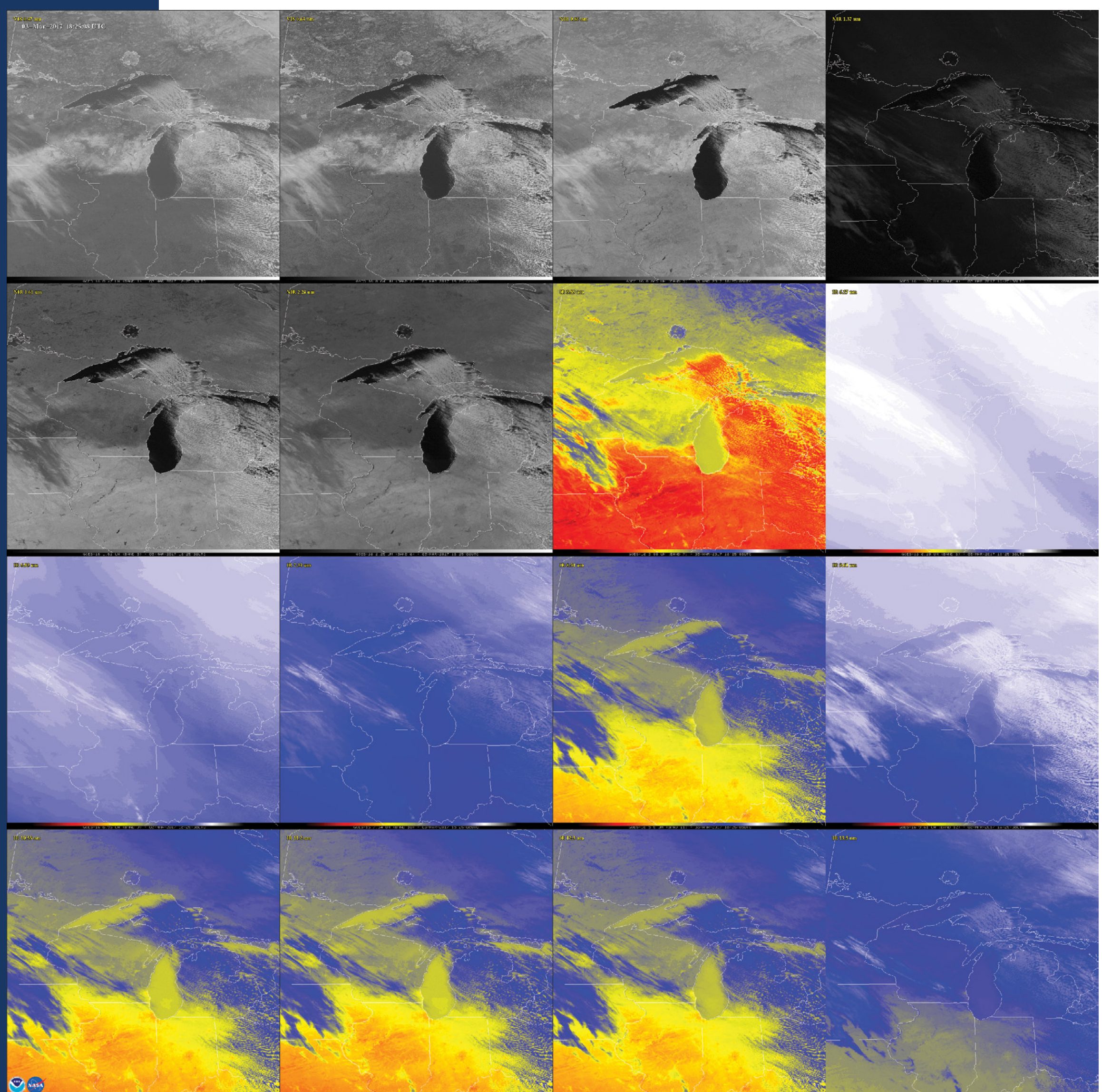
# CIMSS Cooperative Agreement Annual Report

for the period
1 April 2016 to 31 March 2017



GOES-16 ABI
16 channels

3 March 2017
18:25 UTC

Submitted by the
Cooperative Institute for
Meteorological Satellite Studies
University of Wisconsin-Madison
April 2017

## University of Wisconsin–Madison

## Cooperative Institute for Meteorological Satellite Studies (CIMSS)

**http://cimss.ssec.wisc.edu/**

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# Cooperative Agreement Annual Report

**for the period**
**1 April 2016 to 31 March 2017**
**Cooperative Agreement Number: NA15NES4320001**

## Submitted to:
## National Oceanic and Atmospheric Administration (NOAA)

# Cooperative Agreement Annual Report from the Cooperative Institute for Meteorological Satellite Studies University of Wisconsin–Madison

1 April 2016 to 31 March 2017

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**Wayne Feltz**
**Executive Director-Science, SSEC**

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# I. Director's Executive Summary

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin–Madison (UW–Madison) continues to build on the strong collaborative partnership forged with the National Oceanic and Atmospheric Administration (NOAA) in 1980. The goal is to improve remote sensing measurements and their utilization in the pursuit of better monitoring of the earth environment, more accurate and earlier weather prediction, and long term climate perspectives. Through the foundation established by the UW-Madison and NOAA memorandum of understanding, scientists from NOAA/NESDIS and the UW–Madison Space Science and Engineering Center (SSEC) conduct ongoing collaborative research and education. In particular, this includes the NOAA/NESDIS Advanced Satellite Product Branch (ASPB) and a scientist from the National Center for Environmental Information (NCEI), all stationed at the UW–Madison campus.

This annual report gives detailed updates on the projects supported through the cooperative agreement. Our work is aimed at achieving the three mission goals:

1. Foster collaborative research between NOAA and UW–Madison in those aspects of atmospheric and earth science that exploits the use of satellite technology;
2. Serve as a center at which scientists and engineers working on problems of mutual interest may focus on satellite related research in atmospheric studies and earth science; and
3. Stimulate the training of scientists and engineers in those disciplines comprising the atmospheric and earth sciences.

Highlights from the past year have been chronicled in the semi-annual magazine "Through the Atmosphere" which can be found at http://www.ssec.wisc.edu/through-the-atmos/. Eight items that stand out include:

1. CIMSS contributes to long, sustained preparatory work that culminates with the successful launch of GOES-R.
   http://www.ssec.wisc.edu/news/articles/9626
2. NOAA scientist stationed at CIMSS indicates that hurricanes that approach the U.S. coast are more likely to intensify during less active Atlantic periods.
   http://www.ssec.wisc.edu/news/articles/9577
3. New AERI research at CIMSS, funded by NOAA through its Joint Technology Transfer Program, is speeding the transition of technological advances into National Weather Service (NWS) day-to-day operations.
   http://www.ssec.wisc.edu/news/articles/9322
4. CIMSS Technical Computing group in SHOUT mission study hurricane with unmanned aircraft to determine whether the storm will intensify before making landfall near Florida's panhandle.
   http://www.ssec.wisc.edu/news/articles/9091
5. Total precipitable water estimates, developed at CIMSS a decade ago, are upgraded to provide weather forecasters with seamless, satellite-based values from around the globe—over sea and land.
   http://www.ssec.wisc.edu/news/articles/9050
6. Collaborative Lake Michigan Ozone Study (LMOS) pursues sources and transport of ozone during a field campaign mid-May to mid-June to fill in important knowledge gaps

about ozone formation along the lakeshore.
http://www.ssec.wisc.edu/news/articles/9012
7. Annual NOAA Hazardous Weather Testbed showcases the latest CIMSS products at the height of severe weather season in the Midwest and streamlines research-to-operations communication.
http://www.ssec.wisc.edu/news/articles/8965
8. CIMSS researchers are part of NASA cubesat / nanosatellite mission to study the development of tropical cyclones in Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS).
http://www.ssec.wisc.edu/news/articles/8658

Further indicating strong collaboration, CIMSS published about 30% of its 2014-2016 peer reviewed papers with NOAA co-authors) and 14% of the 2014-2016 peer reviewed papers included an ASPB or other NOAA scientist as first author (see Appendix 2); these papers included reports on research progress with Suomi NPP and GOES-16 as well as future JPSS observations. CIMSS continued work with NOAA to transfer into operations many of the GOES-16 algorithms (including cloud properties, atmospheric motion vectors, volcanic ash and SO2, hurricane intensity, fire and hot spots, fog and low clouds) and to train NWS forecasters and other GOES users. CIMSS continues to support NOAA's education and outreach goals with involvement in K-12, undergraduate, graduate and professional training. NOAA and NASA grants support graduate students in the UW–Madison Department of Atmospheric and Oceanic Sciences (see Appendix 4) who work closely with CIMSS and ASPB scientists.

CIMSS and SSEC also maintain several web sites for external audiences. In addition to the news stories for general public noted earlier (in http://www.ssec.wisc.edu/news/articles), they include:

- Educational resources for students and teachers: https://cimss.ssec.wisc.edu/education/
- The CIMSS Satellite Blog for case study discussion and analysis: http://cimss.ssec.wisc.edu/goes/blog/
- Curated library resources for researchers, students, and teachers: http://library.ssec.wisc.edu/
- Data and imagery used by external media outlets, researchers, and many others: http://cimss.ssec.wisc.edu/data/ and http://www.ssec.wisc.edu/data/

In summary, CIMSS is in the second year of the 5-year cooperative agreement with NOAA to collaboratively work to achieve the mission goals of our two organizations. The remainder of this report provides a description of the activities undertaken during the period April 1, 2016 through March 31, 2017.

# II. Background Information on the Cooperative Institute for Meteorological Satellite Studies (CIMSS)

## 1. Description of CIMSS, including research themes, vision statement and NOAA research collaborations

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) was formed through a Memorandum of Understanding between the University of Wisconsin–Madison (UW–Madison) and the National Oceanic and Atmospheric Administration (NOAA). The CIMSS formal agreement with NOAA began in 1980 and was continued through a competitive review process in 2010. Following a thorough review of the CIMSS, the Review Panel unanimously agreed to a performance rating of Outstanding. CIMSS completed its 5-year review in December 2013 and a new cooperative agreement funding number was in place in 2015.

The CIMSS mission includes three goals:

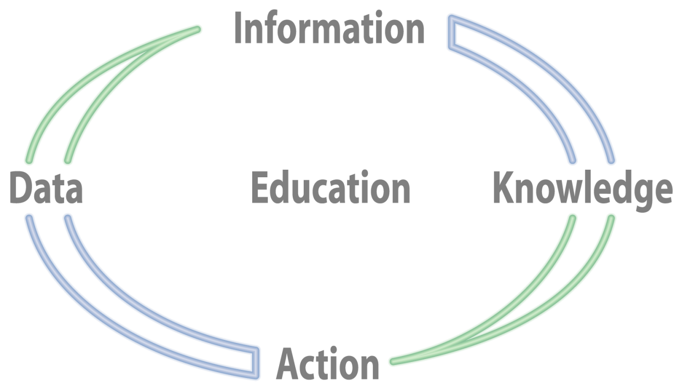
- **Foster collaborative research among NOAA, NASA, and the University in those aspects;**
- **Serve as a center at which scientists and engineers working on problems of mutual interest can focus on satellite-related research in atmospheric and earth system science; and**
- **Stimulate the training of scientists and engineers in the disciplines involved in atmospheric and earth sciences.**

To achieve these mission goals CIMSS conducts a broad array of research and education activities, many of which are projects funded through this Cooperative Agreement with NOAA. This Cooperative Agreement identifies four CIMSS themes:

1. **Satellite Meteorology Research**
2. **Satellite Sensors and Techniques**
3. **Environmental Models and Data Assimilation**
4. **Outreach and Education.**

The collaborative relationship between NOAA and the UW–Madison that led to the establishment of CIMSS has provided outstanding benefits to the atmospheric science community and to the nation through improved use of remote sensing measurements for weather forecasting, climate analysis and environmental issues. CIMSS research investigations increase understanding of remote sensing and its numerous applications to weather and nowcasting / forecasting, clouds, aerosols and radiation, the global hydrological cycle, environmental trends, and climate, as well as education and outreach.

CIMSS scientists are engaged in a broad array of research activities and applications as noted in the executive summary and presented in detail in the following sections. CIMSS develops algorithms that are applied to remote sensing measurements to yield information about Earth. This information leads to knowledge about the Earth system that can be utilized in decision-making processes. CIMSS also demonstrates the advantages of improved observations, and works with partners, within and beyond SSEC, in designing and testing advanced instrumentation. At the center of this research process is education - the training of students, professionals and CIMSS itself.




CIMSS conducts a broad array of activities that engages researchers and students in a variety of research and education endeavors.

CIMSS plays a unique role to NOAA as a non-profit partner, advisor, consultant and link to UW-Madison students and researchers. As a long-term partner of NOAA, CIMSS helps to serve as part of the NESDIS corporate memory, particularly when government staff changes positions and roles. For example, original CIMSS/SSEC staff associated with GOES VAS (the first geostationary sounding instrument) and GOES-8/14 design, testing, and checkout are now assisting with similar activities in GOES-16/S/T/U. On the polar orbiting satellite side, our decades long work with the TOVS and ATOVS sounders and the aircraft HIS (High spectral resolution Interferometer Sounder) and scanning-HIS are aiding in the development of applications for the CrIS (Cross-track Infrared Sounder) hyperspectral sounder on Joint Polar Satellite System (JPSS). In addition to bringing "corporate memory" to these new GOES and JPSS programs, the senior staff help to train the next generation of CIMSS scientists who will support future partnerships between CIMSS and NOAA.

CIMSS scientists work side-by-side with the NESDIS/STAR/ASPB (Advanced Satellite Products Branch) scientists who are stationed in Madison. The advantages of collocation in the same building and similar research interests generate productive collaborations. In addition, ASPB scientists often mentor graduate students on research projects that address NOAA needs while helping to satisfy UW–Madison degree requirements. Based on this positive experience, many of these students go on to work with NOAA and supporting contractors.

Within the NOAA National Weather Service (NWS), CIMSS collaborates on data assimilation projects with the National Centers for Environmental Prediction (NCEP). The CIMSS tropical cyclone research team maintains close collaboration on new products development with the Tropical Prediction Center (NCEP/TPC) in Miami. CIMSS works with the Storm Prediction Center (NCEP/SPC) in Norman, OK on satellite applications to severe weather analysis and forecasting. CIMSS collaborates with the Aviation Weather Center (NCEP/AWC) in Kansas City on aviation safety projects that utilize weather satellite data.

## 2. CIMSS Management and Administration

CIMSS resides as an integral part of the Space Science and Engineering Center (SSEC). The CIMSS Principal Investigator on most programs is Steve Ackerman. Executive Director – Science Wayne Feltz provides day-to-day oversight of the CIMSS staff, science programs, and facilities. The individual science projects are led by University Principal Investigators (PIs) in conjunction with a strong and diverse support staff who provide additional expertise to the research programs. CIMSS is advised by a Board of Directors and a Science Advisory Council (Section II. 4 below).

The CIMSS administrative home is within the Space Science and Engineering Center (SSEC), a research and development center within the UW–Madison's Graduate School. The independent CIMSS 5-year review panel for administration wrote that they were "…impressed by the people, systems and processes in place." The SSEC mission focuses on geophysical research and technology to enhance understanding of the Earth, other planets in the Solar System, and the cosmos. To conduct its science mission on the UW–Madison campus, SSEC has developed a strong administrative and programmatic infrastructure. This infrastructure serves all SSEC/CIMSS staff.

SSEC support infrastructure includes:

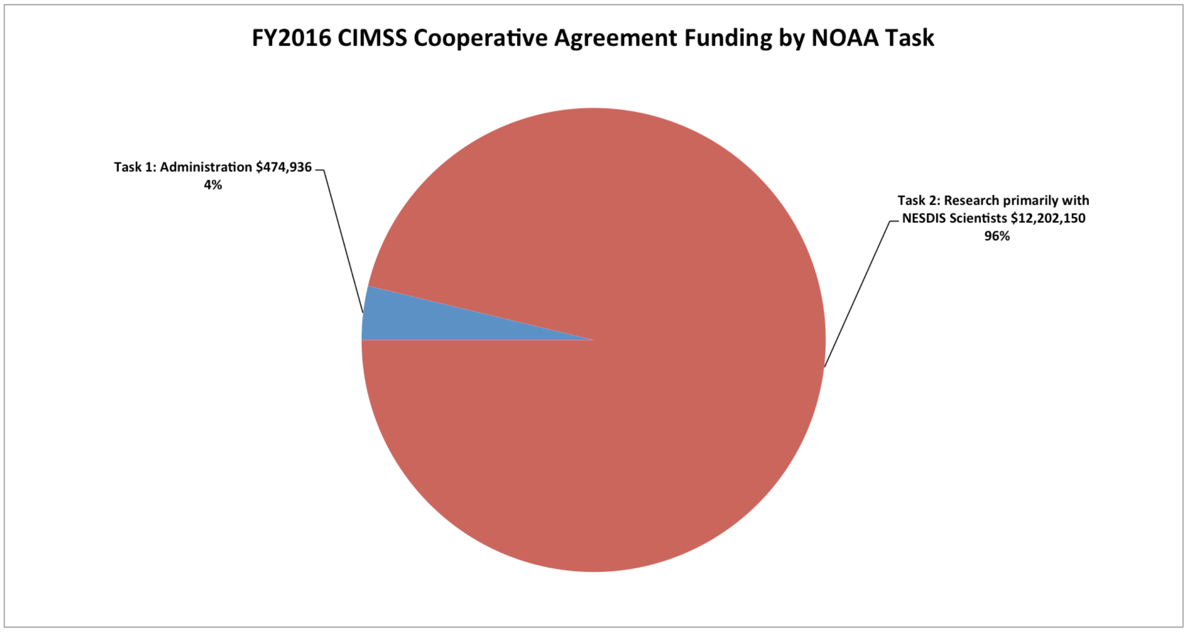
- **Administrative support**
  The administrative support team includes approximately 14 full-time staff and several students providing services that include human relations, proposal processing and publishing, grant and contract management, accounting, financial programming, purchasing and travel.
- **Technical Computing**
  The technical computing support team includes 6 full-time staff and several students providing consultation and implementation on system design, networking infrastructure, and full support for Unix and pc computing.
- **Data Center**
  The SSEC Data Center provides access, maintenance, and distribution of real-time and archive weather and weather satellite data. The Data Center currently receives data from 8 geostationary and 7 polar orbiting weather satellites in real time and provides a critical resource to SSEC/CIMSS researchers.
- **Library and Media**
  SSEC maintains an atmospheric science library as part of the UW–Madison library system. A full time librarian is on staff and two part time assistants. SSEC also employs a full time media specialist to support the dissemination of information on scientist activities and research results and to develop in-house publications.
- **Visualization Tools**
  SSEC is a leader in developing visualization tools for analyzing geophysical data. The Man-computer Interactive Data Access System (McIDAS and McIDAS-V), Vis5D and VisAD software are used worldwide in a variety of research and operational environments. The VISITView software is used extensively as a tele-training tool by the NWS and others. To further support NOAA NWS forecast offices, CIMSS is developing satellite products for AWIPS and AWIPS2, maintaining both systems within our facilities.

## 3. Summary of NOAA Funding to CIMSS in FY2015

In FY2016, funding to CIMSS through Cooperative Agreement NOAA-NESDIS-NESDISPO-2017-2005096 totaled $12,677,086 (includes Task I and Task 2 funding with a $1,000,000 increase over FY15). FY2017 funding is not sufficiently known at this time to include in this report but will most likely be less than CIMSS CA FY2016 budget total due to reductions in meteorological satellite science algorithm development funding for GOES-16 (formerly GOES-R) and JPSS programs. The following tables and graphics show the distribution of these funds by Task, by NOAA Strategic Goal and by CIMSS Research and Outreach Theme. The total represents FY2016 funds provided to CIMSS under the Cooperative Agreement that began on 1 July 2016 and covers the 9 month period from 1 July 2016 to 31 March 2017.

**FY2016 Funding by NOAA Task**

| CIMSS Task | Funding in dollars | Percentage |
|---|---|---|
| Task 1: Administration | $ 474,936 | 4% |
| Task 2: Research primarily with NESDIS Scientists | $ 12,202,150 | 97% |
| Task 3: Research with other NOAA Programs | $ 0 | 0% |
| | $12,677,086 | |

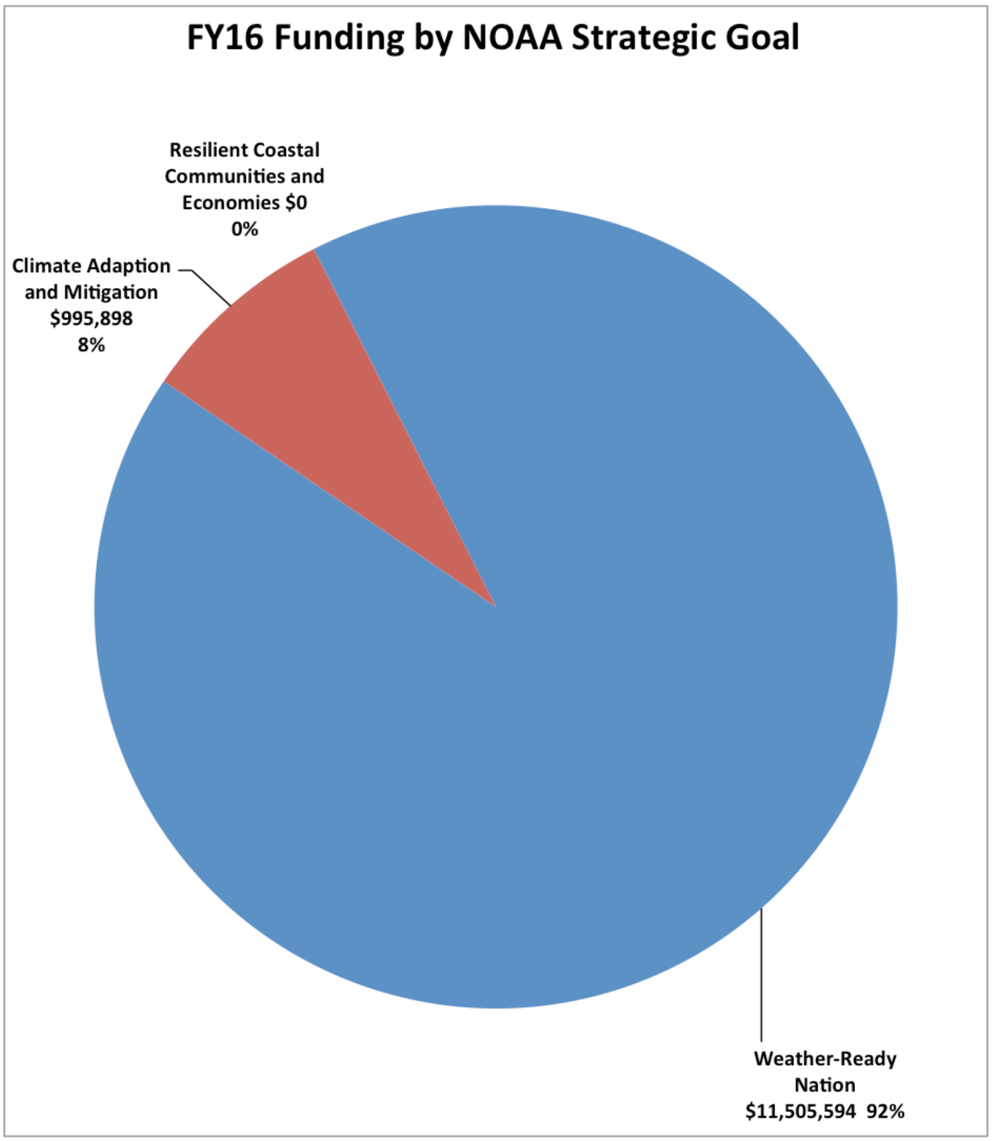



Nearly 96% of CIMSS funding is for Task 2 (~55 employees FTE funded at 50% or greater) and is research conducted with ASPB scientists.

Funding, not including task 1, is shown below and is an increase of approximately $700,000 over last year support. Research primarily falls under NOAA's Strategic Goal Weather Ready Nation.

**Funding by NOAA Strategic Goal**

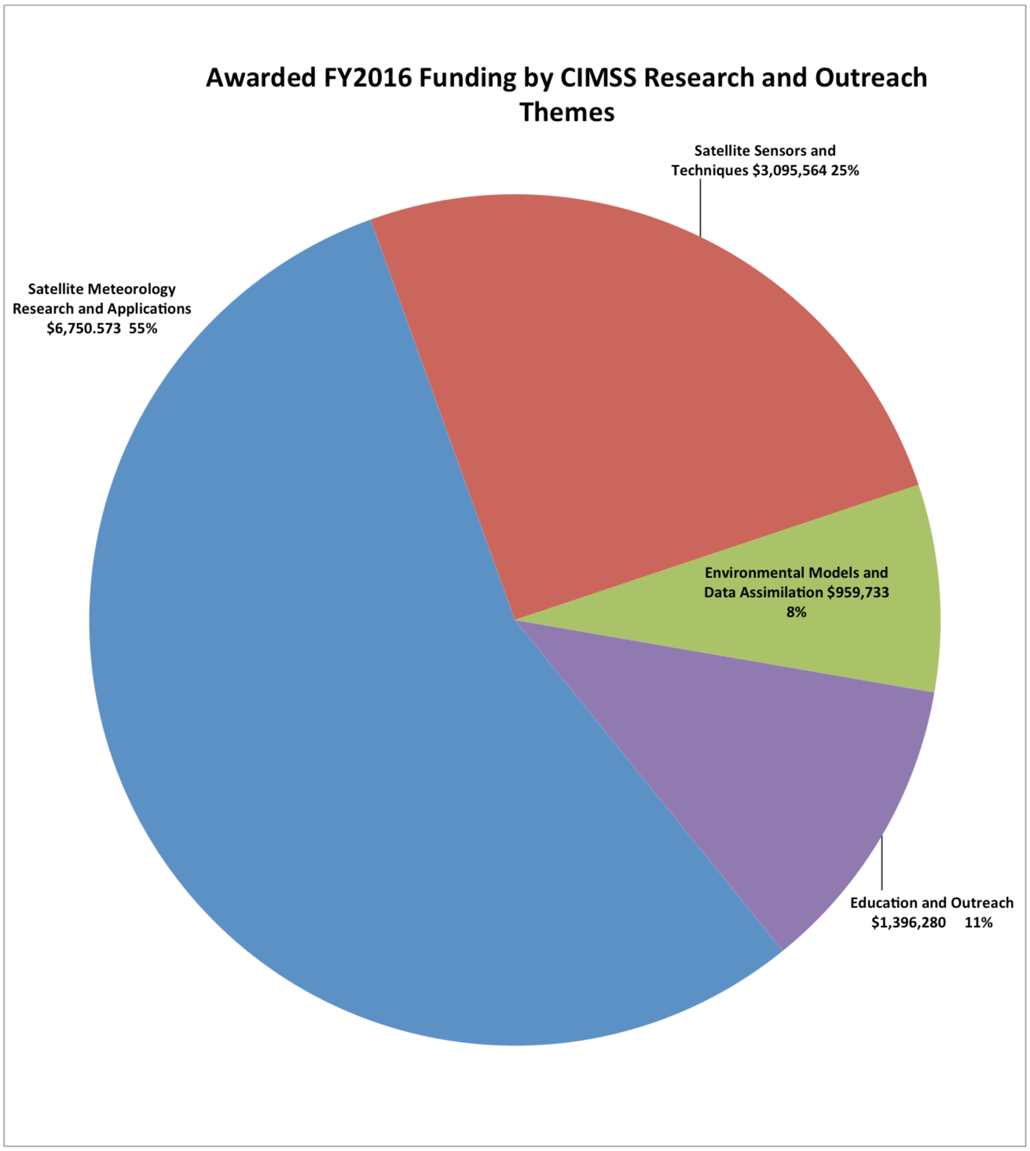
| NOAA Strategic Goal | Funding in dollars | Percentage |
|---|---|---|
| Weather-Ready Nation | $11,505,594 | 92% |
| Climate Adaption and Mitigation | $995,898 | 8% |
| Healthy Oceans | $0 | 0% |
| Resilient Coastal Communities and Economies | $0 | 0% |
| | $12,202,150 | |



**Task 2 Funding by CIMSS Research and Outreach Themes**

| CIMSS Theme | Funding in dollars | Percentage |
|---|---|---|
| Satellite Meteorology Research and Applications | $6,750,573 | 55% |
| Satellite Sensors and Techniques | $3,095,564 | 25% |
| Environmental Models and Data Assimilation | $959,733 | 8% |
| Education and Outreach | $1,396,280 | 11% |
| | $12,202,150* | |

* - does not include the Task 1 funding



# III. Project Reports

The sections below provide two-three page summaries for each of the various projects funded by NOAA through the CIMSS cooperative agreement. Each summary lists the project leader, the NOAA goals and the CIMSS themes followed by a summary of the project accomplishments this past year. Where appropriate, relevant publications and conference presentations are listed.

## 1. CIMSS Task 1A Support – Administration

**CIMSS Task Leader: Steve Ackerman, Wayne Feltz**
**CIMSS Support: Paul Menzel, Maria Vasys, Leanne Avila, Wenhua Wu, Jenny Hackel, Margaret Mooney**

### NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:

- Provide critical support for the NOAA mission

### CIMSS Research Themes:

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

### Objective

The CIMSS Task I funds continue to support the administrative needs for the CIMSS Director, the CIMSS Executive Director - Science and the CIMSS Staff Program Assistant Maria Vasys provides that support and is also supported by student hourly employees to maintain a consistent presence in the CIMSS administrative office.

### Project Overview

The CIMSS Task 1 funding supports activities related to CIMSS administration and non-research programs that are important to the workplace environment of CIMSS. Partial administrative support is provided for the CIMSS Director, Executive Director - Science, the Program Assistant, and the CIMSS Webmaster. Task I activities also includes leveraging support for education and outreach projects, per diem support for visiting scientists, post doctoral positions and first year graduate students.

### Milestones with Summary of Accomplishments and Findings

Task I activities are related to the overall management of CIMSS, as well as general education and outreach activities. These are activities which support the operation of CIMSS; provide outreach platforms to transmit CIMSS science to varied audiences; train and develop future scientists in the workforce; and provide capabilities requested under the Federal Funding Opportunity NOAA-NESDIS-NESDISPO-2015-4320001, but which are not tied to a specific project or projects. Task I funding includes partial funding/salary support for the CIMSS PI/Director, and other support staff, travel, and visiting researcher support. Also, inclusive of Task I are educational and outreach activities including support of post-docs and graduate students within CIMSS not assigned to specific projects or research; support of undergraduate research interns; development of community outreach, education, and training programs; and support for CIMSS education and outreach staff.

Task I funding supports the development and updates of the CIMSS Web page (see http://cimss.ssec.wisc.edu/ ). The CIMSS Web page is closely linked to the NOAA ASPB Web site (http://cimss.ssec.wisc.edu/aspb/) and to the SSEC Web site (http://www.ssec.wisc.edu).

CIMSS has created the "NOAA-CIMSS Collaborative Award for developing NOAA's Strategic Satellite Plan to balance requirements, observation capabilities, and resources." These awards may be given to CIMSS scientists who have worked closely with NOAA scientists who have received a NOAA award. The CIMSS award is to recognize the partnership that occurs in research with ASPB and UW-Madison scientists.

## 2. CIMSS Task 1B Support – Education and Outreach

**CIMSS Task Leaders: Margaret Mooney, Steve Ackerman**
**CIMSS Support Scientists: Scott Bachmeier, Rick Kohrs**
**NOAA Collaborators: Tim Schmit, Steve Goodman, Nina Jackson**
**Budget: $80,000**

### NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:

- 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
- Education and Outreach

### Objective

To maximize the benefit of CIMSS research products to society through a variety of education and outreach efforts.

### Project Overview

CIMSS Education and Public Outreach (EPO) prioritizes awareness around satellite remote sensing and advancing weather and climate literacy across society. CIMSS EPO initiatives include a variety of formal and informal education projects, ranging from classes and workshops at the University of Wisconsin-Madison to presentations at conferences, museums and schools. CIMSS has been on the forefront of educational software design for over three decades and currently supports several on-line curriculums, educational tools, social media sites and blogs.

### Milestones with Summary of Accomplishments and Findings

CIMSS EPO efforts include local and national initiatives. During the 12-month reporting period that began in April 2016, the common thread through all CIMSS EPO initiatives was promoting the historic launch of the GOES-R satellite. Whether it was events on the UW-Madison campus such as the annual CIMSS student workshop or Grandparents University held during the summer, or school tours during the spring, or national events such as ESIP Teacher Workshops and the American Meteorological Society (AMS) annual conference, the most significant, exciting and momentous event to promote this year was our nations' next generation weather satellite.

Along with including GOES-R content at annual public engagement events, several unique efforts were conducted through the GOES-R Education Proving Ground. This included three webinars on Saturdays during the spring, multiple email communications, a "countdown to launch webinar in the fall, and a teacher workshop at the launch in Cape Canaveral. Fifty teachers registered for the event when it was first scheduled for early November but subsequent launch delays resulted in 23 attending, traveling from 10 different states and Puerto Rico. The full agenda is on-line at http://cimss.ssec.wisc.edu/education/goesr/workshop.html. The first day involved professional development off-site culminating in a NOAA mission briefing at the Kennedy Space Center (KSC). On launch day, teachers enjoyed exploring KSC before boarding buses to watch the launch from the Saturn V viewing complex. It was the chance of a lifetime, and attendees were extremely enthusiastic about sharing the experience with their students and promoting GOES-R capabilities. CIMSS will continue to work with these teachers, and all educators, to promote the entire GOES-R series.

**Figure 1. Scenes from the GOES-R Education Proving Ground Launch Workshop.**

CIMSS has also been producing content for NOAA's Science On a Sphere® (SOS) and in 2016 published 4 quarterly climate digests and a feature story entitled "Weather Satellites – past, present and future" which spans satellite history from Sputnik to GOES-16. (http://sphere.ssec.wisc.edu/)

The satellite movie debuted at the American Meteorology Society (AMS) 21st Satellite Meteorology, Oceanography and Climatology Conference in Madison during the month of August in an exhibit room at the conference center. Numerous members of CIMSS, the Space Science and Engineering Center (SSEC) and the STAR Advanced Satellite Products Branch (ASPB) played pivotal roles at the AMS conference, including serving as conference chairs, program chairs and members, session chairs, poster chair and student judges. Two tours of CIMSS/SSEC were conducted during the week providing access to rooftop and data center.

In the digital domain, CIMSS maintains educational content via on-line curriculum for students and teachers linked from the CIMSS education webpage, (https://cimss.ssec.wisc.edu/education/) CIMSS also maintains two twitter accounts and a Facebook page. @UWCIMSS, in its third year, covers broad range of content to 5000 followers. (up from 3000 a year ago) The CIMSS Facebook page (https://www.facebook.com/CIMSS.UW.Madison) has just over 8,200 fans. The top post garnered more than five hundred thousand views.

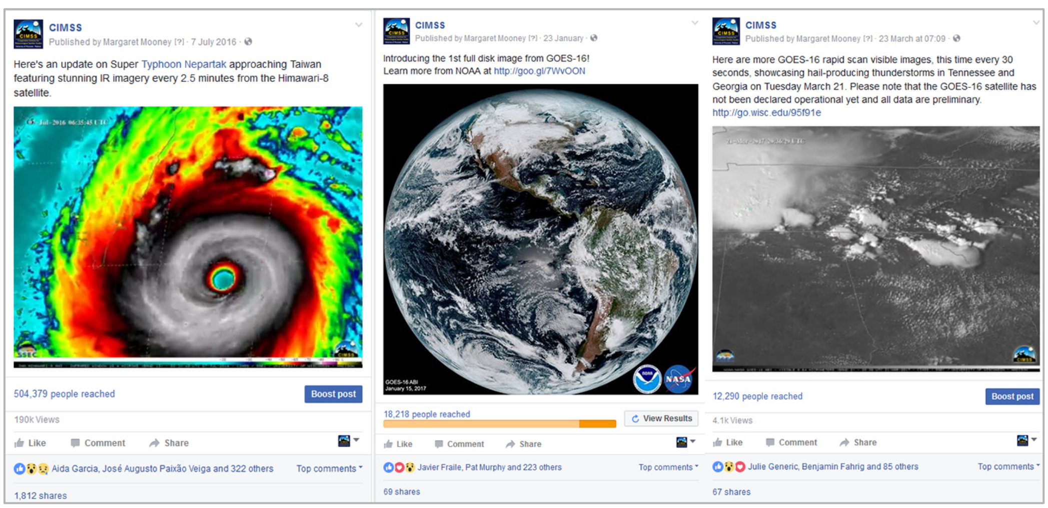


**Figure 2. Noteworthy Facebook posts: Super Typhoon Nepartak via Himararwi-8 with 504, 379 reach (1,812 shares) followed by GOES-16 1st light with 18,218 reach (69 shares) and GOES-16 rapid scan with 12,290 reach (67 shares).**

The CIMSS Satellite Blog (http://cimss.ssec.wisc.edu/goes/blog/) has been showcasing examples of meteorological satellite images and products for over a decade. The associated twitter account (@CIMSS_Satellite) exploded from 6,000 to 33,000 followers during the past year!

## Publications and Conference Reports

Mooney, M., Schmit, T. J., & Gunshor, M., Galvanizing Excitement Around GOES-R with Science Teachers, Science Centers and TV Broadcasters. Seattle, WA, 22-26 January 2017. American Meteorological Society, Boston, MA, 2017.

Schmit, T. J., Gunshor, M., R. B. Pierce, R., Daniels, J., Goodman, S., The Advanced Baseline Imager (ABI) on the GOES-R series. Seattle, WA, 22-26 January 2017. American Meteorological Society, Boston, MA, 2017.

# 3. CIMSS Participation in the Product Systems Development and Implementation (PSDI) for 2016

## 3.1 JPSS PSDI: VIIRS Polar Winds

**CIMSS Task Leader: David Santek**
**CIMSS Support Scientist: Steve Wanzong**
**NOAA Collaborator: Jeff Key, Jaime Daniels**
**Budget: $40,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- 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

### Objective

The objective of the project is to evaluate the suitability of the VIIRS winds algorithm for the JPSS-1 satellite system and make modifications as necessary. We will provide support to evaluate and validate the cloud and wind products updates, participate in the Critical Design Review (CDR), and assist with documentation.

### Project Overview

The VIIRS polar winds product is currently operational for the Suomi National Polar-orbiting Partnership (S-NPP) satellite and provides wind speed, direction, and pressure of cloud-tracked features at high latitudes. These winds have been produced operationally by NESDIS since May 2014 and are also being distributed via the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) EUMETCast broadcast. The VIIRS winds are being assimilated in the Naval Research Lab's (NRL) Atmospheric Variational Data Assimilation System - Accelerated Representer (NAVDAS-AR) and are currently being monitored in NCEP's pre-operational version of the Global Data Assimilation System/Global Forecast System GDAS/GFS. They are also used by some numerical weather prediction centers abroad.

With the expected launch of JPSS-1 in 2017, a modification to winds algorithm will be needed to incorporate updates to the VIIRS cloud mask and height algorithms. The CIMSS polar winds team will participate by providing support to evaluate the cloud and wind products updates, participate in the Critical Design Review (CDR) and other reviews, and assist with documentation. Also, CIMSS will investigate the use of other VIIRS channels (e.g., shortwave infrared and the Day/Night Band (DNB)) to produce polar winds and the possibility of using a mix of S-NPP and JPSS-1 passes to produce winds, if the orbits are offset by ½ orbit in time (similar to Metop-A and –B). This will improve the product due to the shorter time interval when tracking features between images and expanding the coverage into the upper mid-latitudes.

### Milestones with Summary of Accomplishments and Findings

The VIIRS Polar Winds product became operational in NESDIS in May 2014. It is the first polar winds product to use the algorithm that was developed for GOES-R, and the first NESDIS product to become operational using a GOES-R algorithm. Currently, only the 11 µm channel is processed. However, we have been investigating the use of additional spectral channels for tracking cloud features, specifically in the shortwave infrared (SWIR) band. Initial results from the MODIS 2.1 µm channel are encouraging (Figure 3), which show additional winds retrieved (white circle). In addition, a preliminary evaluation by Randy Pauley (Fleet Numerical Meteorology and Oceanography Center) indicates the SWIR winds are of similar quality as the MODIS IR winds when assimilated into the Navy Global Environmental Model (NAVGEM) (personal communication). We will further evaluate the MODIS SWIR winds and extend the winds algorithm to a similar channel on VIIRS, such as the M11 (2.25 µm).

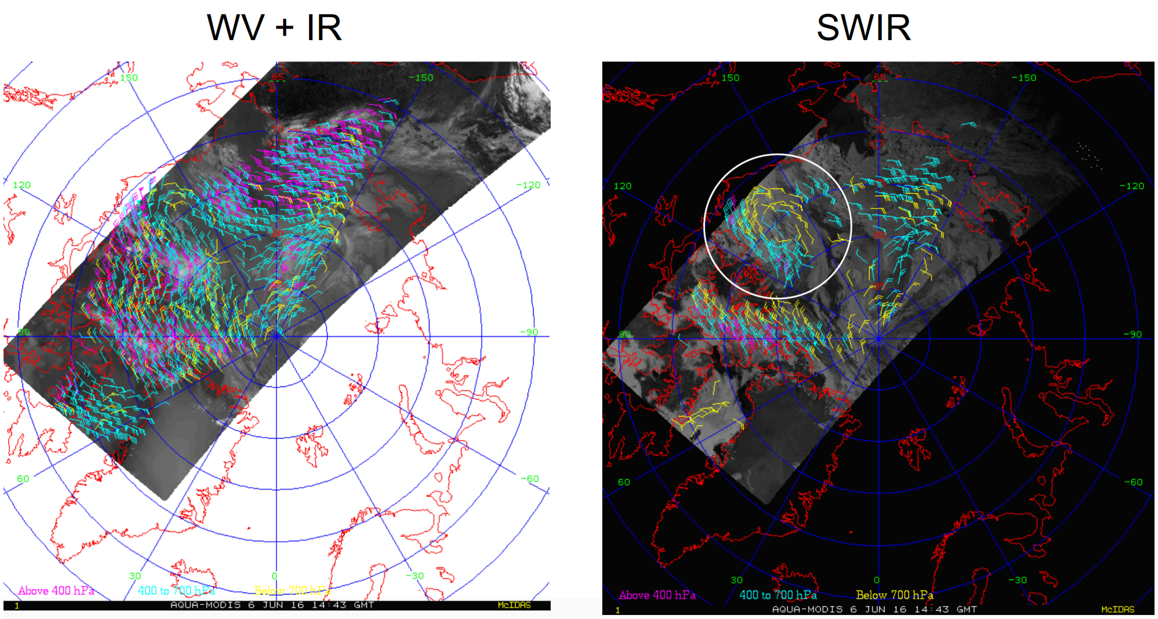



**Figure 3. MODIS polar winds from the typical Water Vapor (WV) and Infrared (IR) channels (left) and the SWIR (right) on 06 June 2016 at 1443 UTC. Colors represent the height of the wind vectors: Yellow (1000 to 700 hPa), cyan (700 to 400 hPa), magenta (about 400 hPa). The white circle denotes a region where the SWIR retrieved additional winds over the WV and IR.**

Also, we continue to maintain and pursue new opportunities to generate the VIIRS polar winds at Direct Broadcast (DB) sites in high latitude locations, such as Fairbanks, Alaska, Sodankyä, Finland, and Antarctica. This results in a product with reduced latency, available approximately 2-3 hours sooner. However, the software that is currently running at DB sites is the heritage winds software, instead of the code used in NESDIS operations. The software at the DB locations will be updated to the operational code, as part of an update to the codebase for the MODIS and AVHRR polar winds products.

## Publications and Conference Reports

Key, J. 2016: Polar winds from near-infrared band cloud tracking. *13th International Winds Workshop*. Monterey, CA.

## 3.2 GEO PSDI: Enterprise Processing Ground System – Fog and Low Cloud Products

**CIMSS Task Leader: Corey Calvert**
**CIMSS Support Scientist: William Straka and Jason Brunner**
**NOAA Collaborator: Michael Pavolonis**

**Budget: $140,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

**Objective**

We seek to transition the GOES-R Fog/Low stratus (FLS) products to NOAA/NESDIS operations within the AIT framework.

**Project Overview**

The goal of this project is to address the Satellite Products and Services Review Board (SPSRB) user request 1305-004, submitted by the NWS, to transition the GOES-R Fog/Low stratus (FLS) products to NOAA/NESDIS operations within the STAR Algorithm Processing Framework (SAPF). We therefore propose to work with the STAR AIT to transition the GOES-R FLS algorithm by developing a product interface that can be used within the SAPF. Once the interface is completed we will continue working with the STAR AIT to evaluate and validate the FLS product output from the SAPF to ensure the quality of the products.

**Milestones with Summary of Accomplishments and Findings**

- *Implementation of the GOES-R FLS algorithm in AIT Framework*
  The implementation of the GOES-R FLS algorithm into the SAPF was successful.
- *Evaluate modifications to the SAPF required to create FLS products*
  Several modifications to the SAPF were needed to ensure the FLS products are produced with the quality and accuracy expected by the developers. The modifications included adding the ability to use the OISST as a surface temperature ancillary data set, incorporation of multiple NWP models and domains (e.g., global GFS and multiple RAP mesoscale domains) and the ability to re-map the satellite data to a constant grid which is necessary to access temporal data. All modifications were closely evaluated and the correct implementation was confirmed.
- *Validate FLS output from the AIT framework*
  Output from 12 days (one day from each month of 2016) was used to validate the GOES-R FLS products from the SAPF. The LIFR/IFR/MVFR probabilities were validated using co-located surface observations of cloud ceiling and surface visibility. The cloud thickness product was previously validated using Sonic Detection And Ranging (SODAR) data.

  For the LIFR/IFR/MVFR probability products, the required specification is 70% accuracy. The validation was performed for each flight rule category for day (solar zenith angle < 80°), terminator (solar zenith angle between 80°-90°) and night (solar zenith angle > 90°) pixels separately using probability thresholds that yielded the maximum skill, determined by the Critical Success Index (CSI), for each dataset. An example of the IFR probability validation for night pixels is shown in Figure 4. The accuracy of the GOES-R LIFR/IFR/MVFR probability products for day/terminator/night were all found to be > 80%, thus easily meeting the 70% accuracy requirement.

Attributes diagrams were also produced to further demonstrate the skill of the probability products. Examples of these diagrams for the IFR probability product (Figure 5) show that the FLS probabilities appear to be well calibrated.

The required specification for the cloud thickness product is to be accurate within 500m for single layer liquid clouds. Using SODAR data as our validation source we determined the GOES-R cloud thickness product produced biases of < 50m for both day and night, indicating that the 500m accuracy will be readily achieved.

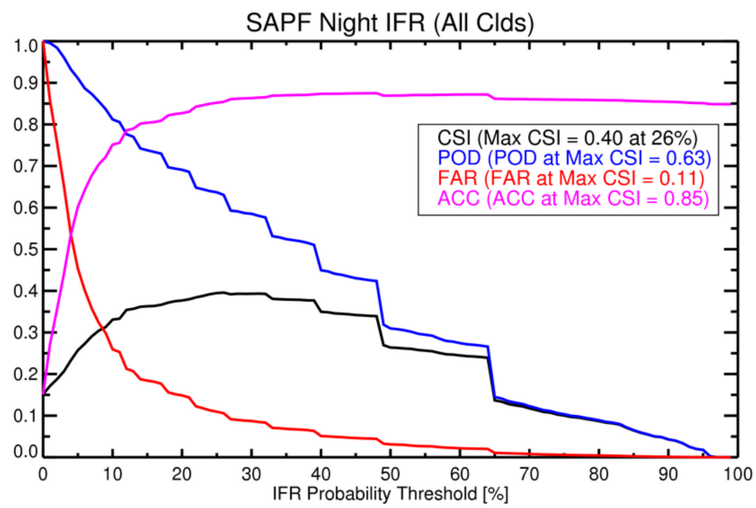



**Figure 4. The GOES-R IFR probability product was validated for night pixels using co-located surface observations of cloud ceiling and surface visibility. The black line is the Critical Success Index (CSI), the magenta line is the accuracy (ACC), the blue line is the Probability of Detection (POD) and the red line is the False Alarm Rate (FAR), all calculated as a function of the IFR probability threshold. The maximum CSI was 0.40 using a probability threshold of 26%. The accuracy of the product using the same threshold was 85%, easily meeting the required accuracy specification of 70%.**

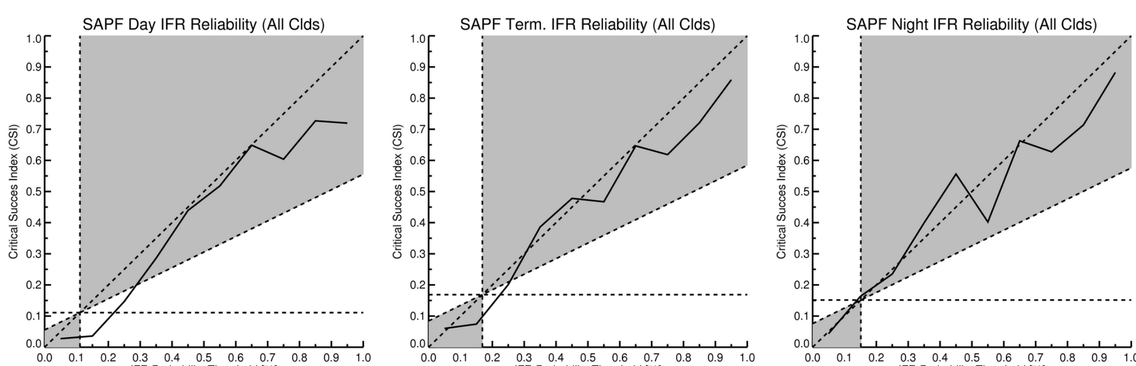



**Figure 5. The attributes diagrams for the GOES-R IFR probability product produced from the NOAA/NESDIS operational STAR Algorithm Processing Framework (SAPF) for daytime (solar zenith angle < 80°), terminator (solar zenith angle between 80°-90°) and nighttime (solar zenith angle > 90°) pixels. These diagrams include pixels composed of both water and ice. Points that lie within the shaded region indicate that the model has skill**

**over climatology. This analysis shows that the GOES-R IFR probabilities being transitioned to NOAA/NESDIS operations are generally well calibrated. Over 1,000,000 surface observations from all 12 months of 2016 were used in this analysis.**

## 3.3 Implementing the GOES-R NOAT Priority Ice Products into the GOES-R Processing System

**CIMSS Task Leader: Yinghui Liu**
**CIMSS Support Scientist: Xuanji Wang, Aaron Letterly**
**NOAA Collaborator: Jeffrey Key**
**Budget: $171,000**

### NOAA Long Term Goals

- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:

- 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

### Objective

The purpose of this project is to implement the three GOES-R Advanced Baseline Imager (ABI) future capability products into the GOES-R Processing System.

### Project Overview

The National Weather Service advisory team for the GOES-R program recently recommended that five future capability (formerly "option 2") GOES-R ABI products be transitioned to operations. Some years ago, many of the original ABI products were reclassified from "baseline" to "future capability" due to budgetary constraints. Now five of those will be implemented in the Harris GOES-R Processing System. They are: Cloud Cover Layers, Aerosol Particle Size, Ice Concentration, Ice Age/Thickness, and Ice Motion.

The purpose of this project is to implement the three GOES-R Advanced Baseline Imager (ABI) future capability products into the GOES-R Processing System. CIMSS will work with the STAR Algorithm Implementation Team (AIT) and the contractor (Harris) to implement the following three ice products:

- Sea ice concentration,
- Sea ice thickness/age, and
- Sea ice motion.

These products were developed by CIMSS and NOAA for ABI.

