over deserts in South America had proved that daytime and nighttime visible reflectance are consistent to first order. These nighttime visible reflection values can be used for cloud properties and cloud mask retrievals.

Several extensive sensitivity studies and theoretical considerations to develop new cloud retrievals were carried out initially. We have been focusing on a bi-spectral approach with observations in the DNB and in M-12 (around 3.8 micron) to retrieve cloud optical thickness and effective radius. Figure 98 shows an example of the theoretical information content for a certain geometrical and surface condition constellation of such retrieval.

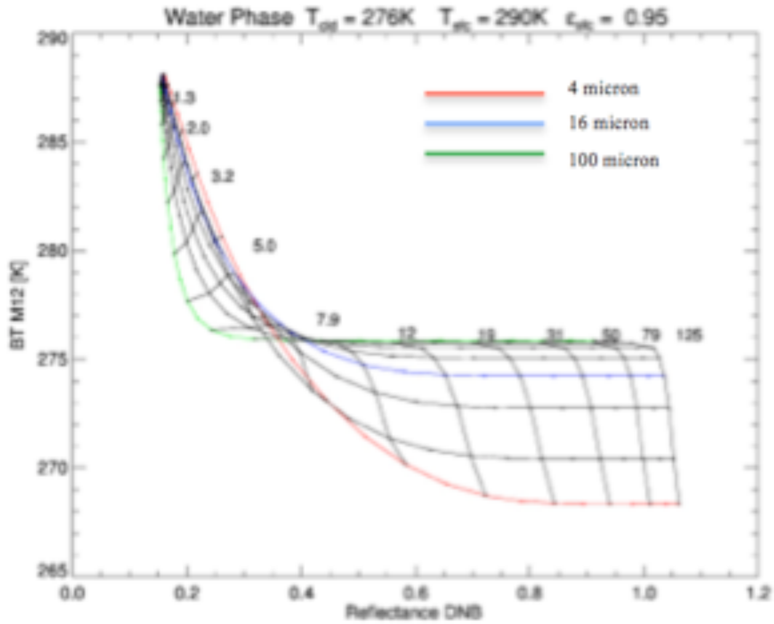

Figure 98. Bi-spectral function of COD and REF as a function of DNB reflectance and VIIRS M-12 brightness temperature for cloud temperature of 276K and surface temperature of 290K.

As a next step, the new Nighttime Lunar Cloud Optical and Microphysical Properties (NLCOMP) retrieval was developed as a stand-alone algorithm tool and as a module of CLAVR-x. First evaluation analysis has shown the potential and the importance of NLCOMP. The figure below shows derived cloud optical thickness from NLCOMP for a nighttime scene in comparison to the GOES-15 daytime retrievals from evening before and the morning after the VIIRS night scene. This is a promising example how NLCOMP can help to investigate diurnal cycle of optical properties.

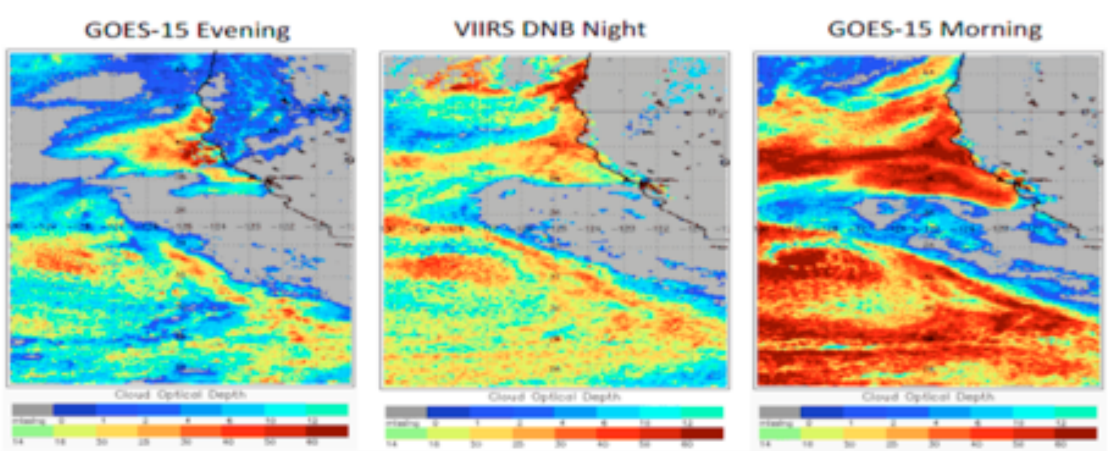

Figure 99. Comparison of the cloud optical depth evolution from VIIRS and GOES-15. All data is from April 26, 2013. Image on the right is NOAA/DCOMP applied to GOES-15 Evening data is observed 6:30 PM local, the GOES-15 Morning is observed at 9:30 AM local, the VIIRS Night are observed at 1:30 AM local.

Publications, Reports, Presentations

Walther, A., A. K. Heidinger and S.D. Miller, 2013: The Expected Performance of Cloud Optical and Microphysical Properties derived from S-NPP VIIRS DNB Lunar Reflectances, submitted to *JGR*.

20 Development of the High Performance JPSS Analysis Facility for Instrument Impacts on Requirements (JAFIIR)

CIMSS Project Lead: Bormin Huang
CIMSS Support Scientists: Allen Huang, Jarno Mielikainen, Mat Gunshor, Hong Zhang
NOAA Collaborator: Mitch Goldberg / NOAA JPSS Office
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques

Project Overview

- JAFIIR is designed to assess and evaluate many of the JPSS data and products (i.e., imagery, clouds, derived products, soundings, fire, SST, ocean color, aerosol, etc.) in a consistent way, to ensure that instrument effects on products can be fully accounted for, characterized and product performance optimized.
- JAFIIR is designed to develop high performance GPU-based radiative transfer modeling, numerical weather prediction, and time-critical analyses; these are required to support JPSS sensor simulation, sensor trade analysis, and high spatial resolution sensor measurement simulation.
- JAFIIR is a coordinated team effort from JPSS Risk Reduction, Proving Ground and other related sensor calibration/validation projects; it will not independently develop any new algorithms or processing methods that are already available or are currently under development.

JAFIIR is a 3-year project.

Summary of Accomplishments and Findings

- Glance expanded capabilities to read AWIPS files.
    - Working toward GEOTIFF file format.
- VIIRS radiance perturbation code being developed.
    - Can currently add a 'calibration offset' of a specified amount.
- CSPP Cloud Mask Example
    - VIIRS 10.8um band M15 altered with 1K and 3K offsets for 3 time periods.
    - Cloud Mask and Cloud Phase generated for original, 1K and 3K cases.
    - Glance used to compare results of 1K and 3K cases to original, unaltered.
- The core WRF model consists of a dynamic solver and 8 physics packages. Each physics package also includes several schemes as users' options. We have finished the following modules with very promising speedups.

WRF Module name	Speedup
Single moment 6-class microphysics	500x
Eta microphysics	272x
Purdue Lin microphysics	692x
Stony-Brook University 5-class microphysics	896x
Betts-Miller-Janjic convection	105x
Kessler microphysics	816x
New Goddard shortwave radiance	134x
Single moment 3-class microphysics	331x
New Thompson microphysics	153x
Double moment 6-class microphysics	206x
Dudhia shortwave radiance	409x
Goddard microphysics	1311x
Double moment 5-class microphysics	206x
Total Energy Mass Flux (TEMF) surface layer	214x
Mellor-Yamada Nakanishi Niino (MYNN) surface layer	113x
Single moment 5-class microphysics	350x
Pleim-Xiu surface layer	665x

Publications, Reports, Presentations

J. Mielikainen, B. Huang, A. Huang and M. Goldberg, GPU Implementation of Stony-Brook University 5-Class Cloud Microphysics Scheme in the WRF, *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (J-STARS)*, doi: 10.1109/JSTARS. 2011.2175707.

J. Mielikainen, B. Huang, A. Huang and M. Goldberg, GPU Acceleration of the Updated Goddard Shortwave Radiation Scheme in the Weather Research and Forecasting (WRF) Model, *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (J-STARS)*; doi: 10.1109/JSTARS.2012.2186119.

J. Mielikainen, B. Huang, A. Huang and M. Goldberg, Improved GPU/CUDA Based Parallel Weather and Research Forecast (WRF) Single Moment 5-class (WSM5) Cloud Microphysics, *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (J-STARS)*; doi: 10.1109/JSTARS.2012.2188780.

J. Mielikainen, B. Huang, A. Huang and M. Goldberg, Development of the GPU-based Stony-Brook University 5-class microphysics scheme in the weather research and forecasting model, *Proc. SPIE* **8183**, 81830V (2011); doi:10.1117/12.901829.

J. Mielikainen, B. Huang, A. Huang and M. Goldberg, GPU acceleration of WRF WSM5 microphysics, *Proc. SPIE* **8183**, 81830S (2011); doi:10.1117/12.901826.

B. Huang, J. Mielikainen, H. Oh, H.-L. Huang, Development of a GPU-based high-performance radiative transfer model for the Infrared Atmospheric Sounding Interferometer (IASI), *Journal of Computational Physics*, **230**, no. 6, pp. 2207-2221, doi; 10.1016/j.jcp.2010.09.011.

21 The Development of a Community Satellite Processing Package (CSPP) in support of Suomi NPP/JPSS Real Time Regional (RTR) Applications

CIMSS Project Leads: Allen Huang (PI), Liam Gumley (PM)
CIMSS Support Scientists: Scott Mindock, Ray Garcia, Graeme Martin, Geoff Cureton, Kathy Strabala, Elisabeth Weisz, Nadia Smith, Nick Bearson, Jim Davies
NOAA Collaborator: Mitch Goldberg JPSS

NOAA Strategic Goals Addressed:
- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

CIMSS Research Themes:
- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques
- Outreach and Education

Project Overview

The Community Satellite Processing Package (CSPP) supports the Direct Broadcast (DB) meteorological and environmental satellite community through the packaging and distribution of open source science software. CSPP supports DB users of both polar orbiting and geostationary satellite data processing and regional real-time applications through distribution of free open source software, and through training in local product applications. The Suomi NPP/JPSS component of the Community Satellite Processing Package (CSPP) for DB transforms VIIRS, CrIS, and ATMS RDRs to SDRs and selected EDRs, and is optimized for real-time processing and regional applications. CSPP has also released software packages supporting processing of IASI, AIRS, MODIS, and AVHRR data.

Summary of Accomplishments and Findings

The CSPP software suite currently includes software for generating the following products:
- VIIRS M-band, I-band, and Day/Night band radiances, reflectances, and geolocation;
- CrIS radiances and geolocation;
- ATMS antenna temperatures and geolocation;
- CrIS, IASI, and AIRS temperature and moisture profiles and cloud-top parameters;
- VIIRS Cloud Mask, Active Fires, Aerosol Optical Thickness, and Sea Surface Temperature; and
- Projected VIIRS and MODIS imagery in AWIPS and GeoTIFF formats, including atmospherically corrected true color imagery.

Software packages currently in testing for release as part of CSPP in the next 6 months include:
- VIIRS Surface Reflectance and Vegetation Index;
- VIIRS, AVHRR, and MODIS Cloud Top Parameters from CLAVR-X;
- ATMS products NESDIS/MIRS; and
- Temperature and moisture profiles via physical retrieval from NESDIS/NUCAPS.

Value added features for Suomi NPP products provided in CSPP include aggregation of multiple granules into one granule per satellite overpass, internal compression of HDF5 product files, and automatic run-time downloading of any required dynamic ancillary data.

The CSPP software for Suomi NPP is based on the Algorithm Development Library (ADL) developed by Raytheon and the JPSS project. This means that the CSPP software is the same software that runs in the operational processing facility at NOAA/NESDIS. SSEC has packaged the software to run from the Linux command line in real-time direct broadcast mode, but we have not changed the underlying processing software, algorithms, or data formats. The output files from the CSPP SDR processing software are identical in naming, format, and structure to the corresponding files from NOAA/NESDIS. The native format for NPP SDR products is HDF5, and descriptions of the NPP file formats are available in the "Common Data Format Control Books".

CSPP software is now in use at operational agencies around the world, including NOAA, UK Met Office, MeteoFrance, DWD, SMHI, FMI, CONABIO, NSMC, JMA, and BoM. Products created by CSPP are in daily use at National Weather Service Offices across the United States. Applications at the NWS include sea ice mapping, hurricane monitoring, night time fog detection. See the following NWS forecast discussion or an example:

NORTHERN ALASKA FORECAST DISCUSSION NATIONAL WEATHER SERVICE FAIRBANKS AK 1258 PM AKDT MON MAR 11 2013

NORTH SLOPE…THE SUOMI NPP VIIRS SATELLITE FOG PRODUCT WAS INDICATING A DECENT LAYER OF STRATUS ALONG THE NORTH SLOPE. OBSERVATIONS ACROSS THE AREA GENERALLY INDICATED 1 TO 2 MILES IN VISIBILITY WITH FLURRIES AND FOG. THE IFR CONDITIONS ALIGN VERY WELL WITH THE HIGHER PROBABILITIES OF MODIS IFR PRODUCT. THERE ARE SOME VERY ISOLATED POCKETS OF HIGHER PROBABILITIES OF THE MODIS LIFR CONDITIONS. THESE CONDITIONS SHOULD REMAIN THROUGH TUESDAY EVENING OR WEDNESDAY MORNING AS THE SURFACE HIGH PRESSURE REMAINS WITHIN THE AREA. BY WEDNESDAY MORNING THE SURFACE PRESSURE GRADIENT BEGINS TO TIGHTEN…PROVIDING AN INCREASE IN WINDS AND PERHAPS A BREAK IN SOME OF THE FOG.

Publications, Reports, Presentations

Presentations on CSPP have been given at the NOAA Satellite Conference (April 2013) and the 2013 IGARSS conference (August 2013).

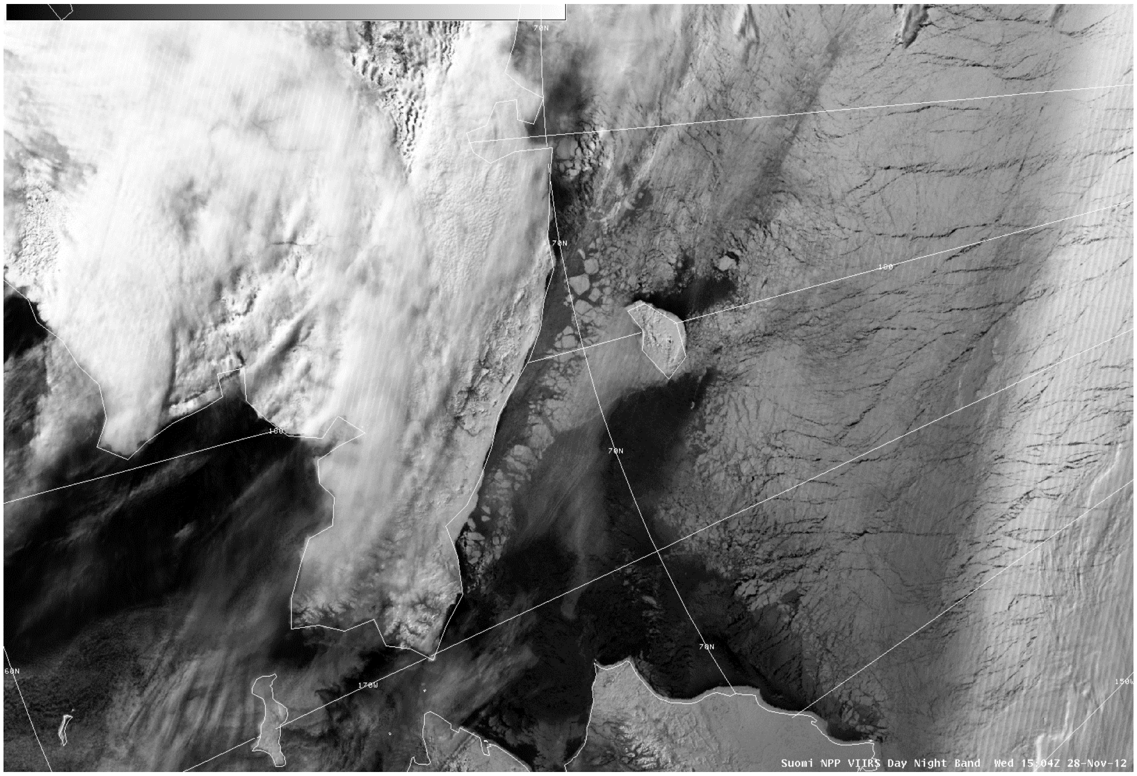

Figure 100. SNPP Day/Night Band Imagery Processed by CSPP at GINA and provided to NWS Anchorage.

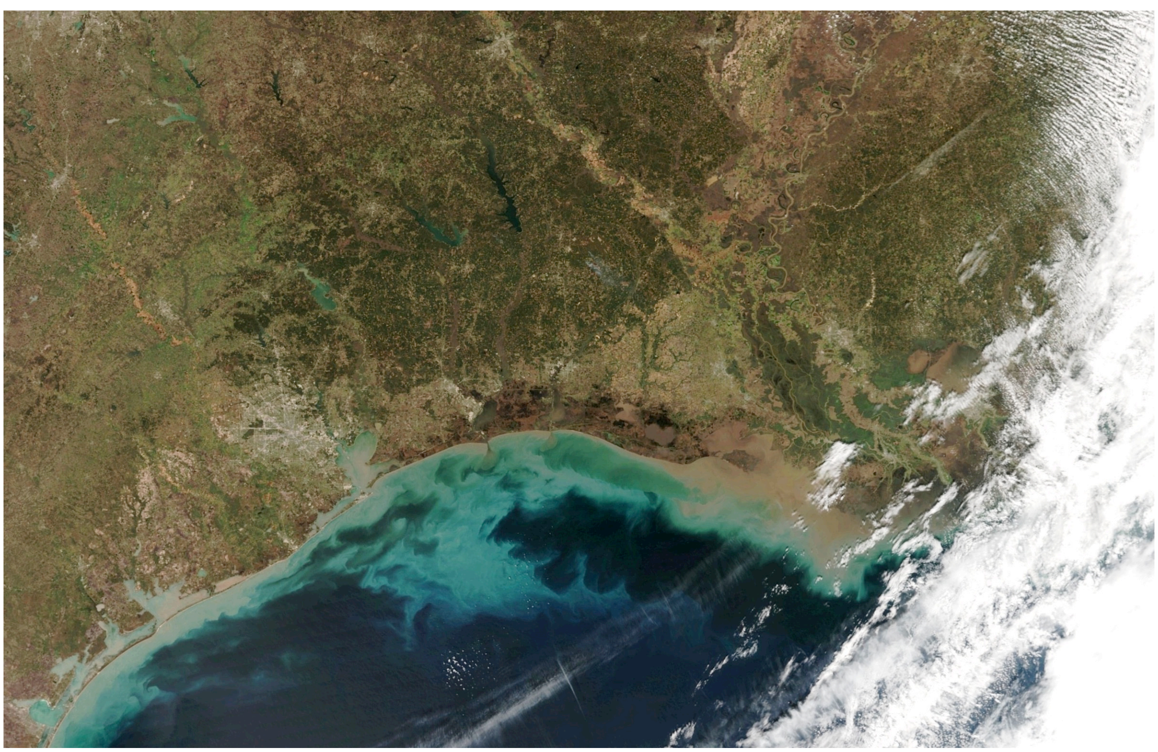

Figure 101. VIIRS True Color Imagery produced by CSPP.

22 SSEC/CIMSS Participation on the Algorithm Development Library (ADL) Team

CIMSS Project Leads: Liam Gumley (PI), Scott Mindock (PM)
CIMSS Support Scientists: Ray Garcia, Graeme Martin, Geoff Cureton, Kathy Strabala, Jim Davies
NOAA Collaborators: Pat Purcell, Richard Ullman (JPSS)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

SSEC supports the JPSS project as a member of the Algorithm Development Library (ADL) Team. SSEC will support the ADL project by:

- Acting as the release point for ADL to the JPSS user community,
- Maintaining the ADL Web site and User Forum,
- Providing user support for installing and operating ADL,
- Providing training material and courses for end users of ADL,
- Developing and enhancing the Virtual Appliance distribution of ADL,
- Developing an ingest and pre-processing capability for dynamic ancillary data in ADL,
- Verifying compatibility with RDRs from Direct Broadcast sources,
- Checking compatibility of Direct Broadcast produced SDRs with the corresponding IDPS SDRs, and
- Verifying robustness of ADL distributions before public release.

SSEC works closely with the Raytheon ADL development team and the JPSS project to ensure that ADL meets the needs of users who wish to execute and modify IDPS PRO algorithms outside the operational IDPS environment.

Summary of Accomplishments and Findings

1. SSEC released ADL 4.0 to the user community in July 2011. ADL 4.1 followed in October 2011. The releases were available in two formats: (a) source code as delivered by Raytheon, with explicit instructions developed by SSEC for installing prerequisite packages and building the software, and (b) a 64-bit Linux virtual appliance where all prerequisites are installed and ADL is built and ready to run.

2. SSEC evaluated robustness of ADL software before public release. Defects were found in the compilation of non-debug mode version of ADL 4.0. These defects were reported to Raytheon Team. The Raytheon Team repaired the defects before public release, saving end users time and money.

3. SSEC investigated methods for improving VIIRS SDR performance by leveraging different platform and compiler combinations. Results of this investigation to were reported to ADL users at the ADL workshop in November of 2012.

4. SSEC supplied Raytheon with patch for improved ADL compatibility with more recent versions of the GCC compiler. Raytheon incorporated many of the changes into the 12 2012 Raytheon patch.

5. SSEC developed and supplied instructions for updating the virtual appliance to leverage Raytheon patches made available in the Common CM environment.

6. SSEC released the updated version of the ShellB3 Python library for working with ADL executable and data files, and supplied this package to the ADL team at Raytheon.

7. SSEC released updated ancillary data including calibration LUTS required for SDR processing.

8. SSEC continued to develop and refine the ADL Web site for documentation and user instructions and the ADL Forum for user interaction. The Web site is available at

https://jpss-adl-wiki.ssec.wisc.edu

and includes information on ADL Software and Downloads, Installation Instructions, Scripts and Helper Applications, ADL Virtual Appliance, HOWTOs, Add-Ons, and a link to the ADL help desk email address. The Web site also contains links to the ADL ancillary data Web site.

9. The ADL Virtual Appliance (VA), built on 64-bit Ubuntu Linux, continued to be a popular method for end users to download, install and run ADL. The ADL VA allows end users who may not have access to a configurable Linux system (e.g., users in the NOAA security zone) a way to get started with ADL using a Windows host computer. The ADL Virtual Appliance functions identically to a native Linux install of ADL, and provides all the functionality of the ADL build and run environment.

10. The ShellB3 Python scripting environment released by SSEC provides a portable pre-built library of read-to-run utility scripts for assisting with common tasks in ADL, including:

- Reading and writing HDF5 and BLOB files,
- Converting native ancillary data formats (e.g., GRIB) to BLOB format,
- BLOB read-write access (big and little endian),
- ASC metadata manipulation,
- Ancillary data gridding and granulation, and
- HDF5 file comparisons (e.g., for comparing output files from different versions of a retrieval algorithm).

11. SSEC operates a real-time ancillary data ingest and distribution site to provide a one-stop shop for ADL users top obtain the ancillary data needed to run SDR and EDR algorithms in ADL. The Web site is available at http://jpssdb.ssec.wisc.edu/ancillary/.

Publications, Reports, Presentations

SSEC participated in ADL workshops held at NASA GSFC in January and November, 2012. Status of the ADL effort at UW/SSEC was presented by Scott Mindock.

23 Science and Management Support for NPP VIIRS Snow and Ice EDRs

CIMSS Project Lead: Yinghui Liu

CIMSS Support Scientist: Xuanji Wang
NOAA Collaborator: Jeffrey R. Key, NOAA/NESDIS
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

The Visible Infrared Imaging Radiometer Suite (VIIRS) provides the majority of the Environmental Data Records (EDR) on the Suomi National Polar-orbiting Partnership (NPP; formerly the NPOESS Preparatory Project) satellite. Cryosphere (snow and ice) products are fundamental to weather prediction, hazard detection, transportation, recreation, and climate monitoring, and are therefore an important part of the suite of VIIRS EDRs.

NESDIS/STAR is taking the managerial and technical leadership of NPP and Joint Polar Satellite System (JPSS) cryosphere product development and evaluation activities. The JPSS Cryosphere Team will produce snow and ice Environmental Data Records (EDRs) from visible, infrared, and microwave data. For the purposes of this proposal, however, only those EDRs produced from VIIRS are considered. The VIIRS snow and ice EDRs are sea ice characterization, ice surface temperature, and snow cover/depth. Sea ice characterization includes an ice concentration intermediate product (IP).

The Cryosphere Team is a unified combination of Subject Matter Experts (SMEs) from academia and government. Scientists from the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison are an integral part of the team. Research at CIMSS focuses on the sea ice EDRs, in collaboration with colleagues at the Cooperative Institute for Research in the Environmental Sciences (CIRES) at the University of Colorado-Boulder. Snow cover research is being conducted at the Cooperative Remote Sensing Science and Technology Center (CREST)/City College of New York (CCNY).

Summary of Accomplishments and Findings

- The Team has developed an automated validation system for VIIRS ice products. This tool routinely acquires VIIRS SDRs, IPs, and ice EDRs, in situ ice data, and ice products from other various satellite sensors. The SDRs include VIIRS moderate resolution band SDRs, VIIRS image band SDRs, and corresponding terrain-corrected geolocation SDRs. The IPs include VIIRS ice concentration IP, VIIRS ice reflectance and temperature IP, VIIRS ice quality flag IP, VIIRS ice weights IP, and VIIRS cloud mask IP. The EDRs include VIIRS ice surface temperature EDR, VIIRS sea ice characterization EDR, VIIRS cloud cover and layers EDR. This tool automatically collocates VIIRS products with other products, does statistic analysis for the collocated VIIRS ice products and other products, plots all the products and presents all the products on the Web site maintained at CIMSS, and archives all the analysis results and plots since July 2012.
- The cryosphere team participates in the evaluation of the snow/ice product gridding process and its impact on downstream products. We evaluate the mechanics and quality of the VIIRS snow/ice gridding procedure and the resulting Snow/Ice Rolling Tiles product. Other EDRs, notably the VIIRS Cloud Mask, use the Snow/Ice Rolling Tiles to determine the locations of snow and ice. The gridding process updates this snow/ice

background by incorporating recent information from the Ice Concentration IP and the Snow Cover EDR, when and where available. Three data pulls haven been done in an attempt to improve this process. A local granule-to-grid running environment similar as the operational process has been set up to facilitate these attempts. Series of tests have been performed to evaluate and improve the snow/ice products gridding process. By adding new filtering of cloud detection quality and ice concentration quality, the updated snow/ice products gridding process has been improved. Fallback to the NOAA GMASI during the gridding process has also been tested.

- All collocated VIIRS and MODIS Terra and Aqua ice surface temperature retrievals under clear sky conditions were collected from August 2012 to May 2013 over both the Arctic and Antarctic. In each month, a histogram of ice surface temperature differences of VIIRS and MODIS was plotted for all cases, binned for MODIS ice surface temperature between 230 and 240 K, 240 and 250 K, 250 and 260 K, 260 and 270 K, and 270 and 273 K. The bias is defined as the mean of the measurement errors (differences). Measurement uncertainty is defined as the root-mean-square of the measurement errors. An example of the histogram and statistical analysis in February 2013 is shown in Figure 102. Over 100 million collocated cases were used. The VIIRS ice surface temperature retrievals show the largest negative bias and measurement uncertainty when the surface temperature is close to melting point. With lower surface temperatures, the VIIRS ice surface temperature retrievals show a smaller negative bias and smaller measurement uncertainty. Overall, the measurement uncertainty of VIIRS ice surface temperature retrievals is slightly over 1 K. The performance in other months is similar for both the Arctic and Antarctic.
- All collocated VIIRS and passive microwave sea ice concentration retrievals in each month were collected from August 2012 to May 2013 over both the Arctic and Antarctic. In each month, histograms of sea ice concentration differences between the VIIRS and passive microwave products were plotted for all cases and for cases with passive microwave sea ice concentrations in the bins 0-20%, 20-40%, 40-60%, 60-80%, and 80-100%. Over 200,000 collocated cases were collected in that month. The VIIRS sea ice concentration retrievals show the smallest bias and precision, defined as the standard deviation of the measurement errors, for surface sea ice concentration between 80 and 100%. With lower sea ice concentration, the VIIRS retrievals show larger values of measurement bias and precision. Overall, the measurement accuracy and precision of VIIRS sea ice concentration retrievals are approximately 5% and 15%, respectively. These relatively small values are due to the larger percentage of cases with sea ice concentration between 80 and 100%. The performance in other months is similar for both the Arctic and Antarctic.

Publications, Reports, Presentations

Key, J., R. Mahoney, Y. Liu, P. Romanov, M. Tschudi, I. Appel, J. Maslanik, D. Baldwin, X. Wang, and P. Meade, 2013, Snow and ice products from Suomi NPP VIIRS, *J. Geophys. Res.-Atmospheres*, submitted (June 2013).

Liu Y., R. Mahoney, J. Key, X. Wang, D. Baldwin, J. Maslanik, and M. Tschudi, Observing Sea Ice from the Suomi NPP VIIRS, 2013 EUMETSAT and 19th AMS Meteorological Satellite Conference, 16 - 20 September 2013, Vienna, Austria.

Liu Yinghui, Key R. Jeffrey, Wang Xuanji, On the Arctic sea ice, clouds and the atmosphere interactions from satellite observations. (talk), 2012 Earth Observation and Cryosphere Science, 13 - 16 November 2012, Frascati, Italy.

Liu, Y., J. R. Key, Z. Liu, X. Wang, and S. J. Vavrus (2012), A cloudier Arctic expected with diminishing sea ice, *Geophys. Res. Lett.*, **39**, L05705, doi:10.1029/2012GL051251.

Wang, X., J. Key, Y. Liu, Arctic Climate Change: Trends in Surface, Cloud, Radiation, and Sea Ice Properties from Satellite Data (Talk), 2012 IPY Conference: From Knowledge To Action, April 22-27, 2012, Montreal, Canada.

Wang, X., J. Key, Y. Liu, Arctic Sea Ice Changes, Interactions, and Feedbacks on the Arctic Climate during the Satellite Era (Invited talk), 2011 AGU Fall Meeting, 5-9 December 2011, San Francisco California, USA.

Liu, Y., J. Key, X. Wang, Understanding the interactions and feedbacks between Arctic sea ice, clouds, and the atmosphere from satellite observations, (keynote talk), 2011 EUMESAT meteorological satellite conference, September 5-9, 2011, Oslo, Norway.

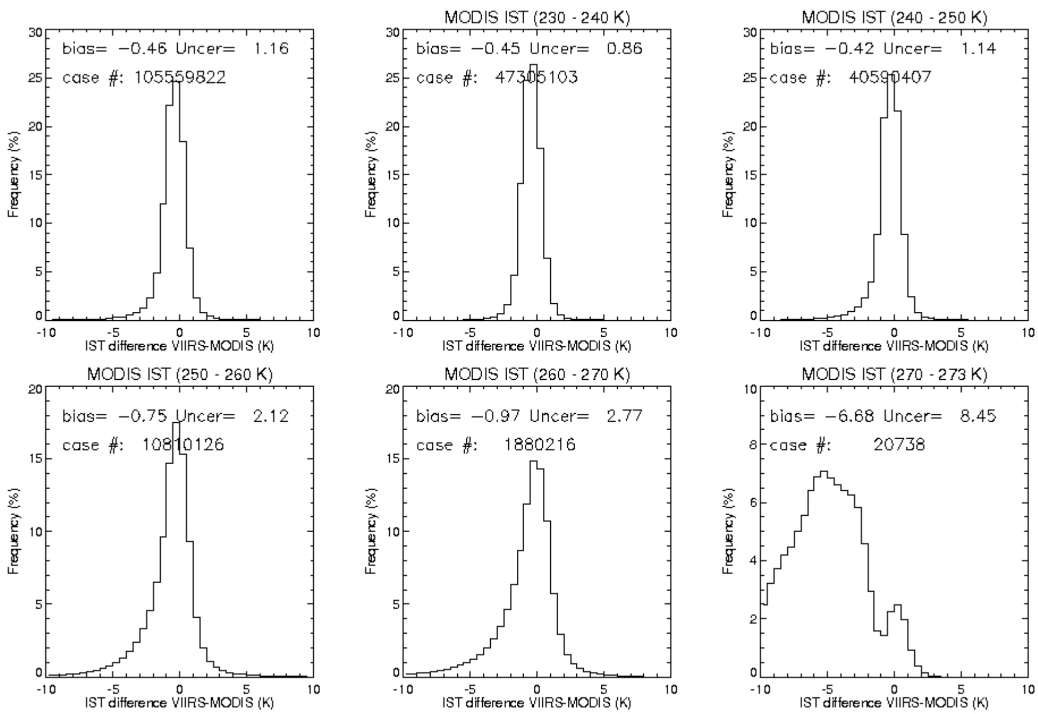

Figure 102. Histogram of ice surface temperature differences of NPP VIIRS and MODIS (Aqua and Terra) in February 2013 in the Arctic for all cases (upper left), and for cases with MODIS ice surface temperature in the ranges 230-240 K, 240-250 K, 250-260 K, 260-270 K, and 270-273 K. Measurement bias (bias) and measurement uncertainty (Prec) are indicated for each bin.

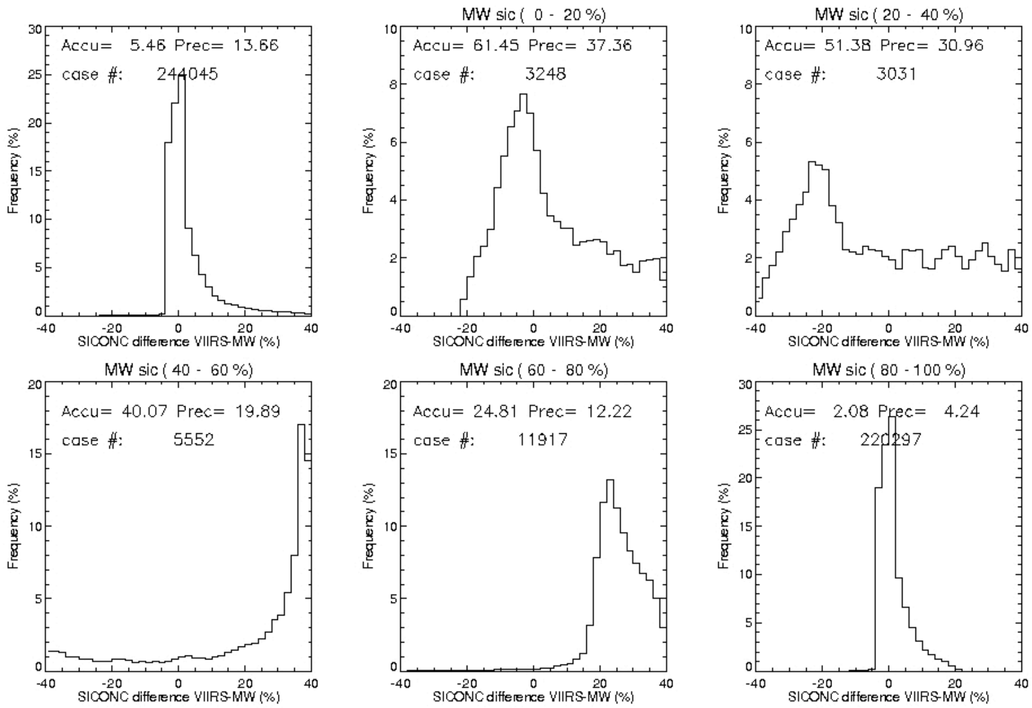

Figure 103. Histogram of sea ice concentration differences of NPP VIIRS and Microwave using NASA team algorithm in February 2013 in the Arctic for all cases (upper left), and cases with Microwave sea ice concentration in the ranges 0-20%, 20-40%, 40-60%, 60-80%, and 80-100%. Measurement accuracy (bias) and measurement precision (Prec) are indicated for each bin.

24 Sea Ice Thickness from Aqua and Terra Data Acquisition, Evaluation and Applications

CIMSS Project Lead: Xuanji Wang
CIMSS Support Scientist: Yinghui Liu
NOAA Collaborator: Jeff Key, NOAA/NESDIS
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

This project is a three yearlong project started in December 2011. The main goals of this project are to:

- Develop and evaluate improved data sets suitable for investigating and predicting inter-annual, global and regional variability in ice thickness and volume;
- Use these products to assess fundamental changes in sea ice thickness, volume and age; and
- Demonstrate the utility of these data for evaluating the performance of sea ice simulations within a state-of-the-art climate model.

To meet the goals, tasks fall into two categories: (1) product generation, evaluation and accuracy assessment, and (2) applications to study spatial and temporal variabilities in ice thickness over a long time period, and to relate these variabilities to various climate forcings. Research at CIMSS focuses on the estimation of ice thickness from optical (visible/infrared) sensors such as AVHRR, MODIS, and VIIRS.

Summary of Accomplishments and Findings

During the project period, specific tasks included:

- All MODIS data starting from 2000 to 2012 have been collected for the Arctic, daily composites of MODIS data at local solar times of 04:00 and 14:00 have been generated on the EASE grid with channel, cloud, and ice surface temperature information for the generation of MODIS sea ice thickness dataset;
- APP-x data now cover the period of 1982 ~ 2012;
- One-dimensional Thermodynamic Ice Model (OTIM) for use with MODIS Terra & Aqua composite data has been further improved and modified, and is undergoing processing to generate MODIS sea ice thickness dataset over 2002 ~ 2012;
- ICESat retrieved sea ice thickness data (Kwok et al., 2009) over 2003 ~ 2008 from Ron Kwok have been remapped to the EASE grid for the evaluation study, and the preliminary comparison between ICESat and OTIM with APPx data has been done; and
- IceBridge retrieved sea ice thickness data over 2009 ~ 2011 have been collected and remapped to the EASE grid for the evaluation study, and the comparisons between IceBridge and OTIM with both APPx and MODIS data are undergoing now.

The OTIM results compare well with in-situ measurements and reasonably well with ICESat thicknesses and CU ice age. Four data sets from AVHRR, MODIS, ICESat, and ICeBridge have been collected and/or generated with updated algorithms and dates as mentioned above. Figure 104 shows examples of the above four data sources for the Arctic.

Publications, Reports, Presentations

Xuanji Wang, Jeffrey Key, Yinghui Liu, Charles Fowler, James Maslanik, and Mark Tschudi, 2012, Arctic Climate Variability and Trends from Satellite Observations, *Advances in Meteorology*, **2012**, Article ID 505613, 22 pages, doi:10.1155/2012/505613.

Liu, Y., J. R. Key, Z. Liu, X. Wang, and S. J. Vavrus (2012), A cloudier Arctic expected with diminishing sea ice, *Geophys. Res. Lett.*, **39**, L05705, doi:10.1029/2012GL051251.

Xuanji Wang, Jeffrey Key, and Yinghui Liu, 2010, A thermodynamic model for estimating sea and lake ice thickness with optical satellite data, *J. Geophys. Res.*, **115**, C12035, doi:10.1029/2009JC005857.

Xuanji Wang, Jeffrey R. Key, Yinghui Liu, Sea Ice Estimation and Inter-comparisons from Different Satellite Data, 2012 Earth Observation and Cryosphere Science, 13 - 16 November 2012, Frascati, Italy.

Xuanji Wang, Jeffrey R. Key, Yinghui Liu, Understanding Arctic Sea Ice and Climate Changes from Satellite Observations (Talk), 2012 EUMETSAT Meteorological Satellite Conference, 3-7 September 2012, Sopot, Poland.

Xuanji Wang, Jeffrey R. Key, Yinghui Liu, Arctic Climate Change: Trends in Surface, Cloud, Radiation, and Sea Ice Properties from Satellite Data (Talk), 2012 IPY Conference: From Knowledge To Action, April 22-27, 2012, Montreal, Canada.

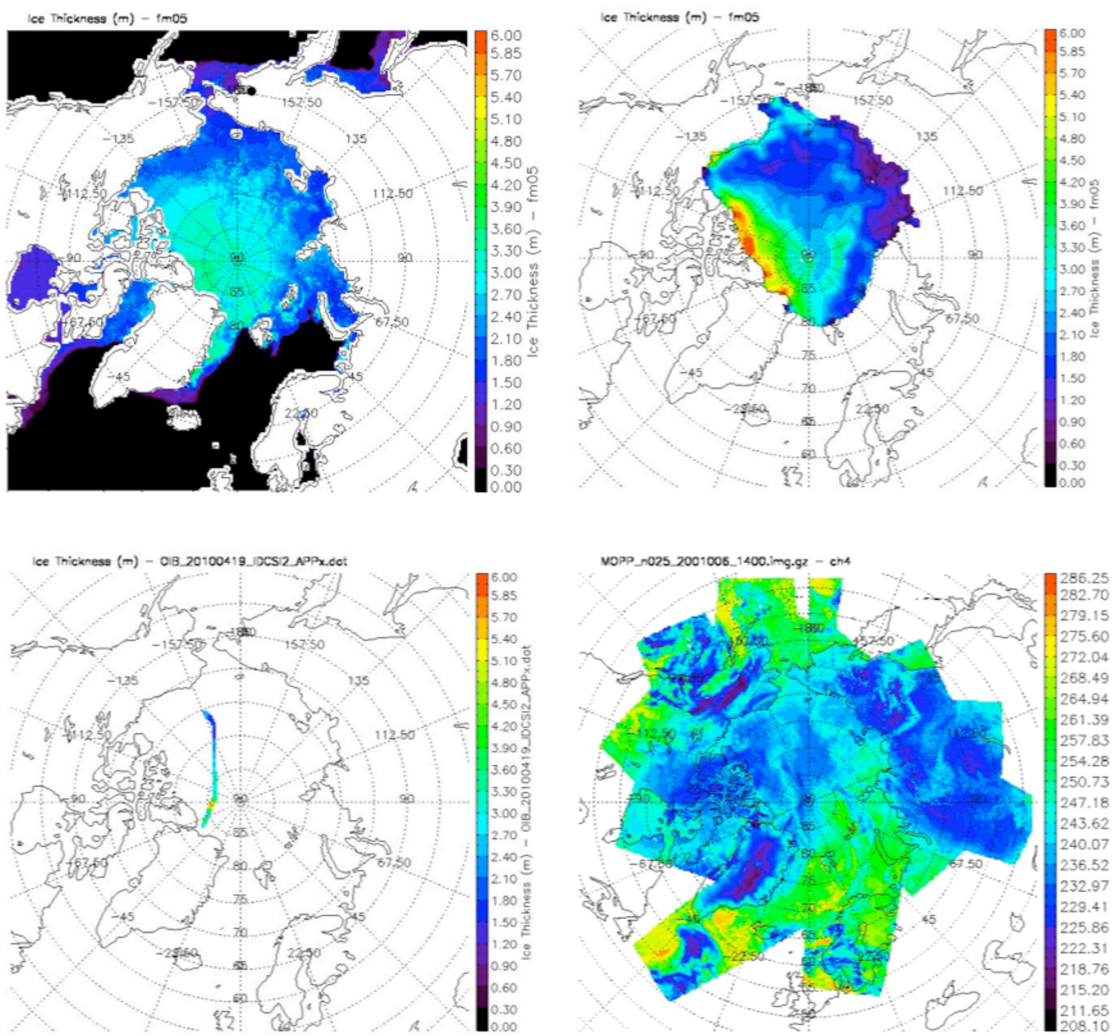

Figure 104. Sea ice thickness fields generated by OTIM with AVHRR data (upper-left) and ICESat altimeter data (upper-right) for the period of Feb 17-Mar 24, 2005, and IceBridge altimeter data (lower-left) for the 19th day of April 2001. An example of MODIS daily composites for the band 31 (equivalent to AVHRR channel 4) brightness temperature is also shown here (lower-right).

25 Implementation of GCOM-W1 AMSR2 Snow Products

<u>CIMSS Project Lead</u>: Yong-Keun Lee

<u>NOAA and Other Collaborators</u>: Jeffrey R. Key and Cezar Kongoli (CICS)

<u>NOAA Strategic Goals Addressed</u>:

- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

<u>CIMSS Research Themes</u>:

- Satellite meteorology research and applications

Project Overview

The Advanced Microwave Scanning Radiometer 2 (AMSR2) is the next generation of the AMSR-E instrument that is currently on NASA's Aqua satellite. AMSR2 is on the Japan Aerospace Exploration Agency (JAXA) Global Change Observation Mission 1st – Water (GCOM-W1) satellite. GCOM-W1 was launched in May 2012. NOAA is supporting work with AMSR2 as part of the Joint Polar Satellite System (JPSS) program.

Monitoring of cryosphere, and in particular of the Earth's snow cover, is among primary applications of the AMSR2 instrument. AMSR2 cryosphere environmental data records (EDRs) are Ice Characterization, Snow Cover/Depth, and Snow Water Equivalent (SWE). Snow Cover/Depth includes a binary snow/no snow mask and the depth of snow on land. Snow Water Equivalent is the liquid equivalent depth of the snow cover.

The objectives of this project include assessing the suitability of heritage snow algorithms, algorithm selection, implementation, testing and validation, and routine product generation with AMSR2 data. The selected heritage algorithms will be modified as necessary. The assessment of the algorithm performance as well as the development of the data processing and product generation system will be conducted using observations from AMSR-E onboard Aqua as a proxy for GCOM AMSR2.

Summary of Accomplishments and Findings

Snow cover is one of the most dynamic hydrological variables on the Earth's surface and it plays a key role in the global energy and water budget. The ability to detect global snow cover and measure snow depth in nearly all weather conditions has been shown using satellite passive microwave measurements such as the Scanning Multi-channel Microwave Radiometer (SMMR), the Special Sensor Microwave Imager (SSM/I), and the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E). Unfortunately, AMSR-E on NASA's Aqua satellite stopped functioning on October 4, 2011. The Advanced Microwave Scanning Radiometer 2 (AMSR2) instrument launched on May 18, 2012 onboard the Global Change Observation Mission 1st - Water "SHIZUKU" (GCOM-W1) satellite. From an operational and functional perspective, it will replace the AMSR-E instrument.

The suite of AMSR2 algorithms that is being developed for the retrieval of snow cover and snow depth using AMSR-E data as a proxy is comprised of well-established methods. The are being modified, as necessary, to adapt them to AMSR2 and to improve their accuracy. The snow cover detection algorithm is based on a brightness temperature-based decision tree approach (Grody, 1991; Grody and Basist, 1996) with additional climatology tests as enhancements. The snow depth algorithm is based on a dynamic empirical approach (Kelly, 2009) blended with a routine for dry/wet snow differentiation. Retrieval and validation cases will also be provided.

Preliminary validation results are encouraging. Figure 105 shows the accuracy of the snow detection algorithm applied to AMSR-E data when compared to the Interactive Multisensor Snow and Ice Mapping System (IMS) as "truth". The correct detection rate is generally above 80%. Based on this result, the product will meet the system requirements. Figure 106 gives a qualitative comparison of snow depth with the Kelly (2009) algorithm and the NASA snow water equivalent algorithm. While these are different parameters, they are related through the snow density. Spatial patters in the two products are similar.

During the next project year we will refine the snow detection and snow depth methodologies and develop the snow water equivalent algorithm. Climatological snow density data will be obtained. All algorithms will then be applied to AMSR2 data, which recently became available.

Publications and Conference Reports

Lee, Y.-K., C. Kongoli, and J. R. Key, 2012: Snow cover detection and snow depth algorithms for the Global Change Observation Mission (GCOM) AMSR2 instrument. AGU 45th annual fall meeting, San Francisco, CA., December 3-7 2012.

References

Grody, N. C. (1991), Classification of snow cover and precipitation using the special sensor microwave imager, *J. Geophys. Res.*, **96** (D4), pp 7423-7435.

Grody, N. C., and A. N. Basist, (1996), Global identification of snowcover using SSM/I measurements, *IEEE Trans. Geosci. Remote Sens.*, **34** (1), pp 237-249.