### Milestones with Summary of Accomplishments and Findings

- Algorithm updates, including algorithm parameters and retrieval algorithm improvements, have been made, and delivered the AIT;
- Algorithms have been implemented on using Himawari-8 AHI data;

- Updated the Algorithm Theoretical Basis Documents (ATBD) that were originally written for ABI. (March 2016);
- Science team updated and delivered algorithm to the AIT for integration into the Framework.
- Ice thickness algorithm has been improved and implemented; results have been compared with other ice thickness products;
- Ice motion algorithm have been improved by parameter adjustments; algorithm has been applied to VIIRS and AMSR2 for a blended ice motion product;
- Quarterly reporting.

### *Ice concentration and temperature*

The GOES-R ABI ice products are available under clear-sky conditions. The GOES-R ABI scans the full disk every 15 minutes and scans the continental U.S. every 5 minutes. Around 144 scans of CONUS are available in the daytime, which greatly increases the chances that ABI sees every part of CONUS under clear-sky conditions at least once during the day. This enables us to get a daily composite of ice cover, ice concentration, ice surface temperature, and ice thickness covering the entire Great Lakes and other inland lakes and rivers from GOES-R ABI. Figure 6 shows daily composite of ice concentration, and ice surface temperature cover the Sea of Okhotsk based on retrievals from all half hourly scans of the Himawari-8 Advanced Himawari Imager (AHI), which has similar characteristics of ABI. The AHI ice concentration daily composite shows much more detailed spatial information than the passive microwave ice concentration, and covers more clear area than any individual scans. With similar temporal resolution of GOES-R ABI, its daily composite is expected to cover significantly wide clear area like that shown here by AHI.

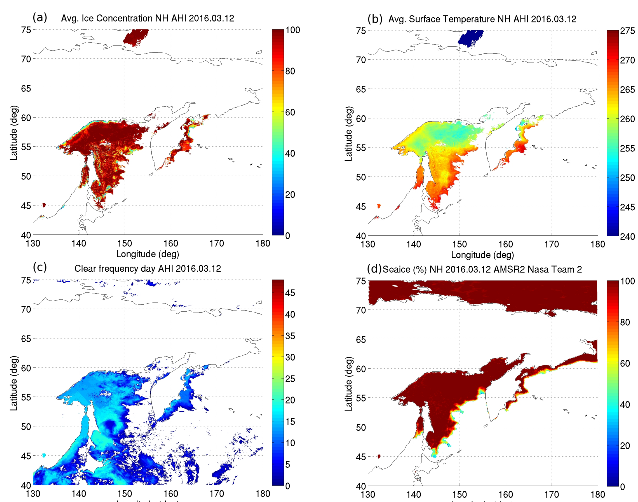



**Figure 6. Averaged ice concentration (a), ice surface temperature (b), clear-sky frequency (c) from retrievals of all half-hour AHI scans of AHI on Himawari 8, and ice concentration (d) from AMSR2 on March 12, 2016 over the Sea of Okhotsk.**

### *Ice age and thickness*

1. The Algorithm Theoretical Basis Documents (ATBD) of sea ice age/thickness was updated for GOES-R project (March 2016).
2. The energy budget based algorithm (OTIM) of sea ice age and thickness estimation has been improved further with research code. The main improvements in the OTIM include the better estimation of residual heat flux with regression method, the addition of sea ice growth/melting-down process parameterization scheme, and the addition of sea ice

dynamic process parameterization scheme. Those improvements were tested good, and ready to implement in the operational code soon.

3. The research code OTIM was applied to Himawari-8 data, and retrieved ice thickness and age products were produced reasonably good, and will be available in near-real-time mode soon (Figure 7).
4. The OTIM retrieved sea ice thickness products with AVHRR data was comprehensively and intensively compared with sea ice products from ICESat, CryoSat-2, SMOS, and IceBridge field campaign (Wang et al., 2016). The results show that OTIM retrieved sea ice thickness product is superior to other satellite products in terms of IceBridge sea ice thickness products (Figure 8).

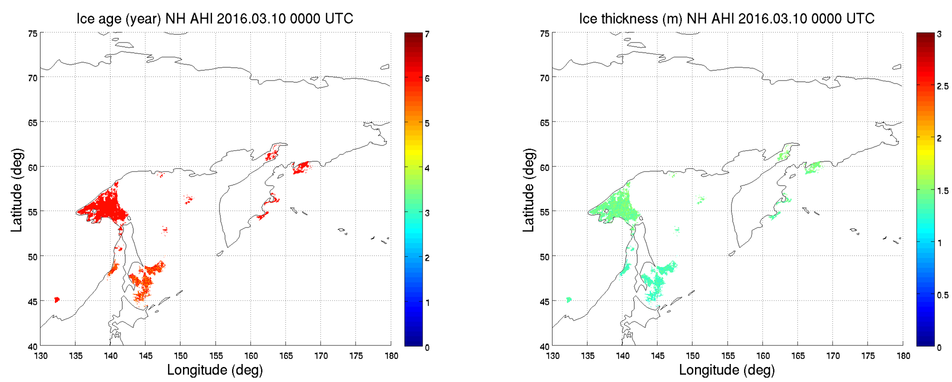



**Figure 7. Sea ice age (left) and thickness (right) retrieved by OTIM with Himawari-8 data for March 10, 2016. For sea ice age, the numbers on color scale have the meanings as below: 0=ice free, 1=new/young ice, 2=grey ice, 3=grey-white ice, 4=thin first-year ice, 5=median first-year ice, 6=thick first-year ice, and 7=old ice (more than one year old).**

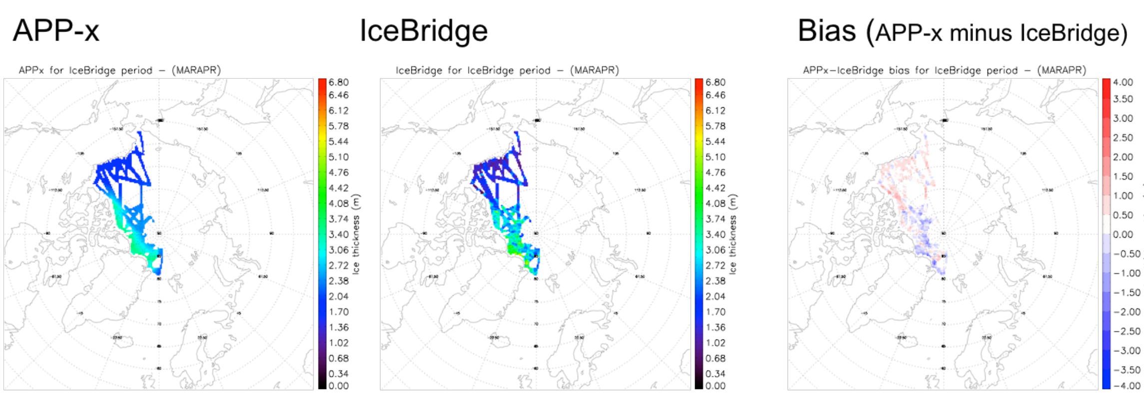



**Figure 8. Inter-comparison in sea ice thickness between OTIM and IceBridge for IceBridge period from March 2011 to April 2013. The mean bias is 0.18 m, and the standard deviation is 0.68 m.**

### *Ice motion*

Daily sea ice motion products have been implemented using AMSR2 89.5 Ghz channel and the VIIRS M15 band. Products are created daily for both the Arctic and Antarctic (AMSR2 only). Due to the difference in native pixel resolution between the two sensors, parameters within the ice motion code are adjusted to provide the most accurate sea ice motion product. A blended product, which combines ice motion output from both AMSR2 and VIIRS, is also produced daily (Figure 9). Both products have been compared quantitatively and qualitatively to EUMETSAT OSI SAF low resolution and medium resolution sea ice drift products and the results are very similar. Delta products, showing the changes in ice motion over a 24-hour period, as well as weekly ice motion products, which may be useful in seasonal sea ice predictive models, are also being produced.

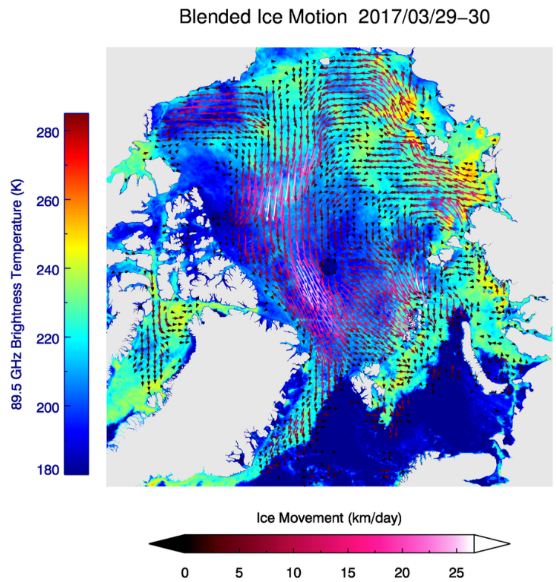



**Figure 9. Blended ice motion product in the Arctic on March 30th, 2017.**

## Publications

Liu, Y.; Key, J.; Mahoney, R. Sea and Freshwater Ice Concentration from VIIRS on Suomi NPP and the Future JPSS Satellites. Remote Sens. 2016, 8, 523.

Baldwin. D., M. Schudi, F. Pacifici, and Y. Liu, Validation of Suomi-NPP VIIRS Sea Ice Concentration with Very High-Resolution Satellite and Airborne Camera Imagery. Journal of Photogrammetry and Remote Sensing, accept pending after minor revision.

Meier, W., J.S. Stewart, Y. Liu, J. Key, and J. Miller, An operational implementation of sea ice concentration and ice type characterization estimates from the AMSR2 sensor. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, in review.

Xuanji Wang, Jeffrey Key, Ron Kwok, Jinlun Zhang, 2016, Comparison of Sea Ice Thickness from Satellites, Aircraft, and PIOMAS Data, Remote Sens., Special Issue: Sea Ice Remote Sensing and Analysis, 2016, 8(9), 713; doi:10.3390/rs8090713.

## 3.4 Implementing the GOES-R NOAT Priority Cloud Cover Layer Product into the GOES-R Processing System

**CIMSS Task Leader: Steve Wanzong**
**CIMSS Support Scientist: Yue Li and Steve Wanzong**
**NOAA Collaborator: Andrew Heidinger**
**Budget: $68,000**

## NOAA Long Term Goals:

- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

### Objective
Transition the Cloud Cover Layer software from research into the GOES-R processing system.

### Project Overview
Due to budget constraints, several GOES-R ABI products were reclassified from "baseline" to "future capability." Cloud Cover Layer is one such product. In 2014, the NWS Operational Algorithm Team (NOAT) selected five future capability GOES-R ABI products to be transitioned to operations. Included are Cloud Cover Layer (CCL), Aerosol Particle Size, Ice Concentration, Ice Age/Thickness, and Ice Motion.

The purpose of this project is to implement the CCL GOES-R Advanced Baseline Imager (ABI) future capability product into the GOES-R Ground System (GS). In this case, the CCL product will report the fraction of cloud at predetermined flight levels. In addition, the Cloud AWG will address other expansions to the CCL products requested by the NOAT. The CCL will also include the probabilities of a cloud comprised of supercooled water and a cloud that is convective. The accuracy of CCL is inherently tied to the ability to accurately detect and vertically place clouds.

Integrating the CCL product into the GOES-R GS is a three-step process:
1. Development/validation of CCL science code within CLAVR-x,
2. Integration of CCL into the STAR Algorithm Processing Framework (SAPF), and
3. Refactoring and integration of the CCL algorithm into the GOES-R Ground System (GS).

The Cloud AWG is responsible for the development of the CCL algorithm and assisting the Algorithm Scientific Software Integration and System Transition Team (ASSISTT) in the integration into the SAPF. Finally, the Cloud AWG is responsible for the evaluation and validation of the output after the CCL is integrated into the SAPF and the GS test and development environments.

### Milestones with Summary of Accomplishments and Findings
The 3-layer CCL is a mature product that is currently in the SAPF. It has also garnered interest from the Aviation Weather Center (AWC) and made it into their 2016 Summer Experiment. The AWC forecasters rank it their 4$^{th}$ most used cloud product after altitude, phase and base. Figure 10 shows the 3-layer CCL as used by AWC in their AWIPS system. In this figure, the darker blue represents clouds from the surface (SFC) to 642 hPa. The greenish color is from 643 to 350 hPa, and the light brown color from 351 to the top of atmosphere (TOA).

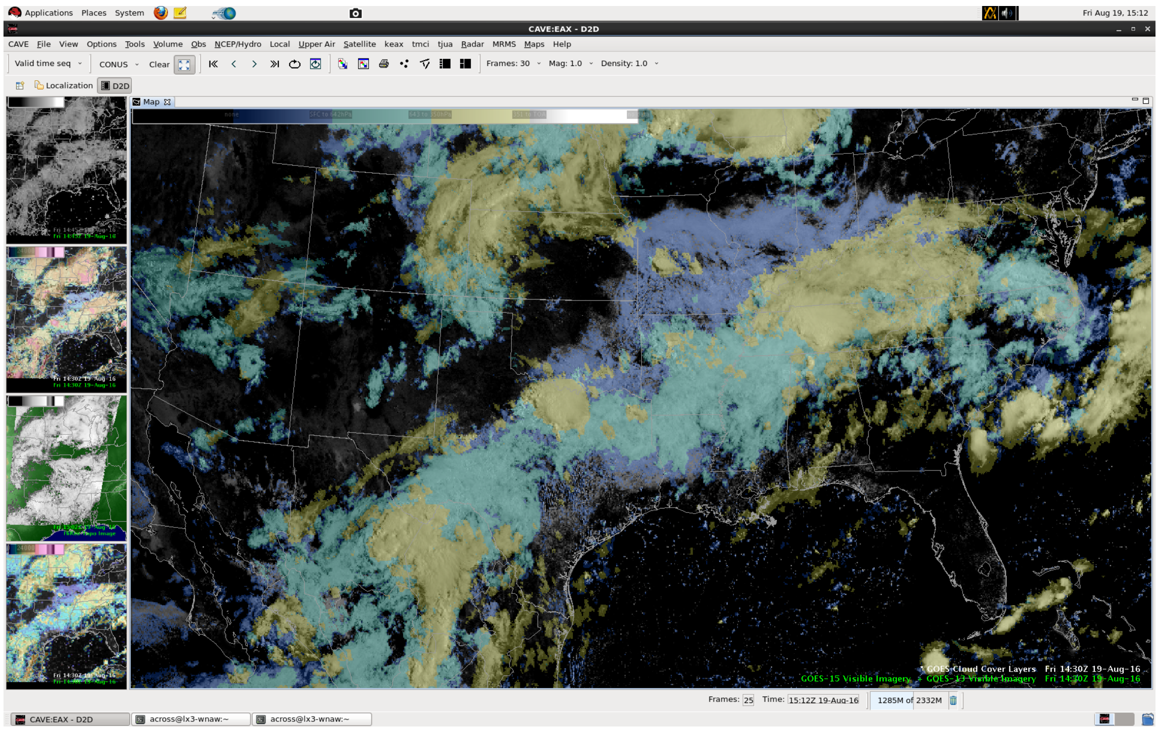


**Figure 10. Example CCL image as used by the AWC in their AWIPS system.**

Example images from the supercooled probability and convective probability are shown in Figure 11 and Figure 12.

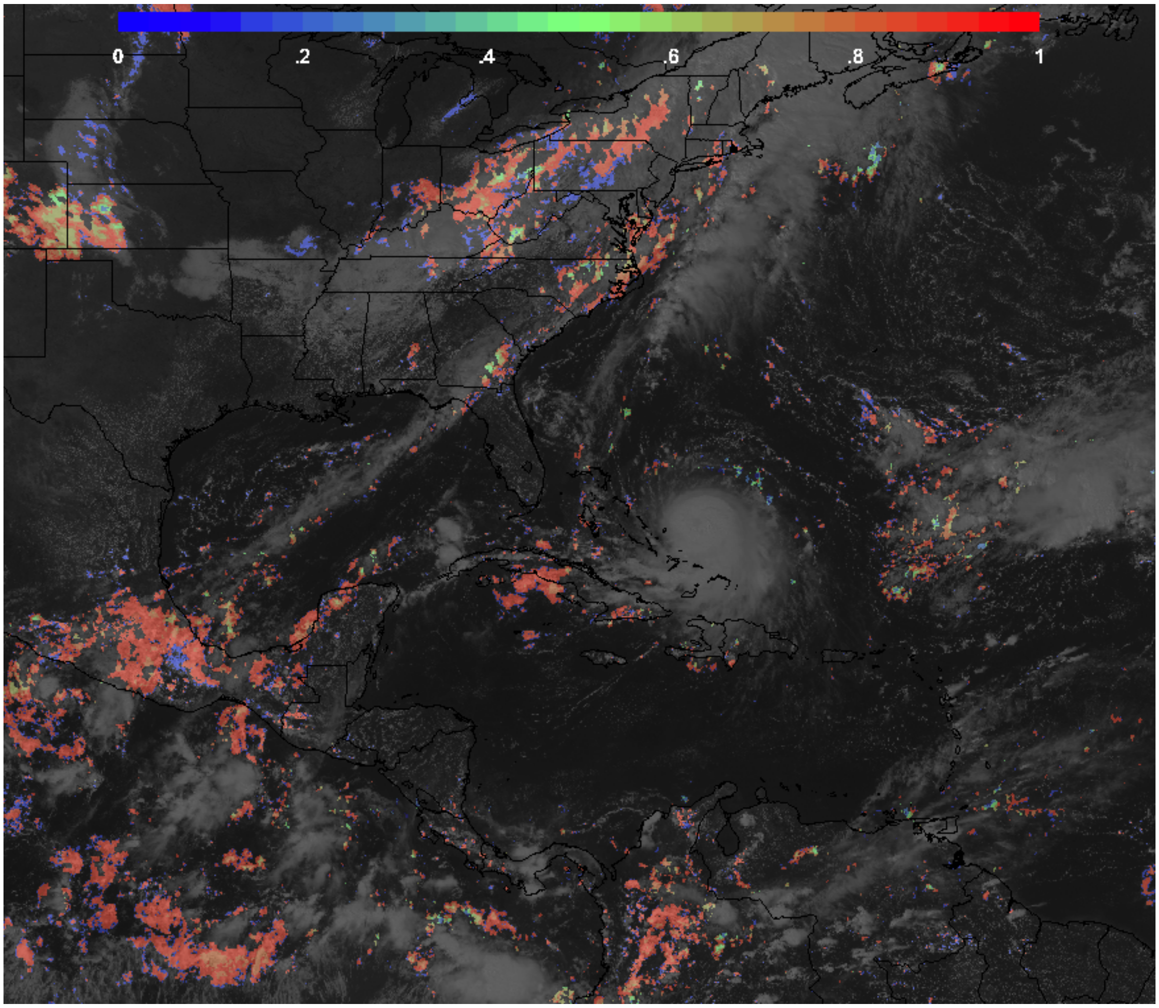



**Figure 11. Supercooled probability overlaid on a GOES-13 visible image.**

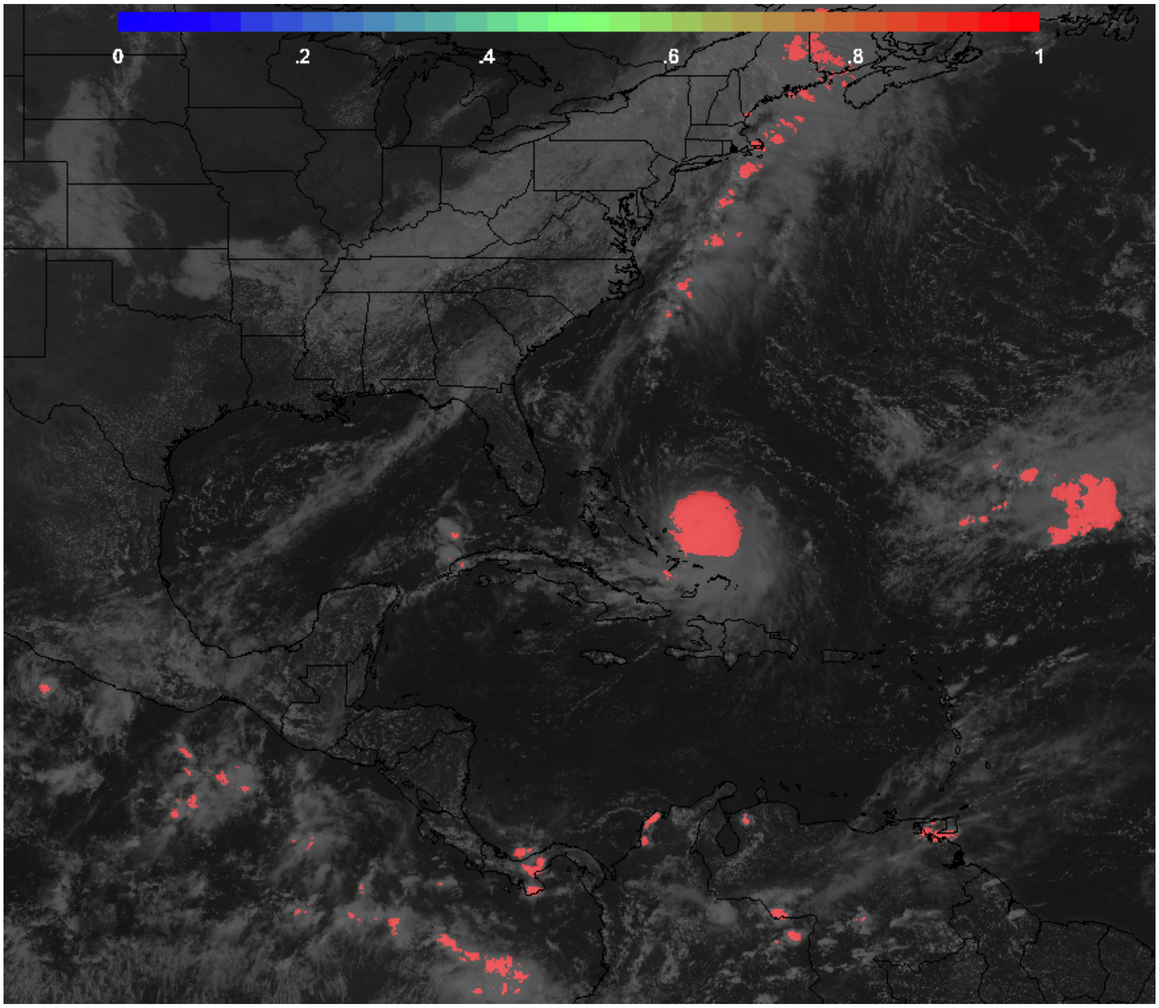



**Figure 12. Convective probability overlaid on a GOES-13 visible image.**

Driven by a request from AWC through the NOAT, a 5-level CCL product will be implemented. It will report the total cloud fraction, and the cloud fraction at SFC – 5,000 feet; 5,000 – 10,000 feet; 10,000 – 18,000 feet; 18,000 – 24,000 feet; and 24,000 – TOA feet. This version of the software will be inserted into the SAPF during the first quarter of 2017.

## 3.5 CIMSS Participation in the GOES-R NOAT Products AIT for 2016
**CIMSS Task Leader: William Straka III**
**CIMSS Support Scientist: Ray Garcia**
**NOAA Collaborator: W. Wolf**
**Budget: $38,000**

### NOAA Long Term Goals:
- Weather-Ready Nation

### NOAA Strategic Goals:
- Provide critical support for the NOAA mission

### CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

## Objective

Provide integration and technical support for the GOES-R Algorithm Working Group teams at CIMSS for the GOES-R NOAT products

## Project Overview

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.

Principal Activities:

- Profile reference algorithm implementations and explore performance, accuracy, and reproducibility improvements;
- Review and update software and deliverables with CIMSS science staff;
- Provide guidance to science staff as needed to improve computer science aspects of algorithm reference software;
- Continued refactoring and migration of science software toward framework- and platform- agnostic software interfaces in order to simplify existing code and provide new avenues for rapid algorithm development;
- Assisted in integration of Future Capabilities products developed at CIMSS (Cloud Cover Layers, Cryosphere products); and
- Feedback and technical interchange with AIT-East and Harris/AER regarding computer science concerns in algorithm implementations and operational framework interfaces.

## Milestones with Summary of Accomplishments and Findings

- Began integration of Cloud Cover Layers into Baseline Cloud Height algorithm. A preliminary version of CCL has been delivered to AIT-East for assessment and creation of a preliminary Algorithm Description Document (ADD). Verification of this delivery to be performed in Spring 2017 in anticipation of Test Readiness Review (May/June 2017).
- Retained and distributed test and ancillary datasets in support of AWG deliverables.
- Increased involvement in AIT reference framework development and maintenance.
    - This includes CIMSS configuration management, build and execution automation for the SAPF. This will provide routine local processing of the SAPF from proxy and simulation datasets specifically for CIMSS AWG uses.
- Collaboration and directed research on SAPF improvements, including modularity and reuse improvements, new features to support increased accuracy or performance, code and documentation review.
- Management and coordination of schedules, deliveries, software configuration items in cooperation with AWG and Harris/AER.

## 3.6 Enterprise Processing Ground System for Geostationary (GSIP) and Polar (CLAVR-X) Cloud Products

**CIMSS Task Leader: William Straka III**
**CIMSS Support Scientist: Steve Wanzong**
**NOAA Collaborator: Andrew Heidinger**

**Budget: $30,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

## Objective
The goal of this project is to first update GSIP and CLAVR-x with the latest cloud algorithms and then assist NESDIS in transitioning their functionality into the SAPF.

## Project Overview
The GOES Surface and Insolation Project (GSIP) has been the operational NESDIS cloud processing system for the GOES Imagers. The Clouds from AVHRR Extended (CLAVR-x) processing system is the current operational NESDIS cloud processing system for the POES (NOAA-18, 19 and MetOp A/B) series of satellites. NESDIS desires that all future operational processing occur within the STAR Algorithm Processing Framework (referred to SAPF in this proposal).

## Milestones with Summary of Accomplishments and Findings
Integration of the updated GOES-R cloud algorithms into GSIP was performed in early 2015 and was successfully tested. Figure 13 shows the results of the latest cloud algorithms integrated into GSIP. Validation of the algorithms was performed as part of the Algorithm Readiness Review (ARR), which was conducted in April 2016. Table 1 includes the GSIP specification summary for cloud mask, phase and height. In addition, the updated GOES-R cloud algorithms have been successfully integrated into the SAPF. Currently we are awaiting test cases from current GOES calculated from the SAPF to perform comparisons.

**Table 1. Summary of GSIP requirements and observed results.**

| | Requirement | GSIP |
|---|---|---|
| Cloud Mask % correct | 0.87 | 0.91 |
| Cloud Phase % correct | 0.80 | 0.90 |
| Ice Cloud Accuracy | +/- 1.0 | -0.81 |
| Ice Cloud Precision | 1.5 | 1.43 |
| Water Cloud Accuracy | +/- 1.0 | 0.08 |
| Water Cloud Precision | 1.5 | 1.47 |

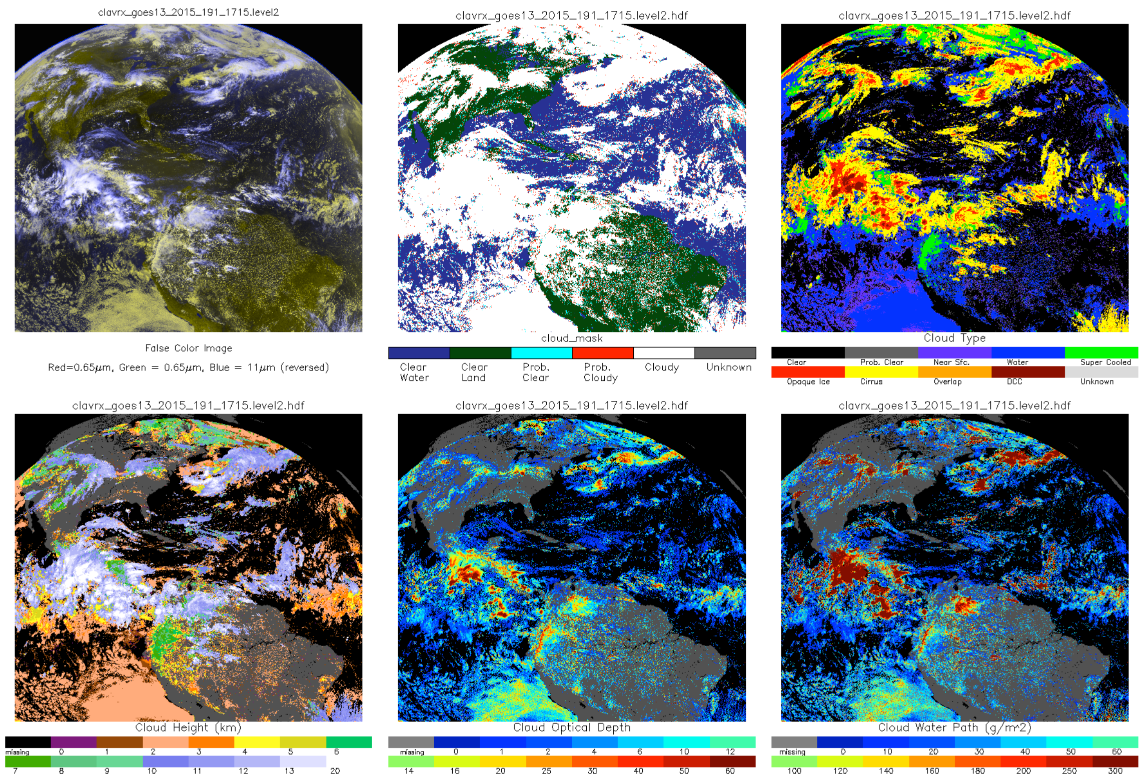



**Figure 13. Example GSIP product output.**

Integration of the read module for AVHRR was also completed during this time. An evaluation of the AVHRR cloud algorithms was performed as part of the Polar Winds and ASOS ARR, which was conducted in late 2016. This is because the AVHRR cloud products (mask, type, height), as integrated into the SAPF, are used in the height assignments for the wind targets as well as the ASOS cloud cover product. The Test Readiness Review for the SAPF integration of the GSIP and CLAVR-x algorithms is scheduled for Spring 2017.

Milestones:
- Prepare for Test Readiness Review (Spring 2017).

## 3.7 Blended Advanced Dvorak Technique (ADT) Upgrades
**CIMSS Task Leader: Chris Velden and Tim Olander**
**NOAA Collaborator: Jeff Key**
**Budget: $50,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

**Objective**
This project addresses the operational transition component of the ADT, and will help carry the recent and expected improvements into the operational version now supported by NESDIS.

**Project Overview**
The Advanced Dvorak Technique (ADT) is an algorithm designed to provide objective estimates of hurricane intensity from GOES and other geostationary satellites. Its long-term development has been partially supported by GIMPAP, and the upgraded algorithm versions have been transitioned through previous PSDI efforts into NESDIS operations at the Satellite Analysis Branch. The National Hurricane Center (NHC) now routinely accesses the ADT data as part of its hurricane analysis 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 SPSRB by NHC, CPHC (Central Pacific Hurricane Center), and JTWC (Joint Typhoon Warning Center). The request, Request No: 1412-0015, Title: "Continue operational transition and upgrade support of the ADT", was approved by the SPSRB for funding considerations starting in FY16. The work proposed in this PSDI proposal addresses the operational transition component. This proposal will help carry the recent and expected improvements into the operational version now supported by NESDIS. This work will also benefit the GOES-R HIE algorithm (ADT adoption) which will represent the future operational version of the ADT in the GOES-R era, and will continue to be demonstrated through the GOES-R Proving Ground.

**Milestones with Summary of Accomplishments and Findings**
Efforts for this first year of the project have focused on adapting the latest ADT version code that will transition into the operational framework at OSPO. Specifically, new science/upgrades are being implemented, as well as new satellites such as Himawari-8, GOES-16, F-19, GCOM and GPM. Experimental real-time testing is being conducted at CIMSS, with associated validation efforts.

### 3.8 Polar PSDI: Transition of MODIS and AVHRR Winds to GOES-R/VIIRS Algorithm

**CIMSS Task Leader: David Santek**
**CIMSS Support Scientist: Steve Wanzong**
**NOAA Collaborators: Jeff Key, Jaime Daniels**
**Budget: $25,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

## Objective

To assist in the transition of the heritage winds software to the new nested tracking algorithm for the MODIS and AVHRR polar winds products, at CIMSS, satellite Direct Broadcast sites, and NESDIS operations.

## Project Overview

The MODIS and AVHRR polar winds products that are currently operational provide wind speed, direction, and height at high latitudes. The VIIRS polar winds product uses the new nested tracking algorithm designed for GOES-R ABI. Because the MODIS/AVHRR and VIIRS winds products are generated with different algorithms, they will exhibit different error characteristics. The nested tracking is more accurate than the heritage algorithm used for MODIS and AVHRR because it uses an externally-generated cloud product and a more robust tracking approach.

The goal is to use the nested tracking winds software across the suite of polar winds products, which will result in a consistent algorithm across the polar instruments (VIIRS, AVHRR, MODIS) and the geostationary satellites (GOES-East and -West).

## Milestones with Summary of Accomplishments and Findings

The CIMSS team continues to work with STAR scientists and contractors as well as the STAR Algorithm Integration Team (AIT) in the implementation of nested tracking code for MODIS and AVHRR polar winds, which is currently underway in NESDIS operations.

Unlike the stand-alone heritage winds algorithm, the nested tracking is part of a larger AIT framework within NESDIS operations. As a consequence, we are not able to run the new nested tracking algorithm at CIMSS using the same codebase as NESDIS. Therefore, we are developing a system based on The Clouds from AVHRR Extended (CLAVR-x), the AWG Cloud Height Algorithm (ACHA), and the GEOstationary Cloud Algorithm Test-bed (GEOCAT). The wind vector height is based on the cloud product from CLAVR-x and ACHA; the nested tracking software is contained within GEOCAT. Figure 14 depicts the comparison of the product applied to the MODIS infrared channel based on the nested tracking algorithm (left) and windco (right) for a test case developed to exercise all the components of the new algorithm. A visual inspection indicates a general agreement between products in terms of wind speed and direction; however, a quantitative evaluation has yet to be done.

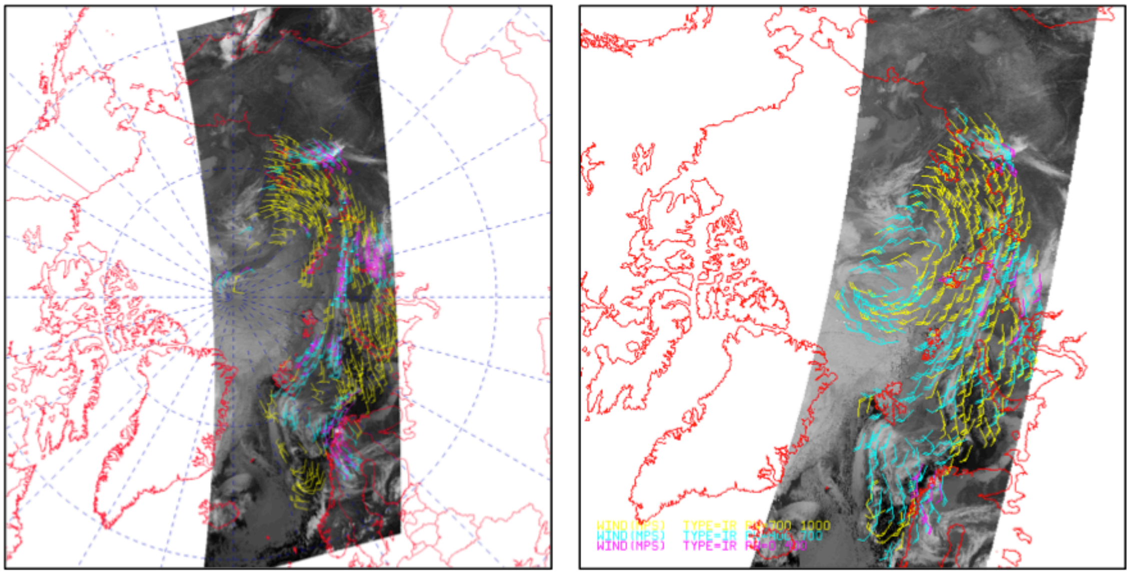


**Figure 14. MODIS polar winds from the nested tracking algorithm (left) and the heritage windco (right) on 22 March 2017 at 0037 UTC. Colors represent the height of the wind vectors: Yellow (1000 to 700 hPa), cyan (700 to 400 hPa), magenta (about 400 hPa).**

Tasks remaining on this project include:

- Begin routine production of the MODIS polar winds using the new algorithm, in parallel with the windco-based product,
- Quantify the differences in the new and heritage algorithms, and
- Prepare for the use VIIRS in the new algorithm.

## 4. CIMSS Participation in the GOES-R Algorithm Working Group (AWG) for 2016-2017

### 4.1 Proxy Data Support
**CIMSS Task Leaders: Tom Greenwald and Allen Huang**
**CIMSS Support Scientists: Jason Otkin, Allen Lenzen, Kaba Bah, Marek Rogal**
**NOAA Collaborators: Brad Pierce**
**Budget: $422,000**

### NOAA Long Term Goals
- Weather-Ready Nation

### NOAA Strategic Goals
- Serve society's needs for weather and water

### CIMSS Research Themes
- Satellite Meteorology Research and Applications
- Environmental Models and Data Assimilation

### Objective
Our main goal is to produce high-quality proxy Advanced Baseline Imager (ABI) imagery and products in real time for supporting pre-launch testing of the GOES-R ground system and the

National Weather Service (NWS) Advanced Weather Interactive Processing System II (AWIPS II), as well as validation of ABI product algorithms.

## Project Overview

This task supports GOES-R AWG Advanced Baseline Imager (ABI) proxy data capabilities with real-time synthetic Cloud and Moisture Imagery (CMI) that includes effects of clouds, water vapor, aerosols and ozone as well as realistic treatment of surface emissivity and reflectivity for all 16 ABI bands (Greenwald et al., 2016). The advanced modeling system used to produce synthetic CMI consists of full-spectral-resolution global meteorological forecasts from the National Center for Environmental Prediction (NCEP) Global Forecast System (GFS), global $1^{o}x1^{o}$ aerosol forecasts from the Real-time Air Quality Modeling System (RAQMS) (Pierce et al., 2007), regional meteorological and aerosol forecasts from WRF-Chem, as well as MODIS-based surface reflectance and emissivity data sets for constructing simulated radiances from the NOAA Community Radiative Transfer Model (CRTM).

The final year of our proxy data project supported:

- Pre-launch end-to-end validation exercises to assess NWS systems readiness to utilize GOES-R imagery and products in support of forecast operations;
- Data Operations Support Team (DOST) for product generation, distribution, and monitoring operations validation;
- AWIPS II testing with real-time simulated ABI proxy data feed;
- Algorithm Integration Team (AIT) with real-time ABI full disk and CONUS data; and
- Post-launch AWIPS II testing up until the release of ABI data

## Milestones with Summary of Accomplishments and Findings

- Our real-time simulated ABI imagery and products played an integral role in the successful 4th GOES-R Data Operations Exercise (DOE)-4 in July/August 2016 that demonstrated NWS systems readiness and realistically prepared forecasters for GOES-R operations in AWIPS II (see Figure 15 and Figure 16).
- Real-time simulated ABI Level 2 products were provided routinely within AWIPS II via NOAAPORT Satellite Broadcast Network (SBN) on the new experimental feed as part of end-to-end testing for ABI data delivery.
- Supported DOST by providing real-time full-disk (East, West and Central) and CONUS (East and West) 16-band imagery for GOES-R ground system testing and validation activities.
- Provided real-time simulated GOES Re-Broadcast (GRB) files for routine ABI product generation by the GOES-R Algorithm Scientific Software Integration and System Transition Team (ASSISTT).
- Continued our support of the AIT by providing simulated ABI L1B files as they developed the capabilities for integrating baseline product algorithms into the framework in preparation for actual ABI data.
- Continued to provide real-time simulated ABI data to RaFTR (Resample and Format, Timed Release) system developed by the NWS Office of Science Technology to test data flow to AWIPS systems at all of the NWS Weather Forecast Offices (WFOs) and NCEP Centers prior to ABI data use.
- Extended WRF-Chem forecast length to 48 hrs to support Earth Resources-2 (ER-2) Sensor Data Record (SDR) and ground-based Environmental Data Record (EDR) GOES-R ABI/GLM (Geostationary Lighting Mapper) Cal/Val field campaign for cloud and aerosol forecasting during the Post Launch Test (PLT) in 2017.

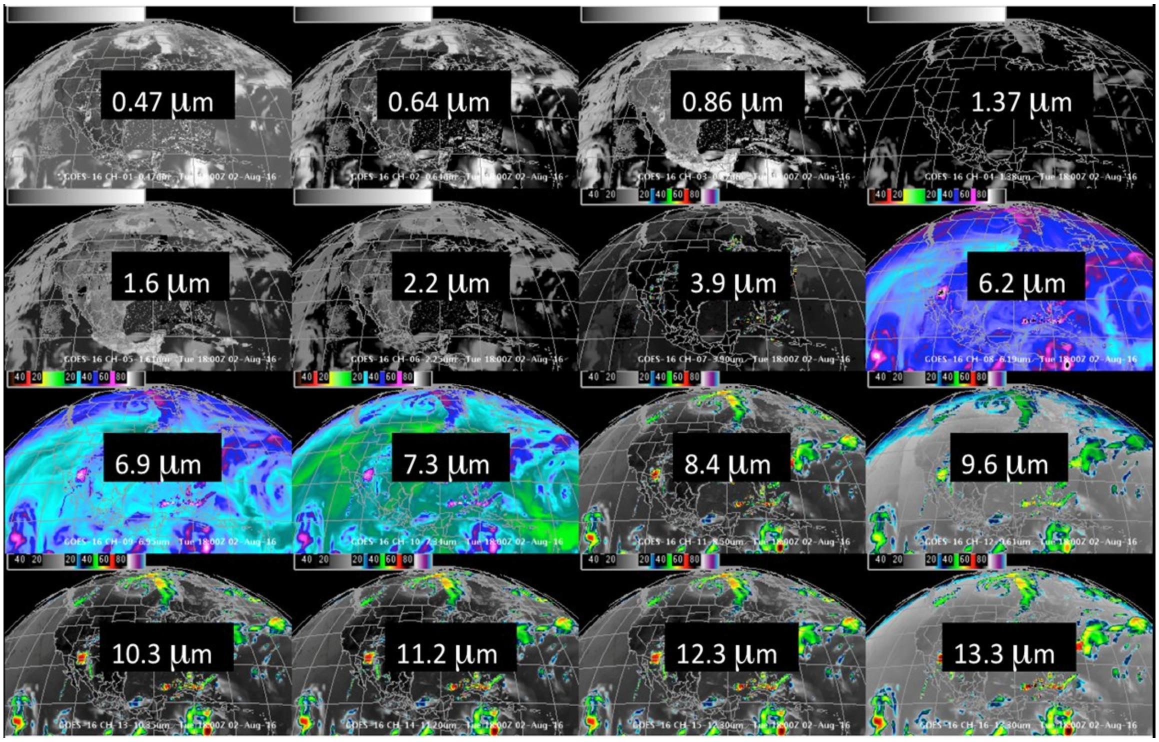



**Figure 15. AWIPS II display of simulated ABI imagery during DOE-4 on 16 August, 2016.**

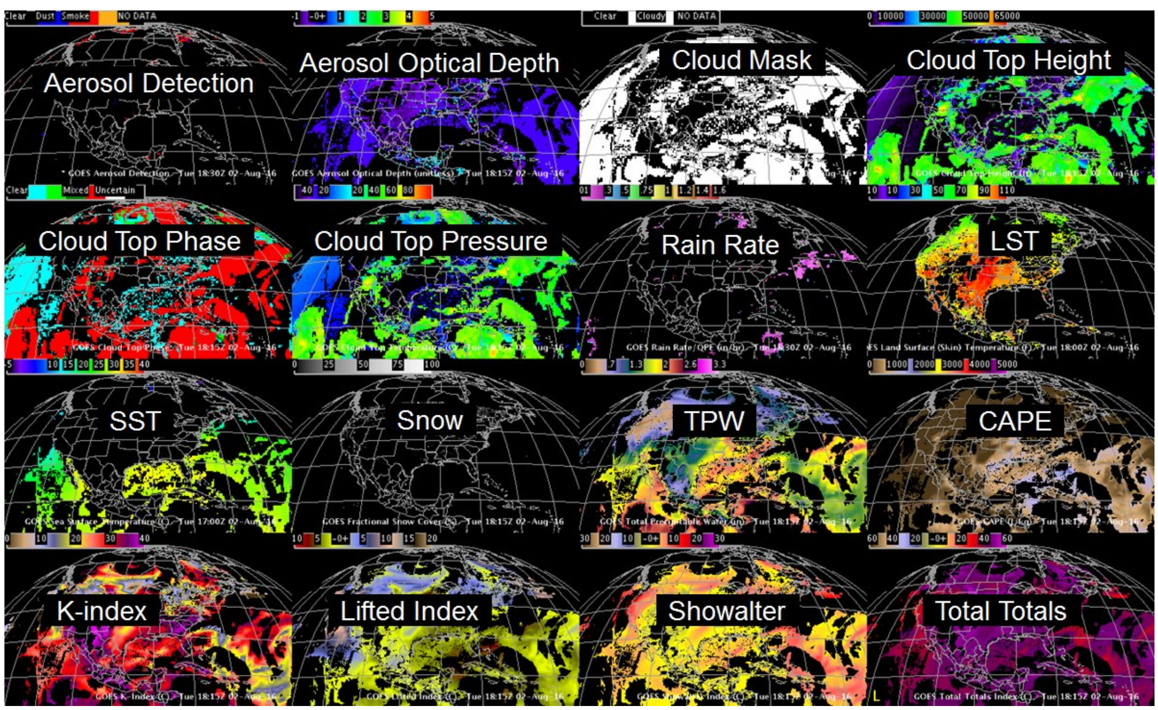



**Figure 16. AWIPS II display of selected simulated ABI baseline products during DOE-4 on 16 August, 2016.**

## Publications and Conference Reports

Greenwald, T., R. B. Pierce, K. Bah, J. Zajic and Allen Lenzen, 2017: Real-time GOES-R ABI proxy data for user readiness, ground system support and product evaluation. 13th Symposium on

New Generation Operational Environmental Satellite Systems, 97th AMS Annual Meeting , 22–26 January, Seattle, WA.

### References

Greenwald, T. J., R. B. Pierce, T. Schaack, J. Otkin, M. Rogal, K. Bah, A. Lenzen, J. Nelson, J. Li, and H.-L. Huang, 2016: Real-time Simulation of the GOES-R ABI for user readiness and product evaluation. Bull. Amer. Meteor. Soc., 97, 245-261, DOI:10.1175/BAMS-D-14-00007.1.

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.

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

**CIMSS Task Leader: Mathew Gunshor**
**CIMSS Support Scientist: Hong Zhang**
**NOAA Collaborator: Timothy J. Schmit**
**Budget: $75,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- 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

### Objective

GRAFIIR is to assist the government in assessing the impact of instrument waivers on ABI level 2 products, including impacts on meeting precision and accuracy product requirements.

### Project Overview

The 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 CIMSS GRAFIIR team interacts with AWG program managers, application and integration team (AIT) members to react to new directions and needs to support associated analysis. Additionally, the CIMSS GRAFIIR team continues to interface with the GOES-R program's Product Working Group (PWG), to assist the government's efforts with ABI waiver analysis and response.

When requested, the AWG utilizes its GRAFIIR-based 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. Note that not all of the following tasks will be necessary for every case; the Government team addressing a waiver or potential waiver would decide which tasks to undertake.

Potential ABI Waiver Analysis Tasks:

- Perturb simulated level 1B datasets to reflect the effects of Government-specified waivers and deviations (perturbations to instrument capabilities or functionality). This will be achieved through application of a mathematical model(s) provided or approved by the Government. Task only necessary if perturbed data are not provided by a non-AWG source.
- Perform a statistical and visual analysis of the unperturbed (control case) and perturbed (test case) simulated level 1B data using GRAFIIR tool sets that include: Glance, McIDAS, IDL, and/or MATLAB.
- Using the AWG framework and baseline GSP approved algorithms, generate level 2+ products from the unperturbed (control run) and perturbed (test run) simulated level 1B data.
- Perform a statistical and visual analysis of the unperturbed (control case) and perturbed (test case) L2+ products using GRAFIIR tool sets (Glance, McIDAS, IDL, and/or MATLAB) and any product validation tools used by AWG product application teams.
- Generate an analysis report that summarizes approach and findings including the L2+ product impacts and conformance/non-conformance to F&PS.

When instrument specifications are changed, new L1B files are produced, products are run, and then products are evaluated in regards to the instrument specification changes (note that imagery is the Key Product Parameter and that analysis may just be of L1B data and images, depending on the needs). The GRAFIIR team will analyze the products to assess the impact of various instrument effects. The GRAFIIR team may utilize AWG product team members to either perform or assist with this analysis when appropriate.

The diagnostic statistics tool originally developed for GRAFIIR known as Glance has also been under continual development. Glance updates have been made available to AIT (now ASISSTT) regularly. Glance provides a statistical analysis comparing variables from two files. For example, Glance can be used to compare two output files from the AIT Framework, helping the AIT to diagnose bugs or installation issues. It also has been used at CIMSS to diagnose issues installing the local processing system, GEOCAT, on various machines and trying to determine if the installation and algorithms work the same on different machines. Glance is used extensively during waiver analysis to compare file outputs statistically determining the differences in algorithm output due to instrument effects introduced to radiances.

Glance can provide a report in HTML format that includes statistics and several types of plots. Plots include a difference image, scatter plot, and histogram of the differences. It is configurable in several aspects, most notably that a value can be set for any variable being compared such that the report will alert the user to when the difference between the two files in that variable exceeds that value, called epsilon.

## Milestones with Summary of Accomplishments and Findings

Continued maintenance of GRAFIIR capabilities and updates to Glance to meet changing needs that developed using real data.

- Maintain GRAFIIR datasets and software
- Glance file comparison tool updates that were needed for GOES-R
  - Version 0.3.2 in May, 2016
    - .nc files handle the _unsigned attribute properly.
    - units=1 should now work just like units="none" when it labels plots.
    - Glance commands should now be case insensitive on the command line.

    - if you call "glance help <CMD NAME>" with a command that doesn't exist, a general list of commands is printed.
    - Glance stats should now give correct answers for variables that are of shape ( ) (i.e., have absolutely no data).
- There were no ABI waivers this year.

**4.3 Algorithm Integration Team Technical Support**
**CIMSS Task Leader: R. Garcia**
**CIMSS Support Scientist: G. Martin, E. Schiffer, W. Straka, A. De Smet**
**NOAA Collaborators: M. Pavolonis, W. Wolf**
**Budget: $395,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- Provide critical support for the NOAA mission

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

**Objective**
Provide integration and technical support for the GOES-R Algorithm Working Group teams at CIMSS

**Project Overview**
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.

Principal Activities:
- Profile reference algorithm implementations and explore performance, accuracy, and reproducibility improvements.
- Review and update software and deliverables with CIMSS science staff.
- Maintain, extend, and deploy verification and automation test tools in coordination with AIT-East.
- Provide guidance to science staff to improve computer science aspects of algorithm reference software.
- Continued refactoring and migration of science software toward framework- and platform- agnostic software interfaces in order to simplify existing code and provide new avenues for rapid algorithm development.
- Add Himawari-8 (AHI) and GOES-16 ABI data processing capability to algorithm development environment software (Geocat, CLAVR-X).
- Continue research/offline framework developments and common satellite library development.
- Test integration work in cooperation with visualization group and AIT-East.

- CIMSS/SSEC infrastructure maintenance in support of AWG algorithm, integration,and Cal/Val work with ABI and proxy data records.
- Feedback and technical interchange with AIT-East and Harris/AER regarding computer science concerns in algorithm implementations and operational framework interfaces.

### Milestones with Summary of Accomplishments and Findings

- Continued work on verification testing of updated CIMSS reference algorithms in SAPF (STAR Algorithm Processing Framework) for use at NOAA.
- Improvements to Glance verification toolset, responding to AWG and AIT-E team requests and objectives. Released Glance 0.3.3 to AWG and AIT teams, specifically improving support for operational ABI data formats.
- Supported Harris test product verification, providing necessary feedback. This included support the GOES-R Ground Segment Project with the verification of the Level-2 product output generated by the GOES-R Ground Segment Contractor (Harris), as well as familiarization and review of Level-2 product software developed by the GOES-R Ground Segment Contractor (Harris / AER).
- Performed assessment of Harris/AER operational code algorithm samples.
- SAPF workflow and automation improvements to improve speed of algorithm integration and testing work. Several software patches contributed to help improve SAPF.
- Continued development on 'libHimawari' C/Fortran/Python callable toolbox used for algorithm development systems to access Himawari Standard Data and HimawariCast formats, permitting imagery and Level 2 algorithms to be tested shortly after the availability of AHI near-real-time data.
- Technical and product feedback for AHI provided to JMA through NOAA channels.
- Technical and product feedback to GOES-R PRO team regarding ABI and associated products.
- Acquired and distributed test and ancillary datasets in support of AWG deliverables, validation, and verification.
- Continued involvement in AIT reference framework development and maintenance.
    - This includes CIMSS configuration management, build and execution automation for the SAPF. This will provide routine local processing of the SAPF specifically for CIMSS AWG uses.
    - Integration activities for CIMSS algorithm updates for delivery to AIT-East.
- Management and coordination of schedules, deliveries, software configuration items in cooperation with AWG and Harris/AER.
- Participated in ongoing training for ground segment Algorithm Test Tools (ATT).
- Supported the storage and distribution of GOES-16 PDA and GRB for GOES-16 datasets as well as Himawari-8 HSD/HimawariCast datasets for verification, validation, integration and research uses within CIMSS/SSEC. This includes acquisition of further storage-area-network (SAN) resources at CIMSS/SSEC to buffer multiple weeks of ABI and AHI for cluster and workstation use by researchers.
- Worked with scientists and SSEC Data Center staff to establish an AMQP-based messaging architecture. This allows research and near-realtime processing to launch immediately upon availability of ABI data on the research SAN and other distribution points.

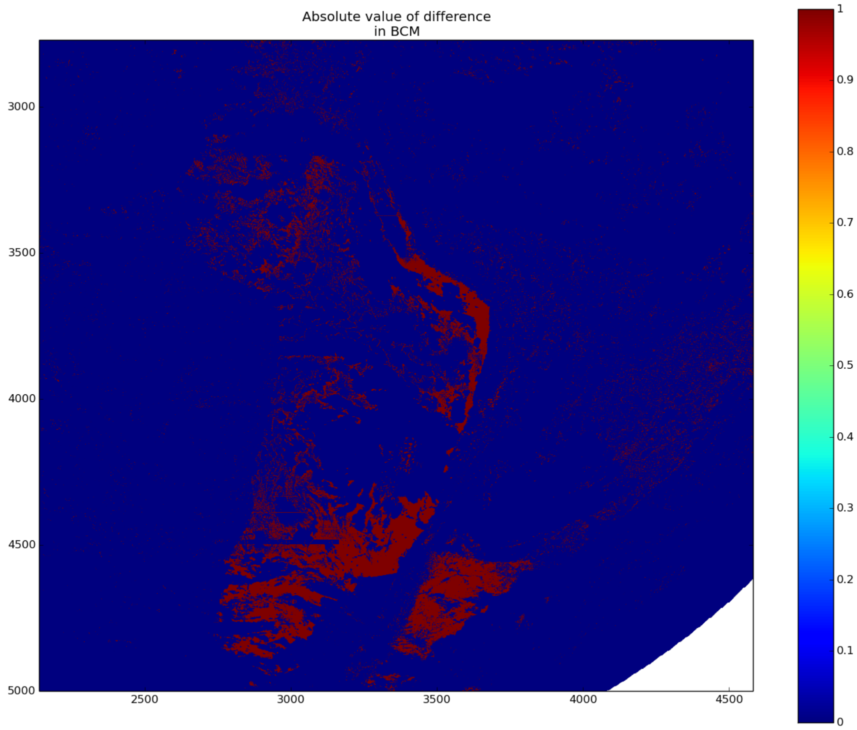



**Figure 17. Glance comparison of operational versus developmental Bayesian Cloud Mask for GOES-16 ABI, performed in the course of resolving a static ancillary mask issue seen in Operational Environment products.**

## 4.4 GOES-R Collocation
**CIMSS Task Leader: Bob Holz**
**CIMSS Support Scientists: Fred Nagle, Ralph Kuehn, and Greg Quinn**
**NOAA Collaborator: Walter Wolf**
**Budget: $75,000**

**NOAA Long Term Goals:**

- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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

## Objective

The main objective of the GOES-R collocation project is to provide a comprehensive evaluation infrastructure in support of GOES-R product development and post launch validation.

## Project Overview

This report provides an overview of the GOES-R collocation project accomplishments with a focus on how the project is supporting the GOES-R AWG teams. The project leverages decades of experience in applying vector algebra and analytic geometry to problems in satellite navigation and collocation at CIMSS. This capability originated in the 1970s as part of the NOAA satellite group lead by Bill Smith Sr. and Fred Nagle to help support the early NOAA polar and geo-stationary instruments. As will be presented, the GOES-R AWG project has provided the support to greatly expand these tools to support the AWG calibration and validation efforts enabling months or years of data to quickly be collocated and compared for statistical analysis and long term monitoring. 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.
- 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.

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.

## Milestones with Summary of Accomplishments and Findings

A major effort of the collocation project is the development of an integrated validation system which will provide the AWG teams access to global, quantitative, inter- comparisons between GOES-R products and both active (CALIPSO and CloudSat) and passive (MODIS, VIIRS, CrIS, IASI) Cloud, Aerosol, Sounding observations. As part of this effort a centralized web interface has been developed (http://kepler.ssec.wisc.edu) allowing both viewing of imagery and access to Match files that provide the collocated data products. Future work will focus on integrating the JPSS products allowing the JPSS teams to easily inter-compare the polar (JPSS) and GOES-R products. We are also working on adding radiance level inter-calibration. The system is designed to automatically identify when there is coincident observations between the geo and leo observations. Once identified the system automatically processes the collocation and inter-comparison software providing about a 15 min delay between when the data is ingested and the inter-comparison products are produced. This capability will support monitoring of the AWG products. The foundation for this system is the collocation and navigation tools presented in the previous section. We now present the components of this this system.

### *Flo processing*

Applying collocation for inter-calibration and product validation usually involves gathering statistics over months or years of data files. Existing GEO and LEO data archives and compute cluster resources at CIMSS simplify this requirement. In addition, the collocation project has both benefitted from and influenced the design of "Flo," a cluster processing system used in production by the NASA Atmosphere SIPS located at CIMSS. Using Flo eliminates the need to manually write scripts to interface collocation tools with the cluster batch scheduler, and makes it easy to process years of archived data with minimal setup or to arrange for forward-stream processing of collocation products in near real time.

### *Match Files*

After identifying the intersecting data files and processing the collocation a matchfile is produced which uses the collocation indices (i.e., the indices that map the VIIRS data into the GEO pixels). For example, when match files are created for the AWG cloud top height retrievals with VIIRS on SNPP, the VIIRS pixels identified to be within the GEO FOV are averaged together to provide a mean and standard deviation of the VIIRS CTH for each GEO pixel with the results of both the GEO and evaluation data set saved in the match file. Prototype match files have been created for the evaluation of the AWG Cloud and Wind products and are available on the AWG validation website at (kepler.ssec.wisc.edu). These files will be continuously generated once the AHI and GOES-R data becomes available.

### *Validation results and imagery*

A recent advance of this project is the development of python software that utilizes an oblique Mercator projection for displaying the imagery which can be applied to both GEO and LEO observations. The oblique Mercator projection is a cylindrical projection where the cylinder intersects the earth along an arbitrary great circle. The benefits of this projection is that images from both LEO and GEO observations can be viewed in a rectangular which is not rotated as they would be with a orthographic projection. Due to the earths rotation and satellite motion granules near the equator take on a parallelogram shape. This capability will be used to generate consistent quick look product images for both AHI and ABI which can be directly inter-compared with SNPP VIIRS retrievals. And example these tools applied to the AWG cloud algorithms on SNPP is presented in Figure 18.

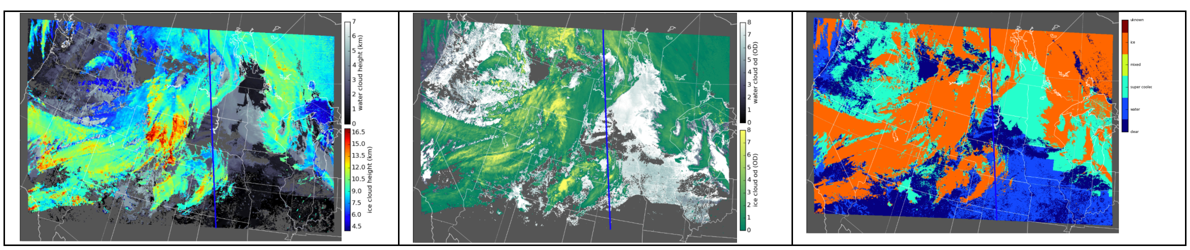


**Figure 18. From left to right: AWG cloud algorithms applied to VIIRS data for retrieved cloud top altitude, effective radius, and cloud mask. Blue line is CALIPSO ground track.**

We have also implemented the corrected reflectance true color [R,G,B], snow/ice [0.86, 1.6, 2.25 um], and natural color [1.6, 0.86, 0.67um] color composite imagery. For daytime observations these images are valuable for algorithm developers to help differentiate liquid from ice clouds and snow or ice surfaces, see Figure 19.

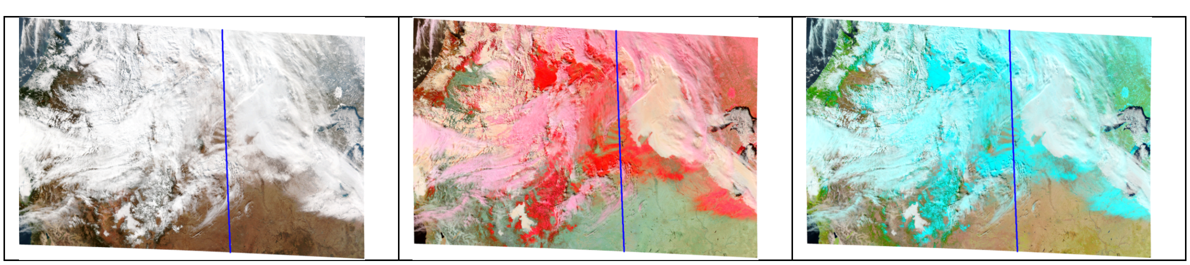


**Figure 19. From left to right: True color, snow/ice composite, natural color. Blue line is CALIPSO ground track.**

Generating color composite imagery is a non-trivial operation as it requires the remapping of the sensor observations into the projection coordinate system. For the large data volume of GEO stationary observations this can be a very time consuming and cpu intensive operation. We have implemented the tools to leverage software developed at SSEC (polar2grid) that utilizes a forward navigation or 'elliptical weighted average' algorithm (i.e., fornav) to efficiently remap the imager data. With these tools we can efficiently generate these images in near real time as the data is made available.

**Publications and Conference Reports**

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.

## 4.5 ABI Cloud Products

**CIMSS Task Leader: William Straka III**
**CIMSS Support Scientists: Steve Wanzong, Andi Walther, Pat Heck**
**NOAA Collaborators: Andrew Heidinger, Michael Pavolonis**
**Budget: $516,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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

**Objective**

To develop a suite of products that will offer advanced cloud detection and retrievals of cloud properties utilizing the GOES-R ABI instrument.

**Project Overview**

The National Environmental Satellite, Data, and Information Service, Center for Applications and Research (NESDIS/STAR) and the Cooperative Institute for Meteorological Satellite 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 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.

**Milestones with Summary of Accomplishments and Findings**

The focus of the Cloud AWG this reporting period was maintaining and updating the various algorithms, validating the updated algorithms and supporting the GOES-R Ground Segment System Prime, Harris Corporation, in their implementation of the cloud algorithms.

The various cloud algorithms have been, or are in the process of, being adapted for sensors other than ABI. These include the current GOES GVAR sensors, COMS, Himawari-8 (ABI like imager), Meteosat, MODIS, VIIRS as well as making sure that the baseline algorithms work on the GOES-16 Advanced Baseline Imager (ABI) datasets. In addition, work began on evaluating cloud algorithm output from the GOES-16 Ground System (GS) starting in early 2017, once data became available. Several issues were noted with the cloud mask output and were passed to the Ground System to be worked on. It is expected these evaluations will continue throughout the post launch period.

Validation of the current and updated algorithms is important to ensure the algorithms perform as expected during the post-launch check out for GOES-R. The Cloud AWG has extensively used other satellite sensors, such as spaceborne lidars, (CALIPSO), passive microwave satellite sensors (AMSU, AMSR-E), ground based lidars (HRSL), ground microwave profilers (MWR at ARM site) and passive imagers (MODIS, AVHRR), as independent validation 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. The Cloud AWG team also 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. The cloud algorithms were also used as part of the first International Cloud Working Group meeting (formerly CREW), where the Cloud AWG algorithms were compared with algorithms from other institutions. Automated validation tools were also worked on in the previous year so that there can be automatic validation of the various cloud algorithms after launch.

In addition to offline validation studies, the cloud algorithms have been used in a near-realtime field campaigns as well as international workshops on cloud properties. For example, the cloud top height algorithm, which also relies on the cloud mask and type/phase algorithms, will be used during NOAA Shout Program (Sensing Hazards with Operational Unmanned Technology). Cloud heights are used to aid in flight path decisions for the Global Hawk Unmanned Aerial Vehicle (UAV) over and around the path of tropical cyclones.. Several cloud products, including cloud mask, cloud type, cloud top altitude, cloud water path and various composite images were supplied in real-time in support of the Korean – USA Air Quality (KORUS-AQ) field campaign from late April to mid June 2016. Figure 20 shows an example of the domain and dust RGB product available during KORUS-AQ.

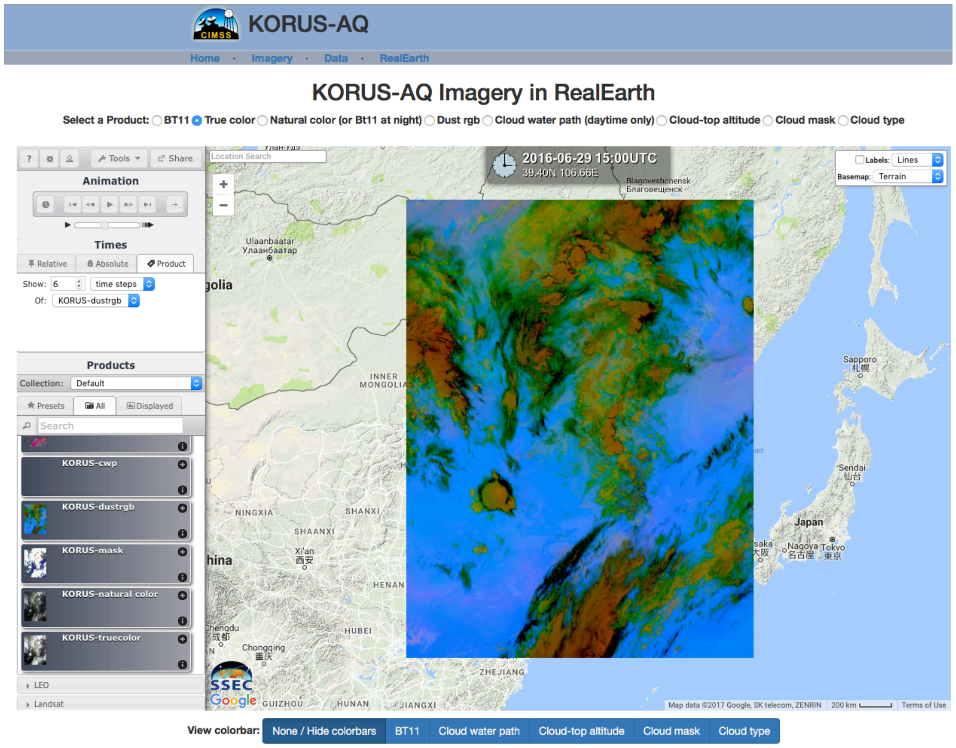



**Figure 20. Himawari-8 dust RGB image created in support of the KORUS-AQ field campaign from April-June 2016. Products were available in RealEarth, a separate web page, and anonymous FTP.**

The cloud team evaluated both the baseline and updated algorithms using the Advanced Himawari Imager (AHI), a ABI-like instrument currently onboard the Japanese Meteorological Agency's Himawari-8 geostationary satellite. In addition, the cloud team participated in several Data Operations Exercises in order to help prepare for the arrival of actual GOES-R data.

GOES-R (now GOES-16) was successfully launched in November of 2016. The ABI was officially turned on in January 2017, with products beginning to flow shortly thereafter. While Imagery data was declared beta on 1 March 2017, the Cloud AWG supported the GOES-R Ground Segment (GS) System Prime, Harris Corporation, in their implementation of the cloud algorithms. Issues were noticed with the data after Imagery had been declared beta and analysis were passed back to the GS for evaluation. Figure 21 shows examples of the cloud mask and cloud top height product using simulated data from DOE4.

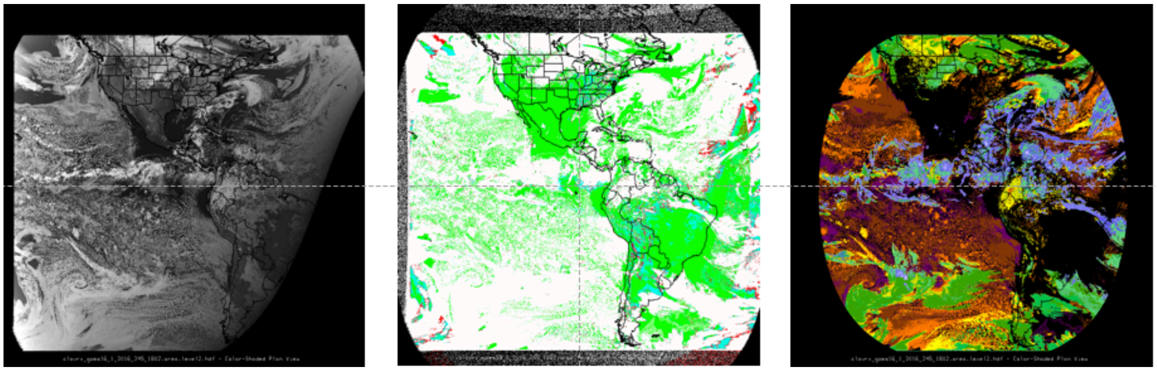


**Figure 21. Simulated GOES-R ABI data with products form CLAVRx. Left most image is the simulated 0.65 um reflectance data. Middle image shows the results of the cloud mask. The right most image is the retreived cloud top height (CTH) product.**

In 2017, the Cloud AWG will continued to improve the various cloud algorithms, support the GS in their effort as they produce output from the baseline cloud algorithms, provide analysis on the output from the GS in support of beta and provisional maturity status, continue development on the automated tools for the validation of the cloud algorithm, support international validation efforts and continue support of near-realtime usage of the cloud algorithms by field campaigns.

## Publications and Conference Reports

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## 4.6 Active Fire/Hot Spot Characterization
**CIMSS Task Leader: Chris Schmidt**
**NOAA Collaborator: Ivan Csiszar**
**Budget: $119,000**

### NOAA Long Term Goals:
- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:
- 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
- Environmental Models and Data Assimilation

### Objective
Maintain and improve the fire detection and characterization algorithm for the GOES-R series ABI

### Project Overview
This effort has adapted the current Global Wildfire Automated Biomass Burning Algorithm (WFABBA) to GOES-R ABI. This activity has been building on historical and current expertise at CIMSS in fire algorithm development for the GOES Imager and the global geostationary fire observation network (MSG, MTSAT, COMS, etc). CIMSS revised the WFABBA to address

GOES-R ABI observational requirements utilizing the improved fire monitoring capabilities on GOES-R. This work included updating modules that identify and characterize sub-pixel fire activity, demonstrating and validating the prototype GOES-R ABI Fire Detection and Characterization Algorithm (FDCA) using various GOES-R ABI proxy data sets, and providing a version of the algorithm for further evaluation by the AWG science team. The collaboration also has led to the development of innovative "deep-dive" validation tools. This activity ensures enhanced future geostationary fire detection, diurnal monitoring, and characterization in the GOES-R era.

### Milestones with Summary of Accomplishments and Findings

Primary milestones of this project included supporting ASSISTT and the ground system contractor during the Data Operations Exercise (DOE), updating product documentation as needed, development of the validation tools, initial post-launch data analysis, and providing maintenance updates as needed. CIMSS provided updates to the Product User's Guide (PUG), corrections which primarily focused on the definitions of valid data for the fire temperature, size, and radiative power fields. Input was provided for the Readiness, Implementation, and Management Plan (RIMP) to define the thresholds for beta, provisional, and validated product readiness. Data provided during DOE4 was analyzed and a handful of small issues identified, including variable type mismatches between the PUG and NetCDF files and discrepancies in valid ranges for the product fields. DOE4 data did not include fires in the model inputs, so product performance was not assessed.

Post-launch data analysis began as soon as L2 data became available. However, image navigation and registration (INR) issues, as well as calibration issues, limited the depth of the analysis through the reporting period. Given the fire product's sensitivity to both navigation and radiometric quality, this was expected. Preliminary qualitative analysis found that the product was performing reasonably well and was not subject to the large number of false alarms as seen with Himawari-8 AHI, most likely due to the narrower spectral width and somewhat longer central wavelength of the 3.9 micron band on ABI. Issues likely related to solar reflection were detected at low zenith angles (forward scattering) and other circumstances that had been observed with previous GOES satellites. Other issues with both false alarms and missed detections were traced to a need to adjust thresholds in the algorithm, though those thresholds cannot be firmly set until INR and calibration are stabilized. Initial deep-dive validation work by Dr Wilfrid Schroeder at CICS found expected patterns of detections and errors, with by far the largest number of errors in the lowest confidence fire category, primarily due to the reasons stated above.

As anticipated, ABI's remapping of the L0 data to L1b is introducing artifacts that affect fire detection. "Smearing" of a fire signal was anticipated due to the nature of the 4x4 sample remapping 'kernel' used for ABI. Pixels that appear cold adjacent to hot pixels were presaged by a similar artifact seem in COMS data and with AHI once Himawari-8 was launched. Those "cold pixel" artifacts are due to negative "tails" on the remapping kernels combined with the exponential nature of radiance in this band for the temperatures seen with fires. A very high radiance in one sample for a fire can contribute to a pixel up to 2 pixels away, and on the edges of the "kernel" that high radiance times a negative value drags the average resampled pixel radiance down, making it appear cold. Figure 22 illustrates the remapping artifacts. On the left is the 3.9 micron image, on the right is the metadata mask produced by the fire algorithm. The yellow box is a hot fire that seems to occupy 4 pixels but actually likely only covers 1 or 2. The magenta boxes contain milder examples of that "smearing" of the fire signal. The light blue box surrounds a hot pixel and fire that covers multiple pixels and has cold pixel artifacts as well. The hottest remapped pixel in this case is 400.18 K (we do not know what the original samples were), and within 2 pixels to the south and west, cloud-like pixels appear. Similar cold pixels do not appear in any other bands. Overall, the detection quality in Figure 22 is pretty good, but the "smearing" may be producing additional fire detections that are not real, and the cold artifacts may mask fire pixels. Both artifacts limit the algorithm's ability to assess fire characteristics. Assessment of the degree of impact depends upon availability of either L0 data or the "sample outlier files" (SOFs) that were created for the fire algorithm, neither of which was fully available during the reporting period.

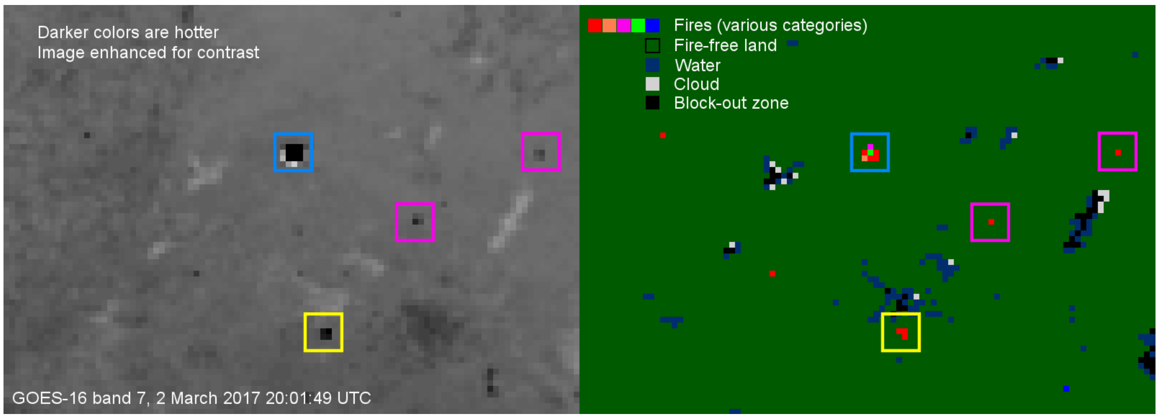


**Figure 22. GOES-16 band 7 and corresponding L2 FDCA output for 20:01:49 UTC over Oklahoma on 2 March 2017.**

## Publications and Conference Reports

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

**CIMSS Task Leader: Jun Li**
**CIMSS Support Scientists: Yong-Keun Lee, Zhenglong Li, Richard Dworak, William Straka, Jim Nelson and Bill Bellon**
**NOAA Collaborator: Tim Schmit**
**Budget: $312,000**

**NOAA Long Term Goals:**
- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

## Objective
The objective is to develop algorithms to produce and validate legacy atmospheric profile, Total Precipitable Water (TPW) and atmospheric instability indices from GOES-R series ABI for weather forecast applications.

## Project Overview
The main focus of this project is to develop the legacy atmospheric profile (LAP) algorithm for the next generation Geostationary Operational Environmental Satellite (GOES-R series) Advanced Baseline Imager (ABI) (Schmit et al., 2005; 2017) product generation. The algorithm retrieves 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 series LAP algorithm to be able to process high temporal and spatial resolution ABI data efficiently. This project provides science codes to the GOES-R series algorithm integration team (AIT) for algorithm integration and helps the system provider to implement the algorithm and prototype codes into the GOES-R ground system. CIMSS scientists will also evaluate and validate the GOES-R series LAP algorithm to assure that the legacy atmospheric temperature and moisture profiles, TPW, LI, CAPE, TT, SI and KI products meet the science requirements and operational applications.

## Summary of Accomplishments and Findings

### *2016 HWT Spring Experiment Participation*
GOES Sounder LAP products are generated at CIMSS in near real-time using GOES-R algorithm and are demonstrated in 2016 Hazardous Weather Testbed (HWT) which is a joint project of the National Weather Service (NWS) and the National Severe Storms Laboratory (NSSL). Overall, the weather forecasters used GOES LAP products in a positive way. Compared with 2015 HWT, the forecasters have increased interesting on the layered precipitable water (LPW). Requirement is raised on the need of LPW with finer vertical resolution and making LPW as a GOES-R baseline product. See below the summary from each week. More detailed report has been provided by the GOES-R liaison.

Very positive forecaster feedback – especially related to LPW during the 2016 HWT, included: (a) Out of all the LAP products, LPW may provide the most added value; (b) LPW was very useful in an operational mode with observing and forecasting; (c) It was very helpful for assessing the pre-convective environment; (d) LPW proved useful, especially with differential moisture advections which are typically not forecast well in the models; (e) LPWs are helpful for diagnosing motions at different levels for the atmosphere; (f) Operational applications are myriad; particularly in heavy precipitation and severe weather scenarios; (g) This LPW information is absolutely vital for forecasting operations, please consider adding this to the baseline products list. The high temporal and improved spatial resolution of these products would be an important addition in the forecasting environment because it could be used daily to define areas of concern, and as a primary source to monitor low and mid-level moisture trends.

### *Validation of the GOES-R Series LAP Algorithm*
GOES-R series ABI LAP algorithms have been validated using AHI as proxy in 2016. With the capability of frequent (10-minute interval) full disk observations over the East Asia and Western Pacific regions, the AHI measurements have been used to investigate the atmospheric temporal variation in the pre-landfall environment for typhoon Nangka (2015). During the pre-landfall

period, the trends of the AHI LAP products indicated the development of the atmospheric environment favorable for heavy rainfall. Even though, the AHI LAP products are generated only in the clear skies, the 10-minute interval AHI measurements provide detailed information on the pre-landfall environment for typhoon Nangka. This study shows the capability of the AHI radiance measurements, together with the derived products, for depicting the detailed temporal features of the pre-landfall environment of a typhoon, which may also be possible for hurricanes and storms with ABI on the GOES-16 satellite (Lee et al., 2017). Figure 23 shows the time series of the averaged AHI all-sky atmospheric temperature and water vapor at 535 hPa, atmospheric temperature at 900 hPa and brightness temperature at band 10 (7.3 μm) over 11 ISD (Integrated Surface Data) locations in Japan where the accumulated rainfall was over 30 mm in July 15, 2015 and over 100 mm during two days in July 15 and 16, 2015: (a) with 1-hour interval between 12 UTC July 14 and 06 UTC July 15 and (b) with 10-minute interval between 22 UTC July 14 and 03 UTC July 15 (data missing at 0240 UTC July 15). The rectangular box in (a) indicates the 10-minute period in (b). The original atmospheric temperature values at 535 hPa and 900 hPa have been subtracted by 10 K and 35 K, respectively, for the convenient comparison with the brightness temperature on the same scale. Vertical bars indicate the standard deviation over the selected 11 ISD locations.

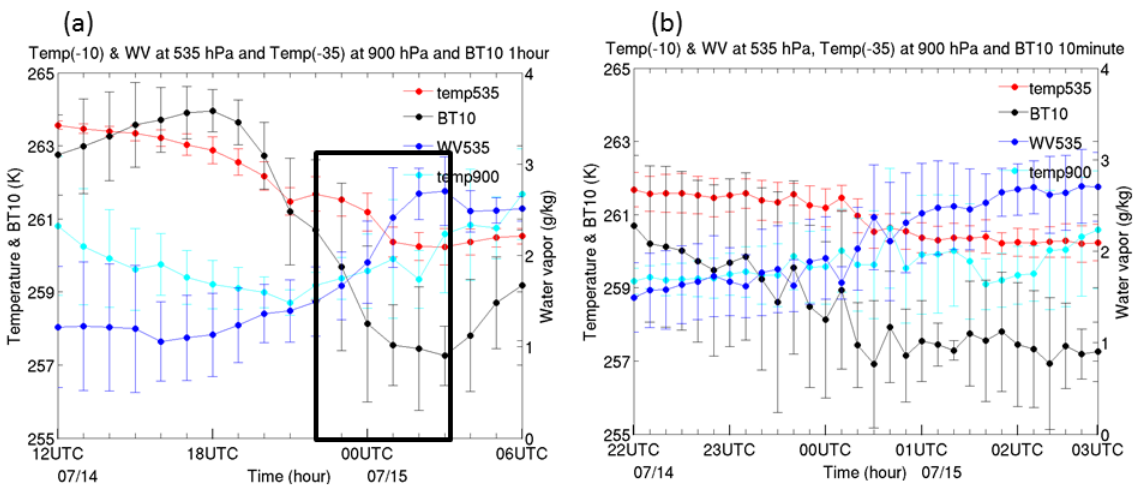



**Figure 23. The time series of the averaged AHI all-sky atmospheric temperature and water vapor at 535 hPa, atmospheric temperature at 900 hPa and brightness temperature at band 10 (7.3 μm) over 11 ISD locations in Japan.**

### *Implementation of LAP Algorithms, DOE Data Check, and RIMP Development*

Activities include but are not limited to: (a) Assisted AIT on Harris codes. Collaborating with GOES-R series Algorithm Integration Team (Walter Wolf, Jon Wrotny, Aiwu Li et al.) on answering questions on LAP algorithms and corresponding the codes (both Harris codes and CIMSS prototype science codes); (b) Assisted DOE data check. CIMSS GOES-R LAP team helped reviewing and checks the DOE-4 datasets. Feedback and suggestions were provided to AWG management (Jaime Daniels) and GOES-R series sounding team Chair (Tim Schmit); (c) Helped RIMP development. CIMSS LAP team helped the development of Validation Readiness, Implementation and Management Plan (RIMP) for atmospheric instability indices, total precipitable water etc. Feedback and suggestions are provided to Andrew K Mollner who is responsible for RIMP.

***Development of Web-based Tool for GOES Sounder/GOES-16 ABI LAP Validation***
Web-based validation tool has been developed for GOES Sounder/GOES-16 ABI LAP validation: http://soundingval.ssec.wisc.edu/, the validation tool were tested successfully with DOE (Data Operational Experiments) data before applied to GOES-16 ABI.

Three main layers in the validation tool:

1. Imagery animations include 24-hour loop for full disk, CONUS and mesoscale coverages; animations can be viewed for variables including TPW, LI, CAPE, KI, SI, TT, temperature, and water vapor (100, 200, 300, 400, 500, 700, 850, and 1000 hPa). Those parameters are displayed in clear skies overlaying on the 11 µm cloudy brightness temperature image.
2. Region-based plotting and visualization include daily, weekly, monthly, and seasonal statistics full disk, CONUS and mesoscale coverages. TPW is compared to GPS and AMSR2 TPW. The atmospheric temperature/water vapor vertical profiles, TPW, LI, CAPE, KI, SI, and TT are compared to RAOBs.
3. Station-based plotting and visualization include daily, weekly, monthly, and seasonal statistics for each GPS, RAOB, and AMSR2 measurement site over CONUS region. TPW is compared to GPS and AMSR2 TPW. The atmospheric temperature/water vapor vertical profiles, TPW, LI, CAPE, KI, SI, and TT are compared to RAOBs. Deep dive capability is included in the time series of each variable including TPW, LI, CAPE, KI, SI, and TT over RAOB sites.

***Daily Monitoring of Operational GOES-16 ABI LAP Products with Reference Datasets***
The ABI LAP products include those from disk, CONUS and mesoscale regional observations. At this moment, the validation tool is password protected during check-out time period following the rules from GOES-R AWG management. The images and results are not shown in this report. CIMSS scientists are ready for ABI LAP beta version review to be held in May 2017.

**Publications and Conference Reports**

Lee, Yong-Keun, Jun Li, Zhenglong Li and Timothy J. Schmit, 2017: : Atmospheric temporal variations in the pre-landfall environment of Typhoon Nangka (2015) observed by the Himawari-8 AHI, Asia-Pacific Journal of Atmospheric Sciences (in press).

Lee, Y.-K., Jun Li, Z. Li and T. J. Schmit, 2017: The Pre-Landfall Atmospheric Environment of a Typhoon Observed By the Himawari-8 AHI, 97th AMS annual meeting, Seattle, WA, 22-26 January, 2017.

## 4.8 ABI Derived Motion Winds

**CIMSS Task Leaders: Chris Velden and Steve Wanzong**
**CIMSS Support Scientist: David Stettner**
**NOAA Collaborator: Jaime Daniels (STAR)**
**Budget: $155,000**

**NOAA Long Term Goals**

- Weather-Ready Nation

**NOAA Strategic Goals**

- 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

**Objective**
Develop an automated atmospheric motion vector derivation algorithm to operate with GOES-R imagery and provide accurate wind estimates.

**Project Overview**
In preparation for the launch of GOES-R, the NOAA GOES-R Algorithm Working Group (AWG) winds team is actively developing derived motion vector (DMV) derivation algorithms and using them in demonstration studies. The software is being tested in a near real-time demonstration mode using GOES-East/West, Meteosat-10 SEVIRI, and Himawari-8 AHI data as ABI proxy imagery, with the resultant DMVs validated against "truth" data sets. Other satellite data have been incorporated into the proxy dataset testing and processing; including GOES Super Rapid Scan Operations imagery. The DMV height assignment methodologies continue to be closely integrated with the developments by the AWG Cloud Team ACHA algorithm.

**Milestones with Summary of Accomplishments and Findings**
- The DMV reprocessing effort using the GOES-R algorithms is underway. The latest DMV code build supplied by STAR is being used for the reprocessing. ERA Interim model analysis fields from ECMWF for the background fields to be used were accessed from the ECMWF Meteorological Archival and Retrieval System (MARS) using a custom scriptable Python interface.
- The DMV validation exercises using real GOES-16 data are underway. CIMSS is assisting STAR in this effort when needed.

## 4.9 Hurricane Intensity Estimation (HIE) Algorithm
**CIMSS Task Leaders: Chris Velden and Tim Olander**
**NOAA Collaborator: Jaime Daniels (STAR)**
**Budget: $150,000**

**NOAA Long Term Goals**
- Weather-Ready Nation

**NOAA Strategic Goals**
- 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

**Objective**
Adapt the existing operational Advanced Dvorak Technique algorithm to operate with GOES-R imagery and provide accurate tropical cyclone intensity estimates.

**Project Overview**
The CIMSS Advanced Dvorak Technique (ADT, Velden and Olander 2007) 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 objective TC intensity estimates, especially where aircraft reconnaissance is not available.

### Milestones with Summary of Accomplishments and Findings

During this reporting period, CIMSS scientists focused on two primary tasks in preparation of data becoming available after the launch of the GOES-R satellite:

- Testing and adaption of the HIE parent algorithm, the Advanced Dvorak Technique, for use with higher spatial and temporal resolution imagery. This was performed through utilization of Himawari-8 imagery. Comparisons are presented via the CIMSS GOES-R Proving Ground HIE webpage.
- The HIE validation exercises using real GOES-16 data are underway. CIMSS is assisting STAR and Harris in this effort when needed.

### Publications and Conference Reports

Velden, C., T. Olander, D. Herndon and J. Kossin, 2017: Reprocessing the Most Intense Historical Tropical Cyclones in the Satellite Era Using the Advanced Dvorak Technique. *Mon Wea. Rev.* **145**, 971-983.

### References

Olander, T. and C. Velden, 2007: The Advanced Dvorak Technique: Continued Development of an Objective Scheme to Estimate Tropical Cyclone Intensity Using Geostationary Infrared Satellite Imagery. *Wea. & Forecasting*, **22**, 287-298.

## 4.10 Volcanic Ash

**CIMSS Task Leader: Justin Sieglaff**
**NOAA Collaborator: Michael Pavolonis**
**Budget: $95,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- 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

### Objective

The GOES-R Volcanic Ash team will ensure the volcanic ash products produced by the GOES-R Ground System meet required specifications.

## Project Overview

We have adopted an infrared-based approach for detecting the presence of ash. This information is supplied to an ash cloud height and mass loading retrieval scheme. In this project we have continued to conduct the cal/val and development work required to assure that we achieve the F&PS specifications for the volcanic ash products. We will perform extensive validation using spaceborne lidar (e.g., CALIPSO) observations of volcanic ash and dust clouds. Any problems discovered in the cal/val process will continue to be addressed. Much of the work will also be aimed at providing GOES-R Ground System (GS) contract support. This work will insure the readiness of the volcanic ash algorithm for operational implementation upon the deployment of GOES-R.

## Milestones with Summary of Accomplishments and Findings

- *Complete modification of all routine and "deep dive" validation tools*
  The validation tools are nearly complete and are ready to begin validation once the team obtains co-located GOES-16 ABI ash products and CALIPSO observations of volcanic ash. Thus far the volcanic ash team has identified one event where volcanic ash was co-located between GOES-16 and CALIPSO observations.
- *Complete beta validation activities*
  We have begun beta validation activities as defined in GOES-R L2 Product Readiness, Implementation and Management Plan (RIMP). Thus far two important issues have been identified during the beta validation activities. 1) The Volcanic Ash Algorithm (VAA) L2 file cadence was examined and revealed occasional missing files. The GOES-R PRO team has investigated the missing files and determined the cause to be primarily with scheduled outages and has marked this issue as resolved. 2) Significant co-registration errors were discovered with GOES-16 IR bands, making the detection of small-scale volcanic ash clouds nearly impossible (not shown). The problem was corrected in February 2017 and the GOES-16 VAA output was greatly improved as shown by the detection of a very small volcanic ash cloud from the Reventador volcano in Ecuador (Figure 24).

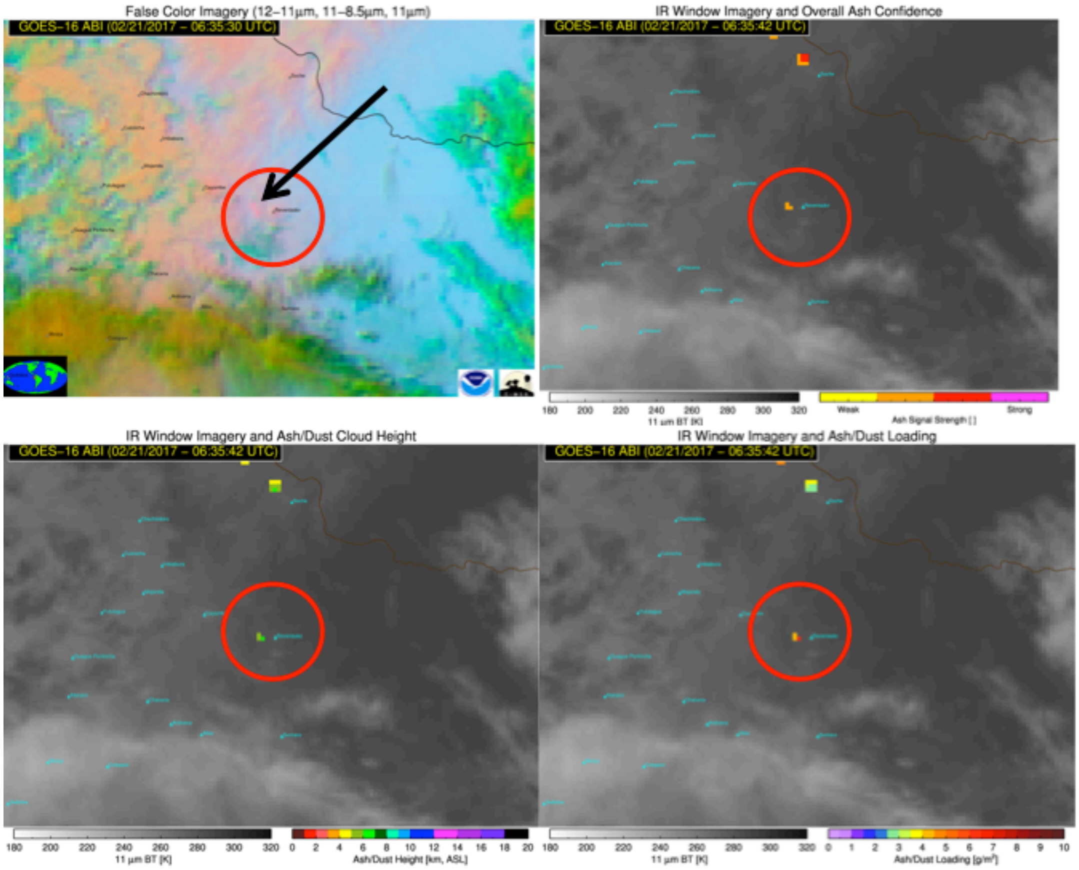



**Figure 24. GOES-16 false-color composite image (upper left) of a small volcanic ash emission from Reventador volcano in Ecuador (0635 UTC 21 Feb 2017). The volcanic ash is the small pink/magenta region within the circle, highlighted by the black arrow. The remaining panels are the GOES-R Ground System produced volcanic ash detection (upper right), volcanic ash height (lower left) and volcanic ash mass loading (lower right) for the corresponding image. The colored pixels in the remaining panels indicate volcanic ash detection/volcanic ash height/mass loading retrievals while the remaining gray scale pixels (10.4 µm brightness temperature) are where the GOES-R volcanic ash algorithm determined no volcanic ash present.**

### Publications and Conference Reports

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.

### References

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.

### 4.11 Imagery and Visualization

**CIMSS Task Leader: Mathew Gunshor**
**CIMSS Support Scientists: Kaba Bah, Joleen Feltz, James P. Nelson, Hong Zhang**
**NOAA Collaborator: Timothy J. Schmit**
**Budget: $312,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

## Objective
The primary objective of the AWG Imagery Team is to ensure the quality of the ABI Cloud and Moisture Imagery Product (CMIP), which is the Key Product Parameter (KPP) on ABI.

## Project Overview
The AWG Imagery Team has developed the format for ABI data which includes the fixed grid format and GRB-like data structure. Still in the validation phase, this proposal year takes us into the post-launch phase. Validation tools need to be tested with the McIDAS-X ADDE server as well as with CMIP-like files generated by ground system testing.

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.

The team assisted the GOES-R "First Light Imagery Team" so that the first ABI images were generated and made available for release.

## Milestones with Summary of Accomplishments and Findings
The Imagery Team proposed to: continue to support DOST/DOE visualizing and validating the L2b imagery outputs and GRB files; support Product Definition and Users' Guide (PUG) releases, validating PUG contents regarding imagery and comparing to file content; continue product validation activities and tool development, including testing on AHI data; support other GOES-R program efforts to refine ADDE servers for visualization and generation of McIDAS AREA files, both AHI and ABI; support study of alternative scan mode scenarios; refine the First Light Imagery "Mock Up"; test validation tools with ABI McIDAS ADDE server; continue algorithm and ATBD maintenance as needed; and transition to post-launch test activities.

FY16 Summary of Milestones
- Apr 2016: Last of the 16 ABI Band Fact Sheets
- Jun 2016: Reported on Ground Readiness Exercise (GRE) DO-3.0b
    - Data (L1b, & L2 CMIP, Total Precipitable Water, Cloud Top Height, etc.) visualized in McIDAS-V
- Jul 2016: ABI L2+ Cloud and Moisture Imagery Product (CMIP) Beta, Provisional and Full Validation Readiness, Implementation and Management Plan (RIMP)
- Sep 2016: Reported on Data Operations Exercise (DOE)-4
    - Test Data were visualized in AWIPS-II

    - Problems reported to AWG
    - Ran Mode 3 and Mode 4 ABI data through Imagery Team tools, such as Glance, McIDAS, etc.
        - Shell scripts to more easily generate images and animations of imagery.
    - Converted L1b radiance file to L2 CMIP file, reported results.
- Sep 2016: "True Color" images generated using a lookup table for the green band.
- Oct 2016: First Light Imagery Mock-ups
    - Full disk images and 16-panel images
- Jan 2017: First Light Imagery (released January 23, 2017)
- Feb 2017: Imagery PS-PVR for beta status
- Mar 2017: Post launch test continues. Validation of Imagery products, reporting of issues through AWG to Program.

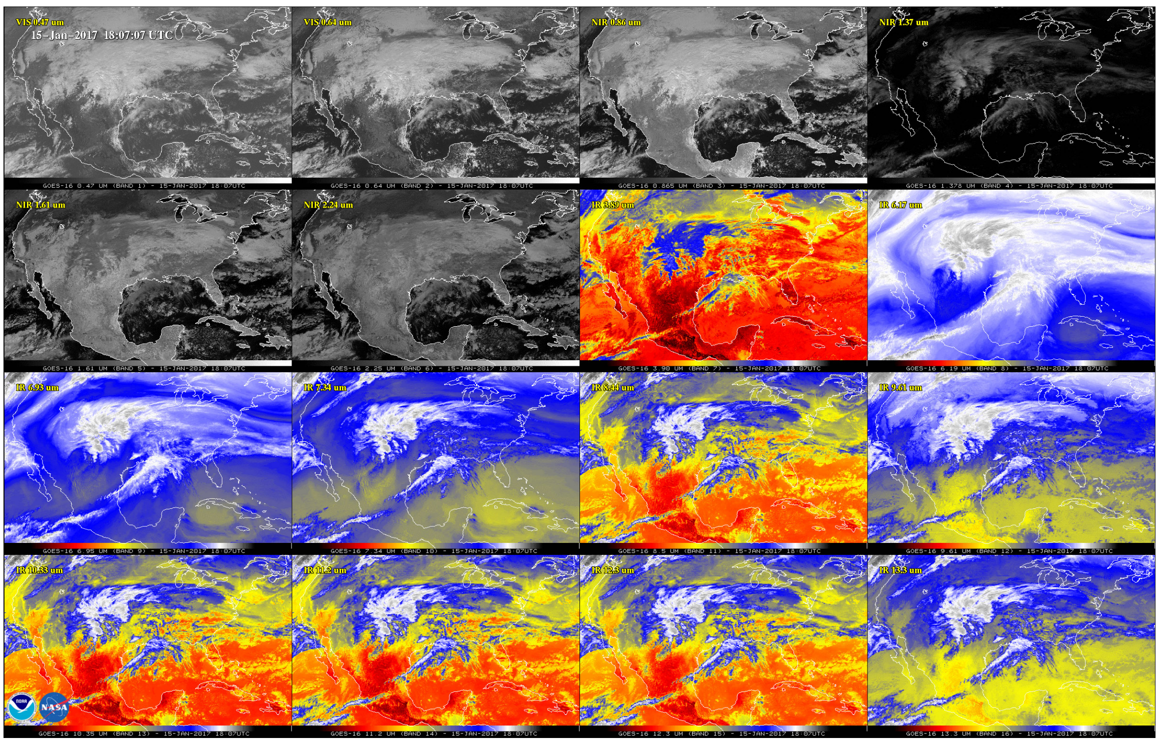


**Figure 25. First Light Imagery from GOES-16 generated by CIMSS for the NOAA press release. Data are from January 15, 2017 at 18:07 UTC, depicting all 16 spectral bands of the Advanced Baseline Imager (ABI) on the first satellite in the GOES-R series, GOES-16.**

## Publications and Conference Reports

Schmit, T. J., P. Griffith, M. M. Gunshor, J. M. Daniels, S. J. Goodman, and W. J. Lebair, 2016: A closer look at the ABI on the GOES-R series. Bull.Amer. Meteor. Soc., doi:10.1175/BAMS-D-15-00230.1, in press.

Schmit, Timothy J.; Gunshor, M. M.; Pierce, R. B.; Daniels, J. and Goodman, S. J. The Advanced Baseline Imager (ABI) on the GOES-R series. Annual Symposium on New Generational Operational Environmental Satellite Systems, 13th, Seattle, WA, 21-26 January 2017. American Meteorological Society, Boston, MA, 2017, abstract only; Abstract 2.1.

Miller, Steven D.; Lindsey, D. T.; Seaman, C. J.; Schmit, T. J.; Gunshor, M. M.; Hillger, D. W.; Sumida, Y. and Grasso, L. D. Himawari-8 AHI proves 'instrumental' in preparations for enhanced

GOES-R ABI imagery applications. Conference on Satellite Meteorology, Oceanography and Climatology, 21st, Madison, WI, 15-19 August 2016. American Meteorological Society, Boston, MA, 2016, Poster; Abstract 8.3.

Schmit, Timothy J.; Gunshor, M. M.; Pierce, R. B.; Gerth, J. J.; Lindstrom, S. S.; Daniels, J. M. and Goodman, S. J. Getting ready for the Advanced Baseline Imager (ABI) on the GOES- R series. Conference on Satellite Meteorology, Oceanography and Climatology, 21st, Madison, WI, 15-19 August 2016. American Meteorological Society, Boston, MA, 2016, Oral; Abstract 8.2.

Nelson, James P. III; Feltz, J. M.; Bah, K.; Gunshor, M. M. and Schmit, T. J. GOES-R imagery: Readiness and quality assurance. Conference on Satellite Meteorology, Oceanography and Climatology, 21st, Madison, WI, 15-19 August 2016. American Meteorological Society, Boston, MA, 2016, Poster; Abstract 113.

Schmit, Timothy J.; Lindsey, D. T.; Goodman, S. J.; Gunshor, M. M.; Line, W.; Bachmeier, A. S.; Lindstrom, S.; Alsheimer, F.; Radell, D. B.; Rabin, R. M.; Gravelle, C. M.; Bah, K.; Orrison, Andrew and Nietfeld, Dan. GOES-14 imager 1-minute rapid scan data: How to decide on sector locations. 2016 NOAA Satellite Proving Ground/User Readiness Meeting, Norman, OK, 9-13 May 2016. National Oceanic and Atmospheric Administration (NOAA), 2016, Powerpoint presentation.