Kelly, R. (2009), The AMSR-E snow depth algorithm: description and initial results, *J. Remote Sensing Soc. Japan*, **29** (1), pp 307-317.

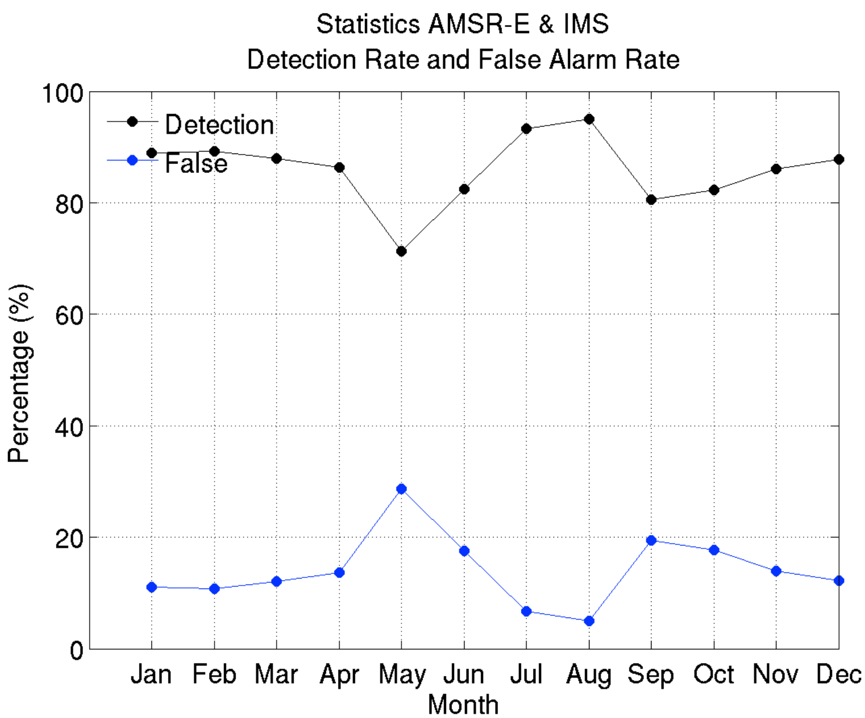

Figure 105. Snow detection/false alarm rate of AMSR-E with Grody's algorithm compared to IMS snow cover for every 15th day of each month in 2008.

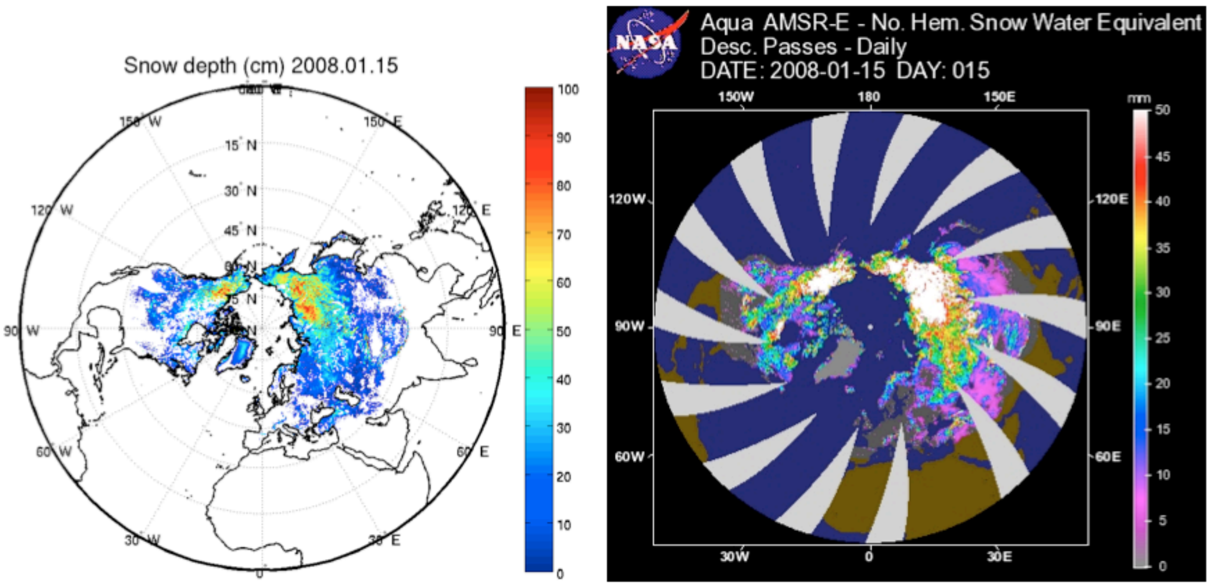

Figure 106. Snow depth from SMSR-E (Kelly's algorithm, left) and NASA AMSR-E snow water equivalent product (right) on 15 January 2008. The two products show similar spatial patterns and variability.

26 Detection and Characteristics of Aurora from VIIRS on Board the Suomi NPP

CIMSS Project Lead: Steven A. Ackerman
CIMSS Support Scientists: T. Jasmin, Eric Tobias (undergraduate student), William Straka
NOAA Collaborator: T. Schmit (ASPB)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Outreach and Education

Project Overview

The VIIRS instrument onboard the Suomi-NPP satellite is able to observe auroras at nighttime using the day-night band (or DNB) (e.g., Lee et al., 2006). The primary goal of this project is to detect aurora regions using VIIRS observations and correlate VIIRS DNB observations with other measures of the aurora.

Summary of Accomplishments and Findings

We have analyzed numerous cases and locations where the aurora occurred and utilized McIDAS V software to interpret data from the Suomi-NPP DNB (.7 micron). An example image of an aurora that occurred on February 7, 2013 is shown in Figure 107. The goal is to combine the DNB with the 11 and 3.7 micron bands to develop a method of masking the region with the aurora. These bands were selected as:

- The DNB is able to observe the aurora phenomenon along with both high and low clouds;

- The 11.45 micron IR band can detect high cloud features, but is unable to “see” the aurora signature; and
- The 11-3.7 micron band, or “fog/stratus product,” can detect low clouds and fog but is also unable to “see” the aurora.

One of the accomplishments was being able to update McIDAS-V to access the DNB and do some analysis. Automatic detection is a challenge and so a case study was used to determine aurora properties.

This study focuses on utilizing these aurora observations to retrieve radiance values in the visible spectrum for 10 aurora cases. The aurora was characterized using McIDAS-V computer software and compared to 3 measures of geomagnetic indices: K-index, nighttime hemispheric power total (NHP), and energy flux derived from the National Oceanic and Atmospheric Administration and Space Weather Prediction Center’s OVATION-Prime aurora forecast product. It was hypothesized that the radiance values of the aurora would have a strong correlation with all 3 of the geomagnetic indices; however, there was no conclusive correlation of aurora radiance intensity to K-index. Furthermore, the location of energy flux maximum was not necessarily the exact same location as where the aurora occurred. The most significant finding was that aurora radiance did show a positive linear correlation (with one outlier) with nighttime hemispheric power total; an increase in NHP correlated with an increase in both average aurora radiance and aurora radiance maximum.

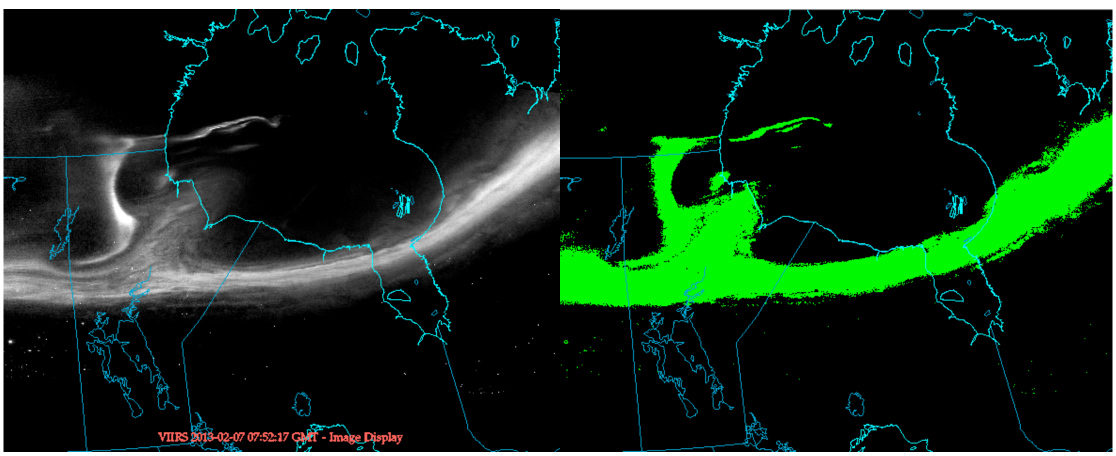

Figure 107. A) the DNB over Canada and the Hudson Bay on February 13, 2013. B) The green region represents the aurora mask that corresponds to 1A.

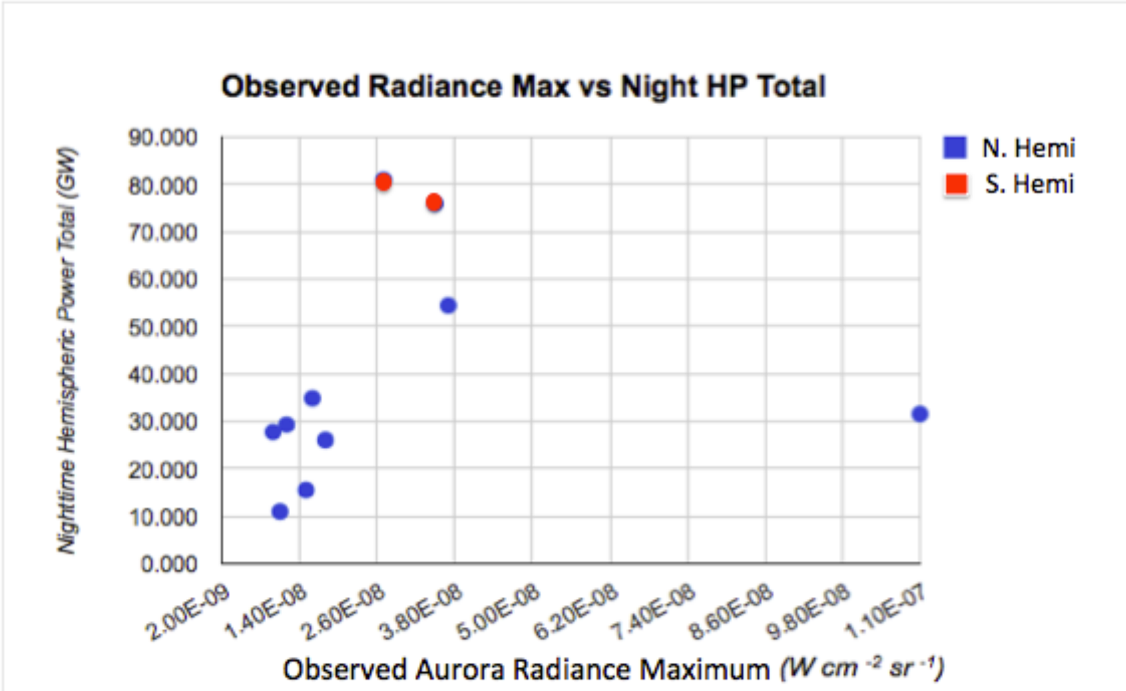

Figure 108. Observed radiance maximum plotted against OVATION nighttime hemispheric power totals. Northern hemisphere cases are plotted in blue, southern hemisphere in red.

References

Lee, Thomas E., Steven D. Miller, F. Joseph Turk, Carl Schueler, Richard Julian, Steve Deyo, Patrick Dills, Sherwood Wang, 2006: The NPOESS VIIRS Day/Night Visible Sensor. Bull. Amer. Meteor. Soc., 87, 191–199. doi: http://dx.doi.org/10.1175/BAMS-87-2-191

Publications, Reports, Presentations

Tobias, E., 2013: Analysis of Visible Aurorae Viewed from the Suomi NPP Satellite. Undergraduate Senior Thesis for the Department of Atmospheric and Oceanic Sciences, pp 10.

27 Combined Geo/Leo High Latitude Atmospheric Motion Vectors

CIMSS Project Leads: Matthew Lazzara, David Santek, Chris Velden
CIMSS Support Scientists: Brett Hoover, Rich Dworak, Nick Bearson, Rick Kohrs
NOAA Collaborators: Jeffrey Key NESDIS/STAR/CRPD/ASPB,
Jaime Daniels NESDIS/STAR/SMCD/OPDB
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The spatial coverage of satellite-derived Atmospheric Motion Vectors (AMV) is generally equatorward of 60° latitude for geostationary satellites and poleward of 70° latitude for the polar satellites. This results in a 10-degree gap in coverage, which has been noted as a problem by numerical weather prediction (NWP) centers. Specifically, the dynamically active polar jet stream can be located in this latitudinal zone and improper model initialization can lead to rapidly growing errors in the forecasts. Therefore, developing novel ways to fill this AMV-void gap is the next logical step toward providing complete wind coverage for the NWP applications.

The approach taken was to develop an innovative technique to blend satellite data from geostationary Earth orbit (GEO) and low Earth orbit (LEO) satellites to create composite imagery. An Advanced Image Compositing Technique (AICT) was developed to blend the data from a variety of satellites with differences in calibration, viewing geometry, and temporal offsets. The resulting images are composites of the global GEO (GOES, MTSAT, Meteosat) and LEO (NOAA-15 through NOAA-19 and Metop-A, along with NASA's Terra and Aqua) satellites. These composites are used to generate AMVs in the geographic gap from 60° to 70° N/S latitudes.

Summary of Accomplishments and Findings

Image Compositing Technique

The cornerstone of this project is the AICT, which creates composites of the satellite data, including pixel-level metadata that are necessary in the compositing and AMV generation. The quantities are: Brightness temperature, scan time, pixel distance from the satellite subpoint, pixel area, satellite ID, sensor wavelength, parallax distance, parallax direction. The final blended satellite images are created by retaining the multi-banded pixel information for the pixel with the best area resolution, that falls within a +/- 15-minute window from the nominal image time. This results in composites containing pixels from many different satellites, varying times, and different viewing angles, with the best spatial resolution.

The satellite image composites are being routinely generated every 15 minutes for the infrared window channel at 4 km resolution in polar stereographic projection over each pole. These images can be viewed in real-time at:
http://stratus.ssec.wisc.edu/cgi-bin/polarwinds?leogeo

AMV Generation

The algorithm used for generation of composite Leo/Geo AMVs is very similar to the methods used for the Moderate Resolution Imaging Spectroradiometer (MODIS) and GOES AMVs. The AMV algorithm makes use of the metadata to:

- Ensure that the targeted and tracked features contain data only from a single satellite, although the correlating feature in each image of the triplet may be from a different satellite;
- Determine the wind vector using the actual pixel times of the feature being tracked, not the nominal image time; and
- Account for image parallax when computing the AMV.

In this case, the AMVs are generated using three successive 1/2-hourly composites, separated in time by 45 minutes (Figure 109).

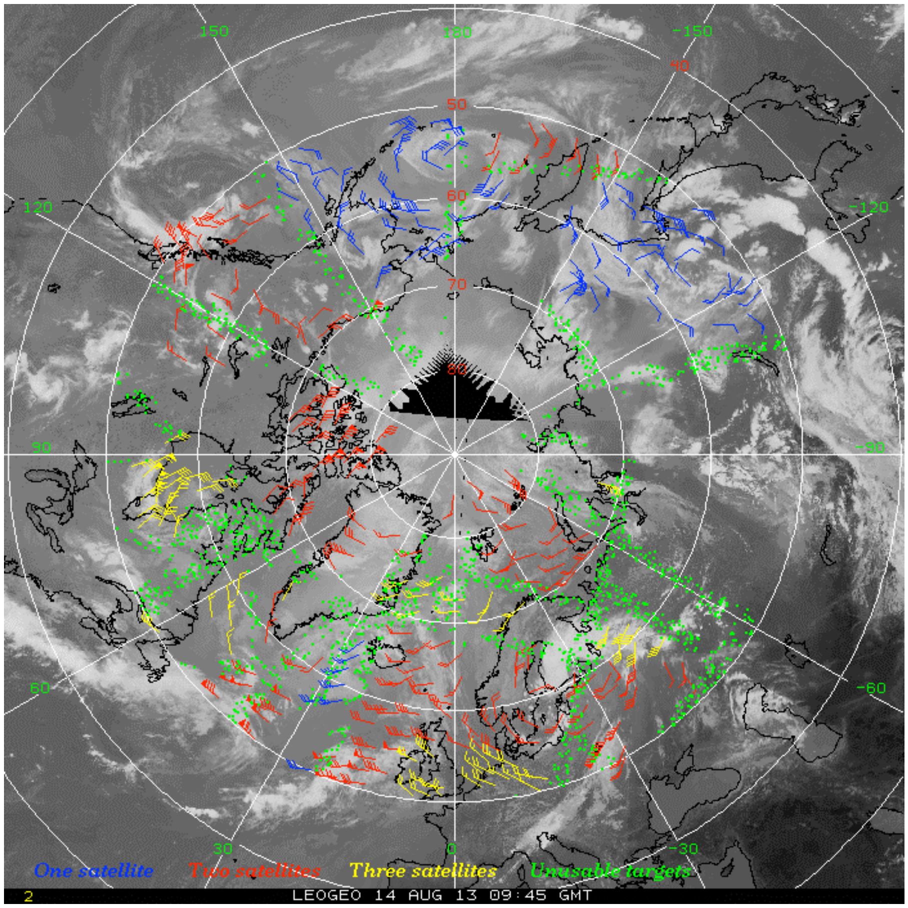

Figure 109. AMVs derived from composite imagery consisting of data from one satellite (blue), two satellites (red), three satellites (yellow). Green dots represent cloud targets that are unusable because they fall on the boundary between data from different satellite images.

Validation of Leo/Geo AMVs

To assess the quality of the Leo/Geo AMVs, a significant sample was collected from the period 2011 into 2012 and compared to collocated rawinsondes. Due to few rawinsondes over the Southern Hemisphere, the majority of collocation matches occur over the Northern Hemisphere. The vector Root Mean Square Error (RMSE) is 6.3 ms^{-1} in the Northern Hemisphere and 8 ms^{-1} in the Southern Hemisphere. This is similar to the typical RMSE values of 6-7 ms^{-1} for GOES and 8 ms^{-1} values for LEO derived winds.

Model Forecast Impact

A two-season impact study of these AMVs in the Global Data Assimilation System/Global Forecast System (GDAS/GFS) model was run at CIMSS. The results show an overall near neutral impact in the Northern Hemisphere, and a small positive impact in the Southern Hemisphere, with a tendency to improve the low-skill forecast “dropout” events. Forecasts in the Southern Hemisphere tend to be most improved in its warm season when the jet migrates to higher latitudes and would otherwise cause rapidly-growing analysis errors in the 60°-70° latitude band. In the Northern Hemisphere, Leo/Geo AMVs tend to mitigate analysis errors appearing at the leading edge of the eastern Pacific jet, which grow as they cross the mainland United States and interact with the Atlantic polar and subtropical jets. See Lazzara et al. (2013) for more details.

An additional experiment was run using the hybrid GDAS/GFS for the time period of Hurricane Sandy in late October 2012. Figure 110 shows the forecast position of Sandy for the control (blue) and experiment (red, which include the Leo/Geo winds) for forecasts from 23-28 Oct 2012. Preliminary results indicate that the forecasts are similar, except for 25 Oct 2012 (circled) when the Leo/Geo winds appear to help steer Sandy into a recurvature-pattern earlier than the GFS control through manipulation of the mid-latitude trough.

NWP Use

The Leo/Geo winds product is being used routinely in the US Navy's NRL Atmospheric Variational Data Assimilation System Accelerated Representer (NAVDAS-AR) since November 2010 and at the National Center for Atmospheric Research (NCAR) in their Antarctic Mesoscale Prediction System (AMPS) model beginning in August 2011. The AMVs are used experimentally in the NASA Global Modeling and Assimilation Office (GMAO) Goddard Earth Observing System Model Version 5 (GEOS-5) and are being monitored by the UK Met Office.

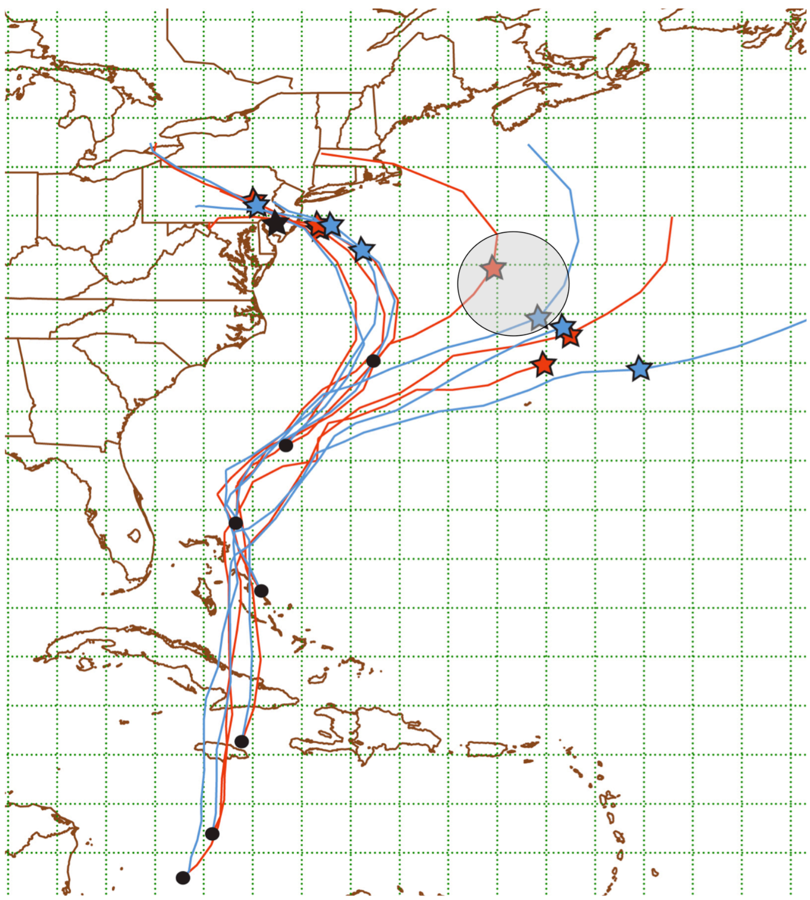

Figure 110. Results from a hybrid GDAS/GFS experiment using the Leo/Geo winds. Control (blue) and experiment (red) of Sandy's forecasted tracks from 23-28 Oct 2012. Black dots are the position in the analysis every 24 hours; stars are the times of the actual landfall.

Publications, Reports, Presentations

Hoover, B., D. Santek, M. Lazzara, R. Dworak, J. Key, C. Velden, N. Bearson, 2012: High Latitude Satellite-Derived Winds From Combined Geostationary and Polar Orbiting Satellite Data. Proc. of the Eleventh International Winds Workshop, Auckland, NZ, 20-24 February 2012.

Lazzara, M.A., D.A. Santek, R.A. Kohrs, N.A. Bearson, J. Robaidek, and S.L. Knuth, 2010a: Satellite composites: techniques in combining geostationary and polar orbiting observations. 17th Conference on Satellite Meteorology and Oceanography. American Meteorological Society, Annapolis, MD 27-30 September 2010.

Lazzara, M.A., D.A. Santek, R. Dworak, J.R. Key, C.S. Velden, and S. Wanzong, 2010b: High latitude atmospheric motion vectors from combined geostationary and polar orbiting observations. 17th Conference on Satellite Meteorology and Oceanography. American Meteorological Society. Annapolis, MD 27-30 September 2010.

Lazzara, M.A., R. Dworak; D.A. Santek, N. Bearson, C.S. Velden, and J.R. Key, 2010c: Composite satellite atmospheric motion vectors. In: 5th Antarctic Meteorological Observation, Modeling, and Forecasting Workshop, Byrd Polar Research Center, Columbus, OH, July 2010 (preprints). Columbus, OH, Ohio State University, Byrd Polar Research Center, pp.18-20.

Lazzara, M.A, R. Dworak, D.A. Santek, C.S. Velden, and J.R. Key, 2010d: High latitude atmospheric motion vectors: Applications for Antarctic and Arctic composite satellite imagery. In: International Winds Workshop, 10th, Tokyo, Japan, 22-28 February 2010.