## 4.12 Estimate of Fractional Snow Cover with ABI
**CIMSS Task Leaders: Yinghui Liu, Xuanji Wang**
**NOAA Collaborator: Jeffrey Key**
**Budget: $120,000**

### NOAA Long Term Goals
- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:
- 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

### Objective
The goal of this project is to continue to test, implement, and document the fractional snow cover algorithm for the GOES-R Advanced Baseline Imager (ABI).

### Project Overview
The product will provide the sub-pixel area covered by snow. The primary users of the snow cover product are the National Ice Center (NIC), NCEP, and NWS forecasters.

We will continue with algorithm validation, which is largely an effort to expand the scope of validation to a broader range of geographic areas and conditions. AVHRR, MODIS, and SEVIRI data are being used as proxy data for the purpose of testing and validating the algorithm. In situ and other satellite data, e.g., JMA's AHI and passive microwave-derived snow cover, as available, and independent estimates of fractional snow cover retrieved from higher resolution imaging systems (e.g., LANDSAT) under a variety of conditions will also be used to evaluate the accuracy of the product.

### Summary of Accomplishments and Findings

Starting in FY12, the Option 2 ("future capabilities") cryosphere products are not being funded. The Option 2 products are Ice Cover, Ice Concentration, Ice Age/Thickness, Ice Motion, and Snow Depth (tall grass prairies). CIMSS has played the leading role in developing ice products for ABI. The snow cover algorithm was developed by members of the AWG Cryosphere Team at the NWS National Operational Hydrologic Remote Sensing Center (NOHRSC) and the University of Utah (Tom Painter, now UCLA/JPL) (Dozier et al., 2009; Painter et al., 2009). For long-term maintenance of the algorithm it is decided that CIMSS and the NOAA Advanced Satellite Products Branch (ASPB) will take ownership of the software and documentation to ensure long-term viability as a NESDIS operational product. This proposal is for the early steps of the process: obtaining, evaluating, and implementing the fractional snow cover software, and expanding the validation activities.

Previous work has been focused on becoming familiar with the Fractional Snow Cover software package, documentation, and its test data. The software was compiled, tested, and implemented at CIMSS. Running the software on the test data showed and gave the same results as provided by GOES-R AWG AIT.

The GOESRSCAG (GOES-R Snow Cover And Grain Size) algorithm has been implemented to generate near real-time Fractional Snow Cover (FSC). FSC is the fraction of a GOES-R ABI pixel covered by snow. The near real-time processing uses surface reflectance and other products from MODIS as a proxy of GOES-R. MODIS surface reflectance product, MOD09, geolocation data, MOD03, and Level 2 cloud mask product, MOD35, are the inputs of this algorithm. In the MOD09 product, 5 bands (band 3, 1, 2, 6, and 7 of MODIS) are selected as proxy for GOES-R channels 1, 2, 3, 5, and 6. The output includes snow fraction and its quality information.

The algorithm is run daily on all MOIDS overpasses over the North America, and the retrieved snow fraction and its quality information for each overpass are archived. A daily composite of snow fraction over the North America is produced from all the overpasses, with snow fraction retrievals with smaller solar zenith angles replacing those with larger solar zenith angles in the composite. Quality control is done based on quality bit information included in the output. Figure 26 shows a daily composite of snow fraction on October 12, 2016 with quality control. Most of North America is, of course, snow free at this time of the year, yet the figure shows large area with retrieved snow fraction. Most of pixels with snow fraction retrievals are believed to be cloud covered pixels. The GOESRSCAG algorithm is designed to treat cloud as potential snow cover, and to retrieve snow fraction and snow grain size for those cloud-covered pixels. Cloud contamination is apparent in the snow fraction product even after quality control is done.

We have implemented two approaches to screen the cloud. The first is based on snow grain size retrieval, and the second is based on cloud mask. For the first approach, Clouds are best addressed are high-flying, small-particle snow. Because the particle size is small, snow grain size retrieval less than a threshold 50 microns is flagged as cloud. The second approach is to flag the snow fraction retrievals as invalid when the cloud mask identifies the pixel as cloud. Figure 26 shows a daily composite of snow fraction on October 12, 2016 with quality control, and after cloud screens using cloud mask, and using retrieved snow grain size. Both approaches are efficient in eliminating most of the cloud contaminations. But, they do show differences on the boundary of U.S.A and Canada, where snow appears after cloud screen using cloud mask, while not after screen using retrieved grain size.

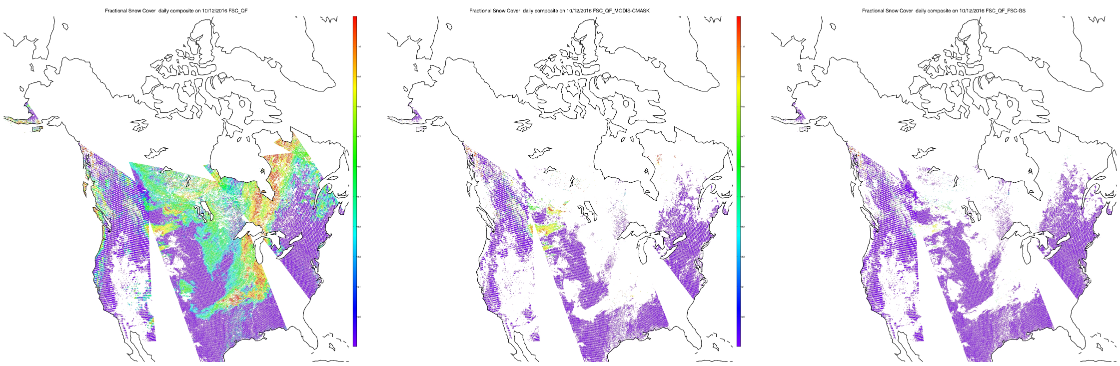


**Figure 26. Fractional Snow Cover daily composite on October 12, 2016 with quality control using GOESRSCAG with MODIS data as proxy(left), after cloud screen using cloud mask (middle), and using retrieved grain size (right).**

We have examined the GOES-R ABI fractional snow cover product. Figure 27 shows an example of the fraction snow cover product from 17:03 to 17:05 UTC on February 19th, 2017. The preliminary conclusions after careful examination of the products include: (1) the product appears to have implemented the cloud removal procedure as we suggested; (2) surface reflectance after atmospheric correction has not been implemented in the algorithm, and this affects the product accuracy and quality; (3) river and water mask impact on the product quality needs further investigation.

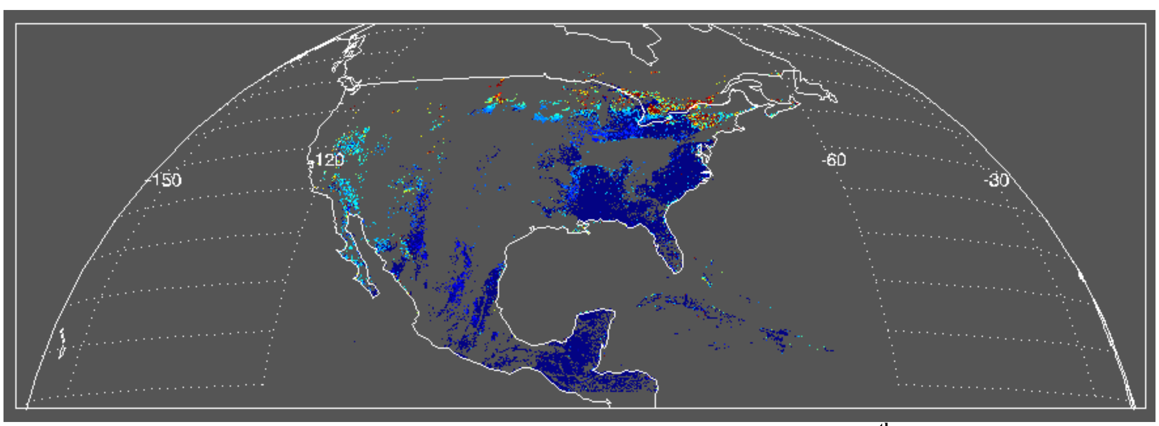



**Figure 27. Fractional snow cover at 17:03 to 17:05 UTC over CONUS on February 19th, 2017.**

## References

Dozier, J., R. O. Green, A. W. Nolin, and T. H. Painter (2009), Interpretation of snow properties from imaging spectrometry, *Remote Sensing of Environment*, doi: 10.1016/j.rse.2007.07.029.

Thomas H. Painter, Karl Rittger, Ceretha McKenzie, Peter Slaughter, Robert E. Davis, Jeff Dozier, 2009, Retrieval of subpixel snow covered area, grain size, and albedo from MODIS, *Remote Sensing of Environment*, 113, 868-879, 2009.

# 5. CIMSS Support to GOES-R NOAT Priority Research Risk Reduction

## 5.1 GOES-R Future Capability: $SO_2$ Detection
**CIMSS Task Leader: John Cintineo**
**CIMSS Support Scientist: Justin Sieglaff**
**NOAA Collaborator: Mike Pavolonis**
**Budget: $75,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

### Objective
We will utilize the VOLCAT system and expand the VOLCAT system to detect and characterize sulfur dioxide clouds in addition to volcanic ash clouds.

### Project Overview
The GOES-R ABI will have the unique capability to detect and characterize $SO_2$ clouds from a geostationary orbit. The GOES-R Algorithm Working Group (AWG) developed an ABI $SO_2$ detection algorithm to take advantage of this capability (Pavolonis and Parker, 2010). The $SO_2$ detection algorithm utilized infrared channels that are sensitive to $SO_2$ absorption, specifically the 7.3 and 8.5 μm channels. These spectral channels, combined with the 11 and 12 μm channels, were used to distinguish $SO_2$ clouds from all other features. At the 80% code delivery, the GOES-R AWG $SO_2$ algorithm was very close to meeting the performance specification of 70% correct detection for $SO_2$ concentrations of 10 Dobson Units or greater (actual correction detection accuracy was 64%).

The timely detection of $SO_2$ is important to aviation and, as such, $SO_2$ detection (and volcanic ash detection) is a priority of the National Weather Service. Through GOES-R Risk Reduction, a fully automated volcanic ash cloud alerting system was developed. The system automatically alerts users to the presence of new volcanic ash clouds in near real-time with an accuracy that is comparable to a trained human expert. The automated notification of volcanic hazards is absolutely critical, as even current data volumes prohibit manual analysis of all satellite images. The increase in data volume with GOES-R will make manual analysis even more challenging. The automated system, known as the Volcanic Cloud Analysis Toolkit (VOLCAT), utilizes spectral, spatial, and temporal metrics provided by the GOES-R ABI and other sensors to detect and characterize volcanic ash clouds. (VOLCAT can actually be applied to nearly any geostationary or low earth orbit sensor.) Volcanic ash detection techniques and previous GOES-R AWG $SO_2$ algorithm development have been leveraged to incorporate $SO_2$ detection capability within the VOLCAT system. Within VOLCAT, we can then readily merge information from high spectral resolution low-earth orbit IR sensors with geostationary satellite data to further improve the GOES-R $SO_2$ detection and property retrieval products.

## Milestones with Summary of Accomplishments and Findings

- Manual analysis of $SO_2$ features from 204 MODIS scenes was combined with 2561 5-minute MODIS granules, without detectable $SO_2$, to train a Naïve Bayesian classifier for computing the probability that a given pixel contains $SO_2$. MODIS data were used to train the classifier because the length of the MODIS data record (~17 years) allows for the inclusion of many more volcanic $SO_2$ events. As shown with volcanic ash detection (Pavolonis et al., 2015a; Pavolonis et al., 2015b), the MODIS training data can effectively be applied to ABI and other sensors with similar channels. The predictors derived from the training data set are shown in Figure 28. Four predictors, derived from 8.5 µm measurements, are utilized. The predictors capture the spectral variability of cloud emissivity under different background conditions and cloud height assumptions (in our conceptual framework $SO_2$ is considered to be a cloud). When $SO_2$ is present, the 8.5 µm emissivity will be large relative to the 11 µm emissivity since $SO_2$ absorbs radiation at 8.5 µm, but not 11 µm. These four metrics, known as β-ratios (Pavolonis 2010), provide a robust mechanism for capturing the anomalous absorption at 8.5 um while minimizing the impacts of background conditions (background = emission and reflection not related to $SO_2$).
- The MODIS training data were used to compute $SO_2$ probability and the Ozone Mapping Profiler Suite (OMPS) was used to assess the performance of the naïve Bayesian classifier (Figure 29).

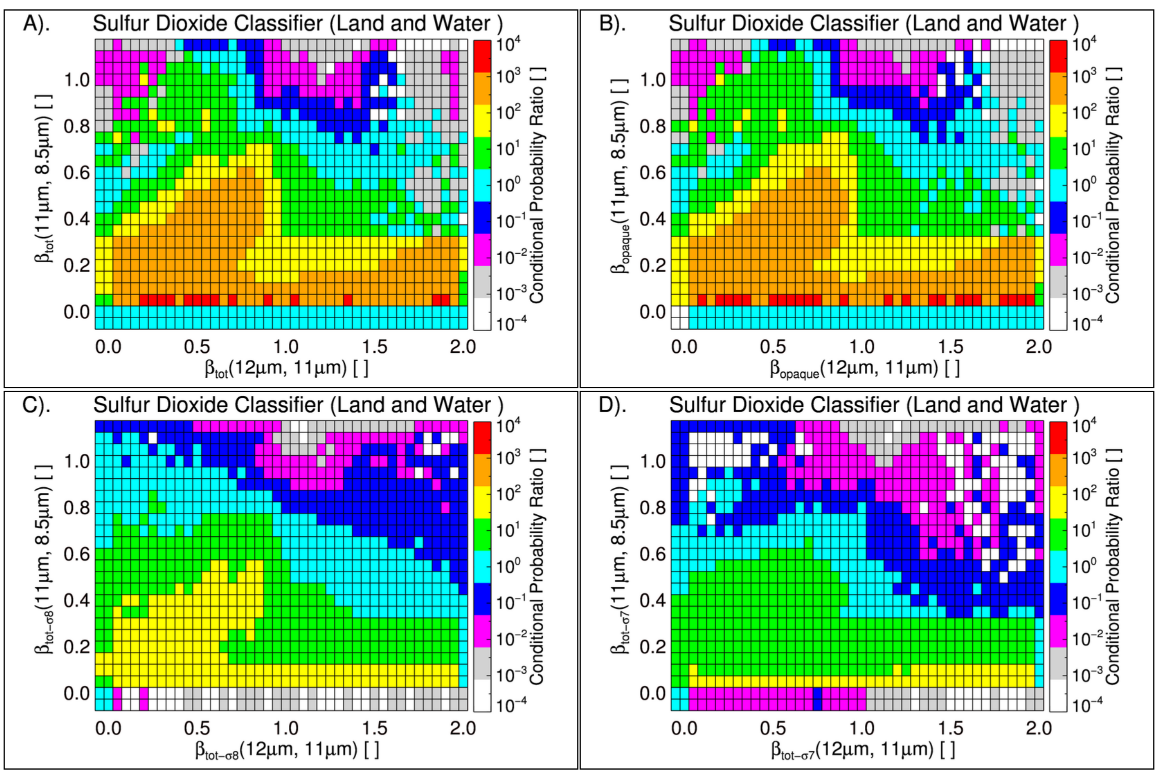
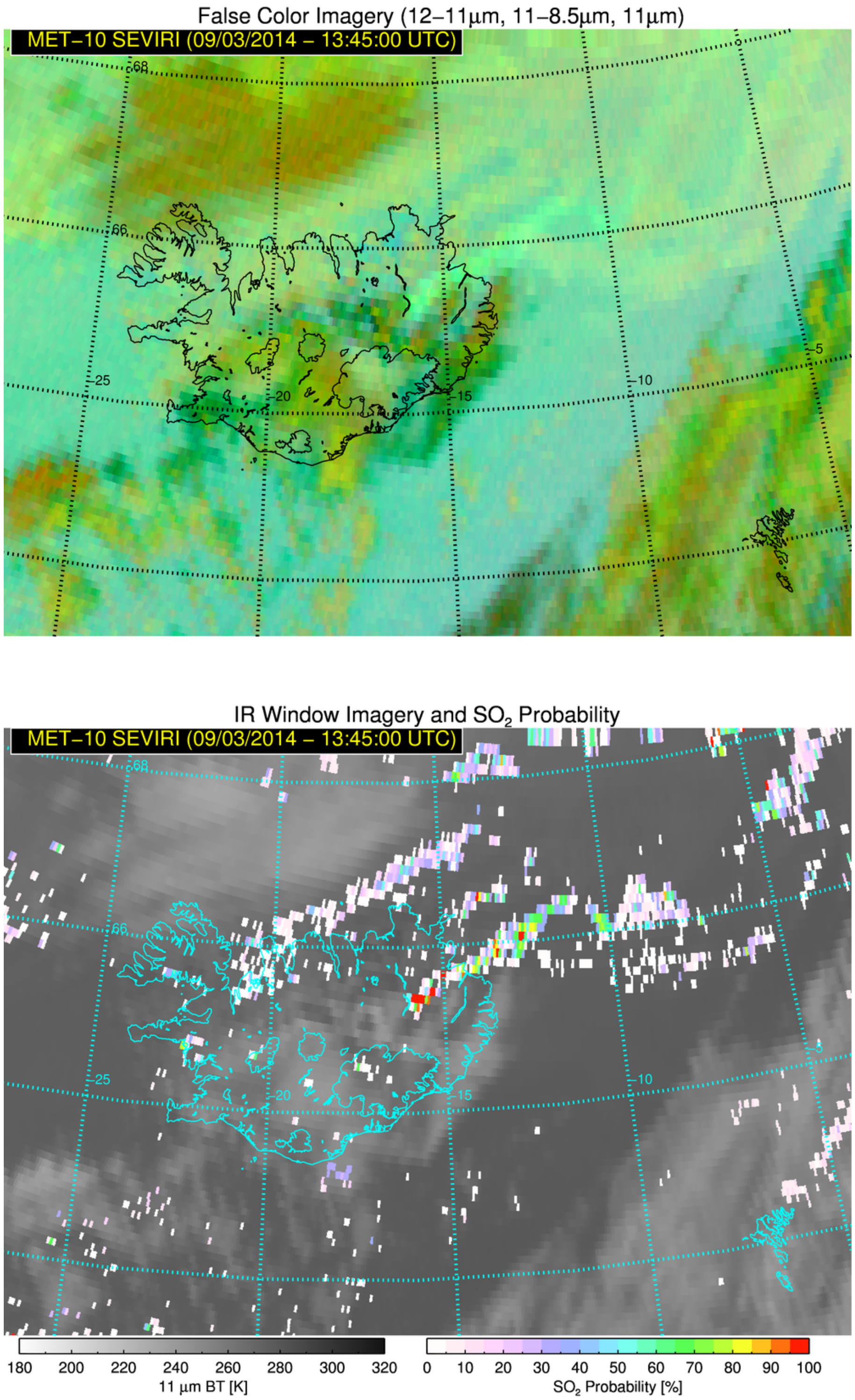



**Figure 28. The ratio of the SO2 class conditional probability to the class conditional probability of all other features is shown as a function of four multivariate spectral classifiers. The cyan through red portion of the color scheme indicates that the class conditional probability of SO2 is greater than the class conditional probability of all non-SO2 features for that histogram bin. A). βtot(12µm, 11µm) vs. βtot(11µm, 8.5µm), B).**

**βopaque(12µm, 11µm) vs. βopaque(11µm, 8.5µm), C). βtot_σ8(12µm, 11µm) vs. βtot_σ8(11µm, 8.5µm), D). βtot_σ7(12µm, 11µm) vs. βtot_σ7(11µm, 8.5µm). These β-based predictors are explained in greater detail in Pavolonis et al. (2015a).**



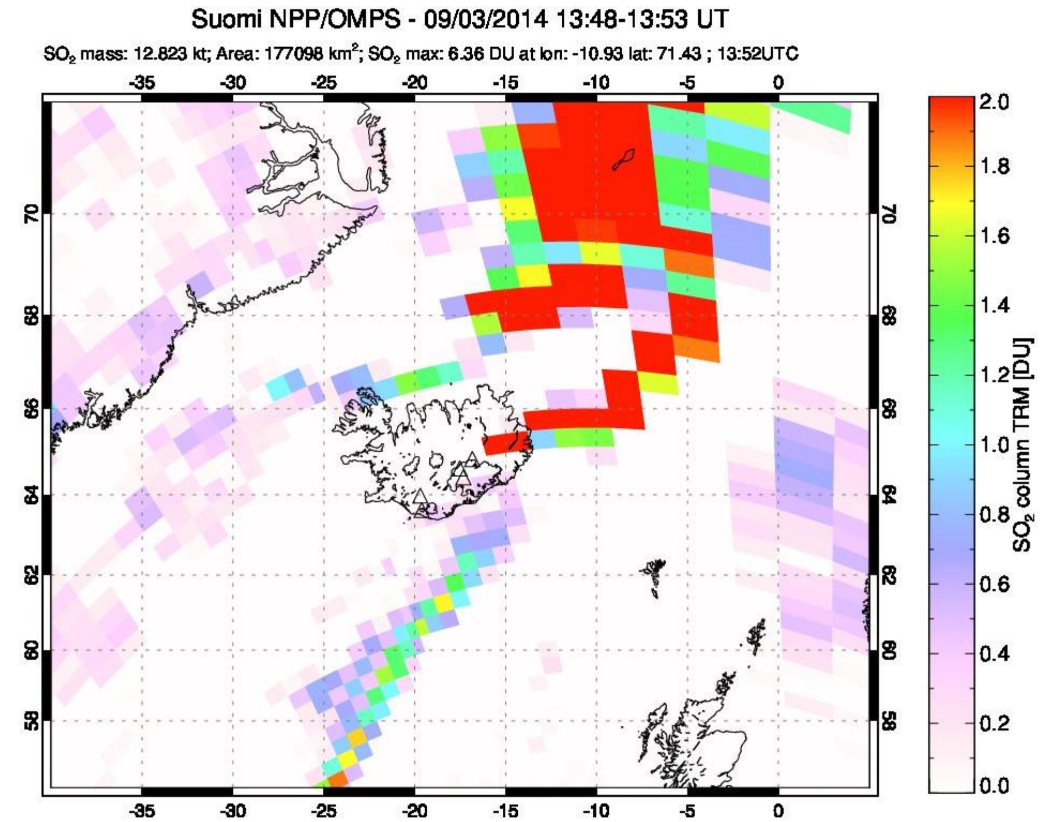



**Figure 29. A SEVIRI false color image from 13:45 UTC on September 3, 2014 is shown in the top panel. The SEVIRI image is centered on Iceland where the Bárdarbunga Holuhraun lava field was producing significant SO2 emissions. Large concentrations of SO¬2 will appear green in the false color image. The corresponding SEVIRI SO2 probability is shown in the center panel, where only probabilities greater than 1% are imaged (the 11 µm brightness temperature is shown elsewhere). The bottom panel shows the OMPS SO2 loading derived using the NASA algorithm. The SO2 probability field is generally consistent with the false imagery and the OMPS SO2 analysis.**

## References

Pavolonis, M.J. and A. Parker, 2010: GOES-R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document for $SO_2$ Detection, http://www.goes-r.gov/products/ATBDs/option2/Aviation_SO2_v1.0_no_color.pdf.

Pavolonis, M. J., 2010: Advances in Extracting Cloud Composition Information from Spaceborne Infrared Radiances-A Robust Alternative to Brightness Temperatures. Part I: Theory. *Journal of Applied Meteorology and Climatology,* **49**, doi:10.1175/2010JAMC2433.1.

Pavolonis, M. J., J. Sieglaff, and J. Cintineo (2015a), Spectrally Enhanced Cloud Objects (SECO): A Generalized Framework for Automated Detection of Volcanic Ash and Dust Clouds using Passive Satellite Measurements, Part I: Multispectral Analysis, *J. Geophys. Res. Atmos*., 120, doi:10.1002/2014JD022968.

Pavolonis, M. J., J. Sieglaff, and J. Cintineo (2015b), Spectrally Enhanced Cloud Objects (SECO): A Generalized Framework for Automated Detection of Volcanic Ash and Dust Clouds using Passive Satellite Measurements, Part II: Cloud Object Analysis and Global Application, *J. Geophys. Res. Atmos*., 120, doi:10.1002/2014JD022969.

## 5.2 GOES-R Future Capability: Continued Development of the GOES-R AWG Fog/Low Cloud Products

**CIMSS Task Leader: Corey Calvert**
**CIMSS Support Scientists: Scott Lindstrom, Amanda Terborg and Chad Gravelle**
**NOAA Collaborator: Michael Pavolonis**
**Budget: $75,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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

### Objective

We are developing the next generation fog/low cloud detection algorithm that improves upon heritage methods by fusing satellite, numerical weather prediction model and other ancillary data sets to produce a probability that various hazardous low cloud conditions are present.

### 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. 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. In an effort to address the limitations of the 3.9-11 μm BTD, the GOES-R Algorithm Working Group (AWG) developed 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. The GOES-R fog/low cloud algorithm is an enterprise system in that it can use satellite data from a variety of current data sensors (GOES, MTSAT, MODIS, AVHRR, VIIRS, SEVIRI, AHI and ABI) and future operational sensors and NWP data from a variety of models (GFS, RUC and RAP). Validation efforts, using surface observations over CONUS from each month of the year, indicate that the GOES-R IFR probability product is nearly twice as skillful as the traditional 3.9-11 μm BTD product at identifying IFR conditions, while also providing additional probabilities about whether the cloud meets MVFR or LIFR criteria. The GOES-R approach incorporates the information given by the 3.9-11 μm BTD, so the traditional BTD product never significantly outperforms it. Further, unlike the traditional product, the GOES-R probabilities have the same interpretation day and night. Thus, the GOES-R probability products should be thought of as an upgrade to the traditional product, not a complement or supplement. Finally, in addition to the probability products, the GOES-R FLS algorithm also produces an estimation of the fog/low stratus thickness (cloud top height minus cloud base height). The GOES-R FLS thickness product can be used to infer dissipation time for single cloud layer radiation fog events.

The GOES-R FLS probability and thickness products are available in AWIPS and are routinely utilized by nearly every National Weather Service (NWS) Weather Forecast Office (WFO) and National Center. The MVFR, IFR, LIFR, and FLS thickness products developed for the GOES-NOP series are in the process of being transitioned to NESDIS operations. The goal of this project is to conduct research to extend the capabilities of the FLS products for future operational implementation with on-orbit GOES-R series data.

## Milestones with Summary of Accomplishments and Findings

- *Continue to validate GOES-R fog/low cloud products using standard surface observations.*
  An extensive validation analysis was conducted using data from all 12 months of 2016. The accuracy of the LIFR/IFR/MVFR probability products for day/night/terminator conditions, computed using probability thresholds that yielded maximum skill, was found to be well over 80%, easily exceeding the 70% accuracy requirement. The FLS probabilities were also shown to be well calibrated and more much more skilful than the traditional BTD based product. This validation analysis also helps support the transition of the GOES-NOP products to operations.
- *Many new examples have been added to the GOES-R FLS Blog ("the fog blog") for user training purposes (http://fusedfog.ssec.wisc.edu).*
- *Continue to refine approach used to blend morphometric landform information and LEO data into GOES-R FLS algorithm.*
  The incorporation of morphometric landform classifiers and the merging of GEO and LEO data have been even more fruitful than originally thought. By combining GOES-R IFR probabilities with high-resolution topographic information, the low-resolution GOES-R FLS product can be downscaled to the spatial resolution of the digital elevation model thereby greatly improving the spatial detail provided by the FLS products. In addition, data from LEO satellites are being used in concert with the morphometric landform metrics to further improve the Bayesian classifier via the *a priori*. The downscaling procedure is still being developed, but shows great promise.
- *Continue development of fog formation alerting capability.*
  The downscaled FLS probabilities are still being developed. Once at a mature level they will be used to develop a valley fog formation alerting capability.
- *Continue to develop procedure to convert fog thickness product into a map of estimated fog dissipation times.*
  A relationship between the GOES-R cloud thickness product and the dissipation time of single cloud layer radiation fog events has been calculated. We are developing methods to best incorporate this information into a product that can be adequately displayed on a map or in AWIPS/NAWIPS/AWIPS-II.
- *Began developing an enhanced version of the FLS products using additional spectral information that will be offered by the GOES-R ABI.*
  Research is underway to incorporate the 8.5μm channel into the GOES-R FLS algorithm by using the 8.5-11μm BTD bias. The 8.5-11μm BTD bias is the difference between the observed 8.5-11μm BTD and the clear sky 8.5-11μm BTD calculated from the PFAAST RTM. The 8.5-11μm BTD bias identifies areas of smaller particle liquid stratiform clouds

and, when combined with the surface temperature bias (provides information on cloud height), can help differentiate areas of hazardous, low liquid clouds from those that are elevated and less hazardous. Because the 8.5-11μm BTD bias and surface temperature bias are produced using IR channels they can be applied both day and night and will be increasingly helpful in the day-to-night and night-to-day transition (terminator) regions (see Figure 30).

- *The AWC, AAWU, and, nearly every NWS WFO are currently utilizing the GOES-R FLS products in operations.*
  Feedback provided from Amanda Terborg (Satellite Liason at AWC) highlighted a fog event that attracted the attention from upper NWS management showing a great example of the benefit of the GOES-R FLS products for aviation (see Figure 31). The National Aviation Meteorologists (NAMs), long time users of the FLS products, utilized the GOES-R IFR probabilities over Denver, CO on September 22, 2016. A large area of fog, that numerical prediction models failed to accurately forecast, was headed straight towards the airport during a time of peak traffic. The GOES-R IFR probability product highlighted the area very well, indicating very high probabilities near the terminal, and the NAMs advised the FAA and folks in Denver of the impending low ceiling conditions. After some deliberation, United ended up ground stopping all Cat 2/3 aircraft (i.e., those who were unable to land in ceilings of less than 1/4 mile visibility) for 2-3 hours. In the end, the GOES-R FLS products provided them three hours of lead-time for this event and aided in the decision to ground stop aircraft, avoiding a lot of fuel costs due to diversions. Dissipation was also very well forecasted with this event.

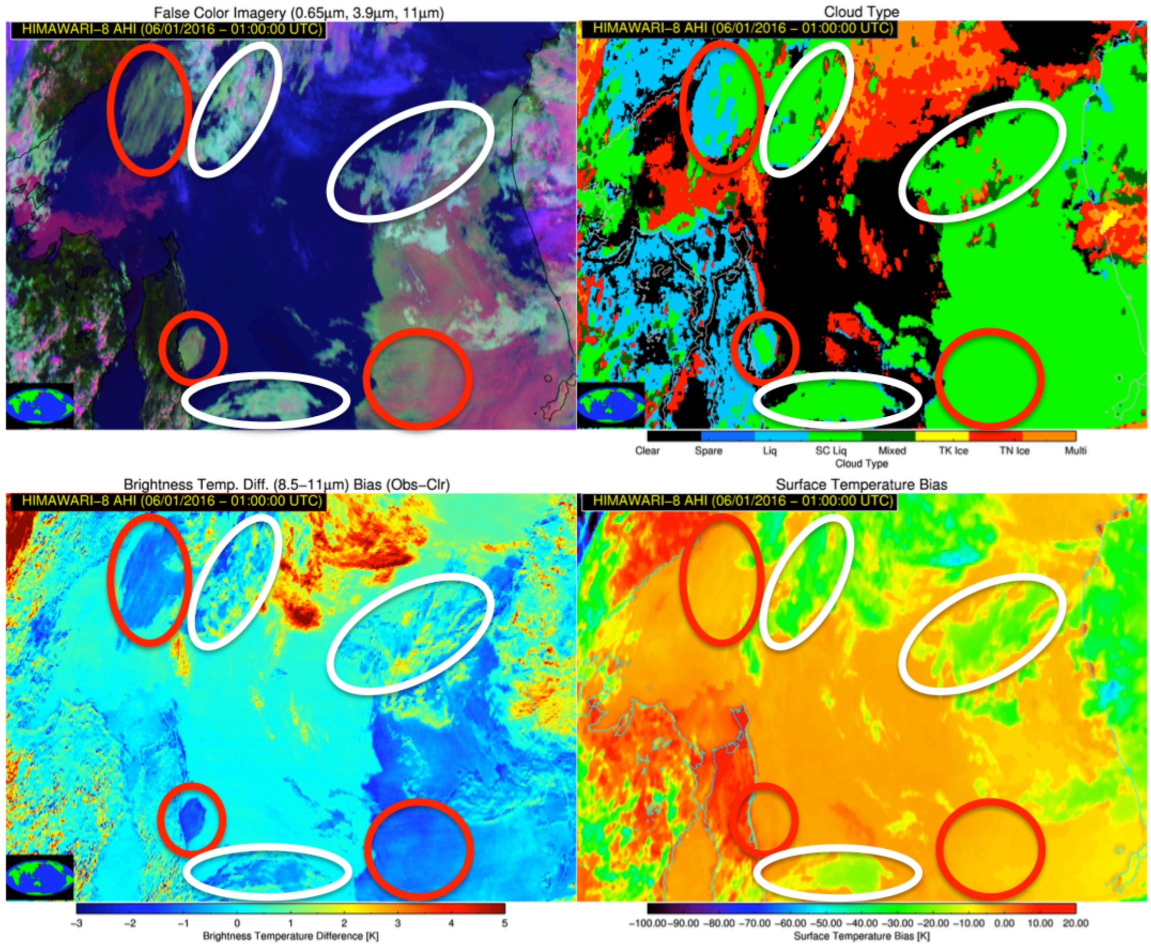



**Figure 30. An example false color image (top left), cloud type (top right), 8.5-11µm bias (bottom left) and surface temperature bias (bottom right), are shown for a Himawari-8 scene over the Sea of Okhotsk (west of the Kamchatka Peninsula) on June 1, 2016 at 1:00 UTC. The 8.5-11µm bias is the difference between the observed 8.5-11µm BTD and the clear sky 8.5-11µm BTD calculated from the PFAAST RTM. The areas circled in red contain hazardous low clouds while the areas circled in white contain elevated clouds. The 8.5-11µm BTD bias identifies areas of smaller particle liquid stratiform clouds (values < 0K) while the surface temperature bias provides information on the height of cloud layers (values ~0K indicate lower clouds near the surface while largely negative values are indicative of elevated clouds). These parameters, used together, help differentiate areas of hazardous low clouds from less hazardous, elevated cloud layers.**

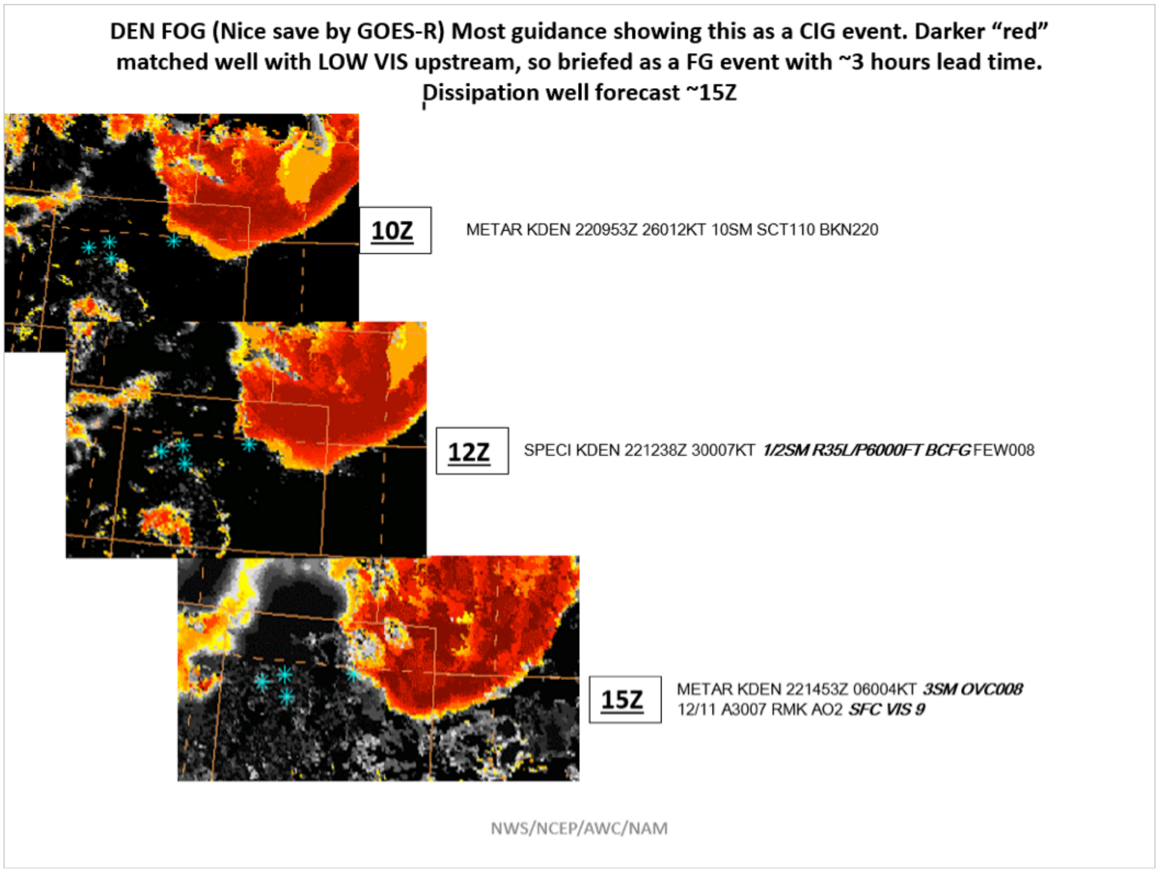



**Figure 31. The GOES-R FLS products alerted NWS aviation forecasters to an area of IFR ceilings backing into the Denver airport from the east that numerical prediction models failed to accurately forecast. The GOES-R FLS products lead to a ~5 hour ground stop, thereby limiting the number of arriving aircraft. The GOES-R FLS products provided enough lead-time to avoid diverting any incoming aircraft due to the ground stop. Diversions are extremely costly for airlines – more so than delays or cancellations. Figure courtesy of Michael Eckert (NWS).**

## Publications and Conference Reports

Calvert, C.G. and M. Pavolonis, 2017: Probabilistic identification of hazardous fog and low stratus clouds using satellite and numerical weather prediction data. *To be submitted to Weather and Forecasting*.

## 5.3. Evaluation of Turbulence-Detection Methods on Himawari-8

**CIMSS Task Leader: Anthony Wimmers**
**CIMSS Support Scientists: Sarah Griffin, Jordan Gerth, Amanda Terborg (CIMSS, Aviation Weather Center)**
**NOAA Collaborator: Bill Ward (Honolulu NWS)**
**Budget: $100,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- 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

**Objective**

The creation of new, real-time turbulence viewing tools for Himawari-8 and GOES-16 (online and through AWIPS) and their ongoing refinement based on feedback from NOAA aviation hazard forecasters.

**Project Overview**

Stakeholders in the Pacific Region have stated the need for products that provide warning for atmospheric conditions leading to aircraft turbulence, and these are underrepresented in the GOES-R generation ABI product stream. So far we have tested and evaluated three new types of turbulence-warning derived products on Himawari-8 (and soon on GOES-16). These three products are Overshooting Tops, the Tropopause Folding product, and the Gravity Wave detection product. We will add the best-performing products into the AWIPS2 datastream at CIMSS and continue to work with NOAA operational collaborators to do field testing and further refinement for accuracy and effectiveness.

**Milestones with Summary of Accomplishments and Findings**

***Online Presentation of Real-time Products and Turbulence Reports***

Sarah Griffin has created a real-time web viewer for the Pacific Region displaying Himawari-8 and GOES-West water vapor imagery with overlays of: the Tropopause Folding Product; the Overshooting Tops product; manual pilot reports and automated pilot reports (Figure 32). This has been used for near-real time reference and consultation with aviation forecasters at the Honolulu WFO, the Alaska Aviation Weather Unit, and the Aviation Weather Center.

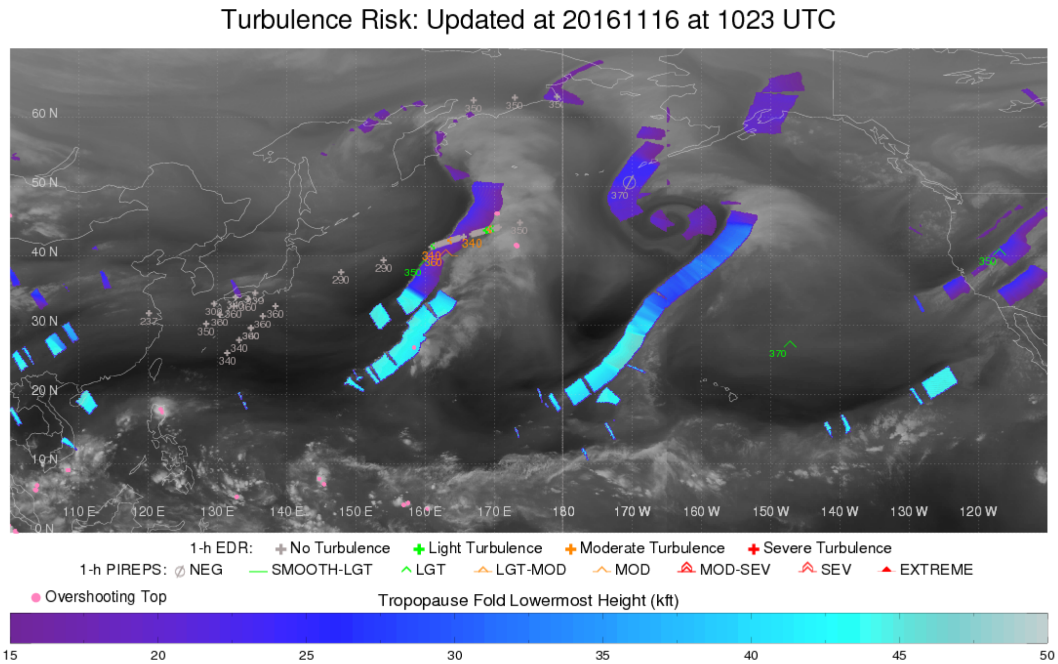



**Figure 32. Tropopause fold and overshooting tops in the northwest Pacific coincident with automated and manual reports of moderate turbulence. Also evident is a tropopause fold around the Aleutian islands with a coincident null (no turublence) report.**

### *Evaluate Product Effectiveness with Forecaster Feedback*

We have examined several cases of turbulence detection in collaboration with the Honolulu Forecast Office and the Aviation Weather Center and have used these examples to refine the forecast tools. More importantly, their feedback helps to direct the project into even more effective applications in the next reporting period, explained as follows.

Our original project plan was to investigate the relative merits of the Tropopause Folding Product, Overshooting Tops product, and Gravity Wave Detection algorithm as tools of real-time turbulence warning. Over the course of our research we have learned that the Tropopause Folding Product has skill, but has too high of a false alarm rate to maintain the regular attention of operational forecasters (Figure 33).

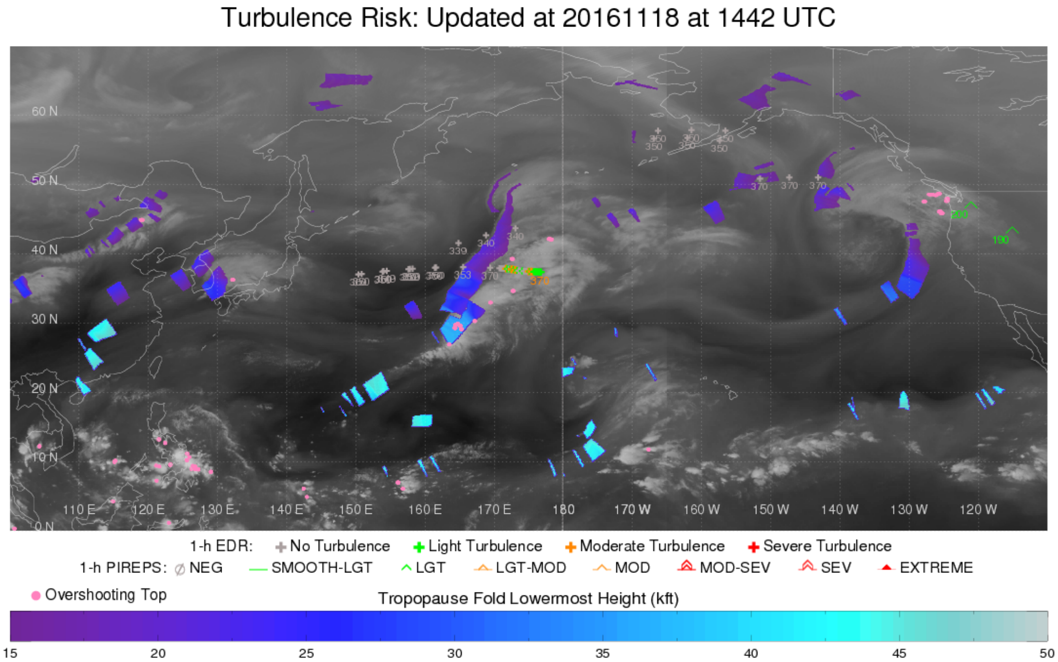



**Figure 33. Tropopause fold in the central Pacific with coincident automated null reports (no turbulence), and light/moderate turbulence afterward. This could be especially troublesome as a warning if the warning is "lifted" just before the aircraft encounters turbulence.**

The Overshooting Tops product, on the other hand, is already closely tied to forms of guidance that prevent most aircraft from encountering these hazards. So although the Overshooting Tops product still appears very skilful, we have not yet collected enough data to validate.

Finally, we have found new opportunities to exploit the detection of high-resolution gravity waves to predict aircraft turbulence. As we examined cases of moderate-to-severe turbulence, we frequently found evidence of gravity waves that were only detectable at the resolution of the AHI (or ABI), and they were often not revealed with existing visualization tools. To address this, we tested a new visualization of Himawari-8 using high-pass filtering, which displays only the small-scale variations around the local average brightness temperature (Figure 34).

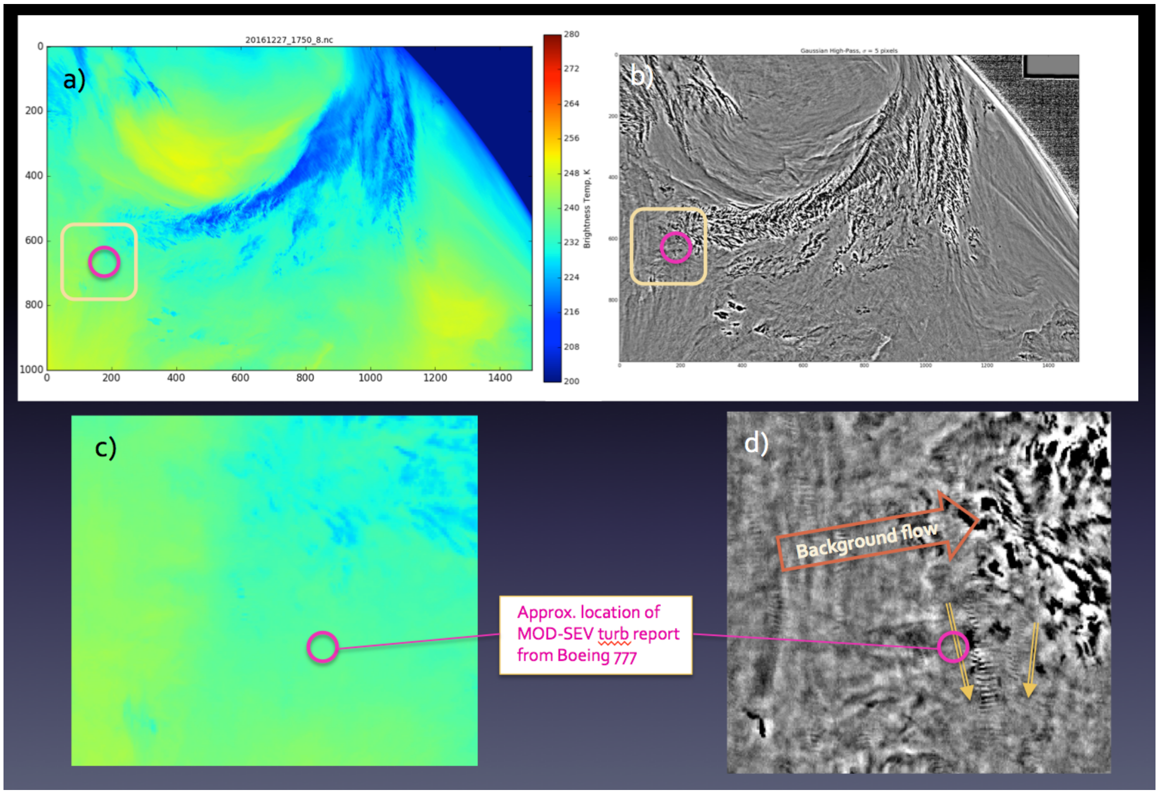



**Figure 34. Example of enhanced visualization of gravity waves using the high-pass filter (27 Dec 2016 1750 UTC). The magenta ring in each image is the approximate location of a MOD-SEV turbulence report from a Boeing 777. a) Himawari-8 Channel 8 image (upper tropospheric water vapor) using a high-contrast colorscale; b) Same data, using a Gaussian high-pass filter (gray color scale varies between -1K and 1K difference from the background average); c) Detail from image (a); d) Detail from (b) over same area, showing many gravity waves. Viewing this data in animation clearly shows that the gravity waves seen in (d) move orthogonally to the background flow, and possibly interfere with one another. The two yellow arrows are an estimate of the direction of propagation.**

High-pass filtering reveals an abundance of gravity waves in AHI (or ABI) water vapor imagery, which were not detectable in previous-generation GOES imagery (Figure 35). The goal then, for identifying associated turbulence in the GOES-R era is not simply to identify the gravity waves alone (which was often done in practice in the past), but rather to identify the subset of gravity waves prone to interference and wavebreaking. We theorize that this subset either propagates *against* the background flow, or is interfering with other waves in the imagery (Figure 34d). These patterns are known to lead to a downscale cascade into turbulence either from encounters with a critical layer (e.g., Grubisic and Smolarkiewicz 1997), wave-induced criticality or wave compression (e.g., Lane 2003). This new focus on gravity wave visualization has garnered the greatest interest by far from our NWS collaborators, and we are responding by making this the primary area of product development in the remainder of Year 1.

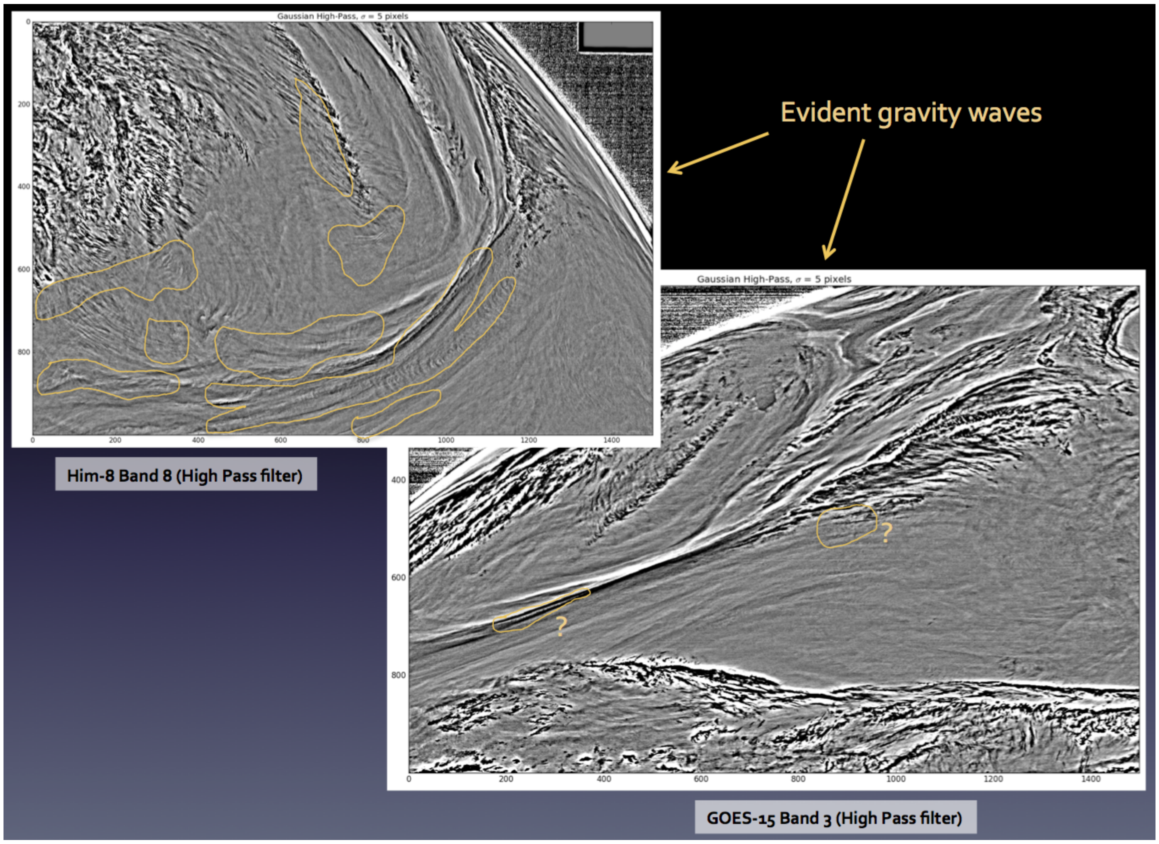



**Figure 35. High-pass filter of Himawari-8 Channel 8 (upper left) and GOES-15 Channel 3 (lower right) from 14 Dec 2016 1800 UTC. The Himawari-8 product shows large areas of easily identifiable gravity waves (outlined in yellow) because of its 0.1K brightness temperature resolution and 2km spatial resolution, whereas the 0.5K brightness temperature resolution and >4km spatial resolution of GOES-15 makes most gravity waves indistinguishable from noise.**

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Lane, T. P., R. D. Sharman, T. L. Clark, and H.-M. Hsu (2003), An investigation of turbulence generation mechanisms above deep convection, *J. Atmos. Sci.*, **60**, 1297–1321.

## 5.4 Identification of GOES-R Storm Top Features
**CIMSS Task Leader: Pao K. Wang**
**Budget: $80,000**

### NOAA Long Term Goals:
- Weather-Ready Nation

### NOAA Strategic Goals:
- 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

### Objective
To identify storm top features using GOES-R data.

### Project Overview
Severe storms impose substantial risk on human lives and property and influence the economic activity of human society greatly. This projects aims at finding visible and IR features seen in satellite storm imageries that can be used as indicators for severe storm nowcasting and forecasting. Many visible and infrared features at the top of thunderstorms as observed by meteorological satellites are intimately related to the physics and dynamics in the most active part of the storm. By identifying these features and investigating the physical processes responsible for generating these features, much information about the current state of the storm can be retrieved from satellite images which can then be used for the purpose of storm forecasting/nowcasting purpose. In this project, we utilize a physics-based cloud resolving model to simulate thunderstorm processes so as to see if the simulated storm exhibits the same visible and IR features as observed. If the simulating is successful, then we use the model physics to explain the physical processes responsible for producing these features. The characteristics of the features so identified and physically interpreted can used to form quantitative relations between them and physical variables of the storm (e.g., winds, updraft, humidity, turbulence, etc.). Such relations will serve as the basis for quantitative retrieval of storm properties. We propose to continue examining existing and identifying new storm top features and studying the physics and dynamics responsible for producing them.

## Summary of Accomplishments and Findings
In this period, we studied the storm top dynamics by comparing the satellite storm top imageries with that of aircraft observations and model simulation results so as to ascertain the physical interpretation of the features observed in satellite data. We are fortunate to have encountered a series of storms developed in coastal China on July 29, 2016 on a flight from Beijing, China to Taipei, Taiwan. Geostationary satellite images of these storms are taken from Himawari 8 (courtesy of Dan Lindsey of CIRA/NOAA). We used our cloud model WISCDYMM-II to perform simulations and showed that the simulated storm top features match that observed by aircraft and satellite very nicely, thus prove that the model interpretation of the storm top features is indeed accurate.


**Figure 36. A large thunderstorm cell showing a jumping cirrus feature at the storm top photographed on July 29, 2016 near Shanghai, China (Photo by Pao K. Wang).**

Figure 36 shows a thunderstorm cell photographed on July 29, 2016 on the rip as mention above. It is seen that there is a huge jumping cirrus occurring at the cloud top. It is pointing toward the overshooting top direction, exactly as described by Fujita (1974). We have theorized previously that the satellite observed above anvil cirrus plumes (AACP) reported by Setvak and Doswell (1991) and Levizzani and Setvak (1996) form first as jumping cirrus and then elongated along the storm top by the storm top winds as time goes on (Wang, 2003; 2004). But there was no direct evidence to show that this in indeed the case. Figure 36 shows that the jumping cirrus can indeed become elongated and resembling a plume when viewed from above.

Figure 37 is a frame taken from the simulated CCOPE supercell (see Wang, 2003) but using our newer version cloud model WISCDYMM-II which is a double moment model. It is seen that the model duplicates the jumping cirrus process very well, exhibiting all the major features as shown in Figure 36.

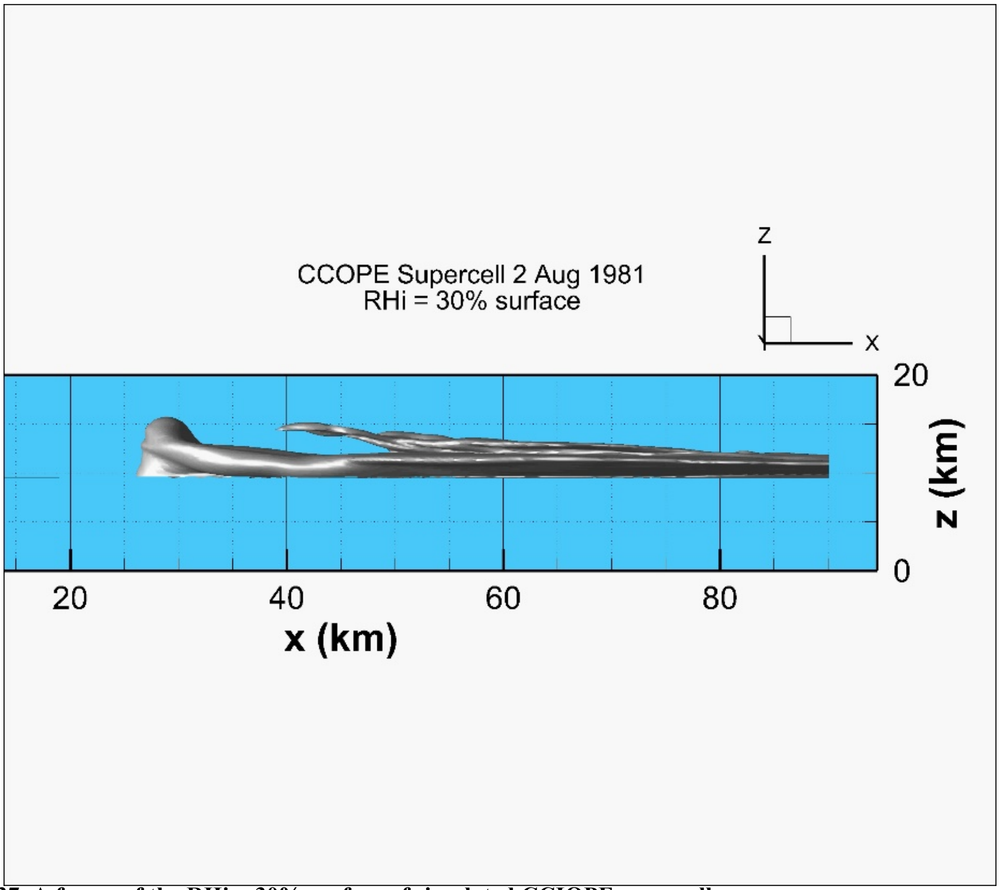


**Figure 37. A frame of the RHi = 30% surface of simulated CCIOPE supercell.**

The jumping cirrus in Figure 37 occurs at certain distance downstream of the overshooting top in the left and form an angle with the anvil. The front of the jumping cirrus points slightly upward, in complete agreement with the photo in Figure 36 and the description by Fujita (1974). It indicates that, although the simulated storm is that of CCOPE supercell occurred in US High Plains, it is the same type as the one shown in Figure 36 as they both have strong wind shear at eh storm top. Hence the internal gravity wave breaking phenomenon which is responsible for the occurrence of the jumping cirrus as explained by Wang (2003, 2004) should produce similar features in both storms.

The success of the model results show that model can indeed produce features similar to that observed and the model physics can be used to explain the physical mechanism involved.

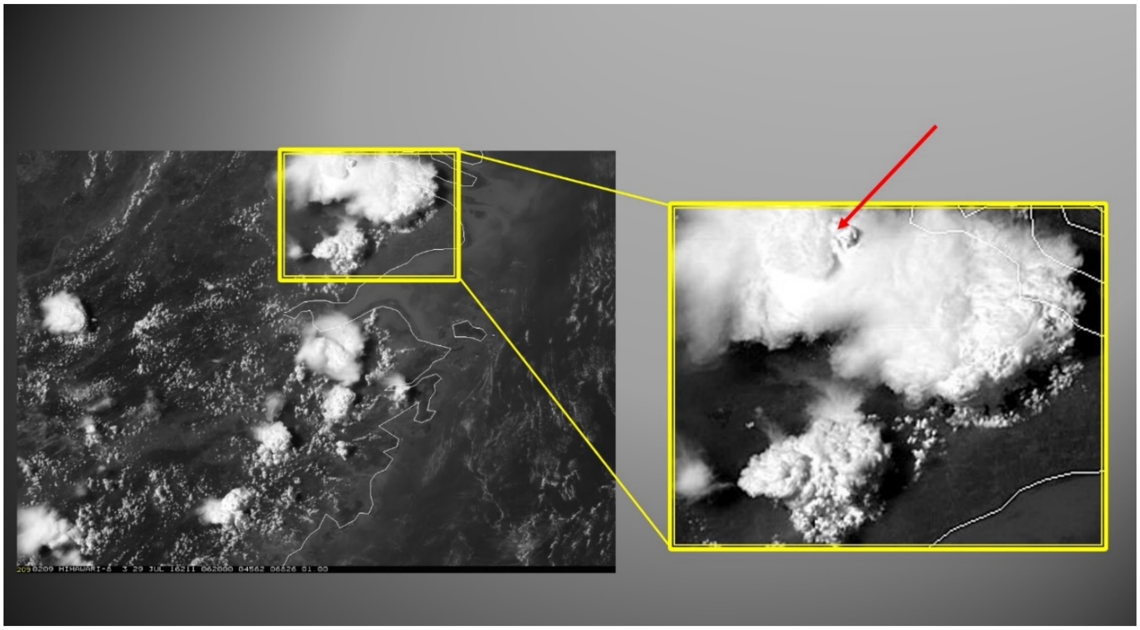

**Figure 38. The storm image of Himawari-8 taken roughly at the same time as the storm shown in Figure 36. The storm in the yellow box (left) and its enlarged image (right) shows the presence of the AACP which corresponds to the jumping cirrus shown in Figure 36. Thus a jumping cirrus can appear as an AACP in a satellite image.**

Figure 38 shows the Himawari-8 image of the particular storm shown in Figure 36. The red arrow points to the AACP that corresponds to the jumping cirrus in Figure 36. Viewed from above, the AACP is seen as a wide and roughly triangular plume which casts a clear shadow on the anvil. Figure 36 and Figure 38 were not occurring exactly at the same time, yet there is no doubt that the AACP indeed is the satellite view of the jumping cirrus in Figure 36. This near-simultaneous observation of aircraft and satellite verifies that the internal wave breaking as proposed by Wang (2003, 2004) is indeed the physical cause of the satellite observed AACP phenomenon.

We are currently summarizing this finding as an article which will be submitted to a scientific journal in the near future.

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Wang, P. K. 2004: A cloud model interpretation of jumping cirrus above storm top, Geophys. Res. Lett., 31, L18106, doi:10.1029/2004GL020787

## Publications and Conference Reports

Wang, P. K. and K. Y. Cheng, 2016: Manifestation of Obstacle-like Effect of Severe Thunderstorms in Satellite Storm Images, AMS Satellite Meteorology Conference, Paper 14.6, August 19, 2016, Madison, Wisconsin.

Wang, P. K., K. Y. Cheng, and S. Bachmeier, 2017: Clear Air Turbulence Caused by Storm Top Internal Gravity Wave Breaking Based on Satellite Data, 8th Conference on Aviation, Range, and Aerospace Meteorology, American Meteorological Society, Seattle, January 25, 2017. Paper 10.2.

## 5.5 Development of the GOES-R Tropical Overshooting Top (TOT) Products
**CIMSS Task Leaders: Chris Velden and Sarah Griffin**
**NOAA Collaborator: Mark DeMaria (NHC)**
**Budget: $61,000**

### NOAA Long Term Goals:
- Weather-Ready Nation

### NOAA Strategic Goals:
- 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

### Objective
Develop a Geo-satellite-based algorithm to identify vigorous active convection in tropical regions and apply this as a tool to analyze tropical cyclone activity.

### Project Overview
The GOES-R Tropical Overshooting Top (TOT, Monette et al., 2012) product is derived from an algorithm designed to identify active convective updrafts and overshooting tops in tropical environments. The TOT algorithm is a derivative of the GOES-R Overshooting Top (OT) product, and utilizes the 10.9-µm infrared window to identify isolated cloudy pixels (or tight pixel clusters) that are significantly colder than their surroundings. The specific application of the TOT product in this project is with respect to tropical cyclone (TC) analysis and potential forecasting uses. TOTs have been a part of the National Hurricane Center (NHC) Proving Ground product list since 2011.

The TOT product has also been used extensively as a real-time hazard avoidance tool for the Global Hawk (GH) pilotless aircraft flown during NASA's Hurricane and Severe Storm Sentinel (HS3) and NOAA's SHOUT field experiments for the past 4 Atlantic hurricane seasons. Feedback from these field programs was positive with regards to GH flight mission support.

## Milestones with Summary of Accomplishments and Findings

1. TOTs were used to diagnose the relationship between Atlantic TC convection, intensity and various environmental factors. TC cases were first partitioned into 4 different categories based on the maximum sustained surface winds $v$: tropical depression (TD; $v < 34$ kt), tropical storm (TS; $34 \leq v < 64$ kt), hurricane (HU; $64 \leq v < 96$ kt), and major hurricane (mHU; $v \geq 96$ kt). For this simple stratification of Atlantic TC cases, it was found perhaps unsurprisingly that within 50km of the TC center, TOTs are more common in the HUs and mHU categories. Between 200-500 km of the TC center, TD and mHU strength TCs experience the most TOTs. With respect to environmental parameters, it was found that TOTs within 300 km of a TC center increase exponentially with increasing sea surface temperatures (SSTs) and decrease with increasing vertical wind shear. TCs experiencing weak vertical wind shear (< 5 m $s^{-1}$) have the highest TOTs $scan^{-1}$, with the number of TOTs $scan^{-1}$ decreasing as vertical wind shear increases to moderate (5-10 m $s^{-1}$) and strong (> 10 m $s^{-1}$). Vertical wind shear also affects the azimuthal distribution of TC convection. Figure 39 shows the distribution of TC convection using an icosagon. Icosagons are created by transforming TOT locations from geographical coordinates into a framework of TOT population and azimuthal angle from the TC center. TOTs are summed into 20 azimuthal bins (18° spacing) with respect to the azimuthal angle from the direction of the shear and by the average number of TOTs per satellite scan for each shear magnitude category. The point of each vertex is plotted at a radius representing the number of TOTs $scan^{-1}$ observed in each azimuthal bin, and these are then connected. The shape of the icosagon shows the preferred azimuthal location of TOTs with respect to the shear direction. For all vertical wind shear categories, TOTs are more predominant downshear. However, the percent of TOTs that are downshear increases from 57.1% to 74.2% for weak shear and strong shear, respectively.

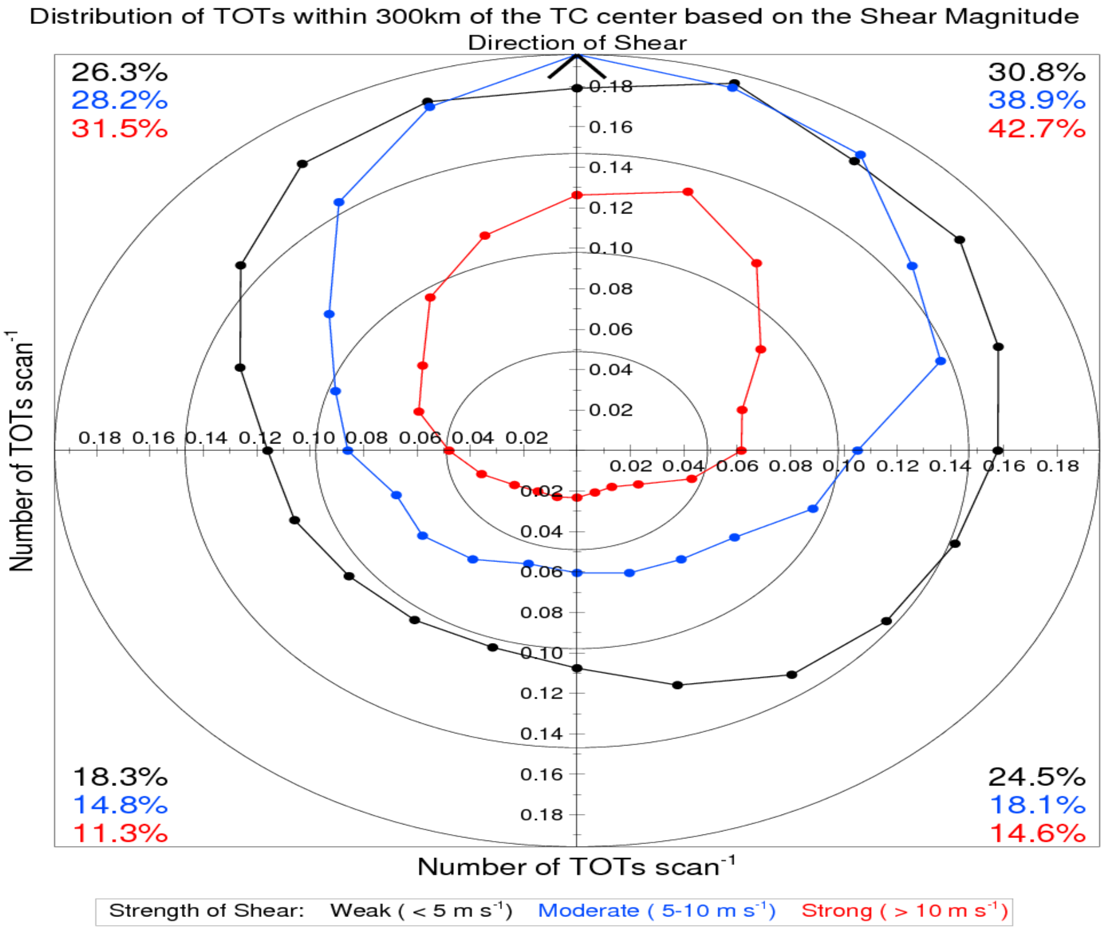


**Figure 39. Icosagon indicating the azimuthal distribution of TOTs within 300 km of the TC center with respect to the direction of the vertical wind shear. The plotted percentages in color represent the percent of TOTs in each given quadrant based on the shear category indicated in the legend. Range rings for each quartile between 0 and the maximum number of TOTs scan$^{-1}$ are plotted for reference.**

2. TOTs can be used in comparisons with lightning-based studies of TC convection. For example, in an analysis of Atlantic TCs from 2006-2014, Stevenson et al. 2016 found a decrease in lightning for TCs with a SST above 30°C. This result was questioned, however, possibly due to a relatively low sample size. An analysis of TOTs from the same Atlantic TC cases from 2006-2014 also indicates a decrease in TC convection with SSTs above 30°C, corroborating the results from Stevenson et al. 2016. However, by adding 3 more (active) TC seasons from 2004-2015, the TOT trend flips sign and indicates an increase in TC convection for SSTs above 30°C, suggesting the results from Stevenson et al. 2016 are likely due to the small sample size.

   For rapidly intensifying (RI) Atlantic TCs, defined as a past 24-h intensity (max sustained surface winds) change greater than or equal to 30 kts, TOTs corroborate the lightning distributions observed in Hurricanes Earl (2010) and Edouard (2014) as reported by Stevenson et al. 2014 and Zawislak et al. 2016. The distribution of TOTs from the Atlantic RI TC sample from 2004-2015 is shown in Figure 40. Each range ring represents 50 km from the TC center, with each box indicating the number of TOTs within an area of approximately 12 km$^2$. TCs are divided into left and right quadrants, with quadrants in (opposite) the direction of the shear vector considered downshear (upshear). TOTs within

100 km of the TC center have a preference for the downshear left quadrant, which supports the lightning observed in Hurricane Edouard (Zawislak et al., 2016). The resulting preference for the downshear right quadrant for TOTs within 100-300 km of the TC center supports the lightning distribution observed in Hurricane Earl (Stevenson et al., 2014).

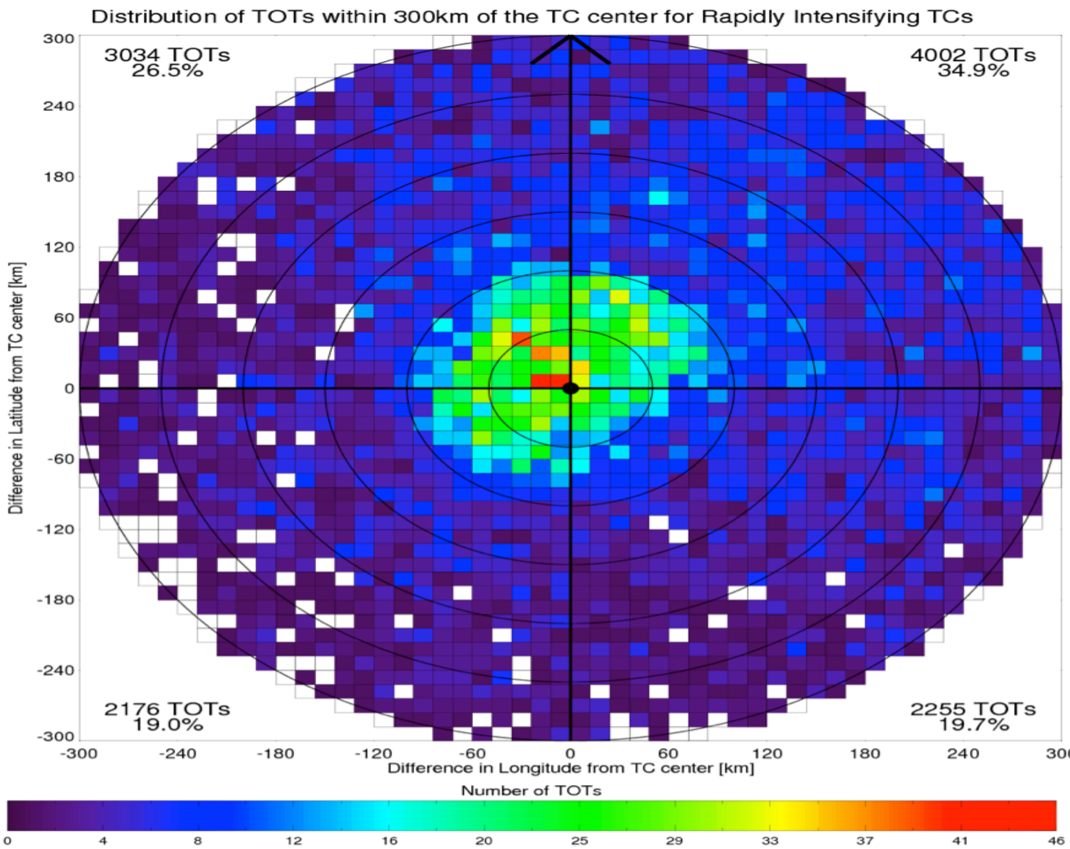


**Figure 40. Distribution of TOTs within 300 km of the TC center with respect to the direction of the vertical wind shear for rapidly intensifying Atlantic TCs from 2004-2015. Each range ring represents 50 km, with each box indicating the number of TOTs within an area of approximately 12 km$^2$ for all rapid intensification cases.**

## Publications and Conference Reports

Griffin, S. M., 2017: Climatology of Tropical Overshooting Tops in North Atlantic Tropical Cyclones, *Provisionally Accepted in J. Appl. Meteor. Climatol.*

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## 5.6 GOES-R VSP: Implementing ProbSevere at CICS-MD
**CIMSS Task Leader: John Cintineo**
**CIMSS Support Scientist: Justin Sieglaff**
**NOAA Collaborators: Michael Pavolonis, Scott Rudlosky**
**Budget: $3,000**

### NOAA Long Term Goals:
- Weather-Ready Nation

### NOAA Strategic Goals:
- 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

### Objective
The NOAA/CIMSS ProbSevere model helps NWS forecasters skillfully increase lead-time to severe convective hazards. ProbSevere was installed and users trained at CICS-MD.

### Project Overview
The NOAA/CIMSS ProbSevere model has been developed as a nowcasting probabilistic guidance tool for forecasters to better predict severe convective storm hazards. ProbSevere utilizes a satellite and radar object-based framework to fuse together NWP environmental information, temporal trends in GOES-derived imagery, Multi-Radar Multi-Sensor (MRMS) products, and Earth Networks Total Lightning Network (ENTLN) data as inputs into a statistical model that calculates the probability of any given storm will produce severe weather in the next 90 minutes.

### Milestones with Summary of Accomplishments and Findings
- The NOAA/CIMSS ProbSevere system was installed on a server at CICS-MD. It was able to run on archived cases of severe weather over maritime regions. Several users at CICS-MD were trained to operate ProbSevere in an offline mode, in order to collect satellite growth rate data (or any number of satellite/lightning predictors) for OCONUS storms. These data are important for generating a training dataset, and this joint effort will eventually lead to a probabilistic product in areas with no radar coverage.
- Lightning experts at CICS-MD also trained CIMSS participants on strengths, weaknesses, and differences between terrestrial lighting networks, since total lightning data will be essential to any offshore or OCONUS statistical model.
- After the visit to CICS-MD, in response to several requests through the summer of 2016, CIMSS provided CICS-MD with additional L1 GOES-East files (area files) for cases that CICS-MD processed through their ProbSevere system, to evaluate their training dataset suitability, and add to a new training dataset for offshore storms.

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## 6. CIMSS GOES-R Risk Reduction Program 2016-2017

### 6.1 Development and Optimization of Mesoscale Atmospheric Motion Vectors (AMVs) using Novel GOES-R Processing Algorithms on 1-5 min. SRSO Proxy Data, and Demonstration of Readiness for GOES-R Applications via Impact Studies in Mesoscale Data Assimilation and NWP Systems

**CIMSS Task Leader: Chris Velden**
**CIMSS Support Scientist: Dave Stettner**
**NOAA Collaborators: Jaime Daniels (STAR), Steve Weygandt (ESRL)**
**Budget: $75,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- 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
- Environmental Models and Data Assimilation

### Objective

Optimize the GOES-R Derived Motion Vector algorithm for processing of mesoscale datasets and applications to short-term forecasts and NWP.

### Project Overview

One of the principle benefits expected from GOES-R is the improvement in temporal sampling of images from the ABI. In addition to qualitative uses by forecasters, the rapid refresh (1-5 min.) should allow for quantitative improvements in derived products normally associated with geostationary satellite imagery. One of those products is atmospheric motion vectors, or AMVs. Derived by tracking coherent cloud motions in successive VIS/IR images, AMVs have long stood as an important contributor of tropospheric wind information to analyses on the global scale. GOES-R will allow superior cloud-tracking and AMV generation on time scales not only useful for global applications, but for mesoscale applications as well.

The reasons we are optimistic that GOES-R AMVs can be an important contributor to mesoscale analyses derive from recent and ongoing studies. This work builds on these pioneering efforts as we also take advantage of GOES-R capabilities and new AMV derivation methods. Our objective is to apply these to the production of mesoscale AMV datasets to extract wind information that benefits short-term forecasts and NWP.

**Milestones with Summary of Accomplishments and Findings**

- Forecast impact experiments with the RAP/HRRR models for the two identified severe weather cases (a flooding event in Texas, and an EF-3 tornado event in Colorado, both in May – June 2015) were conducted with assimilation of the heritage mesoscale AMVs (Benchmark dataset). The Benchmark AMVs have been successfully assimilated within the 13-km RAP, and a control run (without the assimilation) has been conducted. Selected results from the RAP analyses were shown in the last report: the Benchmark AMVs generally show minor initial analysis impacts. The next step will be to run the HRRR model forecast experiments using the RAP again, only this time with AMVs provided by the new GOES-R processing algorithm to see if the forecasts result in better convective evolution.
- The GOES-R AMV algorithm settings, tuning, and QC procedures for mesoscale processing have been improved to increase the data density and quality. This process involved empirical testing and statistical validation of the AMVs. The AMVs for the two cases described above were reprocessed with the upgraded GOES-R algorithm, and those datasets were delivered to ESRL for further testing in the final year of the project.

## 6.2 Applications of Concurrent Super Rapid Sampling from GOES-14 SRSOR, Radar and Lightning Data

**CIMSS Task Leader: Mathew Gunshor**
**CIMSS Support Scientist: Joleen Feltz**
**NOAA Collaborators: Timothy J. Schmit (ASPB), Robert Rabin (NSSL)**
**Budget: $27,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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

## Objective

Find novel ways of making use of 1-minute GOES imagery and combine it with radar and lightning data.

## Project Overview

The GOES-14 satellite was operated in Super Rapid Scan Operation for GOES-R (SRSOR) mode on several days during 2012, 2013, 2014, 2015, and 2016 for the purpose of demonstrating the value of high temporal observations (1-minute intervals) from GOES which will become available regularly with GOES-R. Researchers see potential in simultaneous high temporal observations (1-minute intervals) from radar, satellite and lightning sensors. The goal of the proposed project is to make use of the currently available GOES-14 Super Rapid Scan data in order to assess and further enhance the utility of the high temporal sampling to be available on GOES-R.

This project is being pursued in collaboration with colleagues at NOAA's National Severe Storms Laboratory (NSSL) and the Cooperative Institute for Research in the Atmosphere (CIRA). The contribution by CIMSS/SSEC primarily involves visualization of multiple data sets combined in McIDAS-X or McIDAS-V as well as providing all of the SRSOR data to CLASS that they request for their own archive.

During this reporting year, GOES-14 was in SRSOR mode April 18-May 15, 2016 and August 9-August 29, 2016. All the GOES-14 SRSOR GVAR data to date have been saved at the SSEC Data Centerl. Any gaps in NOAA's Comprehensive Large Array-data Stewardship System (CLASS) data archive for GOES-14 SRSOR data can be filled by the SSEC Data Center, as happened in 2013 and 2014.

## Milestones with Summary of Accomplishments and Findings

FY16 Milestones and accomplishments met working with NSSL and CIRA:

- Continue analysis of additional cases of interest to NWS forecasters.
    - Work continued to provide interactive displays with parallax corrected GOES14 images and overlays of lightning, radar and satellite derived wind data, http://www.nssl.noaa.gov/users/rabin/public_html/09may16/.
    - Efforts began at CIMSS to implement the upgraded parallax correction for testing.
- Continue dissemination of parallax corrected GOES14 imagery and AMVs in realtime during SRSOR (August 2016) to NWS forecast offices for evaluation and possible archiving.
    - Satellite based winds (Atmospheric Motion Vectors, AMVs) were generated at 10minute intervals in realtime during the GOES14 SRSOR operations in August. These mesoscale winds were computed using the Legacy CIMSS winds algorithm in collaboration with Chris Velden and the winds team at University of Wisconsin-Madison.
    - The output was available on an interactive web page which allows the user to selectively overlay winds from 5 different layers: http://www.ssec.wisc.edu/~rabin/winds/srsor/layers_loop.html
    - Operational software from NESDIS was modified to convert AMVs to BUFR format for display of realtime winds in AWIPS2 workstations.
    - An objective analysis of horizontal divergence, vorticity, and wind speed were produced at 10minute intervals in realtime using the AMVs and background GFS wind field. The analysis is run in McIDAS-X using the recursive filter approach

of Hayden and Purser (1995). These analyses were made available in realtime on the web: http://www.ssec.wisc.edu/~rabin/winds/srsor/
  - In addition, these data were converted to GRIB2 files for realtime display in AWIPS2 workstations.

In addition to these milestones, the SSEC GOES-14 SRSOR website was updated with the new 2016 data here: http://cimss.ssec.wisc.edu/goes/srsor2016/GOES-14_SRSOR.html

SRSOR cases from April, May, and August of 2016 include phenomena such as severe thunderstorms, gravity waves, dust, fires, lake effect snow, turbulence, and fog. The website includes links to animations, images, and blog posts from the CIMSS Satellite Blog, SPC, the Hazardous Weather Testbed, Storm Prediction Center discussions, and more.

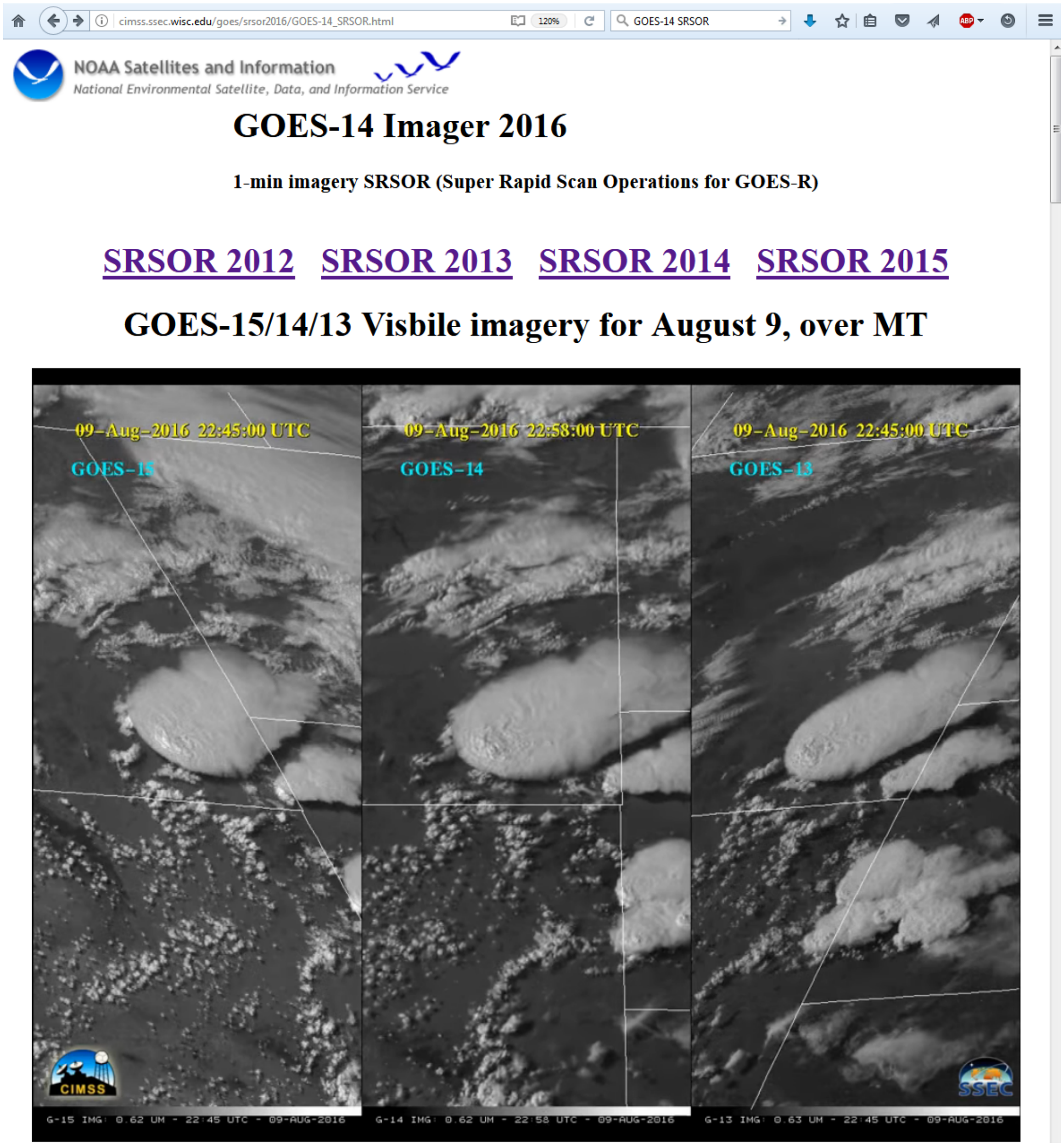


**Figure 41. The GOES-14 SRSOR 2016 Web Page at CIMSS. The embedded YouTube video shown compares operational GOES-15 and -13 data to 1-minute GOES-14.**

## 6.3 Development of Real Time All-weather Layer Precipitable Water Products in AWIPS II by Fusing the GOES-R and NWP for Local Forecasters

**CIMSS Task Leader: Jun Li**
**CIMSS Support Scientists: Jordan Gerth, Zhenglong Li, and Scott Bachmeier**
**NOAA Collaborators: William Line, SPC/HWT - GOES-R Satellite Liaison; Jeff Craven (now John Gagan), NWS Forecast Office, Milwaukee/Sullivan, WI; Tim Schmit, NOAA/NESDIS/STAR**
**Budget: $100,000**

**NOAA Long Term Goals:**
- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

## Objective

The objective is to develop the GOES/GOES-R series near real-time all-weather layered precipitable water (LPW) products in AWIPS II by fusing the GOES-R and NWP for local forecasters.

## Project Overview

Observations of moisture transportation in pre-convection environment and during storm development are very useful for forecasters. NOAA's new generation of Geostationary Operational Environmental Satellite (GOES-R) series provides high temporal (every 5 minutes) and spatial (2 km) resolution moisture information not seen before. Since there will be no sounder onboard the GOES-R series, the GOES-R ABI will be used to continue the current GOES Sounder legacy atmospheric profile (LAP) products. However, the current operational GOES Sounder and the next GOES-R LAP products are only available in clear skies. Extending the use of IR measurements into cloudy regions would increase the completeness of moisture information. In typical scenes, completely clear-sky observations from the infrared (IR) observations are available for only 10 – 50% of the image, depending on the spatial resolution. Studies show that cloudy regions are responsible for the development of error in NWP forecasts (McNally 2002) and exhibit more forecast error than clear skies. Building on the GOES-R LAP algorithm, CIMSS scientists and NOAA collaborators propose to develop all-weather real time layered precipitable water (LPW) analyses and implement them into the Advanced Weather Interactive Processing System (AWIPS-II) to allow operational meteorologists to monitor a controlling ingredient in the initiation, development, and decay of convective cells and systems. The unique LPW products have the advantages of availability in all sky and weather conditions. Three layered PW products with flexible spatial (2 – 10 km) and temporal (5 minutes – 1 hour) resolution will be developed, which will supplement the operational GOES-R LAP products for applications.

## Summary of Accomplishments and Findings

### *All-sky GOES-R series TWP and LPW algorithms applied successfully to process GOES-14 Sounder*

When GOES-13 Sounder failed, only TPW and LPW from GOES-15 Sounder are available. During 2016 HWT spring experiments, GOES-14 Sounder was turned on, in order to make more LAP coverage for 2016 HWT spring experiment, CIMSS scientists have applied all-sky TPW and LPW algorithms to process GOES-14 Sounder at CIMSS GEOCAT frame. Both GOES-14 and GOES-15 Sounder all-sky TPW/LPW products were produced at CIMSS, converted to GRIB2 format, put into AWIPS-II in near real time for 2016 HWT spring experiments.

### *CIMSS all-sky TPW and LPW products used in 2016 HWT spring experiments*

GOES Sounder all-sky LAP products are generated at CIMSS in near real-time using GOES-R series AWG LAP and GOES-R3 algorithms and are demonstrated in 2016 Hazardous Weather Testbed (HWT) which is a joint project of the National Weather Service (NWS) and the National Severe Storms Laboratory (NSSL). Overall, the weather forecasters used GOES LAP products in a positive way. Compared with 2015 HWT, the forecasters have increased interesting on the all-sky layered precipitable water (LPW). Figure 42 shows layered PW (LPW) from 900 hPa – SFC at 22:00 UTC on 20 April 2016 during the HWT.

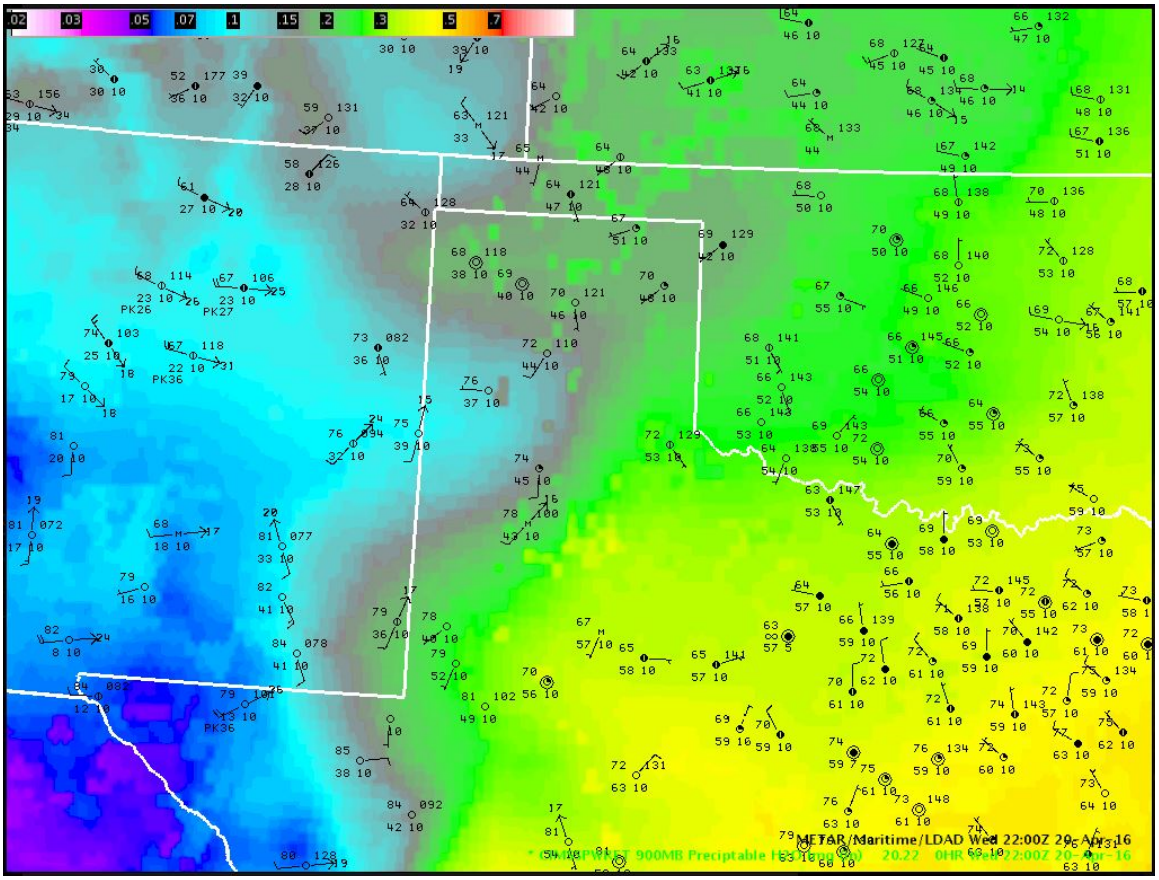


**Figure 42. GOES-15 Sounder LPW from 900 hPa – SFC (with GOES-R3 algorithms) at 22:00 UTC on 20 April 2016 during HWT.**

Requirement is raised on the need of LPW with finer vertical resolution and making all-sky LPW as a GOES-R series baseline product.

### *Algorithms are being refined on cloudy TPW/LPW retrieval by improving the cloudy radiative transfer model (RTM)*

The radiative transfer model (RTM) in cloudy skies is very important for all-sky TPW/LPW retrieval. Improving the cloudy RTM can have better training for regression retrieval under cloudy skies. However, the lack of a clear definition for a cloud top height (CTH) derived from infrared (IR) measurements has posed a substantial challenge in its characterization, interpretation, and understanding. A new definition of infrared (IR) cloud top: the height where a one-level artificial cloud with same optical thickness would have the same radiative property producing the same IR radiances. With this definition, theoretical analysis and simulations are carried out to identify IR cloud top as a function of total cloud optical thickness (COT at 0.55 μm). A one-on-one relationship (a look-up-table (LUT)) between the IR cloud top and the total COT is generated, which can be applied to both high and low clouds independent of the temperature lapse rate within the cloud, including low clouds within temperature inversions frequently seen in polar regions. For thick clouds (COT greater than 6), the IR cloud top resides around the COT of 1; for other clouds, the IR cloud top is higher than the center of the cloud. The local zenith angle has a significant impact on the IR cloud top since increased absorption at larger angles lifts it up; an angle correction procedure is provided. A manuscript on this topic is submitted to Geophysical Research Letters for publishing. This study leads to an improved RTM in cloudy skies by better definition of cloud-top height. Applying this new definition for all-weather TPW/LPW retrieval is ongoing.

### *CIMSS all-sky ABI TPW/LPW algorithms applied to process Himawari-8 AHI in near real-time (NRT)*

By applying ABI all-weather TPW/LPW algorithms to process AHI that has the similar IR spectral bands of ABI, the AHI all-sky LAP products are generated at CIMSS in near real-time. The AHI products are converted to GRIB2 format and have been available in AWIPS-II in near real-time since February 2016 for local forecasters in Pacific region. Now both GOES-15 Sounder and AHI all-weather TPW/LPW are generated in near real-time at CIMSS are available in AWIPS-II. Figure 43 shows one example of AHI all-sky TPW image from AWIPS-II, showing atmospheric rivers. The advantage of using AHI for atmospheric revivers is its high temporal resolution, allowing continuous monitoring the evolution of the rivers. Figure 43 shows the AHI all-sky TWP image at 14:00 UTC on 11 February 2016 from AWIPS-II showing atmospheric rivers. The TPW is derived with GOES-R all-sky TPW/LPW retrieval algorithms.

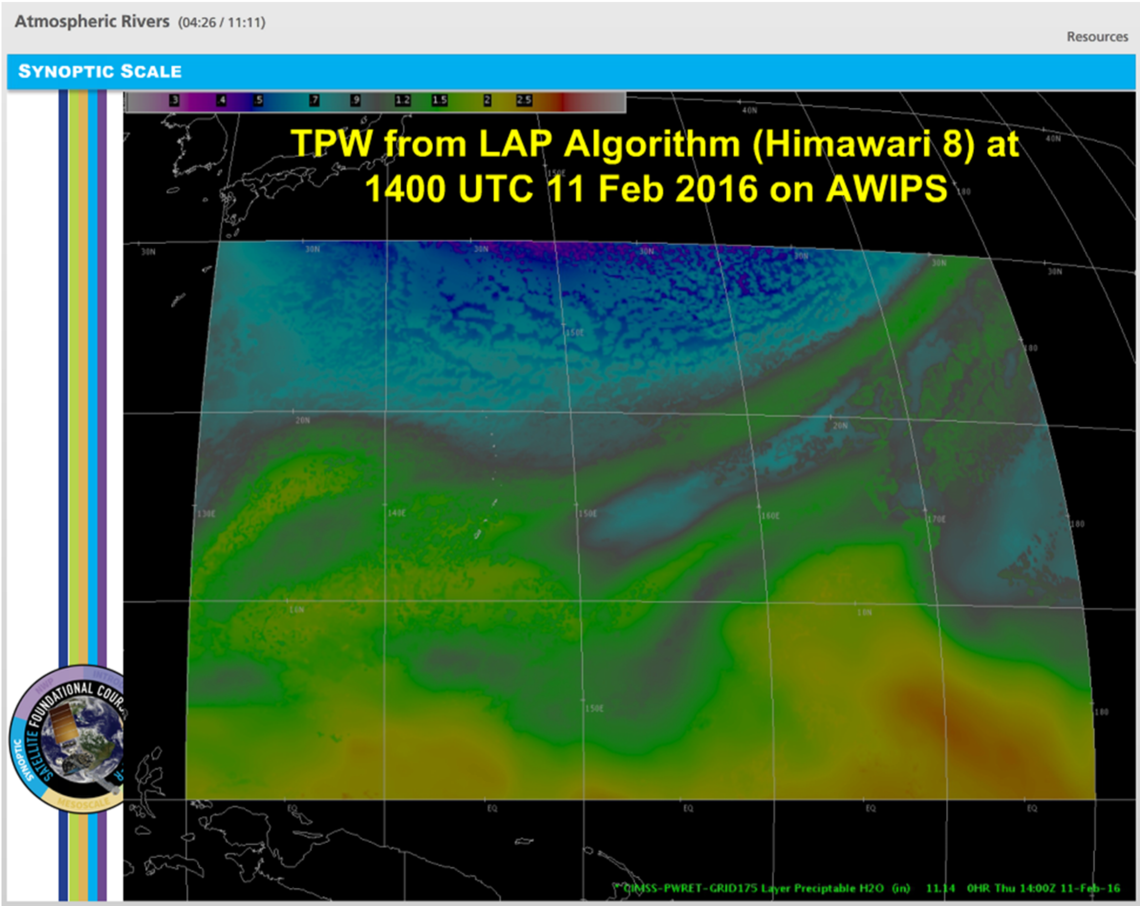


**Figure 43. AHI all-sky TPW image at 14:00 UTC on 11 February 2016 from AWIPS-II showing atmospheric rivers.**

## Publications and Conference Reports

Li, Zhenglong, W. Paul Menzel, Jun Li, Timothy J. Schmit, 2017: What is an infrared cloud top height? Geophysical Research Letters (submitted).

Ai, Y., J. Li, T. Schmit, 2017: Deep Convective Cloud Characterizations from both Broadband Imager and Hyperspectral Infrared Sounder Measurements, Journal of Geophysical Research – Atmospheres, 10.1002/2016JD025408.

Li, Jun, Jordan Gerth, Yong-Keun Lee, Zhenglong Li, Pei Wang, Scott Bachmeier and Timothy J. Schmit, 2016: Near real-time high resolution all-weather atmospheric water vapor products from new generation of geostationary satellite measurements and their applications in weather forecasts, 7th Asia-Oceania/2nd AMS-Asia/2nd KMA Meteorological Satellite Users' Conference, 21 – 28 October 2016, Songdo, Incheon, Korea.

Li, J., J. Gerth, Y. Lee, Z. Li, T. Schmit, P. Wang, and S. Bachmeier, 2017: Near Real-Time High Resolution All-Weather Atmospheric Total Precipitable Water and Layered Precipitable Water Products from GOES-R ABI and Their Applications in Weather Forecasts, 97th AMS annual meeting, Seattle, WA, 22-26 January, 2017.

## 6.4 Development of a Near Real-time Satellite Verification and Forecaster Guidance System for the High-Resolution Rapid Refresh (HRRR) Model

**CIMSS Task Leaders: Jason Otkin and Justin Sieglaff**
**CIMSS Support Scientists: Sarah Griffin, Chris Rozoff, and Lee Cronce**
**NOAA Collaborators: Steve Weiss, Steve Weygandt, David Bright, and Bruce Entwistle**
**Budget: $111,552**

### NOAA Long Term Goals:
- Weather-Ready Nation

### NOAA Strategic Goals:
- Serve society's needs for weather and water

### CIMSS Research Themes:
- Satellite Meteorology Research and Applications
- Environmental Models and Data Assimilation

### Objective
The primary objectives of this project are to develop a satellite-based forecast verification system for the High-Resolution Rapid Refresh (HRRR) model that will provide operational forecasters objective tools to quickly determine the accuracy of the many overlapping HRRR forecast cycles at the current time and to use the simulated brightness temperatures to thoroughly assess the long-term accuracy of the forecast cloud and water vapor fields.