Lazzara, M., R. Dworak, N. Bearson, D. Santek, C. Velden, and J. Key, 2011: Polar Satellite Composite Atmospheric Motion Vectors. 6th Antarctic Meteorological Observing, Modeling, and Forecasting Workshop, Hobart, Tasmania, Australia, 22-24 June 2011.

Lazzara, M., R. Dworak, D. Santek, B. Hoover, C. Velden, J. Key, 2013: High-latitude Atmospheric Motion Vectors from Composite Satellite Data. *J. Appl. Meteor. Climatol.* (Conditionally accepted).

28 JPSS Analysis Facility for Instrument Impacts on Requirements (JAFIIR)

CIMSS Project Leads: Mathew M. Gunshor, Allen Huang
CIMSS Support Scientists: Hong Zhang, Eva Schiffer
NOAA Collaborator: Timothy J. Schmit (NESDIS/STAR/ASPB)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques

Project Overview

CIMSS is designing and implementing a high performance hybrid CPU- and GPU-based analysis facility in support of JPSS. Initially the system is being designed to conduct sensor modeling, measurement simulation, and EDR algorithm adaptation so that VIIRS instrument impact assessment on system requirements can be evaluated. This work follows the successful GOES-R Analysis Facility for Instrument Impacts on Requirements project (GOES-R AWG GRAFIIR), which has so far supported 10 ABI waiver/deviation analyses.

This cost-effective system leverages efforts from project activities of 1) GOES-R AWG GRAFIIR, 2) Community Satellite Processing Package (CSPP), 3) NPP proving ground, 4) VIIRS and CrIS calibration/validation, 5) LEO Cloud Algorithm Testbed (LEOCAT), and 6)

GPU-based high performance WRF model development. The project is in its second year, is expected to continue, but does not have guaranteed continued funding.

In the initial stage of development, JAFIIR will demonstrate NPP VIIRS processing chain to the show instrument impacts on the products of cloud mask, cloud property, fire, sea surface temperature, aerosol/dusts and, ultimately, many other VIIRS products. These demonstrations will use the simulation and/or proxy datasets developed by AWG proxy team and the new high-spatial resolution datasets using GPU-based high-performance forward and NWP models. The EDR/level 2 mask, cloud, wind, fire and other products algorithm required by JAFIIR will be adopted from the Algorithm Development Library (ADL) and Community Satellite Processing Package (CSPP).

JAFIIR will contribute to JPSS directly through an algorithm processing facility capable of taking into account JPSS imaging and sounding instrument effects in order to optimize product performance and meet mission requirements. Any sensor effect that has significant impacts on products can be quantified, and potential processing approaches or quality control procedures can then be identified to minimize and mitigate the risk of failure in meeting product specification requirements.

Since 2007, through its GRAFIIR effort, CIMSS has developed an efficient facility to model specific GOES-R ABI sensor effects. CIMSS also focused on developing a framework, which leverages GEOCAT and the semi-autonomous system GLANCE. GLANCE is a tool, constructed from scientific python libraries, used for comparing complex data sets stored in hdf (ver. 4 and 5) or netcdf (ver. 3 and 4) format. GLANCE is currently used by the GOES-R AWG AIT team.

In addition, the JAFIIR team will continue to leverage GRAFIIR to provide a flexible platform to analyze multiple inputs and outputs to demonstrate sensor impacts on many products. JAFIIR plans to use Unidata's Integrated Data Viewer (IDV), Java WebStart technology, and other existing graphics and data management software to enhance our system's analysis capability and to identify sensor components that might prohibit JPSS VIIRS (and later, CrIS and ATMS) products from meeting measurement requirements. Furthermore, JAFIIR is to leverage GPU-based CRTM/RTTOV and WRF to achieve a timely simulation of the emerging enhancements of JPSS VIIRS, CrIS and ATMS sensor capability toward improved information content; spectral, spatial, and signal to noise. This applies also to other newly identified possibilities such as cross-platform coordination over large spatial domains, and with broad spectral coverage, for instrument cross-validation and potential extraction of 3D feature information.

Summary of Accomplishments and Findings

The JAFIIR project so far has demonstrated with Suomi-NPP VIIRS data that an instrument effect altering the calibration accuracy of a single band can be simulated and that the impact on products can be determined. The capability to run more products outside of operations is still growing, though at this point fire and cloud algorithms seem to be working in CSPP software. Software for JAFIIR is evolving from GRAFIIR software but there are some differences in how the polar and geostationary satellite programs have evolved. A significant difference between the programs of basic importance to calibration is in the use of different radiance units.

An example of an instrument effect simulated with VIIRS data involved adding a calibration offset to the 10.8um (M15) band data. Three granules on 17 February 2012 around 18:50UTC were chosen to add this effect. It was necessary to choose three granules so that cloud products could be generated from the middle one. Two altered datasets were generated for the three granules where calibration offsets were added which amounted to a 1K and 3K equivalent radiance offset at each pixel. These data, along with the original unperturbed data, were used to generate cloud products (cloud mask and cloud phase).

Figure 111 and Figure 112 demonstrate two of the image types generated by the Glance HTML report feature. The full report for this case can be seen here: http://www.ssec.wisc.edu/grafiir/JAFIIR/VIIRS_CloudMask/20120217_t1851476_CalOffset1K/Cloud_Mask_AllQuality/index.html

The cloud mask has values that range between 0 and 3. A change as large as 1K in the 10.8um band can cause a significant problem for the cloud mask for some pixels, where the cloud mask classification changed 3 categories (from "probably clear" to "probably cloudy", or vice versa). However, the overall effect on the cloud mask for this image was small with fewer than 1% of the of the pixels changing at all between the two cases. A similar case study was done with a 3K change to the 10.8um band which resulted in more differences in the cloud mask product.

As changes are made to the CSPP, JAFIIR responds by upgrading and testing the processing on available algorithms. In 2013 CSPP EDR version 1.1 was released and there are more products including Cloud mask, Active Fires, Aerosol Optical Thickness, Atmosphere Suspended Matter, and Sea Surface Temperature (SST).

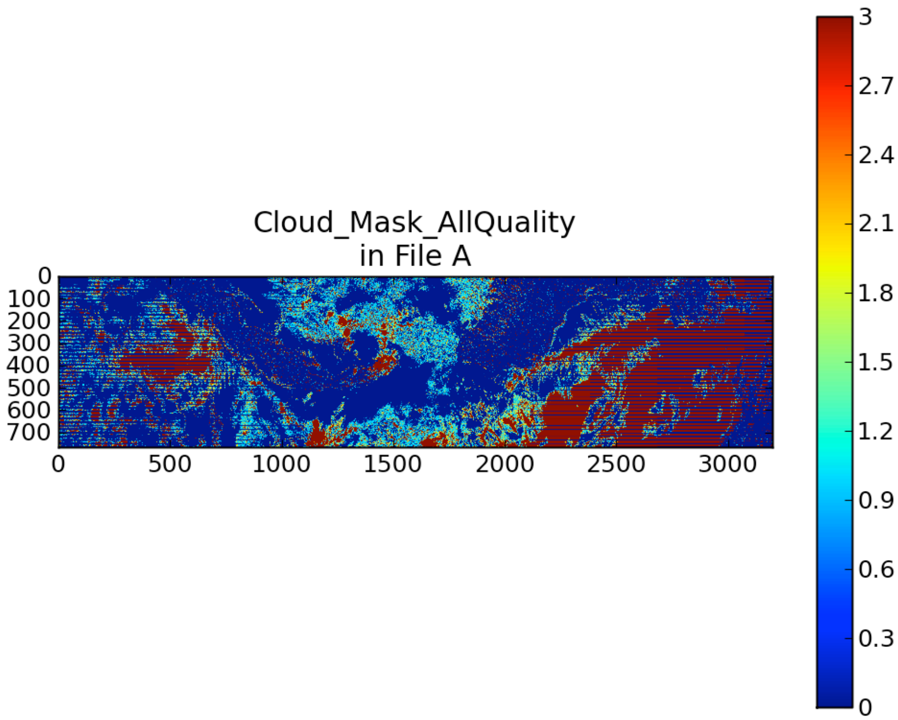

Figure 111. Cloud mask from 17 February 2012, ~18:51UTC, generated from unperturbed VIIRS data. Image generated by Glance comparison report.

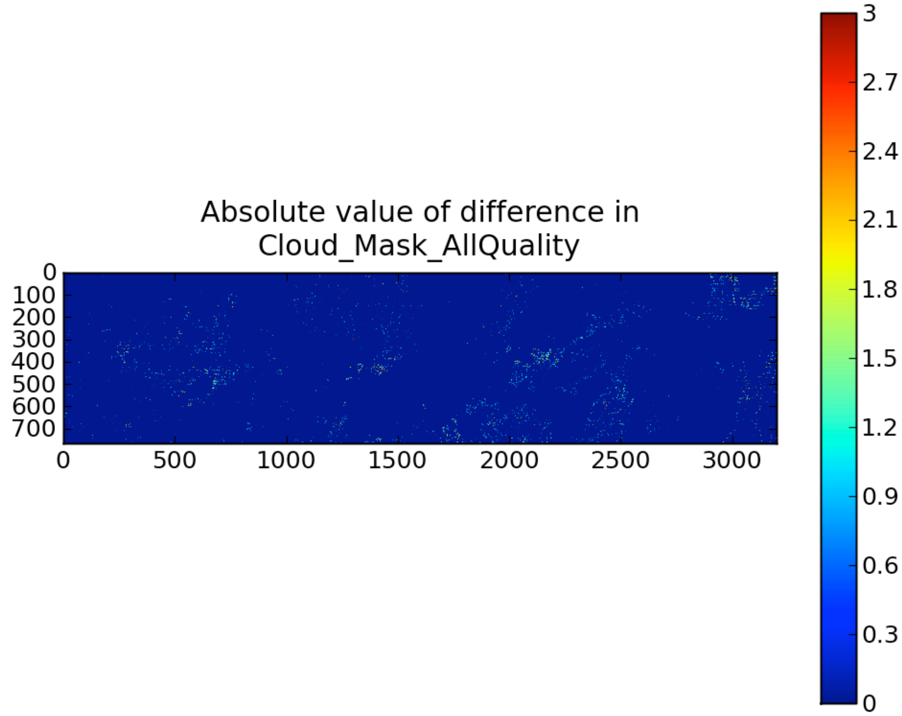

Figure 112. The differences (absolute value) between the cloud mask generated with unperturbed data and with data where the 10.8um band had a 1K offset added to each pixel. Image generated by Glance comparison report.

Publications, Reports, Presentations

Gunshor, Mathew, Hong Zhang, Allen Huang, Eva Schiffer, William Straka, Ray Garcia and Graeme Martin: "GRAFIIR and JAFIIR – Efficient End-to-End Semi-Automated Algorithm Performance Analysis and Implementation Verification Systems" – poster presented at the NOAA 2013 Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users; NOAA Center for Weather and Climate Prediction (NCWCP) College Park, MD; April 8-12, 2013.

29 CIMSS Science Support for the S4 Supercomputer

CIMSS Project Lead: Jason Otkin
CIMSS Support Scientist: Allen Lenzen
NOAA Collaborator: R. Bradley Pierce (NOAA/STAR Advanced Satellite Products Branch)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Sensors and Techniques

Project Overview

In 2011, NOAA/NESDIS/STAR provided the University of Wisconsin-Madison funds to purchase and construct a supercomputer system capable of running the NCEP operational data assimilation and forecast modeling systems. The new supercomputer system, named Super Computer for Satellite Simulation and Data Assimilation Studies (S4), will support efforts to enhance existing data assimilation techniques with the goal of improving the U.S operational forecast models. In support of these modeling efforts, CIMSS scientists will collaborate with NOAA and JCSDA scientists to exchange ideas and gain knowledge on porting the operational software to S4, running benchmarking tests to assess the consistency of model output, and demonstrating that the S4 system can be used as an experimental surrogate for the NCEP operational system.

Summary of Accomplishments and Findings

During this 1-year project, CIMSS scientists provided support to JCSDA and NESDIS efforts to port and benchmark the operational Global Data Assimilation System (GDAS) on S4. Model verification software was also installed and tested. A monitoring system was developed to quickly identify which nodes on S4 are free, being used, or in an error state. With help from this diagnostic tool, it was found that a previously installed version of the Hurricane WRF (HWRF) model was causing nodes to crash and stay off-line. Several errors in the HWRF processing scripts were identified and removed, thereby improving the uptime and efficiency of the S4 system.

To support hurricane modeling and assimilation studies, the 2012 version of the operational HWRF model was obtained from the Developmental Testbed Center and ported to S4. Several modifications were made to the configure files and PERL scripts to permit compilation on S4. Most of the “kick” scripts used to start the next job in the assimilation/forecast cycle were modified to create the proper run environment. Other modifications were made to the Parallel Operating Environment (POE) emulation script and the HWRF job submission script. Extra logic was added to the job submission scripts to allow jobs to be run on either the serial nodes or the MPI nodes. This option improves run-time performance since there are often idle CPUs available on the serial nodes. After successfully compiling the HWRF model and obtaining initialization and observation files, several assimilation/forecast tests in both cycling and non-cycling mode were performed for Hurricane Nadine (September 2012) and Hurricane Sandy (October 2012). Cycled assimilation experiments were subsequently performed for all tropical disturbances during the 2012 Atlantic and east Pacific hurricane seasons. Track and intensity errors and other diagnostics showed good agreement between the benchmark runs on S4 and those performed at the DTC.

Publications, Reports, Presentations

Otkin, J. A., B. Pierce, A. Lenzen, J. Jung, and S. Nolin, 2012: CIMSS Science Support for the NESDIS S4 Supercomputer. JCSDA 10th Workshop on Satellite Data Assimilation. College Park, MD.

30 Implementation of Advanced Data Assimilation Techniques and Performance of Forecast Impact Assessment Experiments

CIMSS Project Lead: James Jung
NOAA Collaborators: Sid Boukabara NOAA/NESDIS/STAR, Lars Peter Riishojgaard JCSDA, John Derber NOAA/NWS/NCEP/EMC, Mitch Goldberg NOAA/NESDIS/JPSSO.
NOAA Strategic Goals Addressed:

- Serve society’s needs for weather and water information

- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes:

- Environmental Models and Data Assimilation

Project Overview

This project uses Observing System Experiments (OSEs) to quantify the contributions to the forecast made by SNPP/JPSS and other satellite data. The primary goal of these experiments is to identify the contribution of these data sources in the NOAA operational weather forecast models.

A second component develops and evaluates several advanced data assimilation techniques, including but not limited, to assimilate infrared and microwave water vapor channels in NOAA operational forecast models, with a goal to improve the model fields within the analysis (i.e., moisture), with a focus on SNPP/JPSS sensors.

Other responsibilities of this project are to maintain a credible Operations-to-Research (O2R) environment of the NOAA operational weather forecast models and help NESDIS/JCSDA scientists with data assimilation experiment design and coding standards.

Summary of Accomplishments and Findings

S4 and JIBB Software Integration

In May 2012 NCEP moved to a new version of the GDAS/GFS which included an 80 member ensemble. The validation and verification of this version followed similar protocols as the previous installation. This validation consisted of cycled experiments of two months during two seasons. Comparisons were made between Zeus (NOAA/R&D), S4 (NESDIS) and JIBB (NASA) computers. JIBB and S4 used a May 2012 version of the NCEP operational GDAS with modifications for Linux. A one month spin up was used before each season to allow the satellite radiance bias corrections to adjust.

The design of this comparison was to mimic NCEP operations as much as possible. However, differences with NCEP operations were necessary to allow for different machine architecture and operating systems. All of the data files used were from the NCEP operations database. This database was developed in real time and has the real time data cutoff requirements incorporated. All data used by the operational system, except some of the restricted data, were used. The GDAS/GFS was started with the same initial files on each machine. The GDAS/GFS then used its previous forecast as the background field for the next cycle's analysis on each machine. This allowed compiler and machine round off differences to influence each step of the GDAS cycles. At each 00Z cycle, the 7-day forecast was spawned and was consistent with the NCEP Central Operations (NCO) early data cutoff times. This is commonly referred to as the GFS portion of the GDAS/GFS. The case studies chosen consist of ~45-day periods during January – February 2012 and June – July 2012.

The main verification package used for this inter-comparison is the Verification Statistics Data Base (VSDB) developed by NCEP. The VSDB generates and plots time series, 1D and 2D fields, and long term average statistics for various parameters. The most common weather forecast model performance benchmarks are the mid-latitude (20-80^o N/S) anomaly correlations. The day-to-day variation in the anomaly correlation time series plots between the three computers (not shown) is minimal. Obtaining almost the same value each day on the Zeus, JIBB and S4 computers suggests the day-to-day forecast skill is very similar. The 500 and 1000 hPa die-off curves for both Hemispheres in Figure 113 confirm that these forecast skill trends are consistent through all seven forecast days. Most of the forecast differences are not significant at the 95% level, suggesting the three computers are generating similar forecasts.

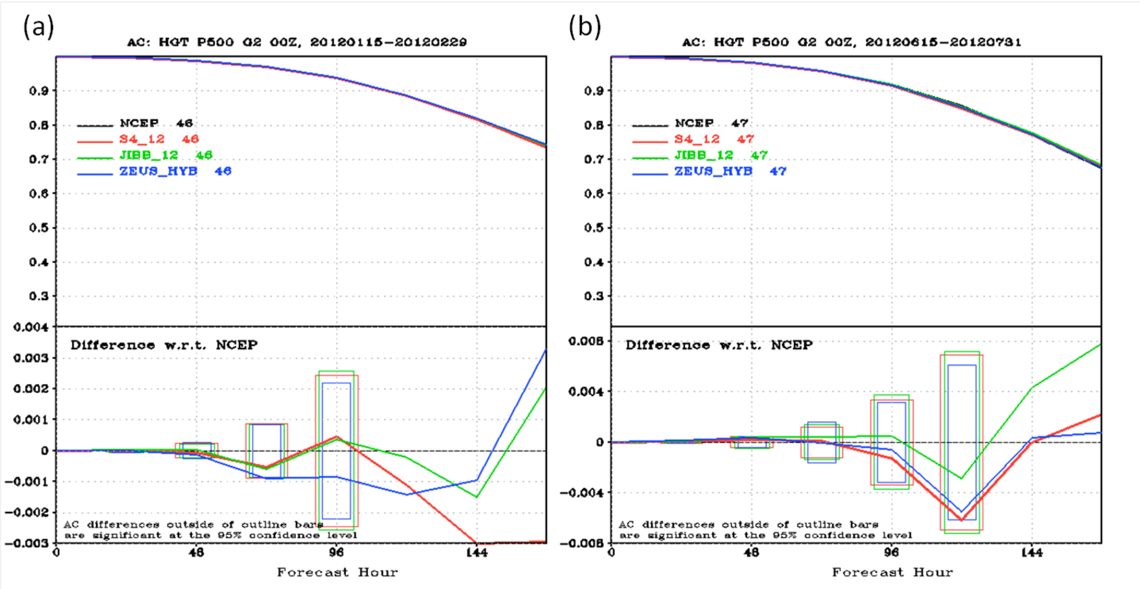

Figure 113. Global500 hPa geopotential height anomaly correlation die-off curves from (a) January – February 2012 and (b) June – July 2012. NCEP operations, S4, JIBB and Zeus are plotted in black, red, green and blue respectively. The top section is the anomaly correlation for forecast day 0 to day 7. The bottom section is the difference with respect to NCEP operations and the significance test. Lines that are inside the same color boxes indicate the difference is not significant. Missing boxes means they were too large to plot on this scale and differences are not significant.

Observing System Experiments

There are two types of observing system experiments, those that start will the full suite of observations and remove one instrument type (data denial), and those that start with a minimum suite of instruments and add an instrument type (data addition). Both types are reported here. The sensor/component data denial experiments directed by the JCSDA included: 1) rawinsondes, 2) AMSU-A, 3) AMSU-B and MHS, 4) hyperspectral infrared (AIRS and IASI), 5) all geostationary and polar atmospheric motion vectors, 6) Global Positioning System-Radio Occultation (GPSRO), 7) all aircraft data. The data addition experiments were limited to understanding the contribution of SNPP-ATMS, N19-AMUS and Aqua-AIRS. All experiments were conducted at a resolution of T574L64 using the GDAS/GFS on JIBB. The experiments consist of 45 days during the summer and winter extreme seasons. The first 14 days are not used in the impact statistics to allow the forecast model to adjust to the missing data. We ran the 00Z GFS out to 7 days for our comparisons. The impact of each data type is assessed by comparing the analyses and forecasts based on an observing system using all operational data types (control).

The top sections of each panel in Figure 114 are the seasonal average anomaly correlation scores. The bottom sections are the difference with respect to the control and the significance test. Lines that are outside the same color boxes are significant at the 95% confidence level.

The data addition experiments started with a baseline of all conventional data. Radiances from SNPP-ATMS, N19-AMSU/MHS or Aqua-AIRS were added to the baseline in subsequent experiments. As shown in Figure 114, the 500 hPa anomaly correlations are relatively equal for each sensor, indicating that SNPP-ATMS, N19-AMSU/MHS, and Aqua-AIRS have about equal contribution to the quality of the GDAS/GFS forecast.

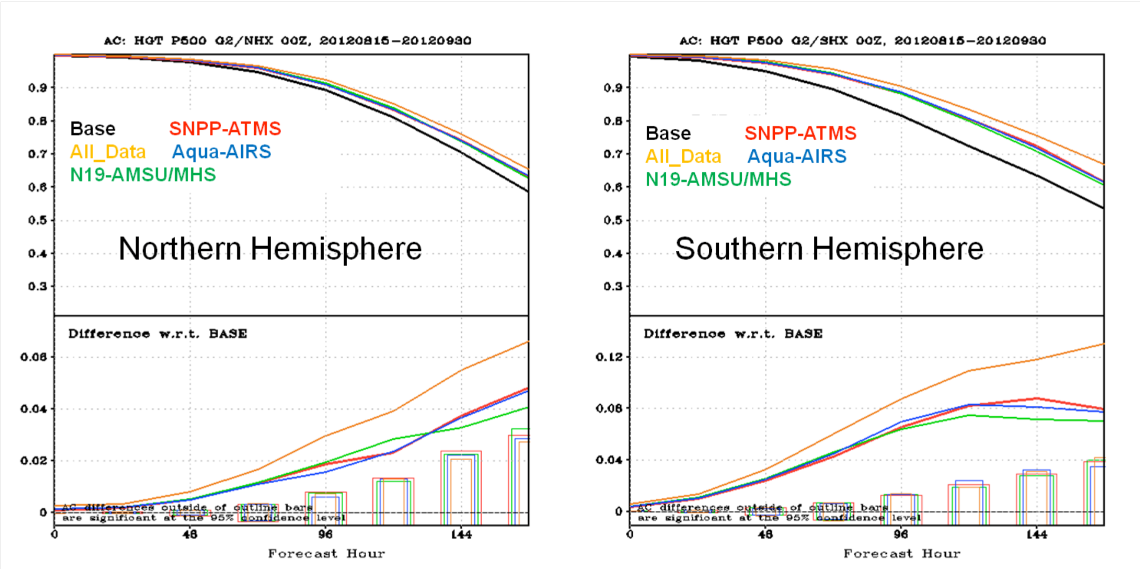

Figure 114. Regional 500 hPa geopotential height anomaly correlation die of curves for 1 August to 30 September 2012. Base includes only conventional data, SNPP-ATMS, Aqua-AIRS and N19-AMSU/MHS includes conventional data plus the specific sensor, All_Data includes NCEP's entire suite of observations.

In general, removing data from all AMSU-A, rawinsondes, or GPS-RO sensors has an overall significant degrading impact on the global forecast skill. Also, as a general rule, removing either AMSU-A, GPS-RO or rawinsondes has a significant short term RMS impacts on temperature and geopotential height (not shown). The removal of AMSU-A or GPS-RO has a significant negative short term RMS impact on upper tropospheric relative humidity possibly due to a degraded temperature field (not shown).