### Project Overview
For this project, we will develop a near real-time satellite-based forecast verification system for the HRRR model. Synthetic GOES infrared brightness temperatures will be generated for each HRRR model forecast cycle using the Community Radiative Transfer Model (CRTM), and will then be compared to real GOES observations using multiple techniques, including traditional grid point statistics, neighborhood verification methods, brightness temperature differences, and probability distributions. These methods will be used to examine the accuracy of the simulated cloud and water vapor fields at each model forecast time. Because forecast skill often varies with space and time, the statistics will be computed for pre-defined regions covering the contiguous U.S. in a manner similar to that used on the Storm Prediction Center (SPC) mesoscale analysis webpage. New verification metrics will also be developed to combine information from the various statistical methods to produce an overall accuracy "score" and ranking for each forecast cycle. A web-based interface will be developed that will allow forecasters to click on a specific geographic region, and then choose which forecast cycles to examine more closely based on the automated rankings. Simulated brightness temperatures accumulated over long time periods will then be used to assess the overall accuracy of the forecast cloud and water vapor fields.

### Milestones with Summary of Accomplishments and Findings

#### *Evaluate the utility of the forecast analysis system and verification webpage*
The real-time forecast verification system (http://cimss.ssec.wisc.edu/hrrrval/) was demonstrated at the 2016 Aviation Weather Testbed Summer Experiment in Kansas City, MO. Feedback from participants, including operational aviation weather forecasters and researchers, was generally positive. For example, the forecasters found the side-by-side animations of the observed and

simulated GOES satellite imagery to be very valuable as a forecasting aid because these images could be used to identify potential areas of turbulence due to convection or mountain waves.

### *Expanded real-time verification system to include output from the operational HRRR model*

We expanded our real-time verification system to use output from the operational HRRR model in addition to the experimental HRRR model. This expansion occurred in August 2016 after the most recent upgrade of the operational HRRR model. Inclusion of the operational HRRR model allows us to have a satellite-based verification system that has near 100% reliability.

### *Completed a visiting scientist project that explored object-based verification*

We completed a visiting scientist project funded by the Developmental Testbed Center (DTC) that supported our ongoing efforts to use object-based verification tools provided by the Method for Object-based Diagnostic Evaluation (MODE) system to assess the accuracy of the HRRR model. This project used simulated and observed GOES 10.7 μm brightness temperatures from August 2015 and January 2016 to assess the accuracy of forecast cloud objects in the upper troposphere during warm and cool seasons given potential differences in cloud characteristics. The edges of the cloud objects were identified based on the $10^{th}$ percentile of the brightness temperature distributions accumulated over the previous 10-day period. Figure 44 shows the number of observed and forecast cloud objects plotted as a function of time of day for each month. Overall, there are more cloud objects in August than in January, which means that the median cloud object size is smaller during August. The diurnal cycle in the number of cloud objects is also more prominent in August compared to January. Both of these characteristics are consistent with the more predominant small-scale convective cloud features found during the summer compared to the larger synoptic-scale cloud systems more frequently observed during the winter. Also, although the general shape of the diurnal cycle is accurately captured during each month, there are usually not enough forecast objects, with the only exception occurring near 00 UTC during August when there are too many.

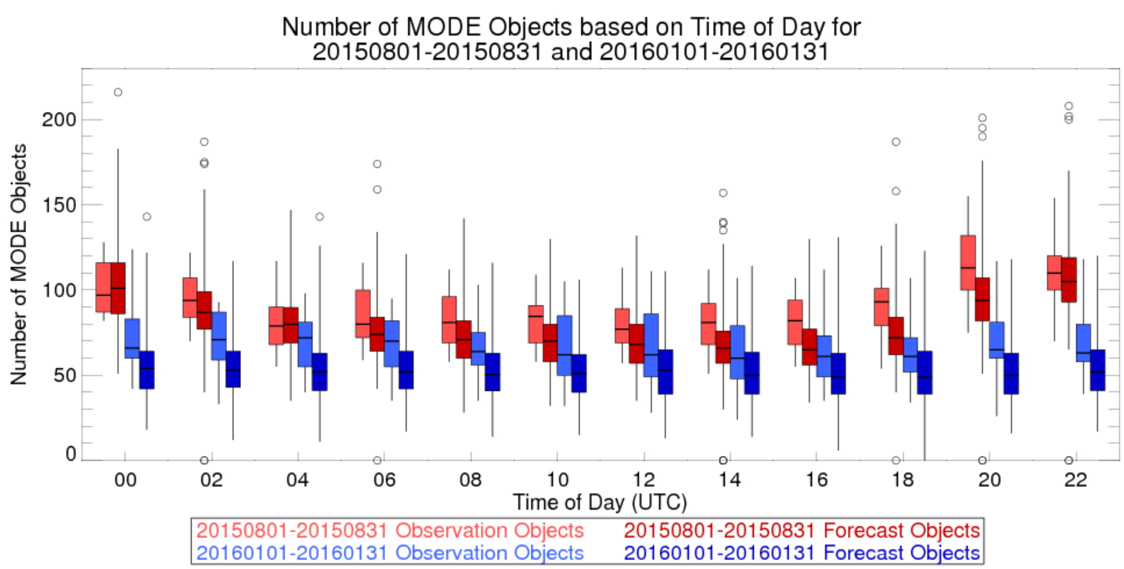


**Figure 44. Box plot diagram depicting the range of the number of observed (lighter colors) and forecast (darker colors) cloud objects identified by MODE during August 2015 (red) and January 2016 (blue) plotted as a function of time of day. Data from all forecast cycles and hours were used to produce the box plot diagram.**

### *Comparison of HRRR forecast accuracy during warm and cool seasons*

We used MODE object-based verification to explore why the HRRR forecasts from August were more accurate than those from January. To do this, we compared the interest values for two object attributes, including the centroid distance (which is the distance between the centers of the forecast and observed cloud objects) and the area ratio (which is the ratio of the forecast and observed object sizes regardless of the amount of overlap). Interest values indicate how well the forecast object attribute matches that of the observed object. The attribute interest values were then placed into one of 50 bins based on the size of the observed cloud object, with the average interest value subsequently computed for each bin. Figure 45 shows the average attribute interest values between matched observed and forecast objects plotted as a function of the observed object size. There are a few things to note on this figure. First, the centroid distance interest values are greater in August compared to January for almost all observed object sizes, indicating that the spatial displacement between the "centers of mass" for the matched object pairs is smaller in August compared to January. In addition, while the area ratio attribute interest values for August and January are similar for most object sizes, the area ratio interest values for the largest cloud objects are greater for August. Therefore, the sizes of the largest HRRR forecast cloud objects were more accurately depicted during August than they were during January.

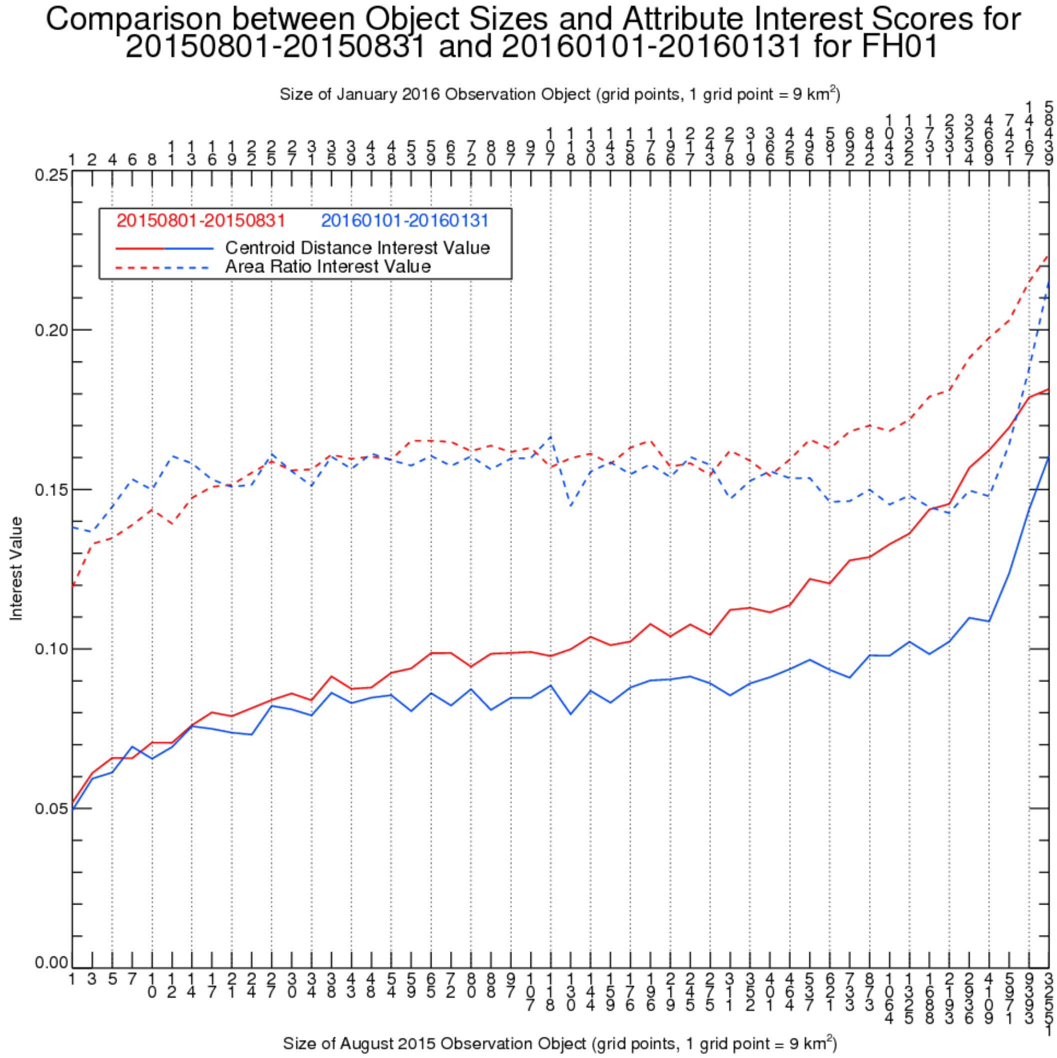


**Figure 45. Line plot depicting interest values for the centroid distance (solid) and area ratio (dashed) object attributes for August 2015 (red) and January 2016 (blue) plotted as a function of observed object size. The matched observed objects are separated into 50 bins, based on the observed object size, and the interest values and observed object sizes for each bin are averaged.**

### *Comparison of HRRR 0-h analysis and 1-h forecast accuracy*

An interesting result from the object-based verification study was that the cloud objects in the 1-h forecasts tended to be more accurate than those in the 0-h analyses. This behavior was explored in more detail using the MODE centroid distance and area ratio attribute interest values from the August 2015 object matches. Because the observed object sizes are the same for 0-h analysis and 1-h forecasts, the attribute interest values are computed as a function of the size of the observed object. However, the number of matches for a given observed cloud object may differ because the observed object may only have a matching forecast object in the 0-h analysis or the 1-h forecast, but not both. Thus, the difference in percent of occurrences for object attributes is calculated, which is defined as the difference in the ratio of the number of instances that objects of a particular size and attribute interest value combination are identified compared to the total number of instances an observed object size occurs in the matched pairs.

Diff. in Percent of Occurrences=Number(interest value, obs_size)0-h analysesTotal(obs_size)0-h analyses -

Number(interest value, obs_size)1-h forecastsTotal(obs_size)1-h forecasts

Figure 46 shows a "quilt plot" that depicts how the centroid distance interest values varied as a function of the observed object size. The observed object size increases upward along the y-axis, whereas the centroid distance interest value increases toward the right along the x-axis. Blue (red) colors indicate that a given interest value and object size combination occurs more frequently in the 1-h forecasts (0-h analyses). For small cloud objects, the interest values tend to be smaller in the 1-h forecasts, indicating that there are larger displacement errors for small cloud features, which is not surprising given their lower predictability. However, for larger cloud objects, more of them have larger interest values in the 1-h forecasts. Likewise, for the area ratio attribute (not shown), the largest cloud objects had higher interest values in the 1-h forecast compared to the 0-h analysis. In both cases, the larger interest scores for the largest cloud objects was the primary driver of the better 1-hr forecast accuracy.

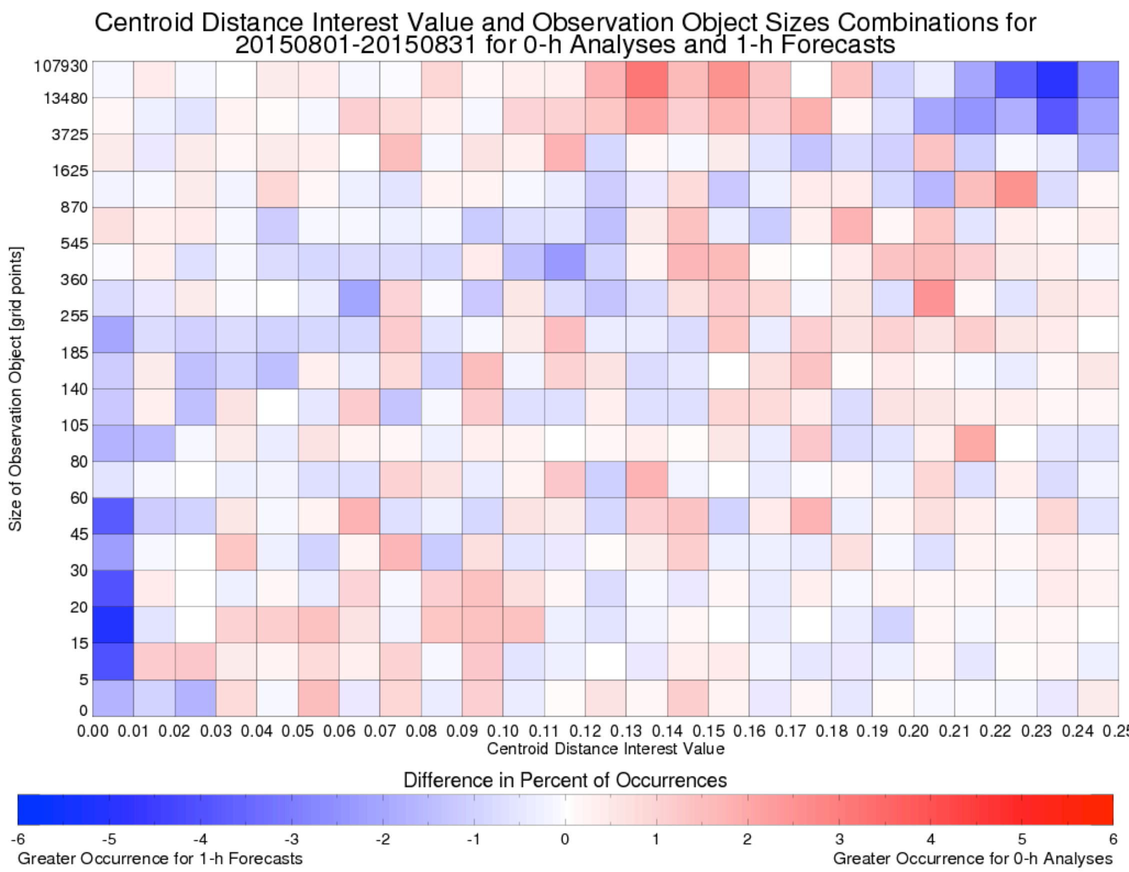


**Figure 46. "Quilt plot" showing the differences in percent of occurrences between the 0-h analysis and 1-h forecasts for August 2015 plotted as a function of observed object size along the y-axis and centroid distance interest value along the x-axis. Blue (red) colors indicate that a higher percent of occurrences of the observed object size and interest values occur more in the 1-h forecasts (0-h analyses).**

### *Development of the MODE Composite Score (MCS)*

We developed a new forecast verification metric referred to as the MODE Composite Score (MCS) that distills the huge amount of information provided by MODE for individual objects into a single value that expresses the overall forecast accuracy for all cloud objects. The MCS is an area-weighted calculation that combines the MODE total interest scores for all forecast-observed object matches. It has a range from 0 to 1 and is computed as follows:

MCS = i=1NCAreaObservation Cluster(i)Total Area*Interest Valuei + j=1NOAreaObservation Object(j)Total Area*Interest Value(j),

where $N_C$ is the number of object clusters and $N_O$ is the number of individual objects. If an object is determined by MODE to be part of a cluster, it will contribute to the first term in the equation, otherwise it is considered an individual object and will be included in the second term. Figure 47 shows the mean MCS plotted as a function of forecast hour for August and January, with the gray shading indicating the 95% confidence interval around the mean MCS. Overall, the 1-h forecast is the most accurate for both months, with discernable skill out to 2 hours and a steady decrease in skill thereafter as predictability decreases. Moreover, the 0-h analysis and 1-h forecasts were more accurate during August.

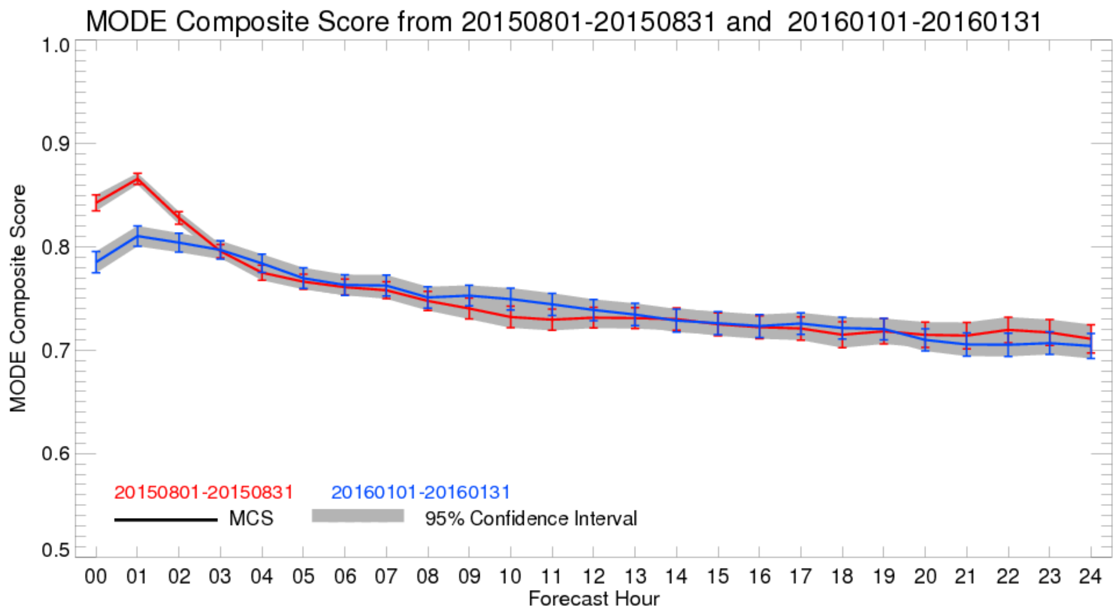


**Figure 47. MODE Composite Scores plotted as a function of forecast hour for August (red line) and January (blue line). Larger values indicate a more accurate forecast. Gray represents the 95% confidence interval.**

## Publications and Conference Reports

Griffin, S. M., J. A. Otkin, C. M. Rozoff, J. M. Sieglaff, L. M. Cronce, and C. Alexander, 2017: Methods for comparing simulated and observed satellite infrared brightness temperatures and what do they tell us? *Wea. Forecasting*, **32**, 5-25.

Griffin, S. M., J. A. Otkin, C. M. Rozoff, J. M. Sieglaff, L. M. Cronce, C. Alexander, T. L. Jensen, and J. K. Wolff, 2017: Seasonal analysis of cloud objects in the High Resolution Rapid Refresh (HRRR) model using object-based verification. Conditionally accepted for publication in *J. Appl. Meteor. Climatol*.

Otkin, J. A., S. Griffin, J. Sieglaff, C. Rozoff, L. Cronce, and C. Alexander, 2016: Development of a GOES-Based verification and forecaster guidance system for the High-Resolution Rapid Refresh Model. National Center for Atmospheric Research, Boulder, CO. (Invited talk)

Otkin, J. A., S. Griffin, J. Sieglaff, C. Rozoff, L. Cronce, and C. Alexander, 2016: Development of a GOES-Based verification and forecaster guidance system for the High-Resolution Rapid Refresh Model. NOAA Seminar Series, College Park, MD. (Invited talk)

Otkin, J. A., S. Griffin, J. Sieglaff, C. Rozoff, L. Cronce, R. Bullock, J. Halley-Gotway, T. Jensen, and J. Wolff, 2016: Using object-based verification with satellite infrared brightness temperatures to assess the accuracy of the HRRR model. *2nd Ensemble Design Workshop*, College Park, MD. (Invited presentation)

Otkin, J. A., S. Griffin, C. Rozoff, J. Sieglaff, and L. Cronce, 2016: Using geostationary satellite observations to assess the accuracy of short-range forecasts from the High-Resolution Rapid Refresh (HRRR) model. *2016 EUMETSAT Satellite Conference*, Darmstadt, Germany.

Griffin, S. M., J. A. Otkin, C. M. Rozoff, J. M. Sieglaff, L. M. Cronce, C. R. Alexander, R. Bullock, J. Halley-Gotway, T. Jensen, and J. Wolff, 2017: Object-based verification for the HRRR model using simulated and observed GOES infrared brightness temperatures. *24th Conference on Numerical Weather Prediction*. Seattle, WA.

## 6.5 Using Multi-sensor Observations for Volcanic Cloud Detection, Characterization, and Improved Dispersion Modeling

**CIMSS Task Leader: Justin Sieglaff**
**CIMSS Support Scientist: John Cintineo**
**NOAA Collaborator: Michael Pavolonis**
**Budget: $60,000**

### NOAA Long Term Goals:
- Weather-Ready Nation

### NOAA Strategic Goals:
- 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
- Environmental Models and Data Assimilation

### Objective
We will continue to develop an advanced volcanic ash detection and characterization system and ensure results of the system can be integrated into volcanic ash dispersion models.

### Project Overview
GOES-R will provide unprecedented capabilities to detect and track hazardous volcanic clouds. These capabilities, however, will only be fully realized using automated algorithms as the impressive GOES-R data volume makes volcanic eruption detection, solely using manual analysis of imagery, impossible. To ensure that the full spectral, spatial, and temporal capabilities of GOES-R are utilized for volcanic cloud monitoring, the Volcanic Cloud Analysis Toolkit

(VOLCAT) was developed. VOLCAT utilizes spectral, spatial, and temporal metrics provided by GOES-R to detect and characterize volcanic ash clouds (VOLCAT can actually be applied to nearly any geostationary or low earth orbit sensor). This project builds upon previous research by incorporating additional key data sources into VOLCAT, performing several case studies, and developing an application that utilizes VOLCAT to improve operational volcanic ash dispersion modeling. The project directly addresses NWS research priorities A (improved model forecasts) and B (improved situational awareness) and is a natural progression of a pre-existing line of (successful) research. This project also addresses several operational challenges associated with tracking and forecasting volcanic clouds, which are a well-known aviation hazard. NOAA operates two Volcanic Ash Advisory Centers (VAACs) and three Meteorological Watch Offices (MWO) with operational volcanic hazard monitoring and forecasting responsibilities. NOAA's total area of responsibility covers a very large region that stretches from the Western Pacific to the Eastern Caribbean and from Alaska to Ecuador. Thus, volcanic cloud monitoring and forecasting is an important component of NOAA operations.

## Milestones with Summary of Accomplishments and Findings

- Based on feedback from operational forecasters at NOAA's Volcanic Ash Advisory Centers (VAACs) we have continue to make improvements to the NOAA/CIMSS Volcanic Monitoring website. The improvements include optional overlays of lat/lon grids, volcano names, and VAAC boundaries. In addition, users can draw polygons on the display and export the associated lat/lon points or get cursor read-outs of lat/lon.
- The latest VOLCAT science advances (refined cloud growth anomaly detection method, better tracking of volcanic clouds, especially after becoming detached from the volcanic vents) were implemented into real-time processing. Figure 48 shows an example of the volcanic convection alerting capability (cloud growth anomaly), using Himawari-8 for Bogoslof (Alaska) in December 2016.
- Performed a false-alarm analysis of volcanic convective alerts from global geostationary satellites (including GOES-EAST, GOEST-WEST, Himawari-8, and Meteosat-10). The results indicate an extremely low false alarm rate - on the order of $10^{-7}$ (100 false alarms of 148 million candidate cloud objects) or about 2 global false alarms per day.
- The usage of automated VOLCAT alerts continues to increase within many VAACs, Figure 49 shows an example of the Washington VAAC referencing a VOLCAT alert as the ash cloud height information source for an emission of the Colima volcano during October 2016. During 2016, the Washington VAAC issued 37 Volcanic Ash Advisories that referenced the VOLCAT system as information contributing toward VAA issuance.

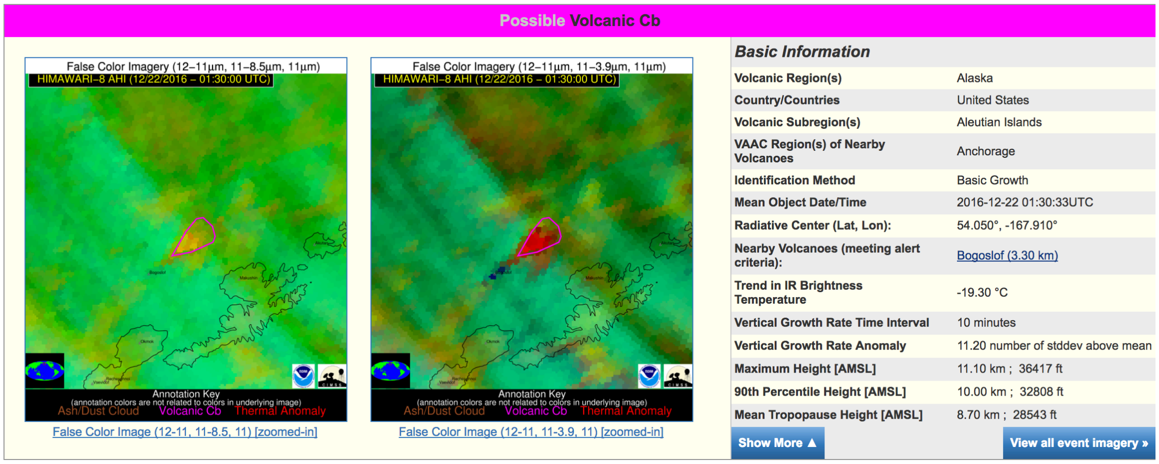


**Figure 48. A screenshot from the NOAA/CIMSS Volcano Monitoring website of a volcanic eruption alert associated with an explosion of Bogoslof volcano in Alaska. The explosion was automatically detected in Himawari-8 data at 0130 UTC on December 22 2016. Bogoslof is a submarine volcano that became active in December 2016. As in this example, many of the Bogoslof eruptions have been very water rich, which precluded multi-spectral detection of volcanic ash and the automated cloud growth anomaly detection method was generally the only satellite-based method to detect these eruptive clouds.**

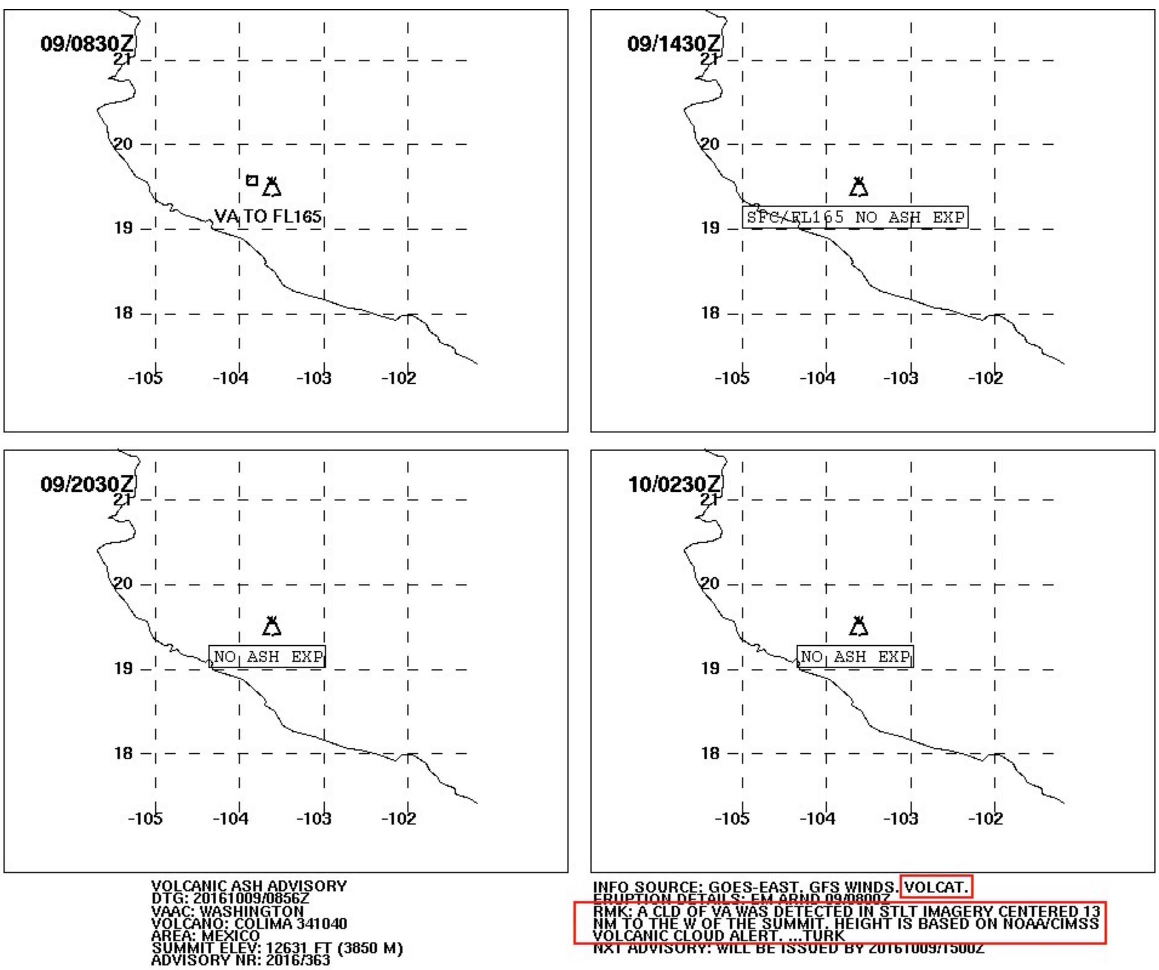


**Figure 49. Volcanic Ash Advisory (VAA) issued by the Washington VAAC for an eruption of Colima volcano in Mexico on 09 Oct 2016. The ash cloud height in this advisory was assigned to FL165 (16,500 feet) by the**

**forecaster based on the information contained in the VOLCAT alert that was automatically delivered to the Washington VAAC. The Washington VAAC regularly cites VOLCAT as an information source.**

## Publications and Conference Reports

Pavolonis, M. J., J. Sieglaff, and J. Cintineo (2015a), Spectrally Enhanced Cloud Objects (SECO): A Generalized Framework for Automated Detection of Volcanic Ash and Dust Clouds using Passive Satellite Measurements, Part I: Multispectral Analysis, J. Geophys. Res. Atmos., 120, doi:10.1002/2014JD022968.

Pavolonis, M. J., J. Sieglaff, and J. Cintineo (2015b), Spectrally Enhanced Cloud Objects (SECO): A Generalized Framework for Automated Detection of Volcanic Ash and Dust Clouds using Passive Satellite Measurements, Part II: Cloud Object Analysis and Global Application, J. Geophys. Res. Atmos., 120, doi:10.1002/2014JD022969.

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.

## References

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.

## 6.6 Towards Providing Forecasters with Better Identification and Analysis of Severe PyroConvection Events using GOES-R ABI and GLM Data

**CIMSS Task Leaders: Bryan Baum, Scott Bachmeier**

**NOAA Collaborators: Andrew Heidinger, Dan Linsey, Roland Draxler, Timothy Lang, Mark Ruminski, Gregory Gallina**

**Budget: $99,000**

### NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:

- 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
- Education and Outreach

### Objective

Our primary goal is to use geostationary satellite data to investigate the impact of wildfire events that become pyroconvective, thereby producing convective smoke plumes that grow to incredible heights and often punch through the tropopause. These pyroCumulonimbus, or pyroCb, are extreme fire events that can cause catastrophic damage to nearby communities, impact aviation, and influence weather far downstream of the event.

### Project Overview

The PyroCb blog (http://pyrocb.ssec.wisc.edu) documents notable pyroCb events as they unfold, provides information to NWS forecast offices as well as the general public, and also supports scientific research that will eventually makes its way into the peer-review literature. New pyroCb events are added continually so that we will have a record of the events for the duration of the blog (roughly covering the 2013-2017 fire seasons). In the first two years (2013-2014), the blog recorded about 20-25 events per year. In 2015, we recorded over 60 events. These events occurred during one of the strongest El Ninos on record. Additionally, the higher temporal resolution of Himawari-8 now permit the documentation of PyroCb events that could not be discerned previously. The past year reverted to more normal number of events. A graduate student, Anna Sienko, is now pursuing a M.S. on this PyroCb work at UW-Madison, with Prof. Grant Petty as her advisor. She is investigating the use of a Heidke skill score (Petty and Li, 2013) to investigate whether there is some predictive capability for PyroCbs based on meteorological conditions. She is additionally performing radiative transfer calculations to investigate the impact of heavy smoke aerosol in the vicinity of cumulonimbus anvils and other high-level clouds. Anna Sienko should finish the requirements for the M.S. degree by the end of the summer semester, 2017.

In the recent period, we worked with Dr. Elisabeth Weisz (SSEC) and her graduate student, Rebecca Schultz, to gain more understanding of atmospheric stability from their analysis of hyperspectral IR data from sensors such as AIRS, CrIS, and IASI. Dr. Weisz developed a regression-based approach to infer atmospheric properties such as temperature and moisture profiles that could be quite informative for the study of these extreme pyroconvection events. Rebecca Schultz anticipates completing her M.S. degree by the end of the spring semester, 2017.

The blog focuses on the more practical, operational aspects of pyroCbs, such as inspection of the OMPS Aerosol Index to identify regions of high-altitude absorbing aerosols, the presence of lightning in the plumes, determination of smoke injection height, and the use of HYSPLIT model trajectories to gain a sense of the plume dispersion.

Unfortunately, this effort was not chosen for continuation by NOAA, so the blog will continue into the 2017 fire season until the available funding is depleted.

### Milestones with Summary of Accomplishments and Findings

- Documented hundreds of notable pyroconvection events (both pyroCb and pyroCu); collected pertinent data necessary for detailed case studies and posted results on the PyroCb blog (http://pyrocb.ssec.wisc.edu).
- Integrated CALIPSO lidar products, OMPS Aerosol Index, GOES, VIIRS and MODIS data into the blog posts. Himawari-8 has also provided extraordinary imagery for several PyroCb events.
- Integrated HYSPLIT model trajectories with satellite image analysis where necessary.
- Built expertise with Heidke skill score to better understand if there is some predictive capability for PyroCbs based on meteorological conditions.
- Performed radiative transfer calculations to gain insight into smoke-ice cloud interactions, with application to geostationary imager data.

- Worked with products from hyperspectral IR sounders such as CrIS and AIRS for regions with significant biomass burning to provide greater understanding of atmospheric stability in the vicinity of the pyroCb events.
- Eased transition from GOES-13/15 (and potentially GOES-14) to GOES-R ABI/GLM sensors by working with Himawari-8 data. We captured more events with Himawari-8 data due to its ability to collect imagery with a more rapid refresh rate.
- Anna Sienko, currently a graduate student in the Atmospheric and Oceanic Sciences department at UW-Madison, built a database of all the PyroCb events captured globally from 2013-present. She is analyzing these events as part of her Master's thesis, and also including analysis of "null" events where pyroconvective development did not transition to PyroCb. She is also investigating additional atmospheric state parameters such as CAPE, the Haines index, and the mid-tropospheric water vapor, in addition to other meteorological parameters for potential inclusion and testing.

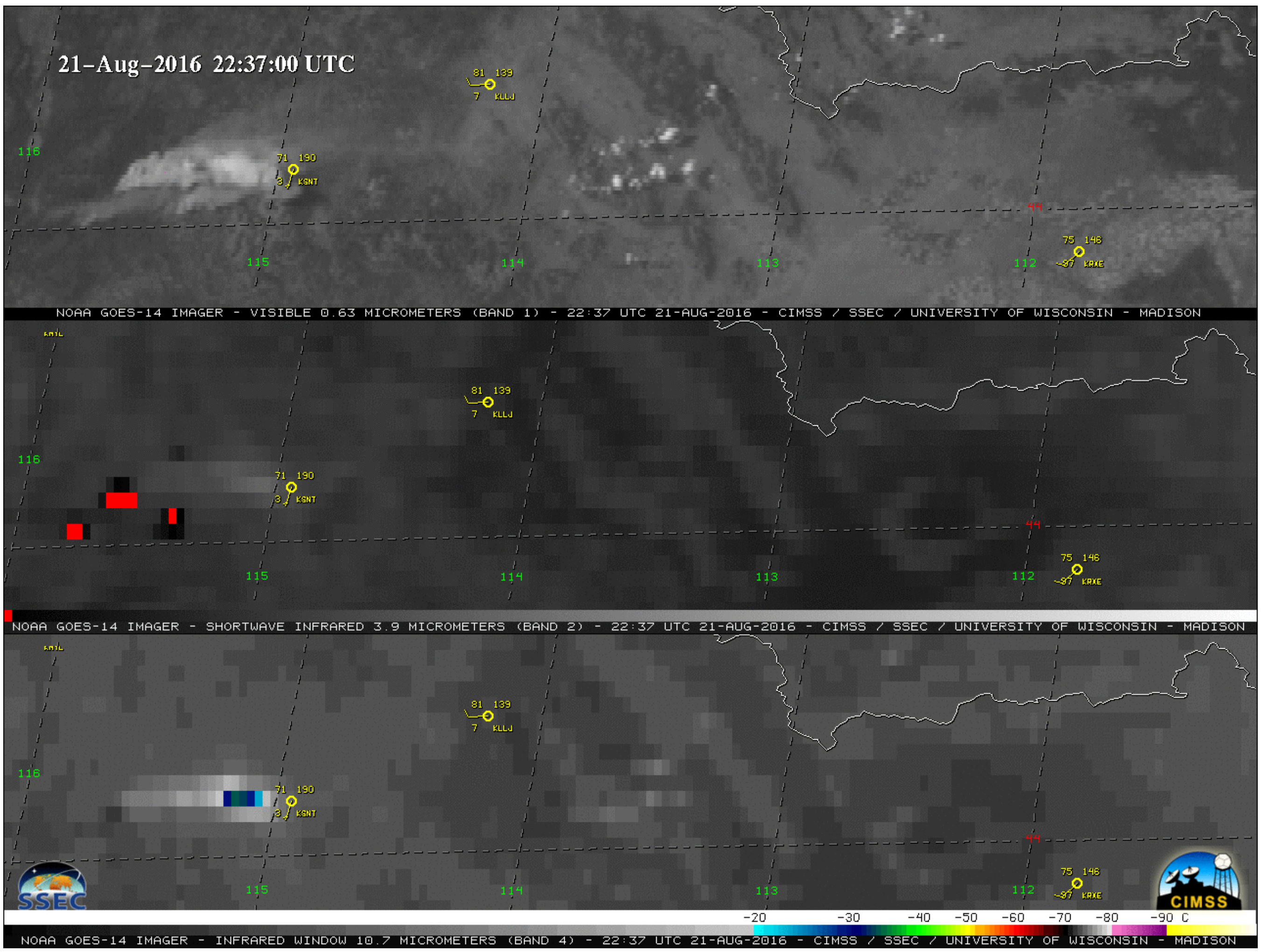


**Figure 50. A GOES-14 image of the Pioneer Fire in central Idaho on 21 August, 2016. The top panel shows the 0.63–µm (visible channel) reflectances, the middle panel shows the 3.9–µm Medium Wave Infrared (MWIR) brightness temperatures, and the bottom panel shows the 10.7–µm (Infrared Window) brightness temperatures, with surface reports plotted in yellow. A large smoke plume was evident in the visible image as it moved eastward; several hot spots are noted (red pixels) in the middle panel that indicate the active fires. While the cloud-top IR window brightness temperature did not quite reach the -40˚C threshold to be classified as a pyroCb, a 1-km resolution NOAA-19 AVHRR image revealed a minimum IR brightness temperature of -48˚C.**

**References**

Fromm, M., D. T. Lindsey, R. Servranckx, G. Yue, T. Trickl, R. Sica, P. Doucet, and S. Godin-Beekmann, 2010: The untold story of pyrocumulonimbus. *Bull. Amer. Meteor. Soc.*, **91**, 1193–1209.

Lang, T. J., S. A. Rutledge, B. Dolan, P. Krehbiel, W. Rison, and D. T. Lindsey, 2014: Lightning in wildfire smoke plumes observed in Colorado during summer 2012. Mon. Wea. Rev., 142, 489-507.

Lindsey, D. T. and M. Fromm, 2008: Evidence of the cloud lifetime effect from wildfire-induced thunderstorms. *Geophys. Res. Lett*., **35**, L22809, doi:10.1029/2008GL035680.

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Trentmann, J., G. Luderer, T. Winterrath, M. D. Fromm, R. Servranckx, C. Textor, M. Herzog, H.-F. Graf, and M. O. Andreae, 2006: Modeling of biomass smoke injection into the lower stratosphere by a large forest fire (Part I): Reference simulation. *Atmos. Chem. Phys.,* **6,** 5247–5260, doi:10.5194/acp -6-5247-2006.

## 6.7 Probabilistic Forecasting of Severe Convection through Data Fusion

**CIMSS Task Leader: John Cintineo**
**CIMSS Support Scientist: Justin Sieglaff**
**NOAA Collaborator: Michael Pavolonis**
**Budget: $85,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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

**Objective**

The NOAA/CIMSS ProbSevere model helps NWS forecasters skillfully increase lead-time to severe convective hazards.

**Project Overview**

The NOAA/CIMSS ProbSevere model has been developed as a nowcasting probabilistic guidance tool for forecasters to better predict severe convective storm hazards. ProbSevere utilizes a satellite and radar object-based framework to fuse together NWP environmental information, temporal trends in GOES-derived imagery, Multi-Radar Multi-Sensor (MRMS) products, and Earth Networks Total Lightning Network (ENTLN) data as inputs into a statistical model that calculates the probability of any given storm will produce severe weather in the next 90 minutes.

## Milestones with Summary of Accomplishments and Findings

- Validation of the current ProbSevere model was expanded to include 120 days from March through December of 2016 and 2014. Regional skill differences exist, and interactive maps demonstrating these differences have been displayed online for investigators' and users' interrogation (http://cimss.ssec.wisc.edu/severe_conv/training/validation.html). These data may help NWS offices utilize ProbSevere guidance better. These results will also be written as part of a journal article (see Figure 51 for an example).
- ProbSevere with total lightning information was successfully demonstrated in the GOES-R Proving Ground at the Hazardous Weather Testbed, as well as within a larger experiment at Eastern and Central Region WFOs, coordinated by the NWS Operations Proving Ground. See Figure 52 and the associated blogpost about the impact of total lightning in the model. A presentation on this topic was also given at the American Meteorological Society's Severe Local Storms Conference.
- A significant analysis was completed, investigating numerous NWP, radar, and total lightning fields associated with specific hazards (wind, hail, tornado). This analysis has enabled the investigators to build statistical models for wind and tornado hazards (see Figure 53 for an example of distributions drawn from the analysis), using data mining methods.
- Significant progress has been made on building a ProbTornado model. This model incorporates NWP, radar, and total lightning predictors. The investigators expect storm top features and GLM data from GOES-16 to add value to this model. The model was validated on over 60 days in the warm season.
- Good progress has been made on constructing and evaluating a ProbWind statistical model. A combination of conceptual models for wind-producing thunderstorms will be merged together to create a unified probability of wind.

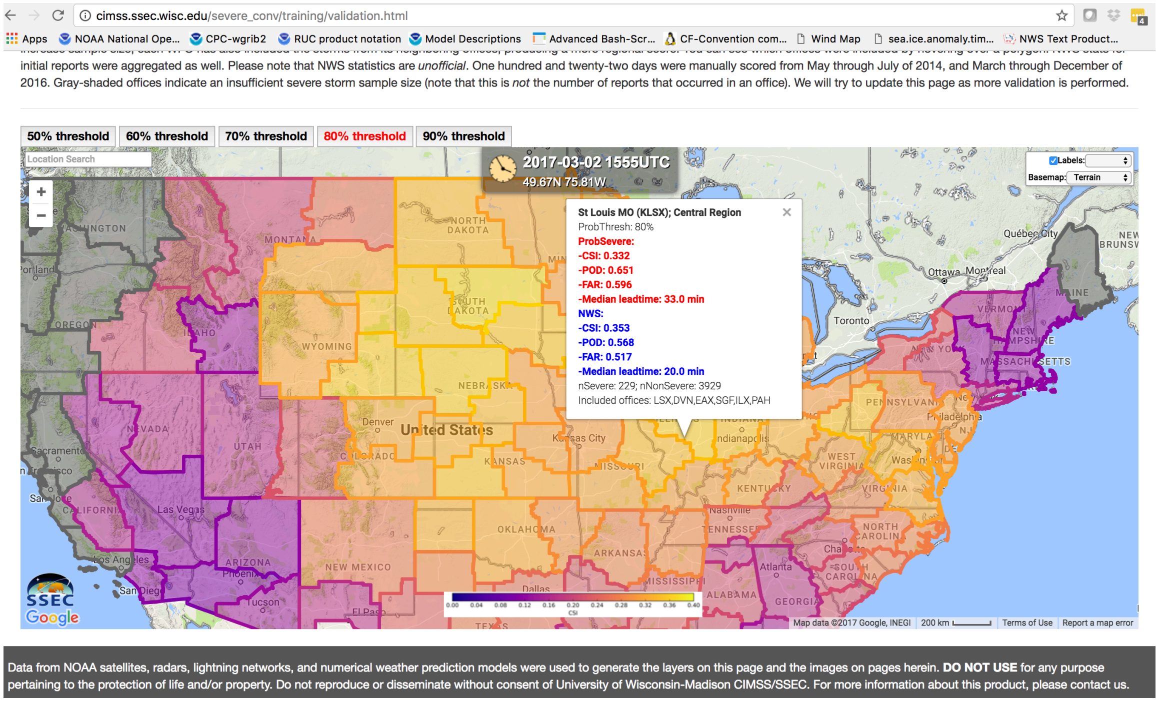


**Figure 51. ProbSevere regional validation webpage, with skill statistics and lead time compared to NWS warnings for aggregated regions.**

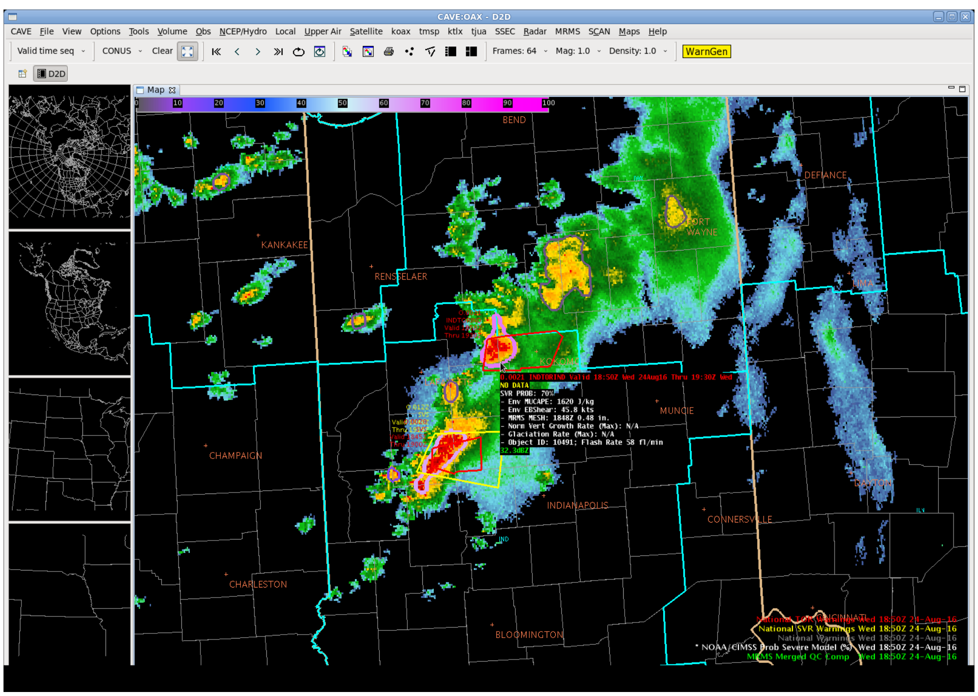


**Figure 52. Example of ProbSevere displayed in AWIPS2, during the start of a surprise tornado outbreak in Indiana and Ohio, 24 August 2016. This blogpost demonstrates the effects of total lightning information in the ProbSevere model: http://goesrhwt.blogspot.com/2016/08/surprise-indiana-tornadoes-and-total.html**

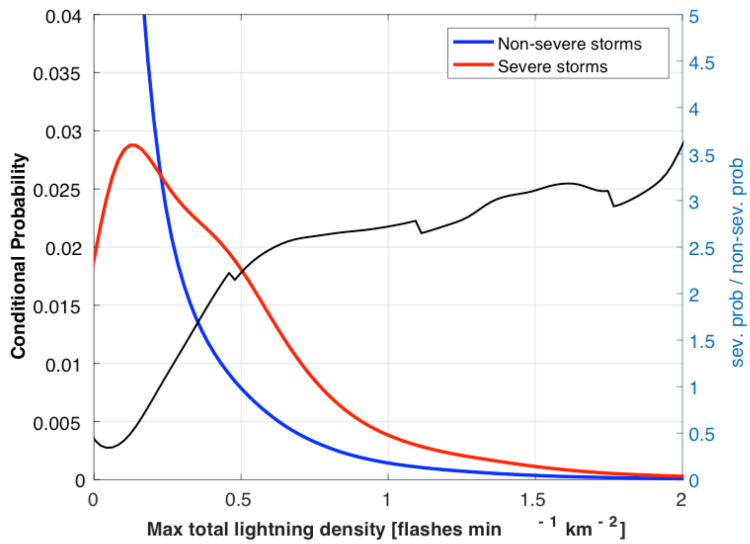


**Figure 53. Distributions of conditional probability for total lightning flash density in severe microburst-producing storms and non-severe thunderstorms. The black line corresponds to the ratio of conditional probabilities between the severe and non-severe distributions. This ratio is a key metric in determining the usefulness of a predictor in a naïve Bayesian model.**

## Publications and Conference Reports

Cintineo, J. L., M. J. Pavolonis, J. M. Sieglaff, and J. C. Brunner, 2016: The Impact of Total Lightning Information in the NOAA/CIMSS ProbSevere Model. 28th American Meteorological Society Severe Local Storms Conference, Portland, OR, 9.1

Pavolonis, M. J., J. L. Cintineo, and J. M. Sieglaff, 2016: The NOAA/CIMSS ProbSevere Model – Integration of NWP, Satellite, Lightning, and Radar data for Improved Severe Weather Warnings. 12th Annual Symposium on New Generation Operational Environmental Satellite Systems, New Orleans, LA, 8.2

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Cintineo, J. L., M. J. Pavolonis, J. M. Sieglaff, and D.T. Lindsey, 2014: An empirical model for assessing the severe weather potential of developing convection. Weather and Forecasting., 29, 639-653.

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Sieglaff, Justin M., D. C. Hartung, W. F. Feltz, L. M. Cronce, V. Lakshmanan, 2013: A satellite-based convective cloud object tracking and multipurpose data fusion tool with application to developing convection. J. Atmos. Oceanic Technol., 30, 510–525.