Water Vapor Assimilation Experiments

We are just beginning to look at how water vapor assimilation could result in improvements in non-traditional forecast skill measurements. Water vapor is a unique greenhouse gas due to its variability throughout the atmosphere. The amount of water vapor in the air has impacts on humidity, cloud formation, precipitation as well as plant and animal life. Yet, water vapor information from satellites is one of the most under-utilized sources in NWP. Its non-linearity and multivariate nature makes it difficult (but not impossible) to use.

Figure 115 illustrates the affect water vapor has on the radiational heating and cooling rates in the GDAS/GFS. When the water vapor concentrations are improved (more realistic) in the experiment, the daily model forecast temperature improves at almost all levels. This is shown by the decrease in temperature bias at almost all levels for the Northern (top) and Southern (bottom) hemispheres.

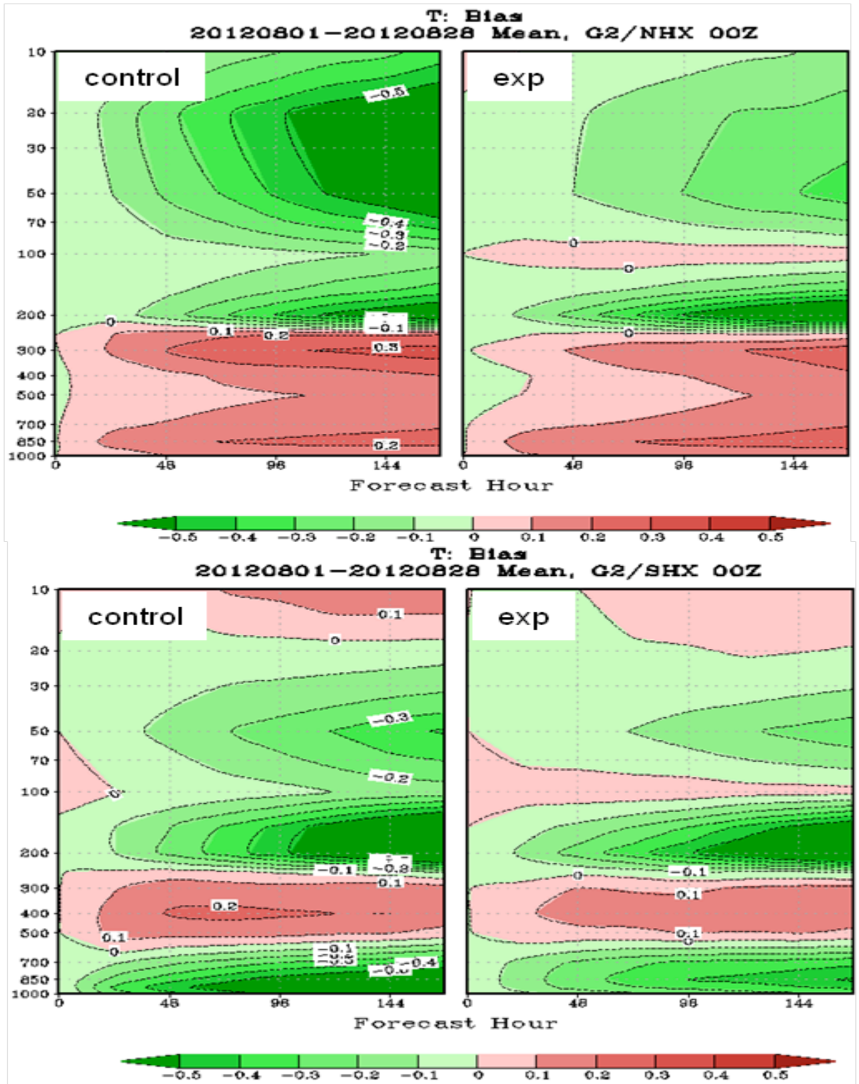

Figure 115. Forecast temperature time series without (control) and with (exp) modifications to the satellite radiance assimilation technique used in the NCEP GDAS/GFS. Top panels are the Northern Hemisphere, lower panels are the Southern Hemisphere. The lighter colors (near zero) are better. At almost all levels, the experiment shows improvement in the temperature bias with forecast time.

Publications, Reports, Presentations

Jung, J. A., 2013: JCSDA O2R / R2O Maintenance, OSEs and Water Vapor Data Assimilation Techniques, JPSS Proving Ground Seminar, 29 May 2013.

Jung, J. A., 2013: Water Vapor Assimilation, Preliminary Results of Correcting for Supersaturation., JCSDA 11th Annual Workshop, 5-7 June 2013.

Jung, J. A. and L. P. Riishojgaard, 2012: Observing System Experiments Using the NCEP Global Data Assimilation System. 5th International WMO Workshop on the Impact of Various Observing Systems on Numerical Weather Prediction. Sedona AZ, 22-23 May 2012.

Jung, J. A. and L. P. Riishojgaard, 2012: Observing System Experiments Using the NCEP Global Data Assimilation System. 10th Annual JCSDA Workshop. Riverdale MD, 10-12 Oct 2012.

Jung, J. A. And L. P. Riishojgaard, 2013: Observing System Experiment Impacts from Conventional and Satellite data using the NCEP Global Data Assimilation System. 93rd Annual AMS Meeting, Austin TX, 6-10 January 2013.

Jung, J. A. and L. P. Riishojgaard, 2013: Observing System Experiment Impacts from Various Satellite Instruments using the NCEP Global Data Assimilation System. 93rd Annual AMS Meeting, Austin TX, 6-10 January 2013.

Riishojgaard, L. P., J. G. Yoe, E. M. Devaliere, A. Pratt, K. J. Garrett, J. A Jung, S. Nolin and S. Sinno, 2013: S4 and JIBB: Building the infrastructure for an Effective O2R and a Streamlined R2O. 93rd Annual AMS Meeting, Austin TX, 6-10 January 2013.

Le Marshall, J. F., J. Jung, R. Norman, J. Lee, P. Gregory, and R. G. Seecamp, 2013: Earth Observation from Space –Advancing Earth System Science. 93rd Annual AMS Meeting, Austin TX, 6-10 January 2013.

Le Marshall, J., J. Lee, J. Jung, P. Gregory, and B. Roux, 2013: The considerable Impact of Earth Observations from Space on Numerical Weather Prediction. Submitted to *Aust. Meteor. Ocean. Journal.*

Le Marshall, J., R. Seecamp, Y. Xiao, P. Gregory, J. Jung, P. Stienle, T. Skinner, C. Tingwell, and T. Le, 2013: The Operational Generation of Continuous Winds in the Australian Region and their Assimilation with 4DVAR., *Wea Forecasting*, **28**, 504-514.

Lim, A., J. A. Jung, A. Huang, and S. Ackerman, 2013: Assimilation of AIRS radiances using GSI/WRF for Short Term Regional Forecasts. 93rd Annual AMS Meeting, Austin TX, 6-10 January 2013.

Lim, A. J. A. Jung, H-L. Huang, S. Ackerman, and J. A. Otkin, 2013: Assimilation of AIRS Radiances in Short Term Regional Forecasts using Community Models. Submitted to *Mon. Wea. Rev.*

Nebuda, S., J. A. Jung, D. A. Santek, J. M. Daniels, and W. Bresky, 2013: GOES-R AWG Atmospheric Motion Vectors: First look at assimilation in the NCEP GFS. 93rd Annual AMS Meeting, Austin TX, 6-10 January 2013.

31 Assimilation of Hyperspectral Ozone Retrievals and Radiances Within GDAS to Improve Lateral Boundary Conditions for NAQFC

CIMSS Project Lead: Allen Lenzen
NOAA Collaborator: R. Bradley Pierce, NOAA ASPB
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Environmental Models and Data Assimilation
- Satellite Meteorology Research and Applications

Project Overview

The project activities are focused on two tasks. The first is to develop and test improving the ozone prediction in the GFS with inclusion of 3 dimensional and diurnally varying ozone production and loss tendencies. The second is to assess the impact of turning off the IASI ozone radiance assimilation in the GDAS analysis system. The first task was "Development and testing of climatological 3D tropospheric ozone P-L in GFS". This task focuses on improving GFS predictions of background tropospheric ozone to facilitate assimilation of ozone retrievals and selected channel radiances within the ozone absorption band (980-1080 cm^{-1}). Collaborator Daniel Jacob (Harvard) provided GEOS-Chem 3 hour ozone production rate (P), loss frequency (L), and surface deposition for July 2011 to test the use of climatological 3D tropospheric ozone P-L within GDAS. Positive or neutral impacts of the updated tropospheric ozone P-L are needed for further development.

The tasks performed for the development and testing were:

- Operational NCEP GDAS (T574L64, 27 KM) analysis system has been ported to NESDIS/STAR S4 super computer at UW-Madison SSEC and July 2011 GDAS control experiments have been completed (cycling 6hr analysis with 5-day forecasts);
- 3D merged GFS (stratosphere) + GEOS-CHEM (troposphere) ozone PL developed for use in GFS and source code adapted for inclusion of 3D O3 P-L;
- GDAS cycling/forecast experiments using 3D diurnally varying merged GFS/GEOS-CHEM O3 PL were conducted during July 2011; and
- The impact of the updated tropospheric O3 PL has been assessed using the Verification Statistics Data Base (VSDB) from the NCEP Verification System.

Summary of Accomplishments and Findings

Figure 116 shows the distribution of tropospheric ozone production and loss that is currently used within GFS (left panels) and zonally and diurnally averaged July 2011 distributions obtained from the merged 3D ozone production and loss (right panels) developed under this proposal. The merged distributions show much more realistic distributions of tropospheric ozone production (which should maximize near the surface at middle latitudes in the Northern Hemisphere due to anthropogenic emissions of ozone precursors) and loss (which should maximize near the surface in the tropics due to higher water vapor mixing ratios leading to increased OH abundances in faster oxidation).

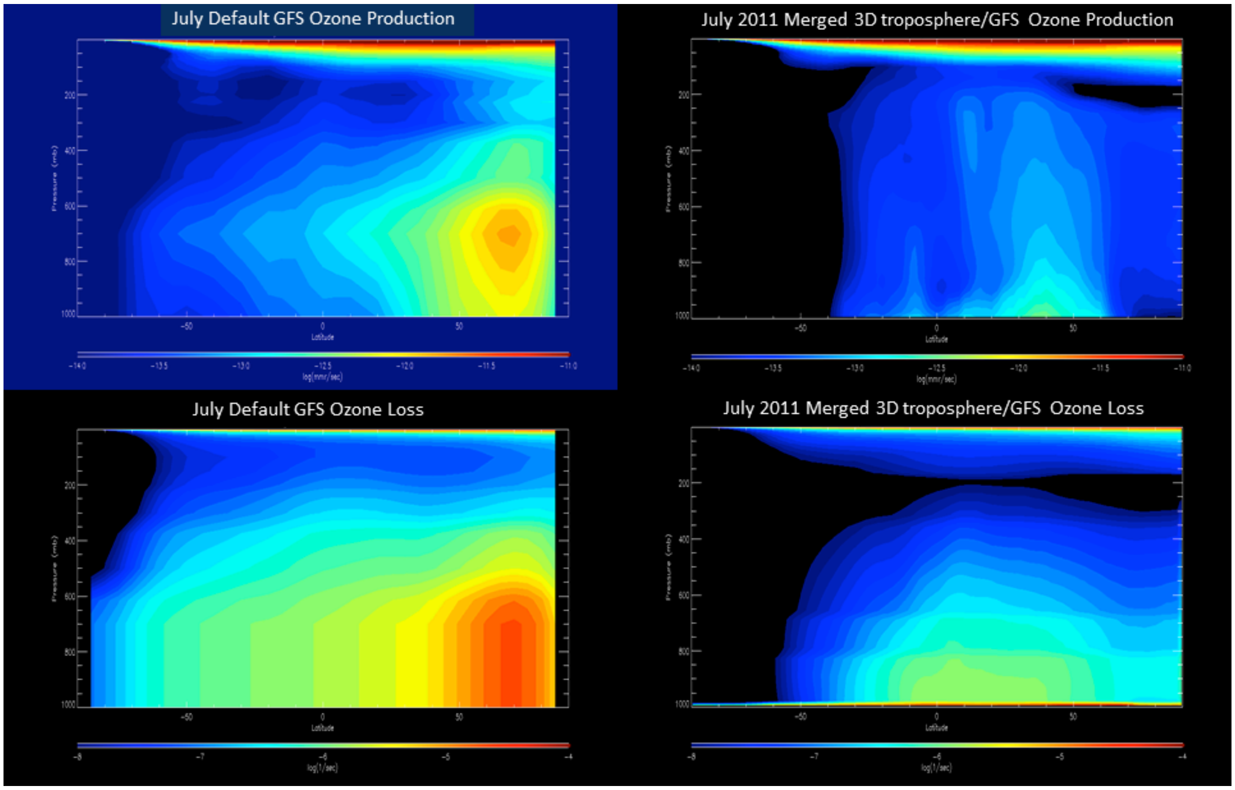

Figure 116. Comparison of Default July GFS Ozone Production (upper left, expressed in logarithm of mass mixing ratio per second) and Loss (lower left, expressed in logarithm of inverse seconds) with Merged 3D troposphere/GFS ozone Production (upper right) and LOSS (lower right).

The impact of the updated tropospheric O3 PL on GFS meteorological forecasts has been assessed using the Verification Statistics Data Base (VSDB) from the NCEP Verification System. Figure 117 shows Northern Hemisphere and Southern Hemisphere AC scores for Day 5 500mb height forecasts for the control and 3D O3 PL experiments. Slight improvements are found in the Northern Hemisphere while slight degradations in Day 5 forecasts are found in the Southern Hemisphere. Day 1-5 die-off curves for Northern Hemisphere and Southern Hemisphere 500mb height forecasts show that the differences shown in Figure 117 are not statistically significant at the 95% confidence level.

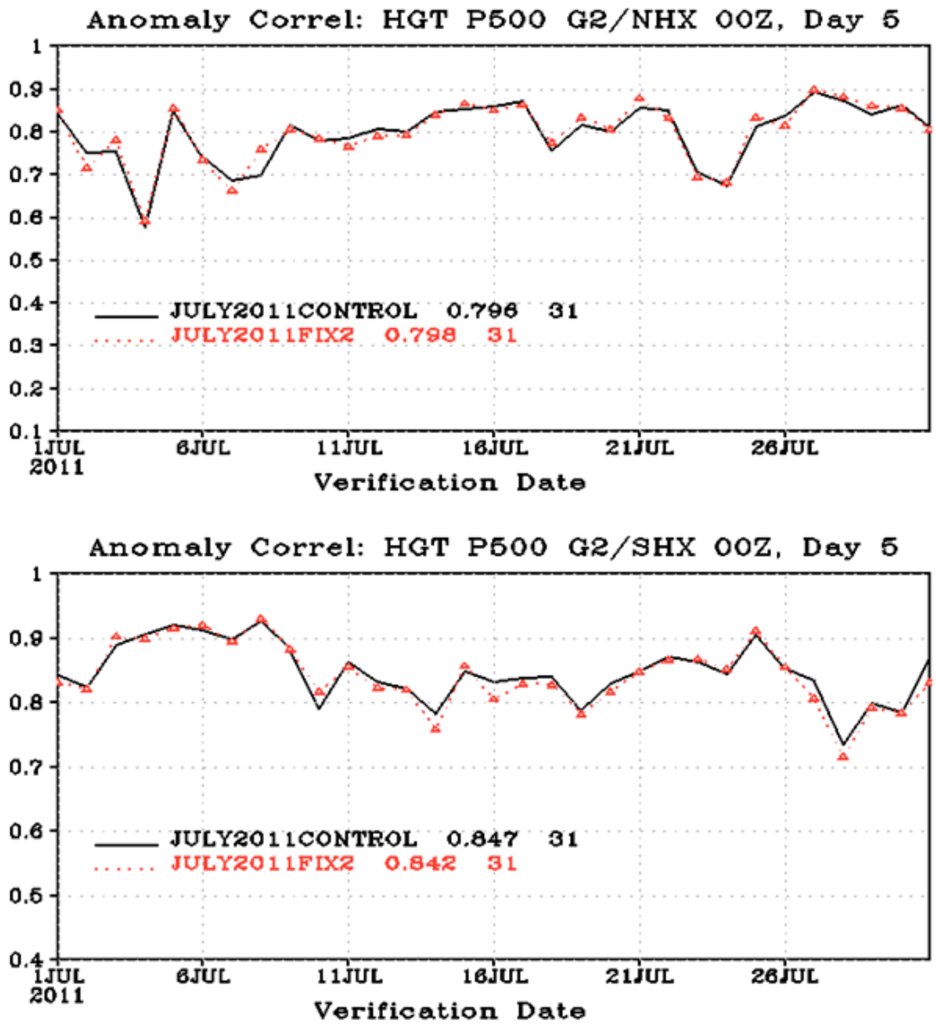

Figure 117. Anomaly Correlations (AC) for Day 5 500mb height forecasts from July 2011 GDAS control (black) and 3D O3 PL (red) experiments for the Northern Hemisphere (upper panel) and Southern Hemisphere (lower panel).

It was found at NCEP that IASI ozone channels had been unintentionally used in operational GSI data assimilation in GDAS system. A data denial experiment was conducted to evaluate the effect of turning off the IASI ozone channels within the GSI for the period mid June 2011 (spin up period) and July 2011. Turning off the IASI ozone channels has a small mixed result. There was a slight decrease in 500 MB height correlation at day 3 to 4 while the Ozone bias is reduced at the 10 and 20 MB layers and the Ozone correlation is higher at days 3 to 4.

Publications, Reports, Presentations

Preliminary results from the 3D tropospheric P-L testing was presented at the 3rd NASA Air Quality Applied Science Team (AQAST) Meeting, June 13-15, 2012 at the University of Wisconsin – Madison.

Presentation at 10th JCSDA Workshop on Satellite Data Assimilation at College Park, MD , October 10-12, 2012 "Implementation of GOES Total Column Ozone Assimilation within NAM-

CMAQ to improve Operational Air Quality Forecasting capabilities” (R. Bradley Pierce(NOAA/NESDIS/STAR), Todd Schaack, Allen Lenzen(UW-Madison, CIMSS), Pius Lee(NOAA/OAR/ARL)

32 Updating the Secondary Eyewall Formation Probabilistic Model, Completing New Climatologies of Intensity and Structure Changes Associated with Eyewall Replacement Cycles

CIMSS Project Lead: Christopher M. Rozoff
CIMSS Support Scientists: William Lewis (CIMSS/SSEC), Matthew Sitkowski (The Weather Channel)
NOAA Collaborator: James P. Kossin (National Climatic Data Center)
NOAA Strategic Goals Addressed:

- Serve society’s needs for weather and water information
- Protect, restore and manage the use of coastal and ocean resources through an ecosystem approach to management
- Support the nation’s commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Environmental Models and Data Assimilation
- Outreach and Education

Project Overview

This project is under the Joint Hurricane Testbed project and is active from August 2009 to August 2013.

The formation of a secondary outer concentric eyewall in a hurricane usually precedes large intensity and wind structure changes. These changes are particularly difficult to forecast because they are not captured well by the standard numerical and statistical guidance. Consequently, when the formation of a secondary eyewall is observed or predicted in an operational setting, forecasters must rely on expert judgment based on past experience to subjectively modify the objective intensity forecasts provided by the available guidance. The goal of this 4-year project was to provide objective models to provide a probability of secondary eyewall formation and the associated intensity and structure changes at various forecast lead times, and to transition these models into operational testing at the National Hurricane Center.

Summary of Accomplishments and Findings

In Year-1 of this project, we successfully transitioned a new probabilistic model into NHC operations to help predict the formation of secondary eyewalls (Kossin and Sitkowski 2009). This model has been incorporated into the operational SHIPS intensity forecasting model and has been performing skillfully in an operational setting. In April 2012, the model was officially chosen for implementation into the National Hurricane Center operational guidance suite. In Year-2, we constructed an expanded record of low-level aircraft reconnaissance data and used this to document an expanded climatology of intensity and structure changes associated with eyewall replacement cycles (ERC) in Atlantic hurricanes (Sitkowski et al., 2011). In Year-3, we used the characteristics of these changes to construct new statistical models that use environmental and satellite data to provide objective intensity guidance that specifically targets the changes associated with ERCs (Kossin and Sitkowski 2012). In Year-4 (the final year of this project), we have been working to further increase the skill of the models through optimized feature selection and other techniques, and working toward transitioning the new models developed in Year-3 to operations.

Publications, Reports, Presentations

Kossin, J., M. Sitkowski, W. Lewis, and C. Rozoff, 2013: A new secondary eyewall formation index; Transition to operations and quantification of associated hurricane intensity and structure changes: A Joint Hurricane Testbed project. *67th Interdepartmental Hurricane Conference, College Park, MA.*

Sitkowski, M., J. P. Kossin, C. M. Rozoff, and J. Knaff, 2012: Hurricane eyewall replacement cycles and the relict inner eyewall circulation. *Mon. Wea. Rev.*, **140**, 4035-4045.

Kossin, J. P., and M. Sitkowski, 2012: Predicting hurricane intensity and structure changes associated with eyewall replacement cycles. *Wea. Forecasting*, **27**, 484-488.

Sitkowski, M., J. P. Kossin, and C. M. Rozoff, 2011: Intensity and structure changes during hurricane eyewall replacement cycles. *Mon. Wea. Rev.*, **139**, 3829-3847.

Kossin, J. P., and M. Sitkowski, 2009: An objective model for identifying secondary eyewall formation in hurricanes. Mon. Wea. Rev., **137**, 876–892.

33 Real Time Prediction of Hurricanes and Investigation of Factors Influencing Numerical Intensity Prediction

CIMSS Project Lead: Gregory J. Tripoli
CIMSS Support Scientist: William E. Lewis
NOAA Collaborator: Mark DeMaria (NESDIS)

NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation

Project Overview

During FY2012 this project supported NOAA's Hurricane Forecast Improvement Project (HFIP) in its primary mission of high-resolution numerical model (NWP) development for the purpose of forecasting tropical cyclone track and intensity. The project recently ended after 1 year, but participation in NOAA HFIP continues in the form of real-time forecasts provided to the National Hurricane Center (NHC) for the 2013 Atlantic and eastern Pacific hurricane seasons.

Summary of Accomplishments and Findings

As part of NOAA HFIP we participated in the 2012 HFIP demonstration, during which we completed in excess of 330 forecasts for Atlantic basin tropical cyclones. The output was communicated to NHC in real time and was instrumental in forming the IV15 intensity consensus guidance product. The results for the 2012 University of Wisconsin Nonhydrostatic Modeling System (UW-NMS) forecasts are shown in Figure 118 and Figure 119. A homogeneous comparison with the other regional dynamical models demonstrates that UW-NMS (UWN8) outperformed all others with regard to track and was a very close second to the Geophysical Fluid Dynamics Laboratory (GFDL) model for intensity.

More recently we completed in excess of 1,000 deterministic and 6,000 ensemble forecasts as part of the 2013 HFIP retrospective test. Model development and refinement carried out during this process led to a higher-resolution version (4km horizontal spacing) of the model being adopted for use in 2013. This increase in resolution, as well as improvements made in model physics and vortex initialization, resulted in UW-NMS again being selected for real-time participation by NHC. Forecast output for the Atlantic and eastern Pacific may be found at several locations on the Web, including:

http://cup.aos.wisc.edu/will/HFIP/
http://www.hfip.org/data_tracker/
http://www.hfip.org/data/

During this time we also completed installation and testing of the model diagnostics module developed by Mark DeMaria (NESDIS), allowing UW-NMS forecasts to be used for statistical intensity guidance (i.e., SHIPS, LGEM, SPICE) as well as providing a common framework for model intercomparison studies.

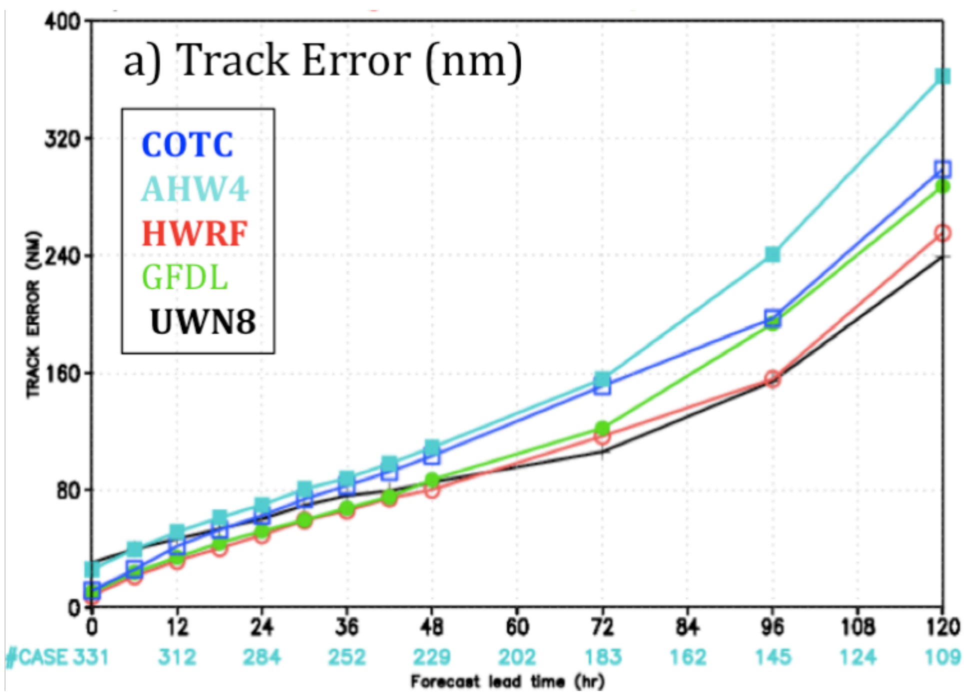

Figure 118. Mean absolute track forecast error for NOAA HFIP regional dynamical models. (COTC=COAMPS TC, AHW4=Advanced Hurricane WRF, HWRF=NCEP Hurricane WRF, GFDL=Geophysical Fluid Dynamics Laboratory, UWN8=University of Wisconsin 8-km model).

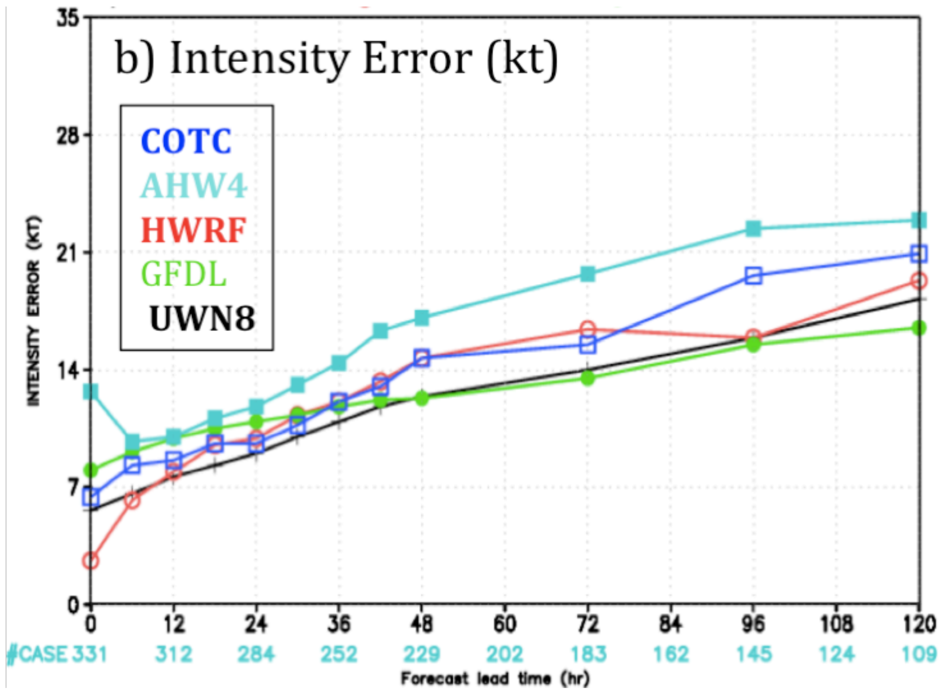

Figure 119. Mean absolute intensity error for NOAA HFIP regional dynamical models. (COTC=COAMPS TC, AHW4=Advanced Hurricane WRF, HWRF=NCEP Hurricane WRF, GFDL=Geophysical Fluid Dynamics Laboratory, UWN8=University of Wisconsin 8-km model).

Publications, Reports, Presentations

Lewis, W.E. and G.J. Tripoli, 2013: Performance of the University of Wisconsin Nonhydrostatic Modeling System in the 2013 HFIP Retrospective Test. In preparation for *Weather and Forecasting*.

34 Improving Very-short-range Forecasts for the NWS Alaska Region Using Objective Tools Designed to Optimize the Retention of Hyperspectral Infrared and Microwave Moisture LEO Soundings

CIMSS Project Lead: Ralph Petersen
NOAA Collaborators: Robert Aune, Gary Wade, Tim Schmit
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Environmental Models and Data Assimilation

Project Overview

This proposal is being submitted in coordination with the National Weather Service (NWS) Alaska Region to provide initial support for a longer-term project intended to increase the operational utility of low earth orbit (LEO) soundings to forecasters and to help fill the large data gaps that exist between the sparse conventional and radar sites. The long-term project objectives are: 1) to assess and validate the 'best' LEO sounder moisture products for very-short-range forecast guidance for products specifically designed for the Alaska Region (AR) forecasting needs, 2) to test the impact of LEO-retrieval based NearCasts on improving a variety of AR operational very-short-range forecasting problems, and 3) to determine the optimal information contained in both hyperspectral and microwave LEO moisture retrievals using a variety of algorithms.

This new applied proposal has just been funded in coordination with the National Weather Service (NWS) Alaska Region, with work beginning in August 2013. NWS Alaska Region (AR) wishes to establish a technical framework and develop a more efficient and scientifically sound forecast process that facilitates improving the use of satellite observations in Impact Decision Support Services (IDSS) in Alaska. Given the limited number of traditional observation systems in the Arctic (e.g., ASOS, upper air, buoys, etc.), NWS AR relies heavily on satellite observations to maintain situational awareness and aid in the forecast process. Alaska is somewhat unique within the NWS in that Low Earth Orbiting (LEO) observations form the dominant satellite data source. And given the latitude, the LEO systems provide sufficient temporal and spatial coverage to play a significant role in that process by providing frequently updated observation (with a 90-180 minutes observation repeat cycles – less when using multiple satellites). Thus most any science and/or technological advances will need to integrate satellite information, especially from LEO satellites, as part of the solution. The high repeat cycle allows the data to be used in a similar ways that used with GOES sounder data (with its standard 1 hour repeat cycle) over the CONUS. This proposal is being submitted at the request of, and in coordination with, the NWS Alaska Region in an attempt to address some of their major unmet and emerging forecast needs.

There are many forecast problems that are especially challenging in Alaska given the aforementioned observational limitations. Some examples of specific challenges that would benefit from improved short-range forecast tools include:

- Convective location, timing and sustainment:
  - Convection over lower terrain.
  - Wildfires and resulting smoke past decade.
  - Mesoscale heavy snow events
- Evolution of Turnagain Arm wind events:
  - Impact air traffic operations.
  - The forecast problem is thus characterizing factors that control the mountain wave response (e.g., Stability, wind, moisture content, etc.) to help forecast the phenomena.
- Heavy Rain events in the Warm Season:
  - Heavy rain events are difficult to accurately pinpoint spatially with the integration of larger scale vertical motion fields, complex terrain, and moisture plumes.

The long-term goal of this effort will focus on improving very-short-range moisture, stability and precipitation forecasts by identifying the 'best' JPSS products and procedures to use in improving forecast guidance for the AR. As the prerequisite step to this effort, we will provide an independent assessment of the accuracy and test the applicability of JPSS moisture data over land at high latitudes based on existing GPS TPW observation using the system is already being developed at CIMSS that compares GOES and LEO Total Precipitable Water (TPW) data to surface GPS data, as well as surface-based microwave radiometer and Raman Lidar data from the ARM CART site and moisture profiles from AMDAR equipped aircraft. This proposal will extend the CIMSS GOES-based system to assess the results from a variety of other AIRS/IASI/CrIS retrieval systems and include microwave retrievals over oceans where possible.

The results of this effort will be important to both subjective (forecaster) and objective (NWP) use of future JPSS observations.

The second part of this new effort will build upon investments already made by the GOES-R program toward the goal of expanding the utility of satellite soundings to forecasters by adding a reliable prediction tool. Although the time between successive LEO soundings over AR is greater than that for GOES data over the CONUS, the quality of the LEO produces will make up for much of the different. Instead of restricting forecasters to use the detailed time/space-frequency LEO soundings only as observations, a major benefit in using the new tools is likely to come through applying proven objective systems that assist forecasters in predicting rapidly developing, extreme weather events. This will be done by adapting the data-driven CIMSS "NearCasting" system developed under the GOES-R program to use LEO observations. The system has proven useful in filling the 1-12 hour information-gap which exists between Nowcasts (based primarily on extrapolation of radar data – which are very limited in AR) and longer-range NWP guidance. The NearCasting system is unique in that it can detect and retain extreme horizontal and vertical variations in the atmosphere (especially moisture fields) and incorporate large volumes of high-resolution asynoptic data, while also being extremely computationally efficient, with analysis and forecast refreshes becoming available immediately after every satellite product update. The systems has been especially useful in expanding the usefulness of current and future GOES-DPI products in NWS WFOs, expanding their use from only offering observations of past conditions to providing predictions of pre-storm conditions in the near future.

35 CIMSS Cal/Val Activities in Support of the Calibration Work Group

CIMSS Project Lead: Mathew M. Gunshor
CIMSS Support Scientists: Anthony J. Schreiner, James P. Nelson III
NOAA Collaborators: Timothy J. Schmit (NESDIS/STAR/ASPB), Changyong Cao (NESDIS)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques

Project Overview

CIMSS has been heavily involved in GOES calibration as well as product generation since its inception. The experience developed at CIMSS on current GOES has been extended to include the GOES-R ABI. Over half of the ABI product algorithms were developed at CIMSS.

There are three objectives to this project. The first is to assist the GOES-R Calibration Working Group (CWG) on matters of ABI calibration by consulting (through the monthly CWG telecons) with the group and, when appropriate, offering a tie-in to products to help quantify and understand calibration issues. This will help ensure ABI L1b calibration and data quality. The capability of generating products, comparing product outputs, and product analysis has been developed at CIMSS already under the Algorithm Working Group (AWG). The second objective is to assist the CWG with Japan Meteorological Agency (JMA)'s Advanced Himawari Imager (AHI) in understanding the calibration and navigation, which allows us to leverage all knowledge gained at JMA and will help the CWG prepare for the ABI. The AHI is very similar to ABI and is being constructed by the same vendor. In addition to this CIMSS continues the monitoring of current GOES Sounder calibration using the "calc versus obs" method developed for this project, in preparation for the GOES-R ABI.

Proposed Tasks:

- Attend monthly CWG telecons
- Assist CWG in analysis of calibration issues as pertaining to their effects on products, supporting L1b calibration and ensuring ABI data quality.
- Assist CWG in analysis of calibration and navigation on JMA's AHI.
- Continue GOES Sounder "calc versus obs" monitoring

Summary of Accomplishments and Findings

CIMSS has had a representative at Calibration Working Group (CWG) monthly meetings (teleconferences). There have been presentations from CIMSS at these meetings to show how CIMSS scientists address issues with current GOES. While the CWG is focused on GOES-R, there is overlap in personnel between current and future GOES calibration teams and projects. While the issues affecting current GOES may not be the same for future GOES, the methods and techniques developed now can either be applied later for GOES-R or can provide guidance on how to handle future situations. One of the topics discussed by CIMSS was an issue of co-registration affecting the GOES-13 Imager. Co-registration is a problem where data from two or more satellite bands from the same instrument are not aligned properly on the Earth coordinate system. Slides were presented illustrating the process of how the issue was discovered (fictitious fog and clouds in river valleys and along other land/water boundaries) and highlighting the effect of the co-registration problem on products such as cloud top pressure and the cloud mask. Before implementing a possible Co-registration correction technique additional testing by the bio mass burning group using GOES-13 Imager data must be completed.

On 22 May 2013, GOES-13 experienced a serious anomaly, now believed to be caused by a micro-meteorite striking the spacecraft, which caused the satellite to place itself in storage mode. CIMSS, SSEC, and ASPB colleagues provided support to the Office of Satellite and Product Operations (OSPO) during the outage. On 30 May 2013 GOES-13 was sending data again. These data were received in realtime by the SSEC Data Center. The Sounder was put through outgassing at the request of T. Schmit (NOAA/NESDIS/STAR) for approximately 4 days in order to improve signal-to-noise before returning to operations. The operational Sounder data were monitored for noise and showed an improvement in the shortwave bands, especially band 15 (4.5 um). This was presented to the CWG in June 2013.

In addition to this, CIMSS continues to maintain a Web page for monitoring GOES Sounder calibration. The method utilized for this is primarily comparing calculations from a forward model using forecast model atmospheric profile data to actual Sounder observations. This is often referred to as "calc vs obs," and is used by EUMETSAT and others as well. The GOES Sounder monitoring Web site has gone through many upgrades, and is now capable of generating custom plots and saving the plots to the user's local computer. This is an improvement over previous versions of the page which had static plots generated automatically. Allowing the user to generate their own plots provides the ability to choose custom dates and overlay multiple variables on one plot.

At this time, JMA is still working on AHI and they do not have any data to share. Several members of NOAA/NESDIS/ASPB have visited JMA to discuss AHI and so collaborations are under way.

Publications, Reports, Presentations

Gunshor, Mathew M., T. J. Schmit, D. Tobin, and P. Menzel, 2011: Intercalibration activities at CIMSS in preparation for the GOES-R era. Seventh Annual Symposium on Future Operational Environmental Satellite Systems, 91st AMS Annual Meeting, Seattle, WA, 23–27 January 2011.

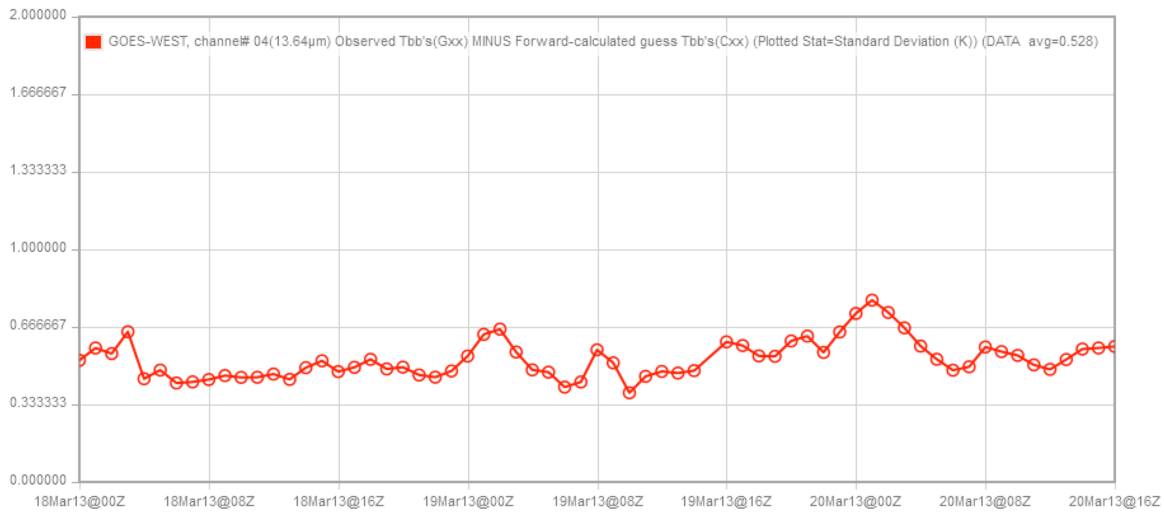

Figure 120. This plot is from the CIMSS GOES Sounder Calc vs Obs monitoring Web site and shows the difference between observed brightness temperatures and forward-calculated (from GFS model data) brightness temperatures for band 4 (13.64 micrometer) for the GOES-15 Sounder. The Sounder patch temperature was "floating" and the effects could be seen around 2-3UTC on these days. http://cimss.ssec.wisc.edu/goes/sounder_tbb_stats/tbbc.html

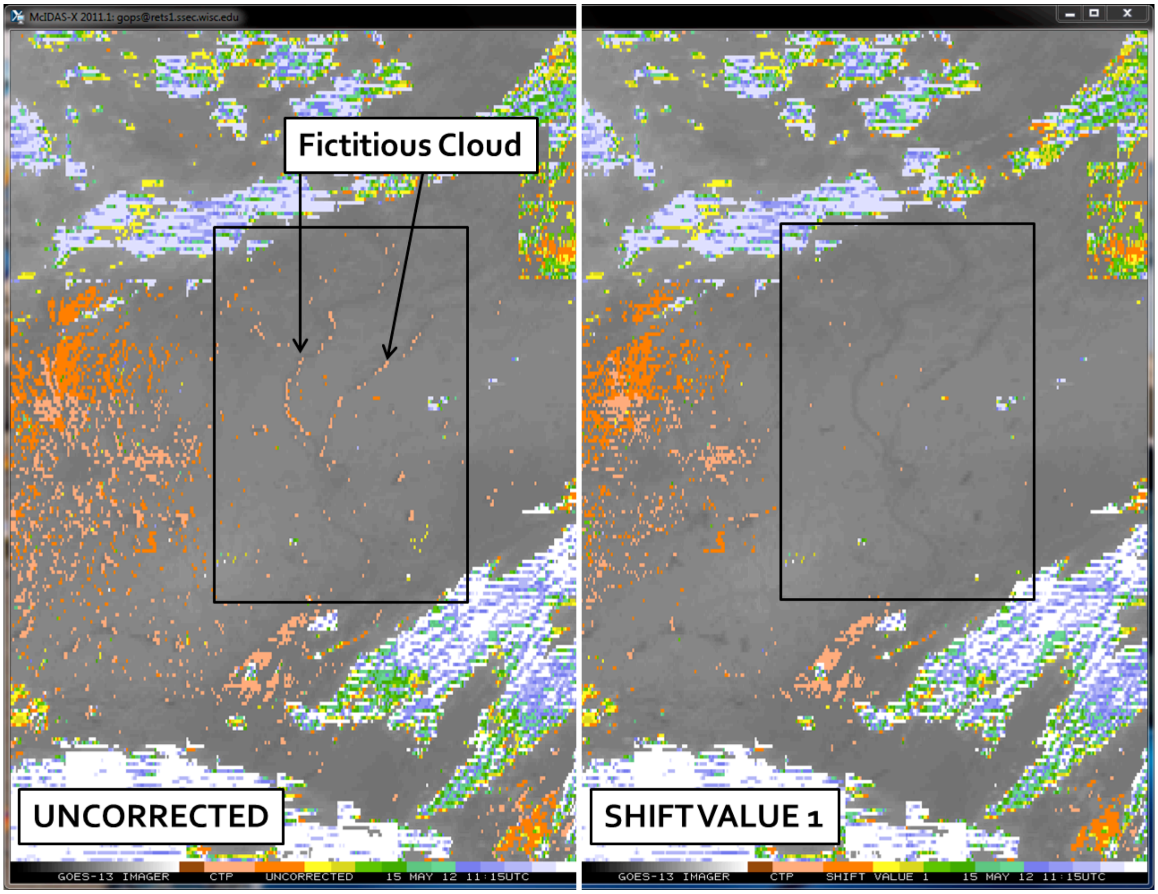

Figure 121. The effects of a co-registration error are seen in this GOES-13 Imager cloud top pressure comparison from 11:15UTC 15May2012. Co-registration is a problem where data from two or more satellite bands from the same instrument are not aligned properly on the Earth coordinate system. Since cloud products, among others, rely on band differencing, this creates a problem. On the left, the uncorrected data show fictitious cloud along several river borders (e.g., Mississippi and Illinois Rivers) as well as along some small lakes. On the right is the cloud top pressure product after the data have been corrected; note that the fictitious clouds along rivers and lakes have been removed.

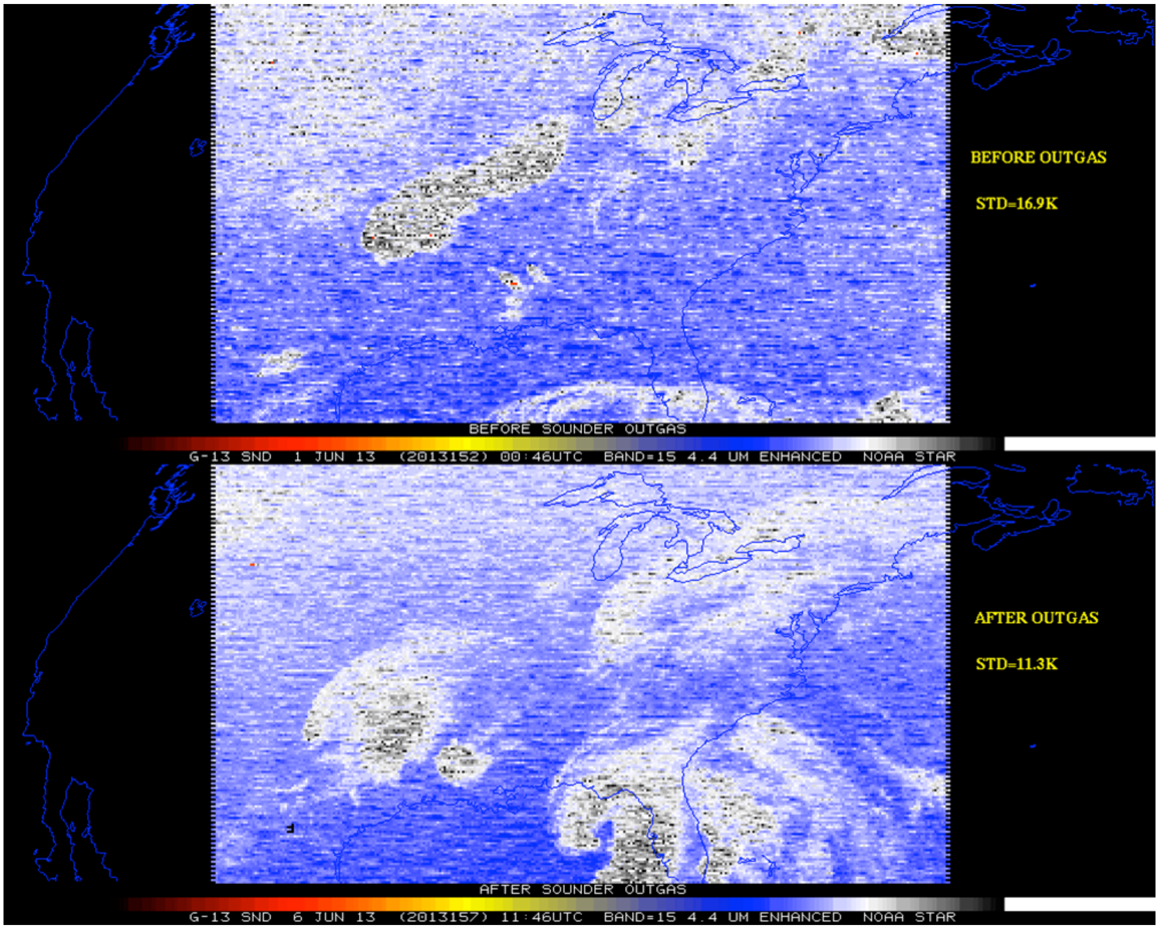

Figure 122. The 4-day GOES-13 Sounder outgas in June 2013 somewhat improved the signal-to-noise ratio, especially for the shortwave band 15 (4.4 um).

36 CIMSS Support of STAR Calibration/Validation Activities

CIMSS Project Leads: Mathew M. Gunshor, Christine Molling
CIMSS Support Scientists: Scott Lindstrom, Sharon Nebuda
NOAA Collaborators: Timothy J. Schmit (NESDIS/STAR/ASPB), Andrew Heidinger (NESDIS/STAR/ASPB), Fangfang Yu (NESDIS)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

NOAA participates in research promoting and advancing the knowledge of intercalibration techniques through the Global Space-Based Inter-Calibration System (GSICS). The primary goal of GSICS is to improve the use of space-based global observations for weather, climate and environmental applications through operational inter-calibration of the space component of the WMO Global Observing System (GOS) and Global Earth Observing System of Systems (GEOSS). GSICS methodology was built in collaboration with input from CIMSS researchers and CIMSS has supported the GSICS effort throughout the development phase. This project supports NOAA's efforts with GSICS and also the NOAA Mission Goals of Climate and Weather and Water.