## 6.8 Development and Demonstration of a Coupled GOES-R Legacy Sounding NearCast with Convective Initiation Products to improve Convective Weather Nowcasts

**CIMSS Task Leader: Lee Cronce**
**CIMSS Support Scientist: Ralph Petersen**
**NOAA Collaborator: Robert Aune**
**Budget: $74,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

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

### CIMSS Research Themes:

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

### Objective

The objective is to provide a more refined convective initiation (CI) nowcast by incorporating additional environmental information provided by GOES to identify where convection is most likely to form through the fusion of two established convective monitoring GOES-R algorithms.

### Project Overview

This objective is being accomplished by reducing over-forecasting and improving under-forecasting of the current 0-1 h GOES-R CI algorithm via integration of 0-3 h NearCasts of GOES-R Legacy Sounding Moisture, Temperature and Stability products within GOES-R CI as a means of better defining areas in which convective clouds are most/least likely to develop into strong convective storms. This approach maximizes the use of all the forthcoming GOES-R Advanced Baseline Imager capabilities: Visible imaging, infrared (IR) imaging, high time resolution (1-5 min) imagery, as well as the 15-30 min interval clear-air profiles (especially moisture). CIMSS responsibilities for this joint project, with the University of Alabama in Huntsville (UAH), focus on modification and support of the GOES-R Legacy Sounding NearCast algorithm.

### Milestones with Summary of Accomplishments and Findings

- *Real-time fused product display*
  Following the establishment of reliable real-time data feeds of both the NearCast and GOES-R CI products, a fused display updated in real time has been created and is currently hosted via webpage for evaluation. This display provides a useful tool to identify relationships between NearCast and GOES-R CI algorithms that can be used to improve product performance and accuracy. The only drawback encountered was the unfortunate GOES-13 sounder failure, forcing real-time focus on western CONUS only with a case study focus supplementing eastern CONUS evaluation.
- *Identification of parameters influencing valid/non-valid CI events*
  Not surprising, it was found that vertical moisture profile knowledge and its horizontal

displacement have a large influence on distinguishing between valid/non-valid CI events. These findings validate the assumption that the inclusion of NearCast projections of observed GOES moisture can enhance the GOES-R CI algorithm in a physically consisten manor.

- *Statistical analysis of matched GOES-R CI objects/NearCast field values*
  Following the matching of CI objects to NearCast fields via bilinear interpolation, a statistical analysis of the matches was performed on a historical CI data set. Early attempts focused primarily on calculations of the mean and variability (measured as standard deviation) of the NearCast fields and their time tendencies at validated (storms ensued) GOES-R CI points througout the day. Preliminary assessments focused on equivalent potential temperature; however, its diurnal variation posed a complicating factor. Therefore, precipitable water, which is derived from the strong moisture signatures present in GOES moisture radiance observations, was used for analysis, providing a more temporally consistent comparator. Initial results (see Figure 54) provide hypothesis support that stable statistical filtering procedures can be trained to represent current convective environments.

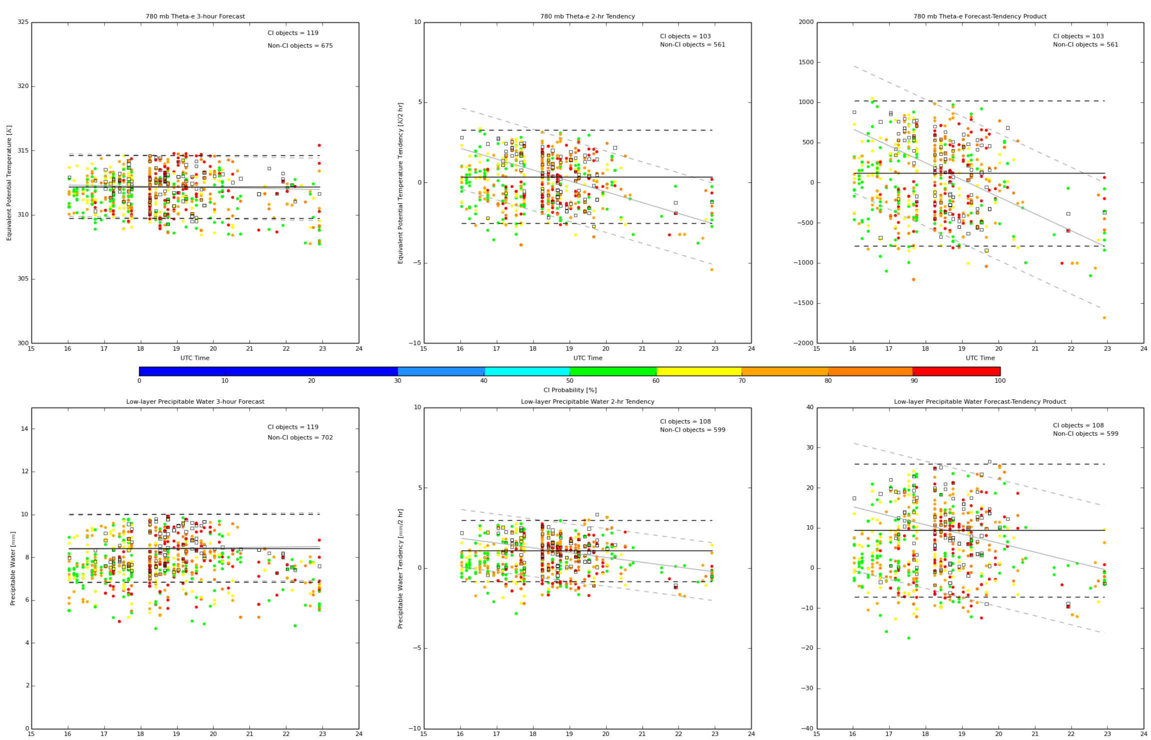



**Figure 54. Scatterplots of NearCast equivalent potential temperature (θe) at 780 mb (top) and low layer (0.9-0.7 vertical σ layer) precipitable water (PW; bottom) at CI object locations versus time of day. Open squares represent validated CI objects (storms ensued) while circles represent non-valid CI objects and are colored by CI probability. Left panels represent the 3-hour predictions, center panels represent the time tendency between 1- and 3-hour NearCasts, and right panels represent the product of the first two. The solid black (gray) lines denote the mean (linear regression) of each NearCast field associated with validated CI objects, with dashed black (gray) lines delineating two standard deviations from the mean (regression). Note, 1) how many more non-valid CI/PW pairs are eliminated (outside 2σ) due to insufficient moisture than for θe, and 2) how the forecast PW and tendencies fit the mean better throughout the day than for θe.**

*Note - Unforseeable data acquisition issues emerged at UAH, slowing progress; however, existing funding is still strong enough to support this project.*

**Publications and Conference Reports**

Petersen, R., L. Cronce, W. Line, and R. Aune, 2016: Providing Forecasters with Tools to improve very-short-range Forecasts using real-time GEO and LEO Moisture and Temperature Soundings. Presentations at EUMETSAT and DWD, April 2016, Darmstadt and Offenbach, Germany.

Cronce, L., R. Petersen, J. Mecikalski, C. Jewett, 2016: Development of a Coupled GOES-R Legacy Sounding NearCast with Convective Initiation Products to improve Convective Weather Nowcasts. AMS 21st Conference on Satellite Meteorology, Madison, Wisconsin.

## 6.9 Transitioning the NASA Aircraft Icing Threat Capability to NOAA Operations
**CIMSS Task Leader: Andi Walther**
**NOAA Collaborator: Andrew Heidinger**
**Budget: $12,000**

**NOAA Long Term Goals:**
- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

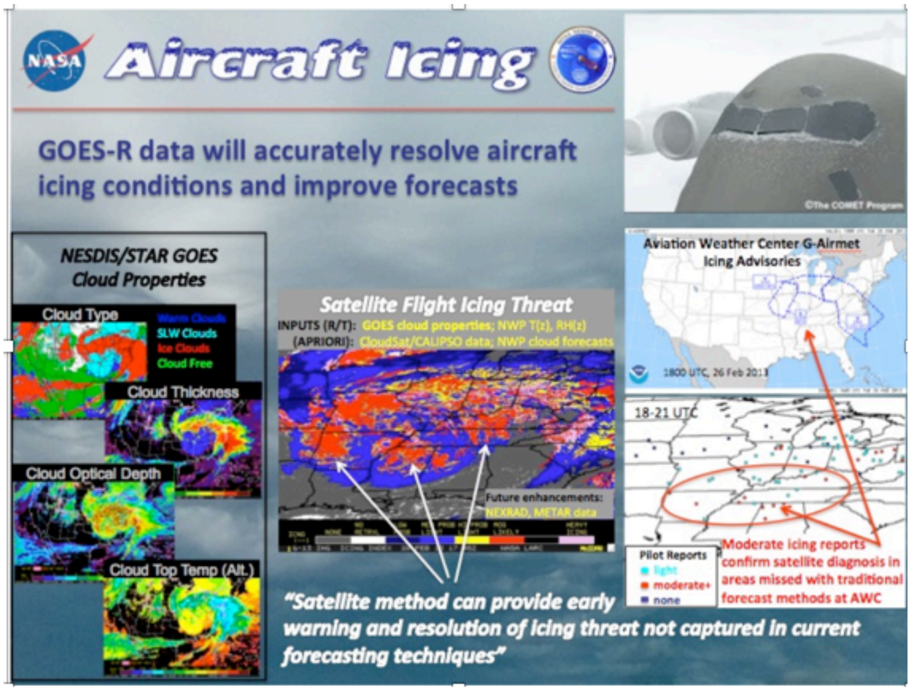
**CIMSS Research Themes:**
- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

**Objective**

This project supports transition of the NASA Aircraft icing threat capability to NOAA operations.

**Project Overview**

Aircraft icing is a major hazard to aviation and no phase of aircraft operations is immune to the threat. This proposal addresses a high National Weather Service (NWS) priority to improve the diagnosis of dangerous aircraft icing conditions for the aviation community. A capability to determine the in-flight icing (IFI) threat to aircraft has been developed that uses satellite derived cloud parameters. The methods are applicable to cloud parameters now commonly retrieved in real-time from meteorological satellite data, and are particularly well suited for application to the high spatial and temporal resolution operational cloud products from the GOES-R ABI. Verification studies indicate that relative to traditional icing forecasting techniques based on NWP analyses, the satellite methods significantly improve the resolution of icing conditions, including the dangerous conditions found to be associated with several recent aviation incidents and accidents. The objectives of this proposal are to (1) integrate a state of the art satellite based icing algorithm into the NOAA GOES-R Proving Ground (PG) processing system at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), (2) validate and tune the algorithm, if necessary, using icing PIREPS as guidance, (3) generate and deliver satellite-based flight icing threat (S-FIT) products to the major NWS aviation weather forecast offices and to the PG with the current CIMSS product suite, (4) develop training materials for the S-FIT products, and (5) participate in and conduct S-FIT product evaluations to acquire feedback. The expected benefits to the NWS and the aviation community include better definition and situational awareness of the in-flight icing threat, improved icing forecasts, and the potential for safer, more efficient aviation.




Basic of icing threat is DCOMP retrieval, which retrieves cloud optical parameters.

**Milestones with Summary of Accomplishments and Findings**

- With the launch of GOES-ABI in 2016 we could start testing our science software DCOMP on real ABI data.
- Further development work of DCOMP are implemented in ice threat retrieval.
- The level-2 files are routinely prepared.
- Prepared further training visualization material.

## 6.10 Preparing the CIMSS NearCast System for Transition from Research to Operations (R2O)

**CIMSS Task Leader: Ralph A. Petersen**
**CIMSS Support Scientist: Lee Cronce**
**NOAA Collaborators: Robert Aune, William Line, and Steve Goodman**
**Budget: $50,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

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

**CIMSS Research Themes:**
- Satellite Meteorology Research and Applications
- Environmental Models and Data Assimilation

## Objective
To facilitate integration of the NearCast model with the other GOES-R products by establishing a 'generalized and operationally maintainable' version of the NearCast model code and script structures.

## Project Overview
*This project is an augmentation in support of the CIMSS Project 6.8: Development and Demonstration of the Fusion of GOES-R Legacy Sounding NearCasts with Convective Initiation Products to Improve Convective Weather Nowcasts.* The overall objective is to provide data driven tools to help NWS forecasters expand their use of GOES clear-sky moisture and temperature soundings by enhancing and expanding existing observations and proving feedback to NOAA through the use of products from current and future GOES satellites. In particular, this effort will assure that NearCast fields will be available in the future both to directly support real-time forecasting and also to enhance other GOES-R products, most notably by reducing the false-alarms present in GOES-R Convective Initiation (CI) products. Specific tasks include:

***Task 1***: The NearCasting model will be generalized to run over any portion of the globe and optionally include a sigma-based (terrain following) vertical coordinate, a critical factor for application over the high elevation and steeply sloped terrain. The inclusion of a sigma-coordinate would also allow better use of GOES-R soundings in areas of higher surface elevation and provide additional information to forecasters about possible orographic triggering mechanisms. The possible inclusion of the generalized NearCast model as a future forecaster application using SEVIRI retrievals over the Lake Victoria Basin (LVB, see Task 3 below) will also improve the use of GOES-R sounding products in tropical environments in the Americas.

***Task 2:*** Output from the generalized NearCast system will then be made available for integration by other GOES-R researchers for integration within their GOES-R algorithm. CIMSS would make a portable version available for generating the NearCast products on site, as well as continue to run the original CIMSS version of the system as a comparison benchmark for a period of time.

***Task 3:*** Work with the WMO to acquire funding to deliver NearCasts over the LVB to provide forecasters with better and more temporally-consistent, real-time products than furnished by SEVIRI observations alone, and to offer a method for using higher time/space resolution SEVIRI products to monitor NWP performance in areas with minimal radar coverage. CIMSS will participate in broader WMO Nowcasting proposal development in coordination with the GOES-R project, NSF, EUMETSAT and WMO, as well as supply case study material and participate in WMO LVB training, as needed.

## Milestones with Summary of Accomplishments and Findings
It should be noted that funding for this project did not arrive until late in FY2015. Since then, the NearCast generalization described in Tasks 1 and 2 has focused primarily on system design and coding standards issues. Further efforts on Task 3 are awaiting decisions from WMO.

### *Task 1 – Model Generalization*

This task has been designed and substantially executed, including simplifying the system software and removing non-operational-standards. The NearCast system is divided into 4 separate components for ease of maintenance and export. These include: 1) NWP background information acquisition and staging to optimize use of NearCast trajectory calculations [completed], 2) retrieval acquisition and categorization (including quality flags) [completing testing], 3) trajectory forecast generation (in lat/lon space) to facilitate multiple output projections and allow easy interpretation of trajectory histories [under development], and 4) output generation, converting the NearCast trajectory output from irregular lat/lon points to multiple regularly-spaced grids for display (including effects of data 'aging', instrument accuracies and observation error estimates, etc.) [under development], and transmission in GRIB-II [completed].

All codes use standard NCEP W-3 routines, with internal coding using the latest versions of Fortran, thereby allowing dynamic array sizing and other software efficiencies. GRIB and NetCDF conventions have also used throughout. GFS inputs for initial parcel winds and height gradient tendencies have also been converted to use higher spatial and temporal resolution now available from NCEP (1/4 degree and hourly).

Corrections to display software provide a robust comparison standard for alternative approaches, including improved use of data age, observation quality, etc. Sigma version of the model is under development with minor modification to codes expected.

### *Task 2 - Model Export Preparation*

Outputs from NearCast model using standard inputs and outputs are available to outside users, including University of Alabama-Huntsville. Lack of GOES sounder retrievals over eastern US has resulted in limited usefulness in testing, however. Real-time tests are planned once GOES-16 retrievals become available.

### *Task 3 - LVB Preparation*

Continued participation in proposal development and training exercises is anticipated in the following year as determined by WMO. Further efforts are awaiting the decision on WMO proposal before proceeding.

## 7. CIMSS Support to GOES-R Proving Ground Activities

### 7.1 CIMSS Participation in the Development of GOES-R Proving Ground in 2016-2017

**CIMSS Task Leader: Wayne Feltz**

**CIMSS Support Scientists: Chris Velden, Sarah Griffin, Scott Bachmeier, Scott Lindstrom, Lee Cronce, Justin Sieglaff, Kaba Bah**

**NOAA Collaborators: Michael Pavolonis (NESDIS/STAR), Bradley Pierce (NESDIS/STAR), Andy Heidinger (NESDIS/STAR), and Tim Schmit (NESDIS/STAR)**

**Budget: $310,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

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

**CIMSS Research Themes:**

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

## Objective

CIMSS researchers will expand partnerships with NWS Forecast Offices and NOAA National Centers to provide these products, train forecasters in their applications, and evaluate their utility. This work will help to ensure that GOES-16 products will be available and useful to forecasters soon after launch.

## Project Overview

UW-CIMSS supported the GOES-16/GOES-S Proving Ground demonstrations by evaluating the GOES-16/GOES-S Algorithm Working Group demonstration algorithms and baseline products, testing enhancements and advanced products (Risk Reduction), and providing user assessments and feedback to the product developers. Partnerships were expanded with NWS Forecast Offices in 2016-2017 to help train additional forecasters in product applications and to evaluate their utility. This work helped to ensure that GOES-16/GOES-S products were available and useful to forecasters soon after launch.

In 2016-2017 research period of performance, the primary focus was to test, apply, and improve select GOES-16/GOES-S satellite baseline, future capability, and risk reduction imagery/products in support of National Centers and local NWS offices. CIMSS researchers and scientists attended the June 2016 Proving Ground and User Readiness Satellite Science week in Kansas City, MO to determine goals/milestones of the GOES-16/GOES-S Risk Reduction and Proving Ground tasks and were present at regular by-monthly GOES-16/GOES-S Proving Ground coordination/reporting teleconferences. GOES-16/GOES-S PG oral and poster presentations occurred at various conferences in 2015-2016 including the American Meteorological Society (AMS) Conference, the National Weather Association (NWA) Conference, and the EUMETSAT Annual conference in Darmstadt, Germany.

### *1. Test and apply algorithms for expected GOES-16/GOES-S satellite data imagery/products in support of National NOAA Testbeds/PG Demonstrations*

The following Proving Ground activities occurred in 1 April 2016 – 30 March 2017 funding cycle where several GOES-16/GOES-S proxy decision support products developed at CIMSS were demonstrated with operational forecasters to obtain feedback:

1. Hazardous Weather Testbed (HWT) Spring Experiment (2 May – 3 June, 2016). Participants included 4 CIMSS researchers, 25 NWS forecasters, 5 Broadcast Meteorologists and several visiting scientists;
2. National Hurricane Center (NHC) Tropical Cyclone Demonstration (1 July – 30 November 2016) Participants included forecasters from NHC;
3. Aviation Weather Center (AWC) Summer Experiment (6 January – 30 September 2016). Participants included AWC forecasters and FAA representatives;

4. HPC/ OPC/ TAFB/ and SAB demonstrations (ongoing: focus on precipitation and ocean applications);
5. High Latitude and Arctic Testbed (ongoing: focus on snow/ cloud/ volcanic ash/ and aviation applications). Participants include NWS Alaska Region;
6. Air Quality (ongoing: focus on aerosol detection); and
7. Pacific Region OCONUS Demonstration (ongoing: focus on tropical cyclones/ heavy rainfall/ and aviation applications). Participants include Jordan Gerth, NWS forecasters and scientists from the University of Hawaii.

UW-CIMSS scientists were engaged with the demonstrations listed above by providing the following GOES-16/GOES-S Baseline, Future Capability, or Risk Reduction decision support proxy data. Product assessment highlights for eight of the UW-CIMSS decision support products are listed below as reported in the GOES-16/GOES-S PG 2016 Annual report (to be published) and HWT/AWC/NHC Testbed final evaluation reports located at: http://www.goes-r.gov/users/proving-ground.html

UW-CIMSS Decision Support Product GOES-16/GOES-S Proving Ground Significant Outcomes and Product Assessment Highlights:

1. The Fog and Low Stratus products are currently scheduled to be operationalized on OSPO ESPC systems and will be delivered to NWS users via Satellite Broadcast Network (SBN), NCEP Central Region Operations (NCO) backbone, Direct Broadcast, and possibly AWIPS Data Distribution Service (DDS) as an alternative. This product was also delivered to the Alaska Aviation Weather Unit for testbed utility discussions.
2. The NOAA/CIMSS ProbSevere model was evaluated in the HWT for the fourth consecutive year, with minor updates made since last year's experiment. The statistical model produces a probability that a developing storm will first produce any severe weather in the next 60 minutes. The data fusion product merges NWP-based instability and shear parameters, satellite vertical growth and glaciation rates, and radar derived maximum expected size of hail (MESH). A developing storm is tracked in both satellite and radar imagery using an object-oriented approach. As the storm matures, the NWP information and satellite growth trends are passed to the overlapping radar objects. The product updates approximately every two minutes and is displayed as contours that change color and thickness with probability to be overlaid on radar imagery. Data readout is available by mousing over the probability contour, revealing the probability of severe along with the model predictor values.
3. Simulated Satellite Forecasts are available in AWC and SPC operations from the GOES-R AWG Proxy Team (experimental).
4. The GOES-16/GOES-S convective overshooting top product was transitioned into SPC and AWC operations (experimental) in 2016 and the use of the product has continued to gradually increase,
   GOES-16/GOES-S OT Proxy 2014 SPC Mesoscale Convective Discussions:
   http://www.spc.noaa.gov/products/md/2014/md1127.html
   http://www.spc.noaa.gov/products/md/2014/md0753.html
   http://www.spc.noaa.gov/products/md/md0401.html
   http://www.spc.noaa.gov/products/md/md0162.html
5. SRSO (Super Rapid Scan Operations GOES-14 was activated February 1-25 , April 18-May 15, and August 9-29, 2016, and was made available to SPC and AWC operations for display in N-AWIPS in addition to Fog/Low Stratus and GOES-R Cloud Top Phase proxy. SRSOR This imagery was popular among the forecasters, particularly for the excellent situational awareness it provides via the additional detail in areas of rapid

convective development. SSEC/CIMSS archived the data and quicklook loops are available here: http://cimss.ssec.wisc.edu/goes/srsor2016/GOES-14_SRSOR.html

6. GOES-R Legacy Atmospheric Profile Products - New to the HWT this year were moisture and stability fields generated via a fusion of GOES Sounder radiance observations and Numerical Weather Prediction (NWP) forecast data using a GOES-16/GOES-S Risk Reduction (GOES-R3) algorithm.
7. ABI Cloud Height Algorithm (ACHA) - The Algorithm Working Group's Cloud Height Algorithms (ACHA), including the Cloud Top Height, Cloud Top Temperature, and Cloud Emissivity products, were provided to the AWC in 2012. Cloud Top Heights saw the most use, and as a result of forecaster feedback over the past two years, a Cloud Top Altitude product was developed for the 2014 demonstration. This product provides cloud tops in feet instead of meters, as feet (or flight levels) are the common unit in aviation forecasting. Multiple concepts for this product were explored in the 2015 demonstration and continued evaluation was requested. Additionally, the need for more ceiling and visibility specific products was noted. From this came the Cloud Cover Layers and the Cloud Base Heights in the 2016 demonstration. The latter of these two was evaluated in both experiments, while the Cloud Cover Layers was evaluated in only the Summer Experiment. The domain of both of these was focused on the CONUS and both were available in N- AWIPS and AWIPS-2 D2D.
8. Atmospheric Motion Vectors (AMV) - Satellite Derived Motion Winds or Atmospheric Motion Vectors, are wind vectors generated by tracking cloud features in visible, IR, and water vapor satellite imagery. The generation process utilizes three satellite images, the first and third to track the cloud feature, and the second to target the features themselves. Heights of these wind vectors are assigned based on 1) measured radiances of the targets and the spectral responses of the satellite and channel that is being sampled.

***WRF Simulated ABI Synthetic Satellite cloud and moisture imagery (Baseline)***

**HWT input:** In general, forecasters found the synthetic satellite imagery to be a useful and unique tool for evaluating a particular model forecast cycle. More specifically, participants speculated the effects that displacements early in the forecast cycle might have on subsequent hours. Forecasters understood that even if feature placement or timing was off, constructive information could still to be gained from the synthetic imagery such as storm character and evolution.

**AWC input:** Various forecast fields are collected from the 00 UTC run of both the NSSL-WRF and the NAM Nest, including pressure, temperature, water vapor, heights, canopy temperature, cloud water, cloud ice, snow, graupel, and rain, all of which are processed as inputs for a radiative transfer model. Synthetic radiances and brightness temperatures are generated through this model and displayed as simulated satellite imagery meant to represent the capabilities of the Advanced Baseline Imager (ABI) on GOES-R.

Newly available in the 2015 demonstration and continually evaluated in 2016 were the synthetic brightness temperatures from the experimental HRRR (hereafter referred to as HRRR-x). These were provided by CIMSS via the HRRR Validation website. This website provides a sectorized validation and guidance of HRRR-x simulated satellite imagery across the CONUS. Not only does it display a side-by- side comparison of the simulated and observed satellite images (water vapor and infrared), it also generates various validation statistics, including RMSE, Bias, and MAE. Additionally, it includes error matrix graphics that compare the statistics of all of the runs for a particular day. This is an easy way for forecasters to identify which run is performing best, as interestingly, it may not always be the current one.

Synthetic satellite imagery continues to be regularly used by forecasters as an additional model tool at the various desks in operations. In particular, the FA forecasters use it when issuing G-AIRMETs for turbulence. In a typical real-time satellite image, they will try and identify certain features specific to turbulence: breaking ridges, jets, mountain waves, and wind gradients, etc. With modeled satellite imagery, forecasters attempt to identify these features later in the forecast period, especially where they are located with certain other model parameters conducive to turbulence. This concept has been in use since the initial introduction of the simulated imagery to operations back in early 2013 and continues to prove valuable. In fact, one AWC forecaster will be presenting on this subject at the 2017 AMS conference in Seattle.

Convection is another area in which the simulated satellite imagery is often used at the AWC. This year, the CAWS desk in particular has found it very useful. One of the goals of the CAWS is to add benefit to the automated CCFP forecast. If the confidence and coverage from the CCFP appears to differ from what various model and other data are indicating, CAWS are typically issued as a heads up for traffic flow managers. This is especially true if it surrounds a busy terminal such as Chicago. For example, CCFP may be showing high confidence of medium coverage over the airport, but simulated satellite and a few other model parameters are indicating earlier clearing. In this case, a CAWS would be issued to note the earlier clearing so that traffic flow managers can release ground stops earlier than planned.

On a final note, synthetic cloud and moisture imagery are currently being generated by the GOES-R Ground Segment via RAFTR, which utilizes Rapid Refresh and GFS data to simulate the sixteen channels and the high temporal refresh of the ABI. This data was made available through SBN in AWIPS-2 and through the NESDIS PDA system in N-AWIPS, and was meant to simulate the future data flow structure of GOES-R ABI imagery through the Ground Segment.

While it was simulating a real-time feed of ABI as will be seen through the Ground Segment after GOES- R is launched, is still provided valuable insight into the 16 channels and temporal resolution, as well as the various sectors available in the GOES-R era. It was a first glance into the procedures necessary to call mesoscale scan sectors or perhaps more important for a National Center such as the AWC, a change to Mode 4 and continuous full disk scans.

***GOES Imager Super Rapid Scan Operations Imagery (Baseline)***

**HWT input:** The most obvious benefit of the 1-min satellite imagery from GOES-14 to the forecasters was the new ability to observe cloud fields as they evolved in near real-time instead after they had changed. Not only was the forecaster receiving new images more often, but the images were available with decreased latency (3-4 min) compared to current routine imagery. This created substantial lead time to the identification of processes and features that are vital to convective 23 nowcasting. The 1-min imagery aided the warning forecaster across the entire convective cycle, including: environmental analysis pre-CI, identification of CI, mature convective monitoring, warning issuance, and storm weakening. Additionally, forecasters were creative in utilizing the 1-min imagery in concert with other very high temporal resolution data sources. Participants answered that the 1-min satellite imagery provided them with significant information not captured in the routine satellite imagery on 93% of the days when it was available.

While some forecasters preferred to load shorter, 20-50 frame loops, others found it more useful to load 100+ frames in AWIPS-II. Additionally, most forecasters experienced the greatest benefit from the imagery when it was “hyperlooped”, increasing dwell rates to greater than what the

AWIPS-II default menu permits. This allowed for a fluid visualization of atmospheric phenomena. There were no major AWIP-II performance issues noted in association with the 1-min satellite imagery, even as over 100 frames were loaded and various data combinations were used.

Various algorithms are being developed to further take advantage of the 1-min satellite data and complement the imagery, some of which were demonstrated in the HWT. The automated Overshooting Top (OT) Detection algorithm is one such product that was generated from the 1-min data and made available to the HWT participants in AWIPS-II. Forecasters felt that the algorithm made it easier to identify and track strong, persistent updrafts, and identify cells that were showing weakening trends via collapsing storm tops. With the 1-min imagery, these trends were easier to monitor and significant changes were not missed as is often the case in routine imagery. Many commented, however, that overshooting tops were especially easy to identify 28 manually in the 1-min visible imagery and were often apparent prior to the algorithm picking it up. This is due to the fact that the current algorithm has set brightness temperature thresholds, so weaker overshoots are missed.

**AWC input:** Three periods of 1-minute Super Rapid Scan imagery (SRSOR) occurred during the 2016 demonstration, the first in February, the second in May, and the third in August. This data was made available in AWC operations via an LDM from CIRA and displayed in both N-AWIPS and AWIPS-2. The goal was to continue to explore the SRSOR and the usefulness of the higher temporal resolution in AWC operations. AWC forecasters made use of this data during all three periods, with more in detail evaluation completed during the first and third periods, as they ran concurrent to the Winter and Summer Experiments within the AWT.

During the Winter Experiment, 1-minute SRSOR imagery was found to be valuable in better highlighting areas of turbulence and more specifically identifying the cause. One such case of this occurred on February 23rd. An approaching low from Canada set off a plethora of turbulence PIREPs throughout the Great Lakes region. Over northern Illinois and Indiana, and SW Michigan, the reports were identifying that turbulence as chop from clear air (CAT). This CAT quickly resulted in the issuance of a SIGMET for turbulence in the area.

GOES-13 visible imagery at the time appeared relatively clear and the ~7-minute rapid scan refresh showed some cloud features in SW Michigan but nothing over Illinois and Indiana that would suggest the cause of the reported turbulence. However, with the SRSOSR 1-minute rapid refresh rate, important cloud movements were revealed. What appeared to be clear air in the GOES-13 imagery was actually a series of waves visible in a very, very thin layer of clouds. Without the 1-minute refresh, these details were extremely difficult to discern.

1-minute imagery has also been continually useful in the issuance of CAWS forecasts. While a CAWS is typically issued as a roughly 4 hour forecast, the 1-minute imagery provides useful situational awareness on the progression of existing convection and initialization of developing convection. One example of this has been show over Chicago. For an existing area of convection a CAWS may be issued, not as a warning, but as a reaction. 1-minute SRSOR imagery can reveal important details of the convective environment such as how fast the convection is pushing east and subsequently when operators may be able to release grounded aircraft, and also whether or not the convection is beginning to dissipate and how long that will take.

***Fog and Low Stratus detection (Future Capability)***

**AWC input:** Forecasters would like to keep this product in operations and also focus more on LIFR probabilities. Additionally, it is possible that an Aviation Weather Statement for C&V will be developed. During the Summer Experiment this was explored and the FLS was found to be a valuable tool here as well. It was requested that evaluation to this end be continued in future experiments.

Furthermore, forecasters would like to look more closely at a comparison of the MVFR, IFR, and LIFR probabilities to observed flight conditions, ceilings and visibilities. To this end, a qualitative view of the product has been designed as a web tool. Twenty of the major terminals that deal with ceiling issues on a regular basis have been input into the tool, with analysis of the past 24-hours available at 3-hour intervals.

***Legacy Temperature and Moisture Profile - Nearcast Atmospheric Stability Indices (Risk Reduction)***

**HWT input:** The enhanced NearCast analyses and short-range forecasts were the primary ways that forecasters used the GOES Moisture and Temperature soundings in their forecasting process. Without the NearCasts, forecasters would have been unlikely to use the GOES retrievals as stand-alone observations. The NearCast products were especially effective in increasing situational awareness to where convection was more and less likely to initiate in the 0-6 hour range and how on-going convection was likely to evolve. The training was certainly an important part of this success, as it focused on what features to look for in the NearCast fields via multiple examples. The theta-e difference instability field was very well-received by the forecasters, garnering an average rating of 4.41 out of 5 from participants when asked how useful its addition would be to their forecast office. Finally, although the data gaps were undesirable, participants understood why they occurred and didn't let that deter them from using the NearCast products due to the valuable and unique information they provide in areas where GOES data have recently been available.

**AWC input:** The CWSU forecasters were particularly pleased with this product. While they noted that the concept of the NearCast required a bit of a learning curve, they liked the fact that the color bar made it very easy to interpret, in this case the dry air associated with the trough sinking into the middle of the country as compared to the higher instabilities associated with the obvious frontal features of the low. All of the CWSU offices in attendance requested the weblink for the imagery as it is not currently available in their AWIPS

***Probability of Severe Model***

**HWT input:** All forecasters recognized the ProbSevere Model as a very useful situational awareness tool, providing them with a quick and easy means of identifying and tracking developing and 16 strengthening storms. This was especially true during busy warning situations when there were many storms that needed to be monitored for the potential to produce severe weather. A high ProbSevere probability value would lead a forecaster to interrogate a storm in more detail, while a low value indicated occurrence of severe was not imminent allowing attention to be focused elsewhere, thus saving the forecaster valuable time. Additionally, rapidly increasing probabilities alerted forecasters to the storm and prompted further interrogation. When operations began after convection had developed, ProbSevere was often the first tool forecasters looked at as it provided them with a quick overview of where the strongest storms were located and where experimental warnings might be necessary. While most forecasters overlayed the ProbSevere data on radar imagery, some preferred to instead load it with satellite imagery in their situational awareness display.

In most cases, forecasters did not issue warnings based solely off of ProbSevere. Instead, significant values or trends would lead a forecaster to interrogate the storm further, using ProbSevere as a supplement to their decision and confirmation for what other data sources were implying. Oftentimes, it would sway the warning decision when the forecaster was still on the fence after appropriate examination. On 95% of days, forecasters answered that the ProbSevere model output helped to increase their confidence in issuing (or not issuing) severe thunderstorm or tornado warnings. For most, it was important to see at least a couple scans of sustained high probabilities for greatest confidence. Importantly, there were many situations where ProbSevere led to quicker warnings, with forecasters answering that the output helped increase lead time to severe thunderstorm and tornado warning issuance on 76% of days. They noticed that lead time was most apparent when the satellite fields were available, and when the satellite was in rapid scan mode. By the final day of each week, all 25 NWS participants answered that they would use the ProbSevere model output if available during warning operations at their WFO.

*Limitations of ProbSevere:* Forecasters found ProbSevere to be more useful in some situations than others. Similar to last year, they noted that the ProbSevere Model provided the greatest benefit for deep, discrete storms and when hail was the main threat, while probabilities were underdone with low-topped convection when severe wind was the main threat. Forecasters would like to see the ProbSevere model better handle upscale growth into line segments and multicellular systems. In such situations, storm cores were often lumped together into one larger object, causing the data to become less useful. On obvious days when the severe threat was considerable and storm development was most rapid, participants saw ProbSevere more as a confidence booster. In such situations, warnings were often necessitated based on radar data before or as the ProbSevere probabilities increased to over 80%. Forecasters quickly learned this and subsequently began the warning process after the first signs of rapid probability increase and significant growth in the satellite predictors. The increased temporal resolution of the GOES-16/GOES-S ABI (5-min vs. 15-min over CONUS) is expected to help increase lead time when storm development is most intense. Forecasters did find that ProbSevere provided more of an impact on days where the severe threat was more uncertain and when there were many storms to monitor.

***Icing***

**AWC Input:** The Flight Icing Threat (FIT) integrates various cloud properties from the GOES-R baseline DCOMP algorithm to generate a probability and intensity of icing conditions. It is composed of three components including (1) an icing mask available day and night which discriminates regions of possible icing, (2) an icing probability, estimated during the daytime only, and (3) a two-category intensity index which is also derived during the daytime only. While it is difficult to validate a product such as this given the lack of icing PIREPs and other methods of ice measurement, it has been shown to have skill in identifying areas of more significant icing conditions.

Funding to continue work on this algorithm was received in late 2015. As such, it was evaluated during Evaluation Period I of the 2016 GOES-R/JPSS Demonstration, and underwent an in detail examination during the Winter Experiment. Prior to this, several improvements had already been made after the 2015 GOES-R/JPSS demonstration. These included the addition of a 'heavy' category to identify the more intense icing associated with supercooled large droplets and convection, as well as improved estimates of cloud vertical structure that enable the inference of icing conditions embedded beneath glaciated clouds. Additionally, this year's evaluation was expanded to include an AWIPS-2 version of the product, which was examined by forecasters in D2D.

In general, forecasters continue to note that the FIT has a lot of potential. It provides situational awareness not typically available for icing conditions, typically in areas that don't see a lot of in situ icing reports from aircraft. This is beneficial both to G-AIRMET and SIGMET issuances. The product was also found useful in the non-convective CAWS portion of the Winter Experiment. While a non-convective CAWS is not likely to be made an operationally issued product, the concept explored the need for a product that would fit in between a G-AIRMET and a SIGMET, similar to what is currently issued at the Alaskan Aviation Weather Unit. This 'in-between' product would identify icing areas not as broad as the forecasted moderate or greater conditions in a G-AIRMET, but less specific than the severe conditions within a SIGMET or 'warning' product.

Its ability to discern icing intensities (during the day only) within the clouds helped to narrow down smaller areas in which a non-convective CAWS may need to be issued. In some cases of widespread clouds of multiple layers, the FIT product is more uncertain and it became somewhat difficult to determine which particular areas to really key in on. While this 'messiness' depicted the inherent nature of multi-layer clouds, forecasters mentioned that it might be helpful to apply some sort of smoothing technique in some cases as N-AWIPS does not current support this capability. AWIPS-2 D2D, however, does provide the ability to interpolate, and forecasters were able to utilize this if they chose.

While the algorithm did show continued improvement over the past few years, there were still a few caveats forecasters noted. Firstly, intensities were overestimated in the terminator region. Low sun angles and the shift from day to nighttime retrievals were the culprits behind this issue. Eclipse periods were also somewhat problematic. With the stray light during these periods, there was a significant erroneous increase in intensities. This occurred at relatively the same time each day and so was easy become accustomed to. Additionally, there were some cases in which undetected thin cirrus clouds overlapping liquid clouds were interpreted as SLD causing an overestimation of the icing threat. Lastly, thin cirrus over snow covered ground also caused overestimation at times. All of these caveats –terminator regions, eclipse periods, and cirrus cloud contamination- were significant, but with a good understanding of the cloud environment, not particularly difficult for forecasters to become accustomed to and subsequently keep in mind when issuing icing forecasts.

Beyond the non-convective CAWS, there were a number of CWSUs who noted the potential benefit of the product in their operations. CWSUs advise the traffic flow managers within their air space of various weather hazards that may impact air traffic. Icing is not typically one of the highest priority issues to forecast for in their daily duties, however it was suggested that the FIT would become useful in and around a major terminal, particularly the top and base of the icing layer. Icing is commonly seen in the ascent or descent phase of flight as a layer of clouds conducive to icing settles over a particular hub. Identifying the extent of the icing layer within these clouds as well as the estimated intensity of icing with the FIT would provide valuable situational awareness. There were several cases were the FIT showed high skill in identifying smaller scale areas of icing around terminals that would have provided this situational awareness

***Legacy Atmospheric Profiling Products - (Baseline)***
**HWT Input:**The GOES Sounder LAP products were viewed most often by forecasters at the beginning of the shift as they conducted their initial environmental analysis. Additionally, some

forecasters viewed the products throughout the shift to get an update on how moisture and instability were evolving. Oftentimes they would use the LAP information as a check on the models and other environmental information (SPC meso-analysis, NUCAPS, etc). Participants liked the full-CONUS coverage of these environmental fields. Past product demonstrations have revealed that a portion of forecasters prefer fields with little-to-no data gaps, even if that means filling in the gaps with NWP data. In addition to the complete spatial coverage, the hourly availability and low-latency of the LAP products were appreciated, keeping forecasters aware of significant environmental trends as they occurred.

Participants consistently commented that gradients, maxima/minima, and trends in the LAP fields provided them with the most unique and accurate information, rather than the absolute values themselves. It was along the moisture/instability gradients and within the areas of increasing moisture/instability that convection most often developed. Alternatively, decreasing moisture/instability trends were often a sign that convective activity would cease. Forecasters would look back at the fields at the end of the day and see that convection had indeed developed along the gradients and in areas of increasing moisture/instability. Observing this early in the week gave forecasters confidence when using the tools as the week progressed. Additional forecast situations in which the LAP products aided participants included: dryline progression, depth of moisture in the atmosphere, progression of moisture return, elevated or surface-based storms, severe vs. non-severe storms, and convection in data sparse regions.

While the PW values appeared to be reasonably consistent with that from other data sources (e.g., Rapid Refresh Model, SPC meso-analysis, radiosondes), the LAP CAPE absolute values were often substantially different. This led participants to lose trust in the absolute values of the LAP CAPE field, which is the instability field of choice for most operational forecasters. The other major issue with the LAP products was the apparent "blotchiness" and unrealistic spatial variations that oftentimes appeared in the fields. This anomaly was addressed and mostly resolved by the developers after week 3, but deficiencies in the Sounder instrument cause some striping to remain.

***ACHA Cloud products - (Baseline)***

**AWC Input:** Estimating cloud bases is a challenging prospect given the lack of information in the satellite observations for some cloud types. How they are derived is therefore highly dependent upon the cloud type. The method is to first derive the cloud top height from ACHA and then to derive the geometrical thickness of the cloud layer. The cloud base height (CBH) is computed as the difference between the two. For cirrus and low-level water cloud, a direct estimation of the cloud geometrical thickness is possible from the satellite observations. For moderately thick clouds throughout the atmosphere, a set of regressions derived from CloudSat are used. Both the direct retrieval and CloudSat regressions use (1) the estimated cloud top, and (2) an estimated cloud layer thickness from cloud optical depth, cloudfrom GOES generated statistics. For the thickest clouds, the satellite observations provide little skill and the CCL Level from the NWP ancillary data is used to estimate the geometrical thickness. However, it is often the case that there are multiple layers of clouds which overlap. In these cases, the derived base is most indicative of that for the highest cloud layer. Treatment of these cases is being actively researched. The Cloud Base Heights were first evaluated in the 2016 Winter Experiment for the C&V effort. As mentioned in earlier sections, one of the major foci of the AWT experiments this year has been the Digital Aviation Services efforts and associated grid editing through GFE. The Winter Experiment was the first deep dive into this process and such was mainly an exercise in knobology. However, a cursory evaluation was done of the Cloud Base Height (hereafter referred to as CBH) product. The initial observation of this product by many forecasters was its high accuracy in single layer clouds. However, it did also have a marked struggled in areas multiple cloud layers. In those multiple layers, the bases were far too high, and it appeared the algorithm was estimating the base of the top most layer of clouds when compared to visible imagery.

***Atmospheric Motion Vectors product - (Baseline)***

**AWC Input:** One of the main concepts for the AMVs taken from last year was the possibility of utilizing them to aid in the forecast or verification of compression issues around major terminals. Compression is caused when the winds at upper levels are much higher than winds near the surface. As arrivals near the terminal, these stronger upper level winds cause aircraft to quickly catch up with those at lower levels in lighter winds. It is the opposite on take off if there are strong surface winds and lighter winds aloft. Because of the minimum distance requirements between aircraft, traffic flow managers are required to spread traffic out further in these cases and often end up having to delay or hold other flights. O'Hare and the New York area terminals are those where compression is a common issue and causes the biggest problems.

In 2016 the AWC began producing forecasts of vertical winds using the SREF, the idea being to provide traffic flow managers a forecast vertical profile of winds. However, this would not be limited to just the terminal point. The arrival and departure points of each terminal contain an expansive chunk of airspace and wind conditions and differ from one end to the other. Therefore, plots from the various approach and departure gates around the main hubs are also created. The first airport this has been explored for is ORD.

This is a very new concept and currently these plots are being verified using aircraft sounds and also RAOBs. The latter are typically only available at the center of the main hub and not at the various departure/arrival points. Additionally, aircraft soundings can be limited at times as they are only produced from certain types of aircraft.

It is here where AMVs could perhaps become useful. While AMVs are derived only for cloud objects in the top layer of clouds, the addition of many spectral channels from which winds can be derived will increase the density of winds in these layers. The layers themselves will not be consistent to a specific point, but by examining winds from various points within a region, forecasters may be able to get a better perspective on the vertical profile of winds. These could be compared to SREF wind forecast departure/arrival points as well as RAOBs and RAOB sounds to potentially 1) provide at least some wind forecast verification, 2) provide more insight on the accuracy and reliability of satellite derived winds, and 3) gauge whether satellite derived winds provide any information over and above current modeled winds.

### 2. Development of new GOES-R Weather Event Simulations and AWIPS-II transition support

CIMSS remains committed to assuring a smooth transition of all CIMSS research to operations products from the existing AWIPS software to the upcoming AWIPS-II. Preliminary work has been done finding a new product implementation approach for AWIPS-II. AWIPS-II activities are rapidly accelerating on the national scale to transition local applications between the two software environments. An AWIPS archive capable of archiving 60 days worth of AWIPS formatted files has been acquired through SSEC funding to support easier generation of WES cases AWIPS-II will soon be accessible for use at CIMSS, with training modules employing the new AWIPS software included as part of the VISIT/COMET training programs for operational satellite meteorology professional development. UW-CIMSS participated in multiple GOES-16/GOES-S Proving Ground organizational and testbed/PG demonstration planning telecons. Unidata is planning on conducting a regional AWIPS-2/Python/MetPy training session within

AOSS building (SSEC is within) in June 2017. This funding will help support the labor to attend since it directly enhanced Proving Ground capabilies.

### Publications (2015-2017)

Bedka, Kristopher M.; Wang, Cecilia; Rogers, Ryan; Carey, Lawrence D.; Feltz, Wayne and Kanak, Jan. Examining deep convective cloud evolution using total lightning, WSR-88D, and GOES-14 super rapid scan datasets. Weather and Forecasting, Volume: 30, Issue: 3, 2015, pp.571-590. Reprint # 7396.

Cintineo, Rebecca M.; Otkin, Jason A.; Jones, Thomas A.; Koch, Steven and Stensrud, David J.. Assimilation of synthetic GOES-R ABI infrared brightness temperatures and WSR-88D radar observations in a high-resolution OSSE. Monthly Weather Review, Volume 144, Issue 9, 2016, pp.3159-3180. Reprint # 7698.

Folmer, Michael J.; DeMaria, Mark; Ferraro, Ralph; Beven, John; Brennan, Michael; Daniels, Jaime; Kuligowski, Robert; Meng, Huan; Rudlosky, Scott; Zhao, Limin; Knaff, John; Kusselson, Sheldon; Miller, Steven D.; Schmit, Timothy J.; Velden, Chris and Zavodsky, Bard. Satellite tools to monitor and predict Hurricane Sandy (2012): Current and emerging products. Atmospheric Research, Volume: 166, 2015, pp.165-181. Reprint # 7433.

Gravelle, Chad M.; Mecikalski, John R.; Line, William E.; Bedka, Kristopher M.; Petersen, Ralph A.; Sieglaff, Justin M.; Stano, Geoffrey T. and Goodman, Steven J.. Demonstration of a GOES-R satellite convective toolkit to 'bridge the gap' between severe weather watches and warnings: An example from the 20 May 2013 Moore, Oklahoma, tornado outbreak. Bulletin of the American Meteorological Society, Volume 97, Issue 1, 2016, pp.69-84. Reprint # 7564.

Greenwald, Thomas J.; Pierce, R. Bradley; Schaack, Todd; Otkin, Jason; Rogal, Marek; Bah, Kaba; Lenzen, Allen; Nelson, Jim; Li, Jun and Huang, Hung-Lung. Real-time simulation of the GOES-R ABI for user readiness and product evaluation. Bulletin of the American Meteorological Society, Volume 97, Issue 2, 2016, pp.245-261. Reprint # 7570.

Line, William E.; Schmit, Timothy J.; Lindsey, Daniel T. and Goodman, Steven J.. Use of geostationary super rapid scan satellite imagery by the Storm Prediction Center. Weather and Forecasting, Volume 31, Issue 4, 2016, pp.483–494. Reprint # 7587.

Miller, Steven D.; Schmit, Timothy; Seaman, Curtis J.; Lindsey, Daniel T.; Gunshor, Mathew M.; Kohrs, Richard A.; Sumida, Yasuhiko and Hillger, Donald. A sight for sore eyes: The return of true color to geostationary satellites. Bulletin of the American Meteorological Society, Volume 97, Issue 10, 2016, pp.1803-1816. Reprint # 7780.

Rabin, Robert M.; Gultepe, Ismail; Kuligowski, Robert J. and Heidinger, Andrew K.. Monitoring snow using geostationary satellite retrievals during the SAAWSO Project. Pure and Applied Geophysics, Volume 173, Issue 9, 2016, pp.3085-3102. Reprint # 7732.

Schmit, Timothy J.; Goodman, Steven J.; Gunshor, Mathew M.; Sieglaff, Justin; Heidinger, Andrew K.; Bachmeier, A. Scott; Linstrom, Scott S.; Terborg, Amanda; Feltz, Joleen; Bah,Kaba; Rudlosky, Scott; Lindsey, Daniel T.; Rabin, Robert M. and Schmidt, Christopher C.. Rapid refresh information of significant events: Preparing users for the next generation of geostationary operational satellites. Bulletin of the American Meteorological Society, Volume: 96, Issue: 4, 2015, pp.561-576, supplement. Reprint # 7393.

**7.2 Participant Support for "GOES-R Preview for Broadcasters" Short Course at the AMS Conference on Broadcast Meteorology**
**CIMSS Task Leader: Mathew Gunshor**
**NOAA Collaborator: Timothy J. Schmit**
**Budget: $6,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

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

**CIMSS Research Themes:**
- Education and Outreach

**Objective**
Provide participant support for a GOES-R Short Course presented at the AMS Conference on Broadcast Meteorology.

**Project Overview**
This small project is meant as a supplement to another CIMSS project that covers instructor time, travel, and preparation for GOES-R short courses at AMS meetings, which is called "ABI Short Courses (CIMSS Support to GOES-R Program)."

**Milestones with Summary of Accomplishments and Findings**
CIMSS participated in the 2016 AMS Conference on Broadcast Meteorology short course and provided support for participants.

**7.3 Delivery of New Generation Weather Satellite Training Workshop for Satellite Liaisons and Related Personnel**
**CIMSS Task Leader: Jordan Gerth**
**CIMSS Support Scientist: Scott Lindstrom**
**NOAA Collaborators: Tim Schmit, National Environmental Satellite, Data, and Information Service Advanced Satellite Products Branch; and Bill Ward, National Weather Service Pacific Region Headquarters**
**Budget: $20,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

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

**CIMSS Research Themes:**
- Satellite Meteorology Research and Applications
- Education and Outreach

## Objective

Ensuring a knowledgeable workforce is an essential component of the National Weather Service (NWS) goal of "day one" readiness for the Geostationary Operational Environmental Satellite R-Series (GOES-R) in the agency. This workshop, leveraging the subject-matter expertise of CIMSS, sought to build the core competency of the satellite liaisons and related personnel to a common baseline, ensuring accessible and consistent resources across the NWS for operational meteorologists.

## Project Overview

Under this project, an instructor-led training workshop on the new-generation geostationary weather satellites and their imagers, the Advanced Himawari Imager (AHI) and Advanced Baseline Imager (ABI), was held at the National Weather Service (NWS) Training Center in Kansas City, Missouri. The workshop established a critical core competency amongst satellite liaisons and related personnel for using and applying Himawari and Geostationary Operational Environmental Satellite R-Series (GOES-R) imagery in the weather analysis and forecast process. A team of two instructors from the University of Wisconsin and a subject-matter expert from the NOAA NESDIS Advanced Satellite Products Branch (ASPB) traveled to Kansas City in March 2016 to deliver a 16-hour workshop, consisting of approximately four three-hour segments over three days. The majority of the workshop time was spent with participants working in groups of two or three on notebook computers that ran visualization software, the Satellite Information Familiarization Tool (SIFT), specifically developed for this and similar workshops.