The first task outlines a plan to perform retrospective analysis using the GSICS method. This effort builds on work done in the previous years to do similar tasks. The operational GSICS team performs intercalibration daily for their host of geostationary imagers and includes the United States, Japan, China, and Europe. CIMSS scientists will conduct a retrospective analysis of all of the instruments being done operationally, as well as several instruments no longer in operations. It was proposed to use AIRS to intercalibrate the GOES, Meteosat, FY-2, and MTSAT Imagers using the NESDIS GSICS algorithm retrospectively for the entire period of data record overlap between AIRS and these geostationary imagers. When that is completed, the same would be done for the GOES Sounders. The GSICS code to be provided to CIMSS by NOAA-NESDIS-STAR. CIMSS implements the code locally and leverages other projects to obtain the AIRS data. The Space Science and Engineering Center (SSEC) datacenter has the geostationary data archive available for CIMSS scientists at a small cost to individual projects.

In addition to this retrospective processing, a second task for this proposal was the development of the sun-glint based visible calibration, a project led by Andrew Heidinger. Sun-glint is apparent in both the 0.65 and the 3.9 micrometer channels on almost all satellite imagers including all geostationary imagers. This work builds on past work using other channels to inter-calibrate satellite radiances. The benefit of this work is the calibration information is available in real-time and is ideal for monitoring the calibration of the global geostationary satellites. This method is also applicable to historical satellite imagers that flew before the current suite of sensors with on-board calibration.

Summary of Accomplishments and Findings

Task 1: The generation of GSICS output is running smoothly. All of the data for the GOES Imagers have been shared with NESDIS. Comparisons with METEOSAT-9, METEOSAT-7, MTSAT-1R, MTSAT-2, and FY-2C have been completed and shared with NESDIS as well. Comparisons continue with METEOSAT-8. In June of 2008 EUMETSAT made changes to their data regarding the definition of radiance. This has caused some confusion here at SSEC as to what data are in the archive and how much of a difference the change has caused in GSICS results. While the questions of the archive's contents have been answered, the answer to how much of an effect remains open.

Working in conjunction with scientists at STAR on prioritizing the order in which the data are produced, all of the GSICS data have been processed and delivered for GOES Imager/AIRS overlap dates. For GOES-08, 148 days during 2002-2003; for GOES-09 854 days during 2003-2005; for GOES-10 2,366 days during 2002-2009; for GOES-11, 1,976 days during 2006-2001; and for GOES-12, 3,138 days during 2003-2010. Some of the data for Europe's METEOSAT have been delivered: for MET-07, 1,035 days during 2007-2009 and for MET-09, 1,644 days during 2007-2011. For Japan's MTSAT-1R 933 days between 2007 and 2009, as well as parts of the end of 2010, 2011, and 2012. For MTSAT-2 913 days were processed between 2010 and 2012. There were 911 days processed between 2005 and 2007 for China's FY-2C. Some more recent data for GOES-13 were processed to support the return of GOES-13 to operations after it was unexpectedly placed in storage mode in spring of 2013. The date ranges listed are not always continuous as satellites go in and out of operational mode and/or are moved.

To date, over 38 satellite years of GSICS data using AIRS have been processed and shared with NESDIS, covering 12 geostationary satellites. Task 1 continues with FY-2D and will continue with the GOES Sounders.

GEO-AIRS GSICS Back-processing

GOES Imager	GOES-08	GOES-09	GOES-10	GOES-11	GOES-12	GOES-13	GOES-14
Days	148	854	2,366	1,976	3,138	7	47
Date Ranges	2002244-2003090	2003113-2005321	2002244-2009334	2006152-2011340	2003016-2010364	2013151-2013157	2012228-2012274

	MET-07	MET-09	MTSAT-1R	MTSAT-2	FY2C
Days	1,035	1,644	933	913	911
Date Ranges	2007001-2009365	2007101-2011364	2007254-2012360	2010182-2012366	2005184-2007365

Figure 123. Over 38 years of satellite comparisons have been processed using the GSICS GEO-AIRS method. This fills in the NESDIS GEO-AIRS GSICS archive for the above instruments. Dates are general ranges of comparisons; the dates are typically not continuous since the GEOs are not continually operated during these dates.

During 2011 CIMSS hosted a visiting scientist from China's National Meteorological Satellite Center (NMSC), Dr. Yong Zhang. Dr. Zhang is involved in the GSICS efforts for China and is a subject matter expert on FY-2 (China's geostationary imager series) calibration. In collaboration with Dr. Zhang, a paper was published on FY-2C/D/E infrared intercalibration using AIRS and GSICS methods. By having the GSICS code at CIMSS installed and access to AIRS data during his visit, CIMSS was able to host Dr. Zhang and assist with his research efforts to improve calibration on environmental satellites internationally.

Task 2:

- The Pathfinder Atmospheres Extended (PATMOS-x) processing system was modified to generate atmospherically corrected 0.65 and 3.9um reflectances. These are the basis of the calibration.
- Technique was demonstrated on MODIS data which has a known accurate and stable calibration.
- MODIS results compared to theoretical calculations using the Fresnel reflectance equations for salt water.

Publications, Reports, Presentations

Zhang, Yong and Gunshor, Mathew M. Intercalibration of FY-2C/D/E infrared channels using AIRS. *IEEE Transactions on Geoscience and Remote Sensing*, **51**, Issue 3, 2013, pp.1231-1244.

Gunshor, Mathew M. "Status of CIMSS Support for STAR GSICS Activities for 2013" presentation delivered at the special GSICS session of the NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, College Park, MD, April 8, 2013.

Goldberg, Mitch, F. Weng, X. Wu, F. Yu, L. Wang, D. C. Tobin, and M. M. Gunshor, 2011: The Global Space-based InterCalibration System (GSICS) for GOES-R and JPSS. Seventh Annual Symposium on Future Operational Environmental Satellite Systems, 91st AMS Annual Meeting, Seattle, WA, 23–27 January 2011.

37 UW-Madison Scanning-HIS Participation in the NPP/JPSS Aircraft Field Campaigns

CIMSS Project Leads: Henry Revercomb, David Tobin, Joe Taylor
CIMSS Support Scientists: Robert Knuteson, Fred Best, Doug Adler, Claire Pettersen, Ray Garcia, Jonathan Gero, Nick Ciganovich, Mark Werner, Dan LaPorte, Dan DeSlover, Lori Borg, Chris Moeller
NOAA Collaborator: Mitch Goldberg, NOAA/NESDIS/STAR

NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Sensors and Techniques
- Satellite Meteorology Research and Applications

Project Overview

To better accommodate climate change monitoring and improved weather forecasting, there is an established need for higher accuracy and more refined error characterization of radiance measurements from space and the corresponding geophysical products. This need has led to emphasizing direct tests of in-orbit performance with SI traceability and high accuracy. For the calibration validation process to be both accurate and repeatable, it is very important that the reference data instrument be extremely well characterized and understood, carefully maintained, and accurately calibrated. The UW-Madison Scanning High-resolution Interferometer Sounder (S-HIS) meets and exceeds these requirements and, along with other sensors, flew on the high altitude NASA ER-2 aircraft during the May 2013 Suomi NPP airborne calibration validation campaign. Continued participation in regularly scheduled aircraft campaigns for Suomi-NPP and JPSS are anticipated.

Summary of Accomplishments and Findings

Primary activities this year included:

(1) Preparations of the Scanning-HIS for participation (including laboratory verification of S-HIS reference blackbody temperature calibration and pre and post campaign end to end calibration verification and testing of S-HIS performance and);
(2) Shipping and integration onto the aircraft and test flights,
(3) In-the-field participation in the campaign and de-integration,
(4) Production of Scanning-HIS calibrated spectral radiances, and
(5) Calibration/validation analysis of the aircraft and satellite observations with emphasis on the radiometric calibration uncertainty of CrIS.

A detailed report on each of these efforts is provided online at :
https://www.dropbox.com/s/ubhyry253cwv39w/UW_SHIS_SNPP_Report_2013-06-25JKTv3a.pdf

Several excellent clear sky underflights of Suomi-NPP were obtained during this year's campaign. An example comparison of CrIS and S-HIS is shown in Figure 124. These preliminary results are representative of other cases, with agreement between S-HIS and CrIS for transparent wavelengths better than 0.1K. Full analysis of all wavelengths using double obs-calc methodology is underway. Along with pre- and post-campaign characterization tests, this provides SI traceable validation of the CrIS radiance data for climate studies.

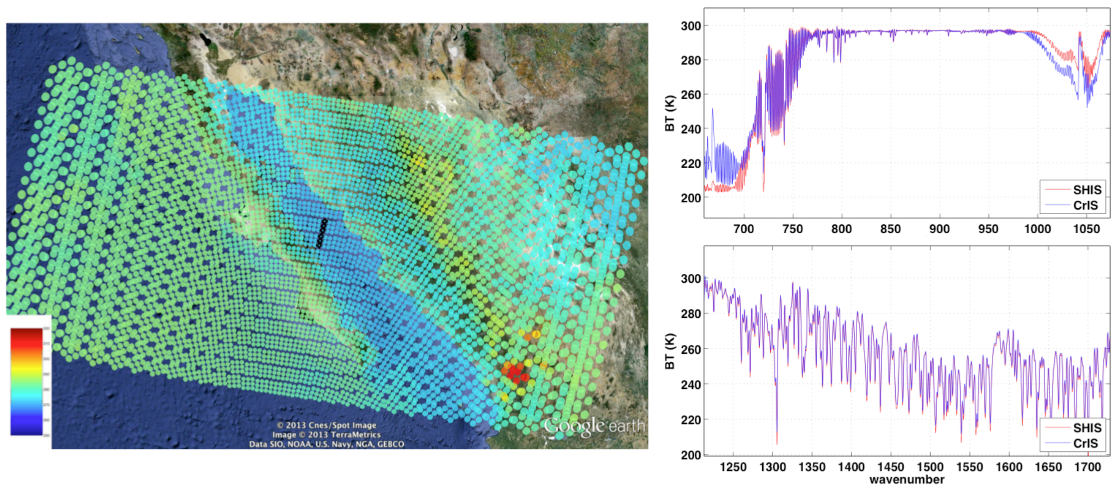

Figure 124. CrIS/S-HIS underflight comparison on 01 June 2013. The left hand image shows the CrIS brightness temperatures for each footprint and the nadir track over the Gulf of Mexico coincident with the ER-2 underflight. The right hand panels show comparisons of the mean CrIS and S-HIS brightness temperature spectra.

Publications, Reports, Presentations

Suomi NPP/JPSS Cross-track Infrared Sounder (CrIS): Calibration Validation With The Aircraft Based Scanning High-resolution Interferometer Sounder (S-HIS), Joe K. Taylor et al., Ninth Annual Symposium on Future Operational Environmental Satellite Systems, 93rd AMS Annual Meeting, 5-10 January 2013, Austin, TX. Extended abstract: https://ams.confex.com/ams/93Annual/webprogram/Manuscript/Paper224132/Taylor%20et%20al%20AMS-10Feb13.pdf

Draft project report: https://www.dropbox.com/s/ubhyry253cwv39w/UW_SHIS_SNPP_Report_2013-06-25JKTv3a.pdf

38 Support for NOAA Cloud Climate Data Records

CIMSS Project Lead: Michael J. Foster
NOAA Collaborator: Andrew Heidinger
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

The Pathfinder Atmospheres Extended (PATMOS-x) is a NOAA/NESDIS climate dataset generated in partnership with CIMSS. Until recently, PATMOS-x dealt exclusively with data from the Advanced Very High Resolution Radiometer (AVHRR) with instruments on the POES and METOP series of polar orbiting spacecraft. PATMOS-x has been modified to generate products from MODIS, GOES and the VIIRS sensor.

In 2010, PATMOS-x was selected as one of the first three Climate Data Records (CDR) to become operational CDRs at the National Climatic Data Center (NCDC). The version of PATMOS-x chosen for this delivery was the AVHRR-only version. NCDC's main goal was to host the PATMOS-x solar reflectance sensor data records (SDRs), which included 0.63, 0.86 and 1.63 μm reflectance.

Summary of Accomplishments and Findings

The milestones necessary to maintain and augment the PATMOS-x operational CDRs at NCDC are as follows:

- Implement quality assurance tools,
- Provide support to NCDC for proper usage of the CDR in operations,
- Implement a system to process and deliver daily updates to the CDR record, and
- Report PATMOS-x usage statistics.

The primary milestone of this year entails shifting from bulk delivery of PATMOS-x calibrated reflectance CDRs to real-time updates with daily deliveries. Efforts have focused on scripting the automated daily delivery of precursor and ancillary data sets as well as the processing of the PATMOS-x CDR from AVHRR Extended (CLAVRX) framework and subsequent delivery to the NCDC archives. To this end the automated generation of these files has been accomplished. The scope of parameters to include has increased to include all calibrated AVHRR channels and a suite of cloud products. Formatting considerations are currently being addressed, and once these details have been ironed out daily deliveries will commence.

Towards the goal of incorporating additional quality assurance tools global mean values of the channel reflectance and brightness temperature were added as global attributes in the PATMOS-x file metadata. Automated plotting of these metrics for the last 30-days has been implemented allowing for simple and quick monitoring of the most recent additions to the CDR record. Figure 125 shows an example of one such plot.

The other milestones set for this period are providing support for the NCDC team for the proper usage of the CDR in operations and collecting usage statistics of PATMOS-x. These are ongoing services that we have maintained throughout this project.

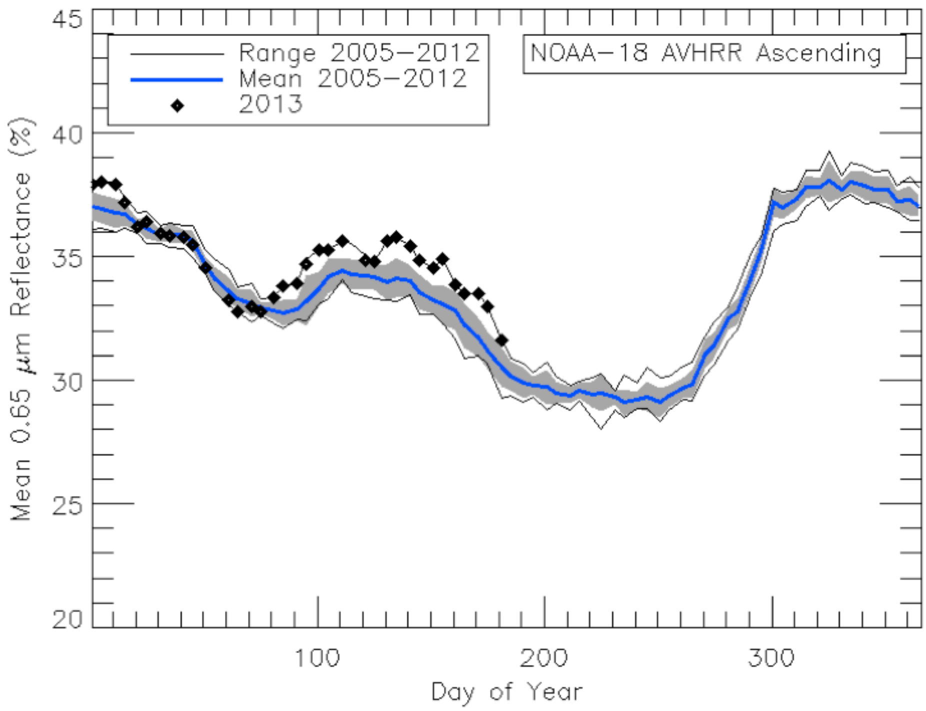

Figure 125. Example of CDR monitoring image from the 0.65 micron channel on the NOAA-18 AVHRR. The blue line represents the annual mean while the shaded gray portion encompasses +/- one standard deviation. Black diamonds each represent one day of data for 2013.

Publications and Conference Reports

Heidinger, A. K., M. J Foster, A. Walther and X. Zhao, 2013: The Pathfinder Atmospheres Extended (PATMOS-x) AVHRR Climate Data Set. Submitted to *Bull. Amer. Meteor. Soc.*

39 Reprocessing HIRS

CIMSS Project Lead: Paul Menzel
CIMSS Supporting Scientists: Bryan Baum, Erik Olson, Richard Frey, Eva Borbas, Nick Bearson
NOAA Collaborators: Jeff Privette, Changyong Cao
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Understand climate variability and change to enhance society's ability to plan and respond
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Summary of Accomplishments and Findings

Mitigating Sensor to Sensor Differences

Sensor to sensor calibration differences continue to be studied in collaboration with the STAR calibration team. The approach is to estimate radiance changes for a specific channel due to Spectral Response Function (SRF) modifications and related uncertainty. A linear model correlates the radiance change in a selected channel with the spectral radiances in selected HIRS channels. The hyper-spectral measurements from the Infrared Atmospheric Sounding Interferometer (IASI) on the MetOp satellite are used to simulate HIRS observations and to estimate the parameters in the linear models. The linear models are applied to the NOAA and MetOp HIRS data at Simultaneous Nadir Overpass (SNO) locations to estimate the inter-satellite radiance differences. The inter-satellite mean radiance biases are minimized with residual maximum uncertainty less than 1% after the impacts of SRF differences and uncertainties are taken out. With use of the MetOp HIRS as a reference, the optimized SRFs for every NOAA HIRS are found by minimizing the root-mean-square values of inter-satellite radiance difference.

After another re-calibration wherein the H_2O channel shifts were finalized, the optimized shifts of the SRF are found to be as large as 2.8 cm-1 for the CO2 channels and 7.1 cm-1 for the H_2O channels. In some cases large differences in the SNO recalibration from the South Pole were found with respect to those from the north pole; these are still being investigated especially for NOAA-11 channel 5. Note that each time a SRF is changed, several years of data need to be processed again to assess the results from the SRF change. That is, the ability to assess changes that result from simple SRF modifications relies on a significant amount of data reduction.

Reprocessing the HIRS Cloud Data Set

HIRS data from NOAA-6 onwards have been re-processed using the original HIRS algorithm software with adjustments suggested by MODIS experience and spectral shifts suggested using Metop HIRS as a reference. Figure 126 shows the resulting afternoon and morning high cloud trends over ocean. Sensor to sensor differences in the high cloud products are found to have been largely mitigated, except for NOAA-11 where large differences in the North and South Pole SNO recalibrations were noted for channel 5. Further study into NOAA-11 (and possibly NOAA-16) is planned.

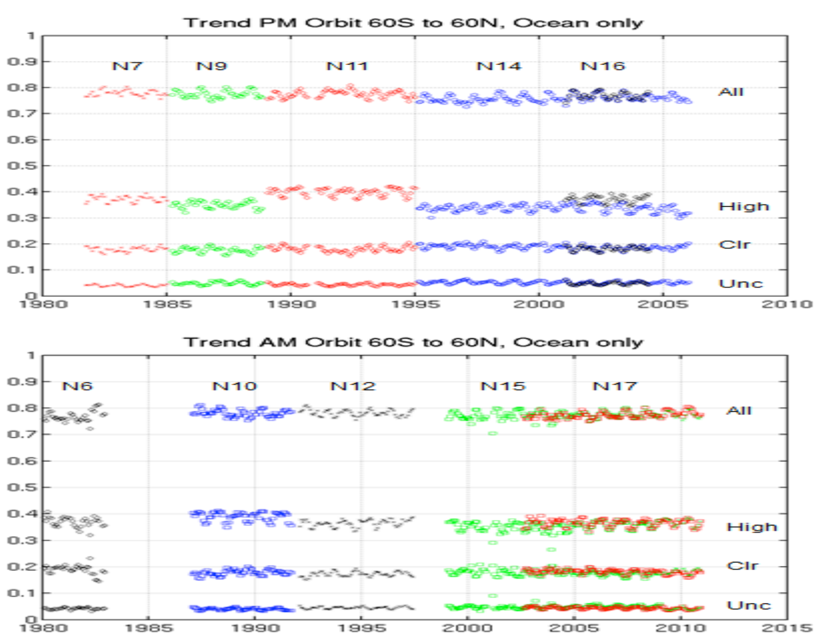

Figure 126. Afternoon and morning high (CTP<440 hPa) cloud over ocean trends from 1980 through 2009 given in fraction of total HIRS observations after the spectral shifts.

Recoding the HIRS Cloud and TPW Algorithms

SSEC delivered to NCDC software for converting HIRS Level 1b and higher level data files to NetCDF-4. In addition the HIRS cloud algorithm software (adapted from MODIS) was delivered to NCDC along with benchmark data and an Algorithm Theoretical Basis Document. The HIRS algorithm software to retrieve moisture layers (high. middle, and low level) and total column moisture will be delivered in September 2013

Investigating HIRS Upper Tropospheric / Lower Stratospheric Cloud Trends

The presence of upper tropospheric / lower stratospheric (UT/LS) clouds has been estimated at the pixel level on the assumption that positive lapse rates above the tropopause imply that the more opaque spectral band sensitive to CO_2 or H_2O in the atmosphere produces a brightness temperature warmer than a less opaque or nearly transparent infrared window spectral band. UT/LS cloud detection trends using measurements sensitive to CO_2 (BT14 > BT13.3) in NOAA-14 data spanning 1995 through 2005 indicated UT/LS clouds in 0.7% of the observations from 60˚N to 60˚S using CO_2 absorption bands; however, in the region of the International Tropical Convergence Zone this increases to 2.5%. Expanding to all the HIRS sensors from NOAA-10 onwards (see figure below) it appears that deep convection in the tropics has been in a slight decrease for the past twenty years. This work was published in JGR.

(a)

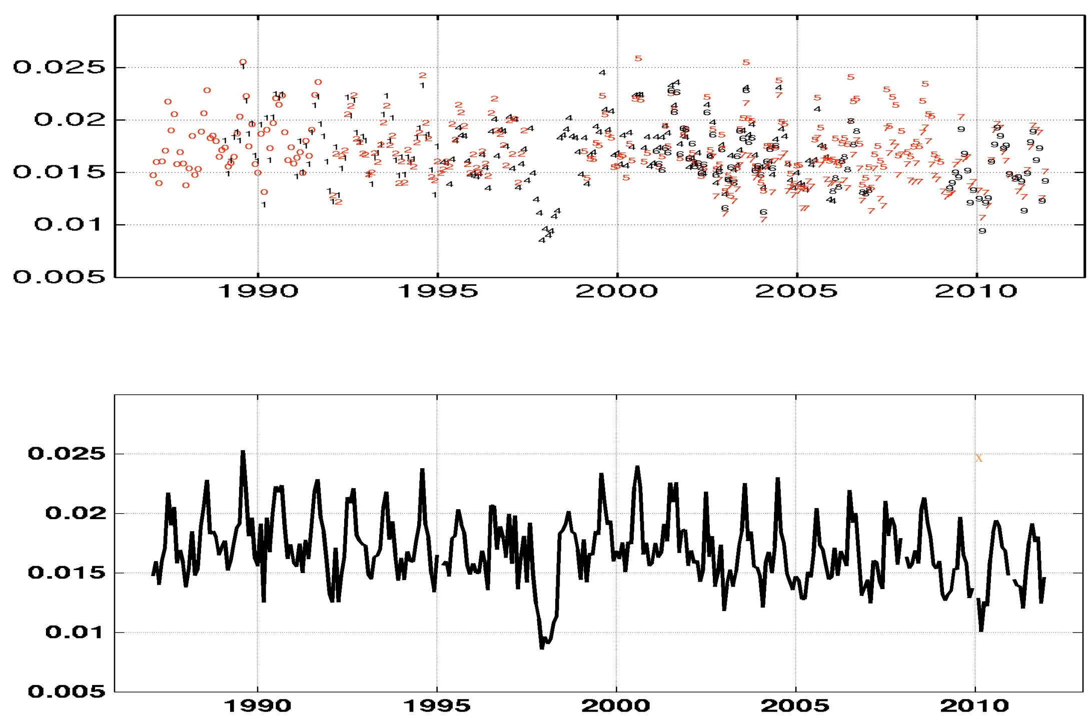

Figure 127. (a) Individual monthly UT/LS cloud fraction detected by each HIRS over the ITCZ (20S to 40N latitude; 45 to180 longitude) from Jan 1987 to Dec 2011. The number indicates the NOAA satellite (e.g., 0 for NOAA-10, 1 for NOAA-11, and so on) and the color indicates the orbit (red for descending morning and black for ascending afternoon). (b) Average monthly UT/LS cloud fraction detected by all HIRS on NOAA-10 through NOAA-19 over the ITCZ from Jan 1987 to Dec 2011.

40 CIMSS Research Activities in the VISIT Program

<u>CIMSS Project Leads</u>: Scott Bachmeier, Tom Whittaker, Steve Ackerman
<u>CIMSS Support Scientist</u>: Scott Lindstrom

NOAA Collaborators: Gary Wade, Tim Schmit, Tony Mostek, Brian Motta
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Outreach and Education

Project Overview

The Virtual Institute for Satellite Integration Training (VISIT) project continues to explore methods to improve and enhance both the content and the techniques utilized for effective distance learning. The VISIT program prepares case studies and examples of satellite data in a form that is appropriate for forecasters (for example, in an AWIPS format for National Weather Service users), with the goal of instructing them on how to best use the satellite data (1) as observations to help increase situational awareness, and (2) as tools to aid in near-term forecasting.

Summary of Accomplishments and Findings

The VISITview software that is used for VISIT training is mature, and only minor improvements have occurred in the past five years. Training module development has focused on products and methodologies that will be useful for the upcoming JPSS and GOES-R satellite era. For example, training modules have been developed for satellite products using algorithms developed as part of GOES-R Risk Reduction or that have emerged out of the GOES-R Algorithm Working Group. These include the UW Cloud-Top Cooling algorithm, the UW Objective Overshooting Top Detection algorithm, and the Fog/Low Stratus data fusion product. One of the most recent training modules describes Suomi/NPP VIIRS data that are available now in AWIPS (via an LDM feed from CIMSS). Recorded versions of these training modules have been inserted into the Department of Commerce Learning Center, and a number of live instructor-led versions of the training modules have also been offered. To date, seventeen different training modules have been developed at CIMSS. Three more are currently in development.

AWIPS (and AWIPS-II) capabilities have been further refined at CIMSS. A stable AWIPS-II platform at CIMSS allows for manipulation of CIMSS-produced datasets into formats that are compatible with AWIPS-II. Thus, the production at CIMSS of products that forecasters wish to see (for example, Cloud-Top Cooling, or MODIS-based Sea-Surface Temperatures) can continue into the AWIPS-II era, and be used for future training modules.

Publications, Reports, Presentations

Bachmeier, A. S. and S. S. Lindstrom, 2014: Blogging as a Training Tool for new Forecast Algorithms, Submitted to 30th Conference on Environmental Information Processing Technologies at the Annual Meeting of the American Meteorological Society.

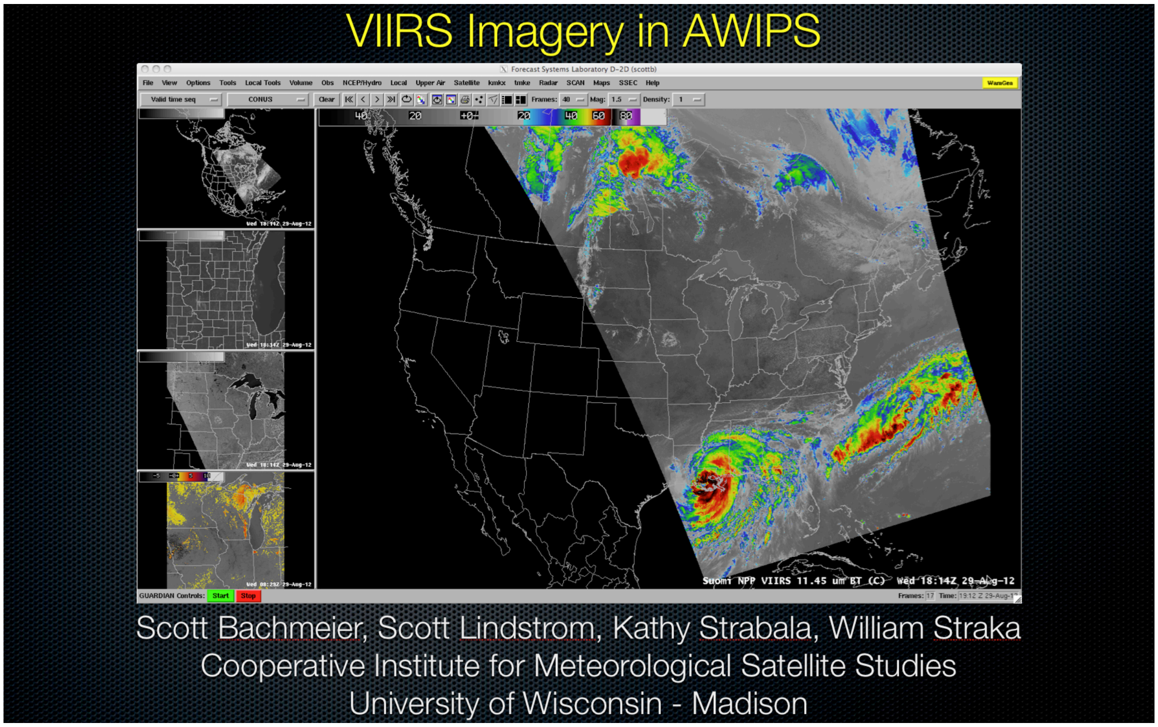

Figure 128. Title slide from the recently-developed VISIT module "VIIRS Imagery in AWIPS"

41 SHyMet Research Activities

CIMSS Project Leads: Scott Bachmeier, Steve Ackerman
CIMSS Support Scientist: Scott Lindstrom
NOAA Collaborators: Gary Wade, Tim Schmit, Tony Mostek, Brian Motta
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Outreach and Education

Project Overview

CIMSS has further developed the Satellite and Hydrology Meteorology (SHyMet) training course through close collaboration with experts at the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University. The role of CIMSS in SHyMet has been to (1) provide advice on the educational design of the program, (2) assist in the development of the curriculum, (3) support distance education activities, (4) develop and test appropriate satellite education materials, and (5) assist in the teaching of the courses as appropriate.

Summary of Accomplishments and Findings

CIMSS has assisted in the development of individual training modules that make up the following SHyMet Courses: Intern, Forecaster, Tropical, Severe Thunderstorm Forecasting, and the pending GOES-R. Much of the data for training modules has been placed on CIMSS Satellite Blog (http://cimss.ssec.wisc.edu/goes/blog); entries include data from MODIS and Suomi/NPP that can serve as a proxy for GOES-R. Training material more appropriate for the Fused Fog/Low Stratus GOES-R products is at http://fusedfog.ssec.wisc.edu/ . The case studies on these blog resources can easily be mined for relevant examples to be used to supplement existing training modules, or to develop new ones.

SHyMet has also benefitted from the real-time AWIPS (and AWIPS-II) capabilities that continue to be refined at CIMSS. The existence of stable AWIPS and AWIPS-II platforms at CIMSS allows for manipulation of unique CIMSS-produced datasets into formats that are compatible with AWIPS and AWIPS-II. Thus, the production at CIMSS of products that are of potential interest to forecasters (for example, GOES-R Fog/Low Stratus products, or VIIRS snow-ice discrimination imagery) can continue to be incorporated into new SHyMet training modules in the upcoming AWIPS-II era.

Publications, Reports, Presentations

Bachmeier, A. S. and S. S. Lindstrom, 2014: Blogging as a Training Tool for new Forecast Algorithms, Submitted to 30th Conference on Environmental Information Processing Technologies at the Annual Meeting of the American Meteorological Society.

42 CIMSS Collaboration with the NWS Training Center

CIMSS Project Lead: Wayne Feltz
CIMSS Support Scientist: Chad Gravelle
NOAA Collaborator: Tim Schmit (ASPB/NESDIS/STAR)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Outreach and Education

Project Overview

CIMSS proposed to support the expanding use of satellite-based weather products by placing a CIMSS satellite scientist at the National Weather Service Training (NWS) Center in Kansas City, MO in 2011. The Dr. Chad Gravelle is providing leadership, satellite expertise, and meteorological support for the GOES-R Proving Ground efforts based at the NWS Training Center (NWSTC) and is funded by GOES-R program.

He works closely with CIMSS researchers, scientists at the NOAA/NESDIS/STAR and GOES-R Program Office and the staff at the NWS Training Center. The position is with University of Wisconsin-Madison and the position's duty station is in Kansas City, MO.

The position will be embedded within the NOAA/NWS Operations Proving Ground (OPG) at the NWSTC. The OPG provides the infrastructure and facilities to effectively transfer new and emerging scientific techniques, products, and services into NWS forecast office operations. The OPG actively engages in the research-to-operations process by supporting applied research, verifying the quality and scientific validity of new techniques and products, and providing a common venue for both forecasters and researchers to engage in developing and testing state-of-the-art aviation weather services.

This project will entail activities focused at maximizing the forecast value of geostationary satellite data and products, particularly activities centered on weather forecast office operations to improve forecast and warning services to the nation. The incumbent will interact with NWS operational forecasters and NESDIS satellite analysts to prepare them for new satellite dependent products that will become available operationally after the launch of the GOES-R satellite series.

Summary of Accomplishments and Findings

Dr. Chad Gravelle was hired on 11 November 2011 to serve as National Weather Service Training Center (NWS TC) "Satellite Champion." He spent one week in Madison, WI at the National Weather Association annual meeting and is stationed permanently at the NWS TC in Kansas City, MO. CIMSS participated in the hiring process and Wayne Feltz is his immediate supervisor at UW-Madison. Chad is providing satellite liaison support for GOES-R baseline and future capability products.

43 CIMSS Collaboration with the Aviation Weather Center

CIMSS Project Lead: Wayne Feltz
CIMSS Support Scientist: Chad Gravelle
NOAA Collaborator: Tim Schmit (ASPB/NESDIS/STAR)
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Outreach and Education

Project Overview

CIMSS proposed to support the expanding use of satellite-based weather products by placing a CIMSS satellite scientist at the Aviation Weather Center (AWC) in Kansas City, MO. The CIMSS scientist, Amanda Terborg, provides leadership, satellite expertise, and meteorological support for the GOES-R Proving Ground efforts based at the NWS Training Center (NWSTC) since 2012.

The new position works closely with CIMSS researchers, scientists at the NOAA/NESDIS/STAR and GOES-R Program Office and the staff at the NWS Training Center. The position is with UW-Madison and the position's duty station is in Kansas City, MO.

This project will entail activities focused at maximizing the forecast value of geostationary satellite data and products, particularly activities centered on weather forecast office operations to improve forecast and warning services to the nation. The incumbent will interact with NWS operational forecasters and NESDIS satellite analysts to prepare them for new satellite dependent products that will become available operationally after the launch of the GOES-R satellite series.

Summary of Accomplishments and Findings

Amanda Terborg was hired on 9 April 2012 to serve as Aviation Weather Center "Satellite Champion." She is stationed permanently at the Aviation Weather Center in Kansas City, MO. CIMSS participated in the hiring process and Wayne Feltz will be her immediate supervisor at UW-Madison. She has assisted in planning and function of Aviation Weather Testbed activities in February 2013. Results can be viewed from the following blog: http://goesrawt.blogspot.com/

44 Weather Information and Research Satellite Products on Mobile Devices

CIMSS Project Lead: David Santek
CIMSS Support Scientists: Russell Dengel, David Parker
NOAA Collaborator: Jeffrey Key NESDIS/STAR/CRPD/ASPB
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Outreach and Education

Project Overview

The Personal Advanced Weather (PAW) (Dengel 2010a, Dengel 2010b) is a free service provided to the general public by SSEC. It is intended to provide access for the mobile Internet community to a suite of enhanced real-time weather products. While the product suite provides a traditional selection of atmospheric products, the underlying goal is to introduce recent and ongoing research in the field of remotely sensed atmospheric parameters. By presenting these advanced elements as blended products, we provide displays that present the community with a standard frame of reference while extending the content with collocated overlays of these newer fields.

The evolution and acceptance of mobile- and Web-based applications has resulted in a number of advanced processing services dedicated to creation, delivery, and interface for the image, field, and point datasets projected over geo-located displays. These tools provide a standard streamlined alternative to the manual approach developed for, and currently use by the PAW product production environment. Within these new server environments, large geo-located fields can be reprojected, co-located, and disseminated from a generic environment.

A new generation of the PAW product production facility based on geo-referenced map servers will provide a standard mechanism to research scientists to render and disseminate enhanced displays featuring leading-edge algorithms. This facility will eliminate rendering restrictions imposed by the current production engine, provide a standard environment for a wide variety of research formats and projections, and enhance the presentation for all levels of browser-based functionality.

To advance this goal, SSEC has created a prototype Web Map Service (WMS) environment. The facility is a technical development tool providing real-time product access and dissemination tuning. The distinguishing characteristic of the WMS is its modular construction. By using standards-based product generation (OGC-WMS 1.1.1 and KML)[1] and separating the products from their visualization, any number of clients can view the resulting products.

The goals were to:

- Enhance the demonstration WMS to handle tiling, subsecting, and other image functions more efficiently and improve user control when displaying portions of large images. The original PAW processing sectorizes large images into smaller regions at fixed boundaries. This negatively affects the user experience (e.g., panning and zooming is not seamless) and makes it difficult to include additional products; and

[1]Open Geospatial Consortium (OGC); Keyhole Markup Language (KML).

- Survey NOAA/NESDIS satellite products, especially those produced at CIMSS, and determine methods to effectively display these products through the WMS for use by the general public and specific groups, such as emergency managers.

Summary of Accomplishments and Findings

A WMS was installed on existing and upgraded hardware at SSEC and we transitioned the current PAW production environment to the WMS-based PAW. This required adapting the process to take advantage of the WMS enhanced capability to build products and deliver to the user in real-time. Specifically, we have created new interfaces for desktop and mobile browsers, provided the user the ability to create custom displays, and added a mechanism to quickly upload new products.

Two Web-based product viewers have been created. The Simple interface (Figure 129) provides access to users with reduced/limited performance devices. This interface allows for product layering, zoom, roam and animation capabilities while being constrained by a minimal hardware and software configuration.

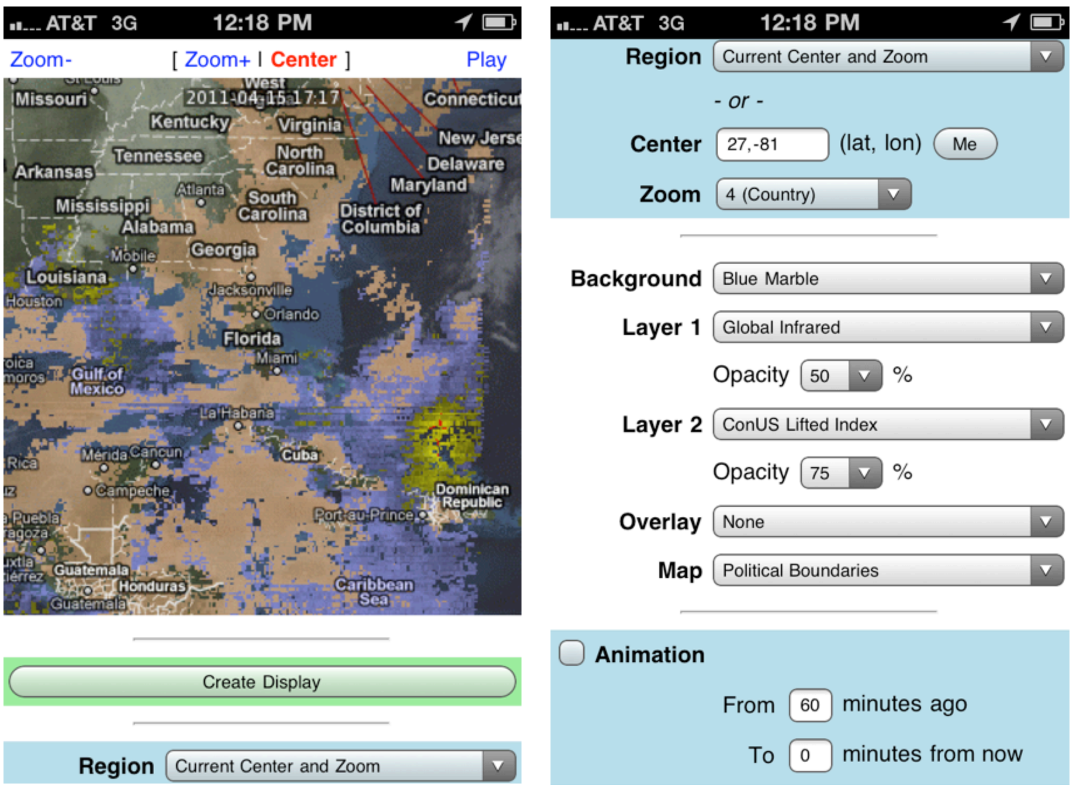

Figure 129. The Simple interface as it appears on an iPhone. The left panel is the view of the products; in this case the GOES infrared channel (gray) is blended with the GOES sounder-derived lifted index product (color shaded). The right panel contains the controls for the user to specify the products to overlay. On the mobile device, the user scrolls vertically between these two panels.

The Gmap interface (not shown) is intended for users of moderate to high performance devices capable of supporting OGC compliant display engines such as Google Maps. Gmap provides users with increased functionality in terms of dynamic zoom/roam with greater product layering potential. While these Web interfaces are quite different in terms of display capabilities, they both retain a common protocol and the ability to scale displays independent of the client device.

Support for scientists wishing to introduce new data fields into the product suite was addressed by providing a script that permits a data provider to directly transfer products to the WMS. This utility uses anonymous ftp to transfer GeoTIFF and McIDAS AREA files to the WMS ingest system. Files are examined and, if necessary, processed before being added to the WMS product suite. A utility to translate standard image enhancement tables between McIDAS and WMS environments was created for researchers to associate a color table with their product.

The product suite includes a comprehensive cross-section of traditional and advanced imagery, field (polygon) and point datasets. Imagery includes examples of both measured and derived parameters from satellite, radar, model, and observed sources. These data are contributed by a number of organizations including both in-house (CIMSS, SSEC) and collaborating institutions (NSSL, NASA Langley, Wisconsin Department of Transportation (DOT)). Field and point data are rendered as tiled graphics overlays, or as interactive "clickable" objects (shapefiles).

Extensions to the standard WMS functionality include a comprehensive animation handler. Animation is a key function due to temporal variability of most atmospheric conditions. This variability is compounded by the generic layering capability provided by a standard WMS server. Users can create multi-layered displays, blending data types with varying sampling rates. The animation controller provides a standard mechanism to create a time-ordered sequence of multi-layered parameters based on the sampling rate of one of the displayed fields. This master layer imposes the time interval around which all other layers are synchronized.

The Simple interface can be accessed at:
http://wms.ssec.wisc.edu/simple/

and, the Gmap interface at:
http://wms.ssec.wisc.edu/gmaps/

Publications, Reports, Presentations

Santek, D., R. Dengel, D. Parker, S. Batzli, N. Bearson, and W. Feltz, 2010: Access to real-time weather satellite products from desktops and mobile devices through a Web Map Service. 17th Conference on Satellite Meteorology and Oceanography. Annapolis, MD, September 2010. American Meteorological Society.

Dengel, R., D. Santek, D. Parker, S. Batzli, and N. Bearson, 2011: Mobile Device Access to Real-time Weather Products using a Web Map Service. 27th Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology. Seattle, WA, January 2011. American Meteorological Society.

Santek, D., R. Dengel, D. Parker, S. Batzli, N. Bearson, W. Feltz, L. Cronce, J. Sieglaff, J. Brunner, and K. Bedka., 2011: Satellite Based Nowcasting and Aviation Applications for Mobile Devices. 27th Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology. Seattle, WA, January 2011. American Meteorological Society.

Santek, D., R. Dengel, D. Parker, S. Batzli, N. Bearson, 2011: A Web Map Service for Display of Real-time Satellite Products. 2011 National Severe Weather Workshop. Norman, OK, March 2011.

References

Dengel, R., 2010a: Adapting satellite data for display on mobile devices. 26th Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology. Atlanta, GA, 18-21 January 2010. American Meteorological Society.

Dengel, R., 2010b: Creation and manipulation of meteorological products for mobile devices. 26th Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology. Atlanta, GA, 18-21 January 2010. American Meteorological Society.

45 Interpretation of Real-Time Weather and Climate Data for Spherical Displays

CIMSS Project Leads: Patrick Rowley and Steve Ackerman
CIMSS Support Scientist: Rick Kohrs
NOAA Collaborator: Dan Pisut, NESDIS/EVL

NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- Understand climate variability and change to enhance society's ability to plan and respond

CIMSS Research Themes:

- Outreach and Education

Project Overview

As the weather and climate science fields have grown, so has the public's uncertainty in the science, especially with regards to global changes and the causes of weather and climate extremes. Fortunately, NOAA's Science on a Sphere (SOS) exhibit, now in over 100 museums worldwide, has been captivating audiences with Earth system science data visualizations since 2004. Informal education venues, like museums and science centers, have been identified as trusted sources for relaying science information to the public. Even with the awe-inspiring nature of the SOS, docents have struggled with providing the public with meaningful weather and climate stories, using the wide-array of dataset visualizations available.

To address this need, a robust data visualization and interpretation project was proposed and implemented. Through a collaboration with CIMSS, the Cooperative Institute for Climate and Satellites (CICS-MD), and the NOAA Environmental Visualization Lab, the *Interpretation of Real-Time Weather and Climate Data for Spherical Displays* project (NOAA OED award number NA10SEC0080015) (*EarthNow*) allows SOS institutions to go beyond the scientific facts to create meaningful visitor experiences about weather and climate connections. Launched in 2011, the *EarthNow* Team regularly updates a blog-style Web site (http://sphere.ssec.wisc.edu/), providing a central location for SOS facilitators to find timely weather and climate stories to speak about how current events affect and are affected by global change. Along with these stories, the Web site also provides relevant, visually appealing SOS-formatted datasets and animations with appropriate annotations, leading to easier comprehension by presenters and the public.

In 2013, the *EarthNow* team launched a series of best-practice trainings and consultancies. The training sessions provide museums with implementation methods tailored to each museum's goals, allowing for a more personalized learning experience for museum visitors. Operational products, like the monthly climate digest based on NOAA's NCDC reports, are also stressed, with docents sharing this climate information regularly with public audiences.

The intended outcomes of this project are:

1. Improvements in the public's science literacy
2. Improvements in the public's climate literacy, and
3. Awareness of NOAA's contributions to weather and climate science.

Summary of Accomplishments and Findings

Since the *EarthNow* Web site launch in 2012, the team has provided the SOS Collaborative Network with over 150 interpreted dataset visualizations for the SOS. Each month, we release a "Climate Digest" post, highlighting the previous month's weather and climate stories anomalies. This is based primarily on NCDC's monthly global climate analysis. Each month, we also share a seasonal outlook, including global temperature, precipitation, and drought forecasts for the coming months. This is based on information from the CPC and the International Research Institute for Climate and Society (IRI). Along with those monthly stories, we also publish more in-depth science stories quarterly. Examples include "Causes and Effects of Tropical Widening," "Effects of El Niño and La Niña on Phytoplankton and Fish," and "How does the Arctic Affect Extreme Weather?". Smaller timely stories are introduced as events warrant. Such stories include a Saharan dust storm over the Atlantic, the 2012 Arctic sea ice extent minimum, and hurricanes.

Publications, Reports, Presentations

Rowley, Patrick; Ackerman, S.; Pisut, D.; and Mooney, M. EarthNow: Weather and Climate Connections for 3D Spherical Displays. Symposium on Education, 21st, New Orleans, LA, January 2012.

Rowley, Patrick; Ackerman, S.; Arkin, P.; Pisut, D.; Kohrs, R.; Mooney, M.; and Schollaert Uz, S. Communicating Climate Forecasts via NOAA's Science On a Sphere: The EarthNow Project. Conference on Applied Climatology, 20th, Austin, TX, January 2013.

Figure 130. EarthNow Web site.