Following successful completion of the workshop, each participant had:

- reaffirmed their understanding of core principles in radiation science;
- developed familiarity with the AHI's and ABI's spatial, spectral, and temporal resolution; and
- Increased their ability to select and use certain bands of satellite imagery from AHI and ABI to solve short-term weather analysis and forecast challenges.

## Milestones with Summary of Accomplishments and Findings

There were twelve participants in the workshop, with the majority of them holding satellite liaison positions. Most participants had served in that capacity for less than five years. An online assessment required of participants at the beginning and end of the workshop was used to determine the extent of learning that the workshop facilitated. Ten of the twelve participants saw an increase in their exit assessment score compared to the entrance assessment, and one of the two participants that saw a decrease had a proficient entrance assessment score and the decrease was slight.

The first day provided background information on the capabilities of the new instruments and reviewed concepts of remote sensing with weather satellites. Specifically, the two time blocks covered:

- Core knowledge, such as the introduction to the GOES-R and/or Himawari imagers and individual bands, including a summary of major concepts in radiation science and major changes to the current imagery (spatial, spectral, and temporal resolutions); and
- Composite imagery (RGBs) and how to use them effectively in the analysis and forecast process alongside quantitative products.

The second day emphasized meteorology skills for analyzing satellite imagery in data sparse regions. The two time blocks covered:

- Methods for identifying, tracking, and corroborating vorticity maxima and minima, and other atmospheric features (mesoscale convective systems), with numerical weather prediction analyses; and
- Roles for satellite imagery in preparing terminal aerodrome forecasts, including determining aircraft hazards, such as low ceilings, turbulence, and volcanic ash.

## 8. CIMSS Support to GOES-R AWC/NWSTC Satellite Liaison and High Impact Weather

### 8.1 CIMSS High Impact Weather Studies with GOES-R Series ABI and LEO Advanced IR Sounder Data

**CIMSS Task Leader: Jun Li**
**NOAA Collaborator: Timothy J. Schmit (STAR/NESDIS), John L. (Jack) Beven (NHC/NWS), Vijay Tallapragada, (EMC/NWS), Mark DeMaria (NHC/NWS), and Andrew Collard (EMC/NWS)**
**Budget: $175,000**

**NOAA Long Term Goals:**
- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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
- Environmental Models and Data Assimilation

### Objective
The objectives of this CIMSS high impact weather (HIW) studies are to improve the high impact weather (HIW) forecasts with high temporal and spatial resolution GOES-R series water vapor measurements, and to study value-added advanced IR sounder measurements from polar-orbiting satellites for HIW warning, nowcasting and short-range forecasting.

### Project Overview
The first objective of this CIMSS high impact weather (HIW) studies is to improve the high impact weather (HIW) forecasts with high temporal and spatial resolution GOES-R series water vapor measurements. High temporal resolution GOES-R series ABI (Advanced Baseline Imager), the current GOES Sounder, and Advanced Himawari Imager (AHI) moisture measurements are used for HIW short-range forecasting through data assimilation in regional and storm scale numerical weather prediction (NWP) models. The second objective is to study value-added advanced IR sounder measurements from polar-orbiting satellites for HIW warning, nowcasting and short-range forecasting, and to demonstrate the advantage of combined GOES-R series ABI and JPSS/Metop advanced IR sounder measurements in HIW nowcasting and short-range forecasting. IASI and CrIS from POES, together with ABI, the current GOES Sounder, and AHI from GEO will be used for this purpose (e.g., study the application of atmospheric moisture and

instability information from the combined POES/GOES measurements in pre-convection environment for warning and forecasting).

## Summary of Accomplishments and Findings

### *AHI observations (AMVs, layered precipitable water - LPW) assimilation experiments were conducted with SDAT, positive impact found from AHI on Typhoon forecasts*

One of the key information GOES-R series ABI will provide is the high temporal and spatial resolution moisture and AMVs. Using CIMSS SDAT as research testbed, the following questions related to better assimilation of ABI moisture information is addressed:

- How to better use GOES-R three water vapor (WV) bands information in regional NWP? What is the impact from assimilating the three layered Precipitable Water (LPW) and AMV information for TC forecasts?
- How to assimilate the very high temporal information from ABI in regional NWP (e.g., 3DVAR, 4DVAR, or more frequent assimilation)? What is the impact from 3DVAR, 4DVAR, and more frequent assimilation?

The AHI three layered PW (LPW) retrievals with GOES-R series legacy atmospheric profile (LAP) algorithm developed by GOES-R AWG sounding team are used for this study. The model resolution is 12 km for tropical cyclones (TCs) and 4 km for local storms in this study. Figure 55 shows the track and intensity RMSE for Typhoon Soudelor (2015) case from CIMSS SDAT (Satellite Data Assimilation for Tropical storms, http://www.ssec.wisc.edu/sdat), which is based on WRF/GSI. The horizontal resolution is 12 km with 51 vertical layers. Data are assimilated and forecasts are updated every 6 hours from 06 UTC 03 to 00 UTC 05 August 2015.

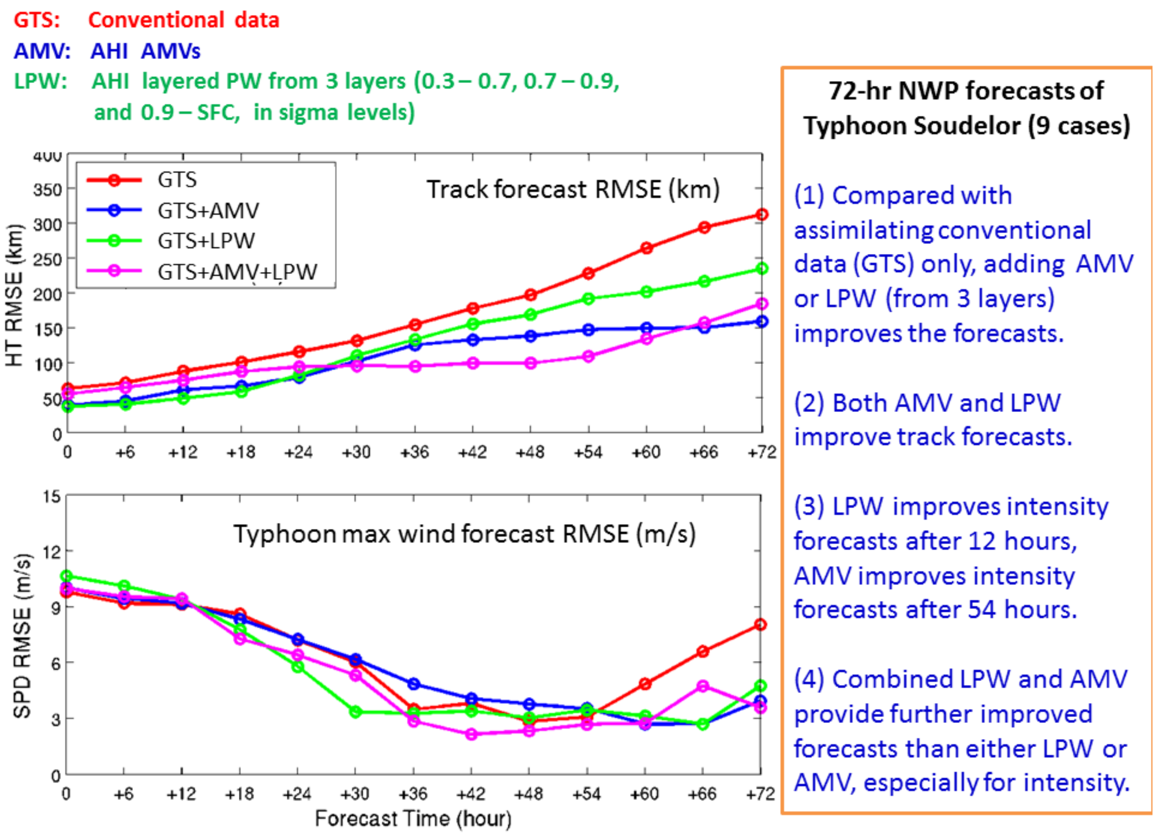



**Figure 55. The track and intensity RMSE for Typhoon Soudelor (2015) case from CIMSS SDAT.**

### *Positive impact from assimilation of AHI LPW on local severe storm (LSS) forecasts*

AHI moisture information (LPW) assimilation experiments were conducted with regional and storm scale NWP models, positive impact found from AHI moisture assimilation on local severe storm (LSS) forecasts, especially for heavy rainfall forecasts, upper and lower tropical moisture in the environment are more important in the assimilation for precipitation forecasts, which is consistent with findings from assimilating the current GOES Sounder LPWs over CONUS for LSS forecasts. The Himawari-8 AHI three LPW retrievals using GOES-R series LAP algorithm are used as proxy of ABI for this study. The model resolution is 4 km for this LSS study. The model and assimilation configurations are indicated in the left panel of Figure 56 for Beijing 7.19 – 7.20 LSS case (2016), while the case domain and precipitation observation is outlined in the right panels of the figure.

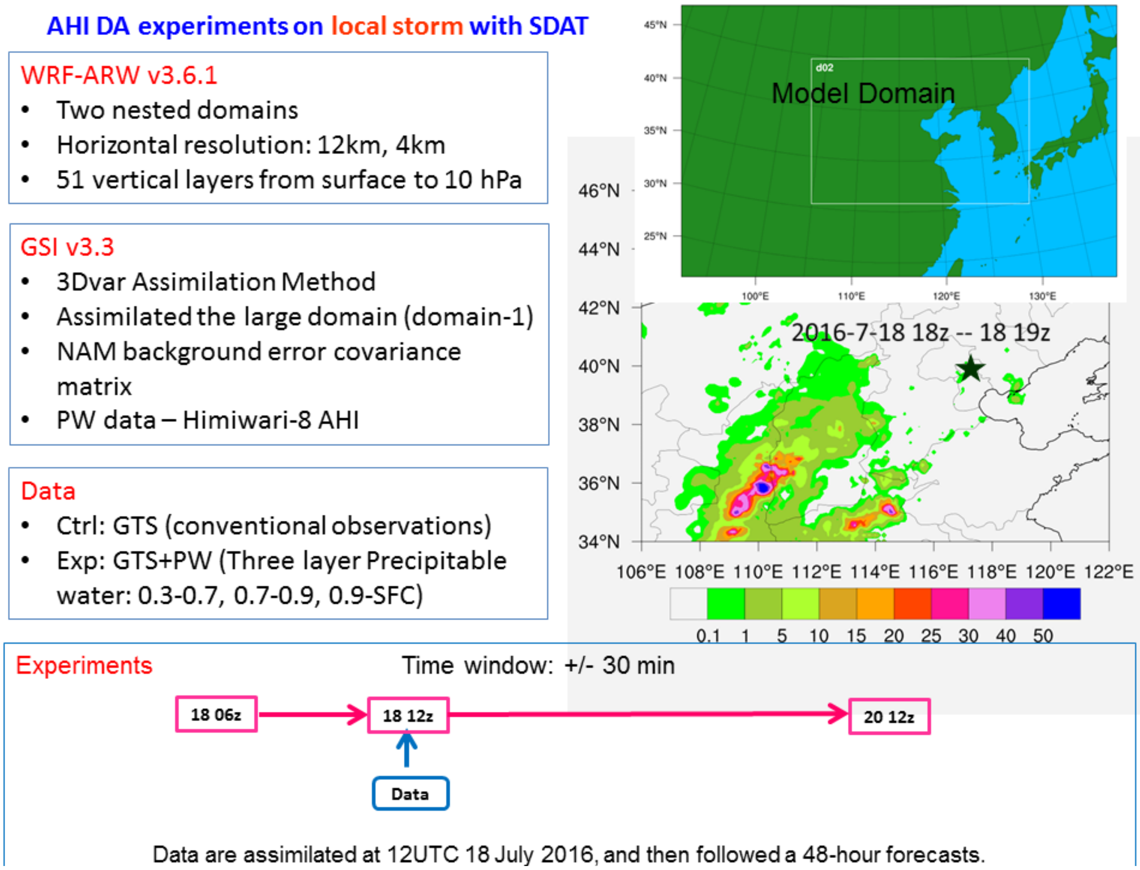



**Figure 56. Model and assimilation configurations (left), model domain and precipitation observation (right panels) for Beijing 7.19 – 7.20 LSS case (2016).**

Figure 57 shows the 12-hour cumulative precipitation from observations (upper left), forecasts with conventional data assimilation (lower left) and with conventional+AHI data assimilated (lower left), along with from two operational models (GFS and CMA BJ-RUC) (upper middle and upper right panels). It can be seen that AHI LPWs improve the precipitation forecasts over conventional data, and are also better than the operational forecasts in this particular heavy rain case.

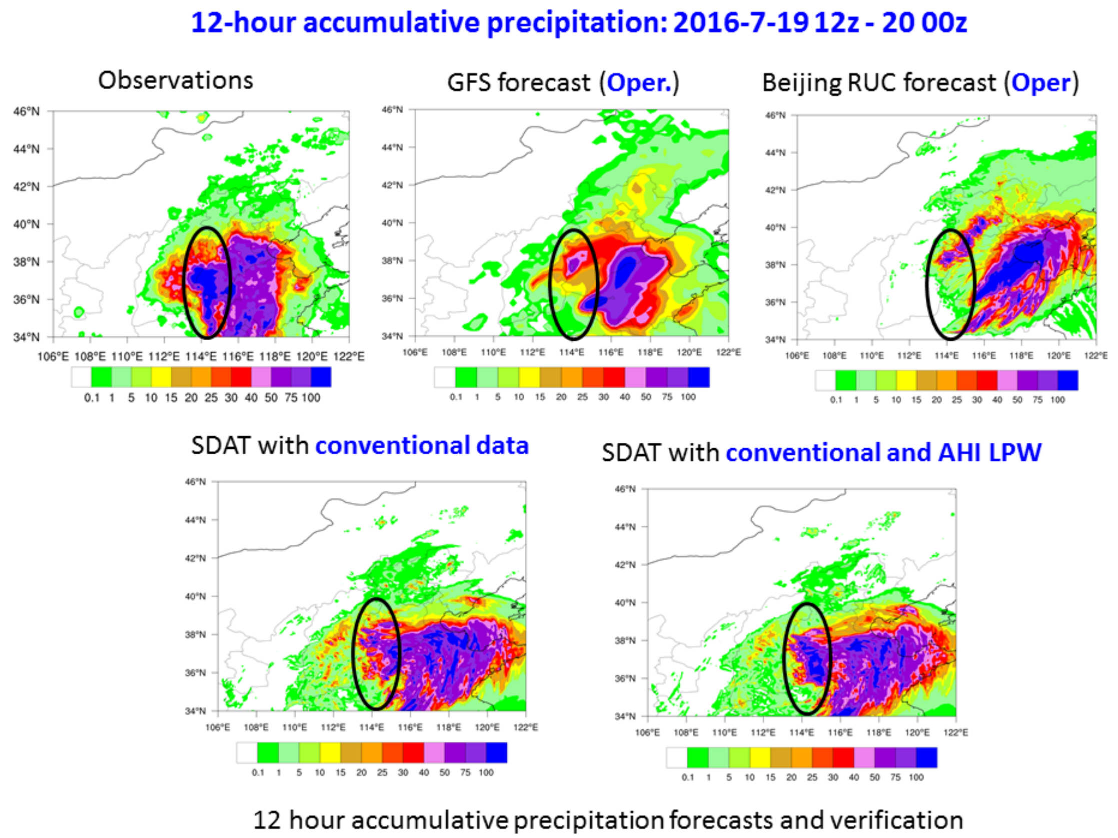



**Figure 57. The 12-hour cumulative precipitation from observations (upper left), forecasts with conventional data assimilation (lower left) and with conventional+AHI data assimilated (lower left), along with from two operational models (GFS and CMA BJ-RUC) (upper middle and upper right panels).**

Figure 58 shows the ETS scores from GTS (red) and GTS+LPW (blue), along with operational forecasts (CMA BJ-RUC, one of the CMA regional operational NWP systems). The 6-hour cumulative precipitation forecasts from assimilating GTS+LPW are significantly improved from assimilating only GTS, and are much better than that from CMA operational forecasts.

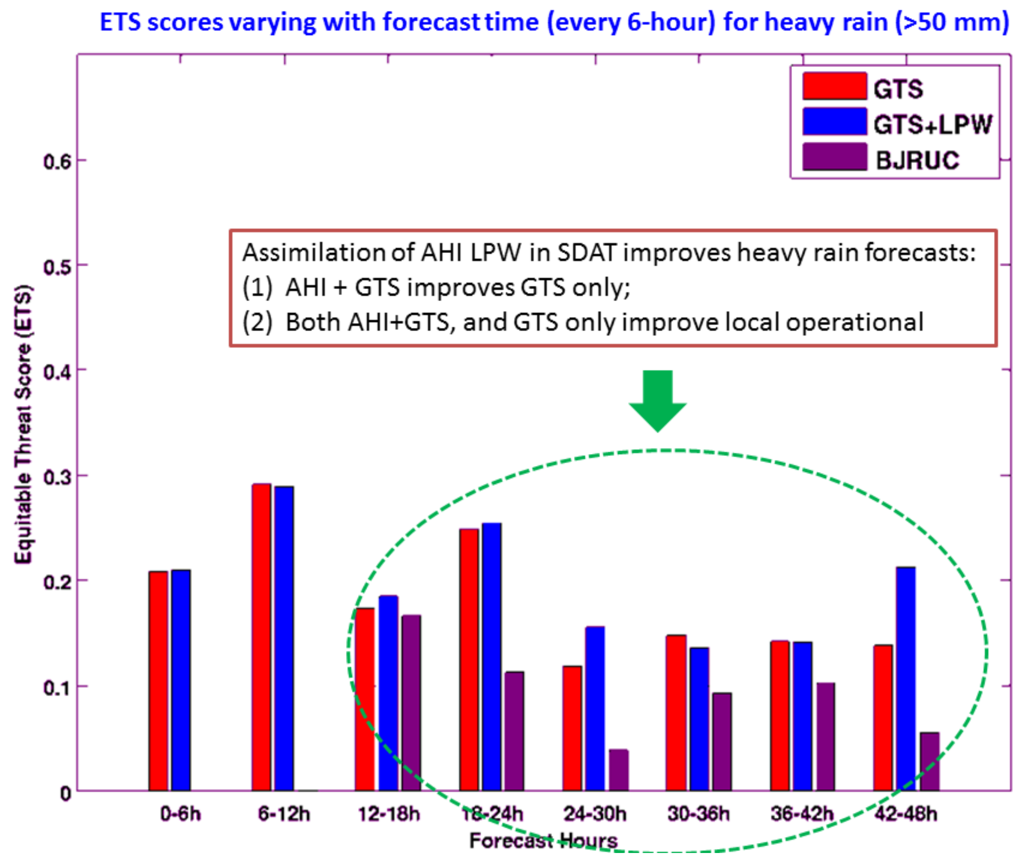



**Figure 58. The ETS scores from GTS (red) and GTS+LPW (blue), along with operational forecasts (CMA BJ-RUC, one of the CMA regional operational NWP systems).**

### Publications and Conference Reports

Ai, Y., J. Li, T. Schmit, and C. Cao, 2016: Deep Convective Cloud Characterizations from both Broadband Imager and Hyperspectral Infrared Sounder Measurements, Journal of Geophysical Research – Atmospheres (accepted).

Li, J., et al., 2016: On the assimilation of satellite sounder data in cloudy skies in the numerical weather prediction models, Journal of Meteorological Research, 30, 169 - 182.

Li, J., 2016: Improving JPSS and GOES-R applications with CIMSS near real-time satellite data assimilation for tropical cyclone forecasts, feature article, JPSS.

Li, Jun, Pei Wang, Zhenglong Li and Mitch Goldberg, 2016: On the assimilation of hyperspectral infrared sounder radiances in cloudy skies in numerical weather prediction models – challenges and practical approaches, 7th Asia-Oceania/2nd AMS-Asia/2nd KMA Meteorological Satellite Users' Conference, 21 – 28 October 2016, Songdo, Incheon, Korea.

## 8.2 CIMSS Collaboration with the Aviation Weather Center

**CIMSS Task Leader: Wayne Feltz**
**CIMSS Support Scientist: Amanda Terborg**
**NOAA Collaborator: Jeff Key**
**Budget: $130,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:** 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
- Education and Outreach

## Objective
This project entails activities focused at maximizing the forecast value of geostationary satellite data and products, particularly activities centered on aviation weather impacts to the National Airspace System and improving the safety of flight.

## Project Overview
The Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison is supporting the expanding use of satellite-based aviation weather products by placing a CIMSS research scientist at the Aviation Weather Center in Kansas City, MO. The CIMSS scientist is providing leadership, satellite expertise, and meteorological support for the GOES-R Proving Ground efforts based at the National Weather Service (NWS) Aviation Weather Center (AWC).

Amanda Terborg is working closely with the Aviation Weather team at CIMSS, researchers at the NOAA/NESDIS/STAR and GOES-R Program Office, and the staff at the Aviation Weather Center. The position is with the University of Wisconsin-Madison and the position's duty station is at the Aviation Weather Center in Kansas City, MO.

The position is embedded within the NOAA Aviation Weather Testbed (AWT) at the AWC. The AWT provides the infrastructure and facilities to develop, test and evaluate new and emerging scientific techniques, products, and services. The AWT 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.

## Summary of Accomplishments and Findings
This project entails activities focused at maximizing the forecast value of geostationary satellite data and products, particularly activities centered on aviation weather impacts to the National Airspace System and improving the safety of flight. The CIMSS research scientist 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.

The principal duties of this position are:

- Serve as a "Satellite Liaison" at the AWC, leading GOES-R Proving Ground efforts on satellite based hazardous aviation weather products and demonstrating the unique value of satellite information to forecasters;
- Lead in the GOES-R ground readiness effort at the AWC;
- Collaborate with Alaska Region in support of GOES-R Proving Ground activities at the Alaska Aviation Weather Unit;
- Serve as "implementation expert" for selected planned GOES-R and Himawari products and their proxies;
- Test and validate proposed new satellite dependent products and decision aids for operational forecasters with an emphasis on exploring the value of advanced satellite derived products for observing or predicting aviation hazards (e.g., turbulence, icing, convection, ceiling, visibility, volcanic ash);
- Develop and/or document how these satellite dependent products and decision aids may decrease the impact of weather on the National Airspace System by improving air traffic flow management and enhancing the safety of flight;
- Participate in routine experimental projects serving as the focal point for all satellite centered activities at the AWC;
- Lead in training operational forecasters on new and emerging satellite-based techniques and tools, particularly those for aviation developed or evaluated in the AWT;
- Provide satellite expertise in the logistical support of any special or field excursion experiments, such as the planned AWT Impact Decision Support Experiments (IDSE);
- Bridge satellite-related activities between the FAA's NextGen Weather Program and the NWS by collaborating with the Aviation Weather Demonstration and Evaluation (AWDE) testbed at the FAA's Tech Center in Atlantic City, NJ;
- Represent the GOES-R effort within the AWT by contributing to formal scientific publications or attending off-site conferences, symposia, and aviation weather-related outreach events;
- Develop synergy and shared accomplishments with the GOES-R Proving Ground at the Hazardous Weather Testbed (HWT) in Norman, Oklahoma and the NWS Proving Ground at the NWS Training Center (NWSTC) in Kansas City, Missouri; and
- Perform related duties as assigned.

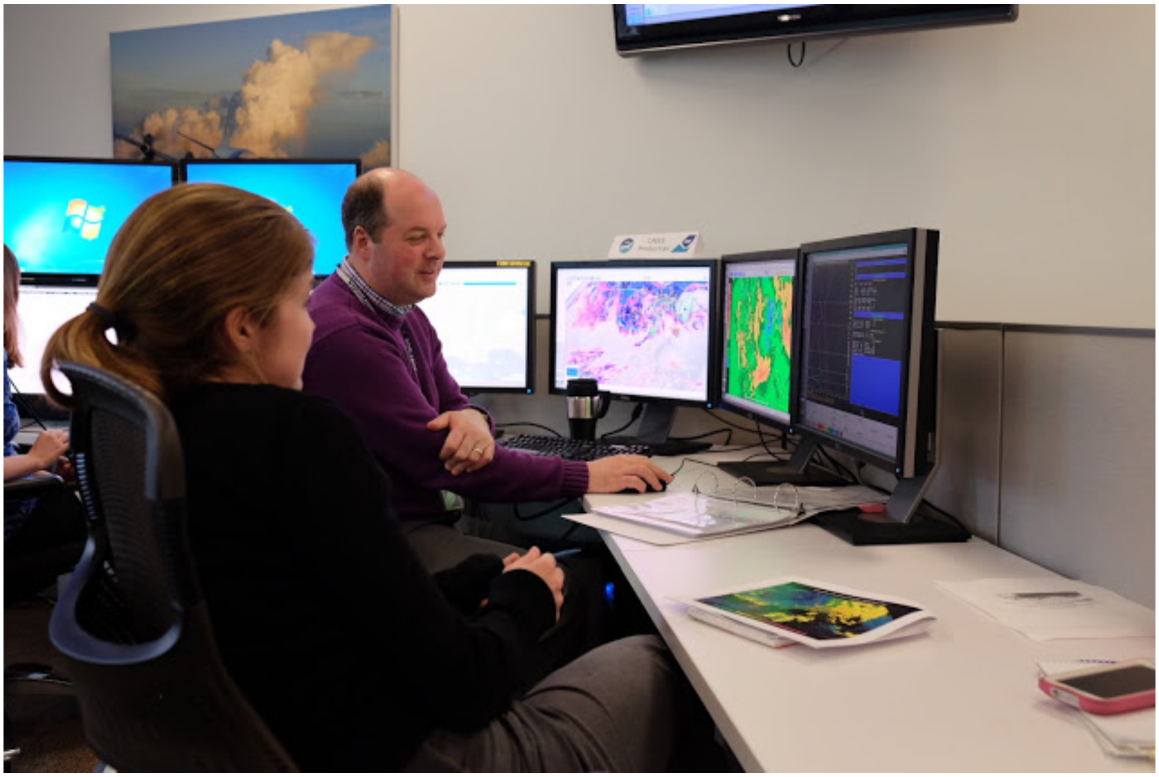


**Figure 59. Discussion of satellite related icing products at the non-convective CAWS product desk during the AWT Winter Experiment 2016.**

## Publications and Conference Reports

Terborg, Amanda M.; Stano, Geoffrey T., 2016: *Impacts to Aviation Weather Center operations using total lightning observations from the pseudo-GLM*, submitted to *NWA J. Operational Meteorology.*

## 8.3 CIMSS Collaboration with the NWS Operations Proving Ground
**CIMSS Task Leader: Chad Gravelle**
**CIMSS Support Scientist: Wayne Feltz**
**NOAA Collaborator: Tim Schmit**
**Budget: $156,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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
- Education and Outreach

## Objective

The CIMSS collaboration with the NWS Operations Proving Ground focuses on maximizing analysis and forecast value of geostationary satellite data and products, particularly activities centered on NWS weather forecast office operations to improve forecast and warning services to the nation.

## Project Overview

This project entails activities focused on interactions with NWS forecasters at weather forecast offices to prepare them for new satellite dependent products that will become operational after the launch of the GOES-R satellite series.

## Milestones with Summary of Accomplishments and Findings

The following are recent milestones and accomplishments:

- 4-h GOES-R session for new NWS Science and Operations Officers during the 2015 COMET Mesoscale Analysis and Prediction course was organized and delivered;
- Manuscript submitted to the American Meteorological Society's Weather, Analysis & Forecasting journal titled "Forecaster Evaluations of High-Temporal Satellite Imagery for the GOES-R Era at the NWS Operations Proving Ground";
- Operations Proving Ground evaluation on operational applications of multispectral bands for the GOES-R era was coordinated and facilitated; and
- NWS Central and Eastern Region evaluation on the CIMSS ProbSevere Model is currently being coordinated and facilitated.

## Publications and Conference Reports

Gravelle, C. M., J. R. Mecikalski, W. E. Line, K. M. Bedka, R. A. Petersen, J.M. Sieglaff, G. T. Stano, and S. J. Goodman, 2016: Demonstration of a GOES-R satellite convective toolkit to ''bridge the gap'' between severe weather watches and warnings: An example from the 20 May 2013 Moore, Oklahoma, tornado outbreak. *Bull. Amer. Meteor. Soc.*, **97**, 69–84, doi:10.1175/BAMS-D-14-00054.1.

Gravelle, C. M., K. J. Runk, K. L. Crandall, and D. W. Snyder, 2016: Forecaster evaluations of high-temporal satellite imagery for the GOES-R era at the NWS Operations Proving Ground. *Wea. Forecasting*, In Press.

43rd American Meteorological Society Conference on Broadcast Meteorology. Raleigh, NC. *GOES-R Derived Products for Operational Meteorology*. 9 June 2015.

2015 Satellite Proving Ground/User Readiness Meeting. Kansas City, MO. *Preliminary Results from the Operations Proving Ground 1-minute Satellite Imagery Evaluation*. 17 June 2015.

2015 COMET Mesoscale Analysis and Prediction (COMAP) Course. Boulder, CO. *Capabilities of The Next-Generation Geostationary Environmental Satellite System for Operational Meteorology*. 17 July 2015.

2015 High Plains Conference. Goodland, KS. *Capabilities of The Next-Generation Geostationary Environmental Satellite System for Operational Meteorology*. 12 August 2015.

2016 American Meteorological Society Annual Meeting. New Orleans, LA. *Enhancing Impact-Based Decision Support Services in the GOES-R Era*. 13 January 2016.

St. Louis, MO AMS Chapter Local Meeting. *Capabilities of The Next-Generation Geostationary Environmental Satellite System for Operational Meteorology*. St. Louis, MO. 18 February 2016.

St. Louis, MO NWS Forecast Office Visit. St. Louis, MO. 19 February 2016.

Douglas County, KS Emergency Management Severe Weather Symposium. Lawrence, KS. *Observing the Initiation and Development of Convection in the GOES-R Era*. 5 March 2016.

## 9. CIMSS Support to GOES-R SHyMET, McIDAS-V, and Program Support Tasks

### 9.1 CIMSS Participation in SHyMet for 2016
**CIMSS Task Leader: Steve Ackerman**
**CIMSS Support Scientists: Scott Lindstrom, Scott Bachmeier**
**NOAA Collaborators: Tim Schmit, Anthony Mostek, Brian Motta, Ross van Til**
**Budget: $150,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

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

**CIMSS Research Themes:**
- Satellite Meteorology Research and Applications
- Education and Outreach

**Objective**
SHyMet work at CIMSS focuses on developing current and pertinent case studies that demonstrate Satellite Capabilities in the forecast process

**Project Overview**
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. SHyMet seeks to educate NWS forecasters on remote sensing in general and satellite capabilities in particular. Now that GOES-16 is launched, particular emphasis is on replacing dated content (GOES-15 and earlier) with GOES-16-based content.

**Milestones with Summary of Accomplishments and Findings**
Potential cases for SHyMet modules are placed on the CIMSS Satellite Blog (http://cimss.ssec.wisc.edu/goes/blog); GOES-16 data are now flowing into both McIDAS and AWIPS at CIMSS; there are many pertinent entries (http://cimss.ssec.wisc.edu/goes/blog/archives/category/goes-16). Himawari-8 data (http://cimss.ssec.wisc.edu/goes/blog/archives/category/himawari-8) is an also excellent proxy for GOES-R and has provided useful data in preparation for GOES-R.

## Publications and Conference Reports

Lindley, T. T., A. R. Anderson, V. N. Mahale, T. S. Curl, W. E. Line, S. S. Lindstrom and A. S. Bachmeier, 2016: Wildfire Detection Notifications for Impact-based Decision Support Services in Oklahoma Using Geostationary Super Rapid Scan Satellite Imagery, *J. Operational Meteor.*, **4**(14), 182-191, doi: http://dx.doi.org/10.15191/nwajon.2016.0414

Ward, B., and co-authors, 2017: The Satellite Foundational Course for GOES-R: A Collection of Lessons to Prepare National Weather Service Forecasters for GOES-R, 13th Annual Symposium on New Generation Operational Environmental Satellite Systems, American Meteorological Society, Seattle, WA, 22-26 January 2017.

Lindstrom, Scott S., T. J. Schmit, J. J. Gerth, M. M. Gunshor, M. Mooney, and T. M. Whittaker, 2017: Hands-on Activities Designed to Familiarize National Weather Service Forecasters with Data from ABI on GOES-R and AHI on Himawari-8, 26th Symposium on Education; and the 33rd Conference on Environmental Information Processing Technologies, American Meteorological Society, Seattle, WA, 22-26 January 2017.

Gerth, Jordan J., D. Hoese, R. Garcia, S. Lindstrom, and K. Strabala, 2017: Visualizing New-Generation Geostationary Satellite Imagery with SIFT**,** 13th Annual Symposium on New Generation Operational Environmental Satellite Systems, American Meteorological Society, Seattle, WA, 22-26 January 2017.

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Garcia, Ray K., D. Hoese, J. J. Gerth, S. S. Lindstrom, K. I. Strabala, T. J. Schmit, and B. Ward, 2016: GOES-R ABI and Himawari-8 AHI Training using SIFT, Oral Presentation at 21st Conference on Satellite Meteorology, American Meteorological Society, Madison WI, 15-19 August 2016.

Schmit, Timothy J, M. M. Gunshor, R. B. Pierce, J. J. Gerth, S. S. Lindstrom, J. M. Daniels, and S. J. Goodman, 2016: Getting Ready for the Advanced Baseline Imager (ABI) on the GOES-R series, Oral Presentation at 21st Conference on Satellite Meteorology, American Meteorological Society, Madison WI, 15-19 August 2016.

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Gunshor, M., T. J. Schmit, J. J. Gerth, S. S. Lindstrom, C. Schmidt, K. I. Strabala, and A. S. Bachmeier, 2016: Helping Prepare Users for the GOES-R Series, Poster Presentation at 21st Conference on Satellite Meteorology, American Meteorological Society, Madison WI, 15-19 August 2016.

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**9.2 Ongoing Support**
**CIMSS Task Leader: W. Paul Menzel**
**NOAA Collaborators: Tim Schmit, Steve Goodman**
**Budget: $50,000**

**NOAA Long Term Goals:**
- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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
- Education and Outreach

**Objective**
Dr. W. Paul Menzel (WPM) to participate in research on environmental remote sensing systems that helps to guide NOAA in evolving the GOES-R and JPSS satellite holdings

**Project Overview**
Project includes (1) facilitating research demonstrations of new capabilities from GOES-R and JPSS, (2) teaching remote sensing seminars to new researchers, (3) participating in Technical Advisory Committees, JPSS Reviews, and other evaluations, (4) presenting research results at appropriate venues, and (5) collaborating with international partners pursuing the same goals.

**Summary of Accomplishments and Findings in Past Year**

***Evolving the HYDRA Toolkit***
"HYDRA2 – A Multispectral Data Analysis Toolkit for sensors on Suomi NPP and other current satellite platforms" by Rink, Menzel, Strabala, and Gumley was published in the July 2016 BAMS. HYper-spectral data viewer for Development of Research Applications version 2 (HYDRA2) is a freeware-based multispectral analysis toolkit for satellite data that assists scientists in research and development as well as education and training of remote sensing applications. HYDRA2 can be used with direct broadcast and archived data from sensors on the NOAA/NASA Suomi National Polar-orbiting Partnership (S-NPP), NASA Aqua/Terra, EUMETSAT MetOp, and Chinese Feng Yun-3 platforms.

***AMS Conference on Satellite Meteorology***
At the request of Dr Steve Goodman, Dr Menzel gave an invited presentation at the 21th Conference on Satellite Meteorology, Oceanography and Climatology of the AMS, "Celebrating the Nation's Operational Environmental Satellites: Past, Present and Future - A Special Session Honoring Gregory Mandt" on 15 August 2016. His talk "R2O with GOES: Remembering GIMPAP & GOES-R3" included several highlights from Greg's career.

### Collaborations with EUMETSAT

(1) On 27 June, upon invitation from EUMETSAT, Dr Menzel attended its 30th anniversary celebration. Approximately 150 administrators and scientists from all over the globe came to celebrate and remember events and people from the past 30 years. Representing SSEC and CIMSS, he presented a plaque of congratulations to Director General Alain Ratier. (2) On 2 August, Stephen Tjemkes and Rolf Stuhlmann visited SSEC to discuss MTG-IRS issues and to give a seminar on the MTG-IRS level 2 processing chain and the near real time demonstration efforts. (3) In September, at the EUMETSAT Conference, Dr Menzel gave an invited talk on "A perspective on the history of satellite observations – from Uncalibrated Flying Objects (UFOs) to Finely Tuned Sensors (FTSs)." It included a brief look at the evolution of satellite sensors in polar and geostationary orbit, the challenges of calibrating the radiometric measurements, the improvement from high spectral resolution infrared measurements in radiative transfer physics (with a focus on CO2, H2O, and O3 molecular interactions) as well as sensor calibrations, and finally a brief perspective on implications of 50 year records for climate and NWP studies.

### Selection Committee for the David Johnson Award

Dr Menzel served again on the David Johnson Award selection panel in October. Dan Lindsey was chosen for his work in preparing NOAA for ABI data usage upon launch.

### Consultation with the Chinese Meteorological Administration (CMA)

(1) Dr Menzel participated in the Third International Strategic Consultative Committee (ISCC) Meeting on Chinese Meteorological Satellite Programmes held from 15 to 18 November 2016 in Shenzen, China. The ISCC-3 was co-chaired by Dr. Tillmann Mohr, Germany, and Dr. Yang Jun, CMA. Ten international experts and by sixty-two experts from China focused on the polar orbiting satellite plans of China, in particular the early morning FY-3E to be launched in 2018. ISCC discussed considerations for spacecraft configuration, imager resolutions, sounder characteristics, NWP impacts, climate data records, challenges of terminator orbits, and space constellation opportunities. NSMC scientists presented updates to their plans for the FY-3 series; early morning FY-3E in 2018 will have an IR FTS sounder (HIRAS), MW sounders (MWTS and MWHS), imager with a DNB, a surface wind radar (WindRAD), and GPS. 15 recommendations were made for CMA administrator Guoguang Zheng to consider; all were accepted. (2) With the successful launch and post-launch checkout of the FY-4A, Dr Menzel is now discussing with CMA the possibility of analyzing a sample of the level 1 geostationary hyperspectral sounder (GIIRS) data. This would include (a) evaluation of the internal consistency of the brightness temperatures in spatial, temporal, and spectral studies along with (b) inter-calibration with CrIS and IASI.

### Coordinating with Indian Scientists on INSAT-3D Utilization

With the launch of another INSAT sounder, Dr Menzel and Dr Sanjay LiMaye have been in conversation with scientists at ISRO to obtain spectral and radiometric information that would enable further SSEC investigations and collaborations. Progress is anticipated in 2017.

### Co-authoring an AMS Monograph on Verner Suomi

A draft of "Verner Suomi's View of Weather and Climate from Space: A Scientific Biography" (authors - John Lewis, Jean Phillips, Tom Vonderhaar, Fred House, and Paul Menzel) was forwarded to the AMS in January 2017; Dr Menzel wrote sections of the chapters on Perfect Timing: NWP and Satellite Meteorology Merge, Panoramic View of Suomi's Research Themes at SSEC, and Suomi's Model for Conducting Research at SSEC.

**9.3 McIDAS-V Development for GOES-R Development**
**CIMSS Task Leader: Tom Rink**
**CIMSS Support Scientist: Brad Pierce**
**NOAA Collaborator: Brad Pierce**
**Budget: $29,000**

**NOAA Long Term Goals:**

- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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
- Environmental Models and Data Assimilation
- Education and Outreach

**Objective**
Develop Interactive, 3D Visualization of Wind Parcel Trajectories.

**Project Overview**
Design and develop forward/reverse wind parcel trajectory computation and visualization through 2D/3D, earth navigated, gridded Eulerian wind fields with interactive control in McIDAS-V. Potential applications relevant to GOES-R, and under development, include: display 3D trajectories through time based on ABI retrieved Aerosol optical depth (AOD) and numerical model wind forecast, visualize the forward trajectories of parcels in the vicinity of volcanic eruption with respect to ash/SO2 retrievals, trace conservative atmospheric stability parameters such as Equivalent Potential Temperature from NWP or analysis wind field.

**Milestones with Summary of Accomplishments and Findings**
Started implementation of backward trajectory computation, i.e., parcel origin from previous time steps for a current selected location. Implement parcel displacement to be computed as in NOAA Hysplit. Leverage new interactive user-interface features for selecting parcel start locations and density. Demonstration of application to JPSS VIIRS Smoke Proving Ground (Figure 60).

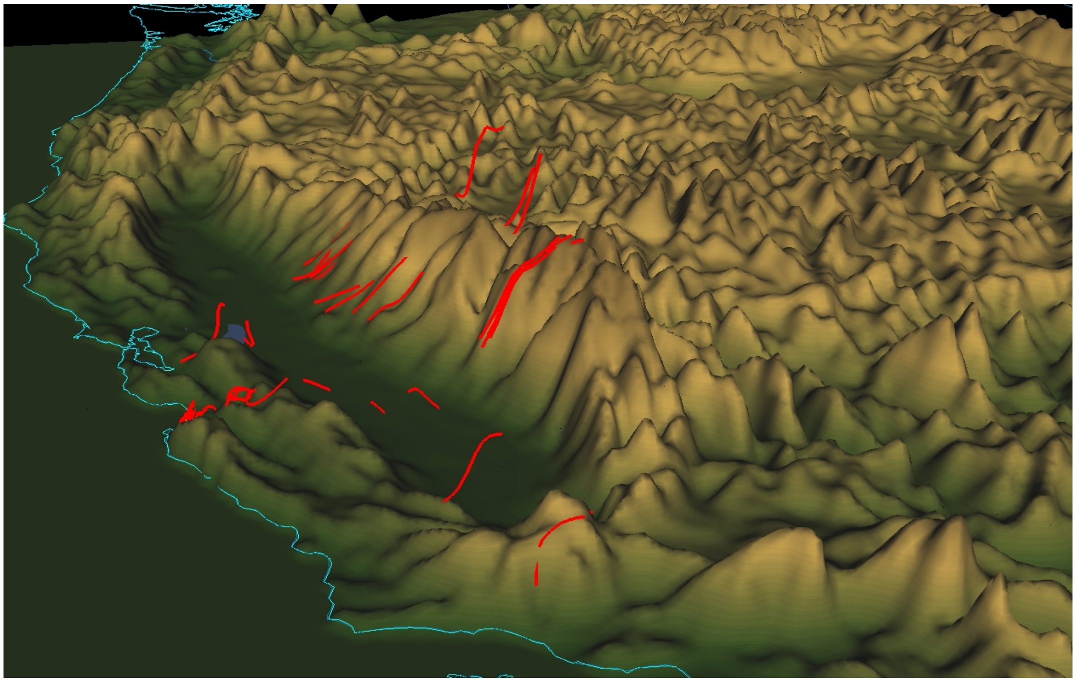


**Figure 60. McIDAS-V generated parcel trajectories (red lines) from NAM hires (4km) 3D wind field. Parcels were initialized in the boundary layer on 07-31-2016, 19Z at locations with aerosol optical depth (AOD) > 0.5 as determined from VIIRS.**

### Publications and Conference Reports

AMS Annual Meeting (IIPS): 2005-2016
AMS Satellite Meteorology Conference: 2007, 2009, 2010, 2012, 2016
AGU Fall Meeting: 2005, 2007-2011
SPIE Photonics: 2007-2011
NOAA Direct Broadcast: 2008, 2011
GOES-R User's Conference: 2009 (workshop), 2010, 2011
EUMETSAT Satellite Conference: 2008 (workshop), 2009-2012
International TOVS Working Group Meeting: 2007, 2008, 2010 (workshop), 2012
McIDAS Users Group: 2006-2016 (workshops 2008-2016)

## 10. CIMSS Support to the Development of a Geostationary Community Satellite Processing Package (CSPP) Supplemental Tasks

**CIMSS Task Leaders: Liam Gumley (PI), Graeme Martin (PM)**
**CIMSS Support Scientists: Nick Bearson, Jessica Braun, Geoff Cureton, Alan DeSmet, Ray Garcia, Tommy Jasmin, Scott Mindock, Eva Schiffer, Kathy Strabala**
**NOAA Collaborators: Steve Goodman, Satya Kalluri, Andrew Heidinger, Michael Pavolonis, Walter Wolf**
**Budget: $592,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

## Objective
To develop and release software allowing direct broadcast users to process data from the GOES-R, GOES-13 and -15, and Himawari-8 satellites.

## Project Overview
The CSPP Geo project supports the international community of direct broadcast users by developing and distributing software allowing them to process data received from geostationary satellites, generating data products in real-time. The primary goal is to support processing of GOES Rebroadcast (GRB) data from the GOES-R mission. Additional goals are to support processing direct broadcast data from the GOES-13, GOES-15 and Japanese Himawari-8 missions.

CSPP Geo software is free to download and install, and is designed to be run at a direct broadcast receiving station on relatively modest hardware. The software is easy to install and run, and all required third-party software is bundled with the software package. Test datasets are provided, to allow users to test the installation and verify correct operation. A high level of technical support is provided.

## Milestones with Summary of Accomplishments and Findings
CSPP Geo software is available to process the GRB data stream, and is currently being run at users' receiving stations to generate products in real-time. Software is also available to process GVAR data from GOES-13 and -15. A beta version of a Level 2 software package for Himawari-8 AHI was released in 2016, and a Level 2 software package for GOES-16 ABI will be released in 2017.

### *GRB Package*
GOES-R was launched in November 2016, and the GRB data stream was first activated in December 2016. Before the GRB stream was activated, prototype versions of the GRB Software Package were released to encourage users to plan for GOES-R, and to support their efforts to build GRB receiving systems in advance. The function of the software is to process the raw GRB stream as it comes from a demodulator, generating Level 1 ABI and space weather products, and Level 2 GLM products. By installing and running the software on simulated data obtained from tests of the ground system, users were able to exercise the capabilities of their systems before the satellite was launched, and to get an idea of the capabilities and volume of data generated by a new generation of instruments.

During the pre-GRB period we provided technical assistance to users as they built and tested their systems, including vendors of commercial direct broadcast receiving stations. The GRB Software Package was developed following the technical specifications described in the GOES-R Product Users' Guide, and was tested on data from the Harris GOES-R Simulator early on, and later on data from tests of the operational ground system. Test datasets from these sources were released to users to allow them to test their processing systems on the most realistic data available in the pre-GRB period. We contributed to efforts to improve and resolve issues affecting the future GRB stream by participating in the GRB Working Group (now GRB User Group), by raising and discussing issues directly with the PRO team, and by communicating issues and expectations to our users.

In the period after the GRB stream was turned on, multiple “dev snapshot” versions of the GRB software have been released via the CSPP Geo User Forum. These interim software releases include the latest improvements, bug fixes, and workarounds for issues affecting the GRB stream, allowing users to generate high-quality products during the Post-Launch Test (PLT) phase. Version 1.0 will be released after products from all instruments have been added to the GRB stream. Multiple users have reported success using the current “dev snapshot” software version, including generation of all products currently being distributed via GRB (ABI, SEISS and EXIS Level 1). We have assisted users with configuring their GRB receiving systems, and have fielded requests from inside and outside of the United States regarding procuring or building GRB receiving systems. The CSPP Geo team is participating in the ongoing PLT of the GRB stream, providing feedback and product generation statistics via the GRB User Group, and reporting issues affecting the data stream as they are found.

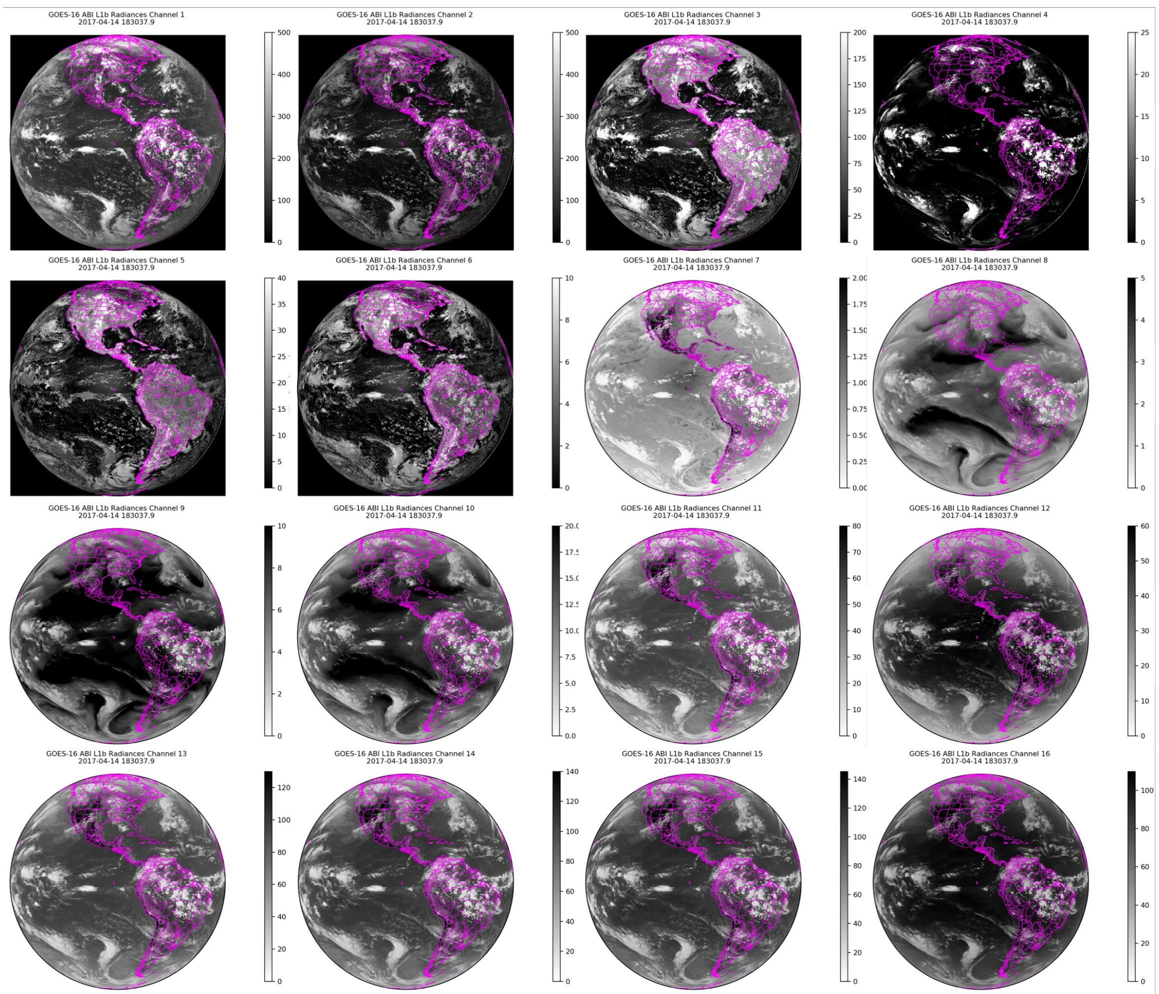



**Figure 61. Quicklook images generated from GRB data received at SSEC/CIMSS and processed by CSPP Geo software (ABI Radiances).**

### *Level 2 software packages*

Significant progress was made on developing Level 2 software to process ABI and AHI data. Level 2 packages were developed by adapting existing science software for use in a direct broadcast setting. Scripting infrastructure was developed to perform job sequencing, ancillary data downloads, data format conversion, parallelization, logging and error recovery. Quicklook and RGB image generation capabilities were developed. Ancillary data required for Level 2 processing such as NWP, OISST and snow mask are routinely acquired, converted as needed and staged on servers at SSEC / CIMSS.

An alpha version of the AIT Level 2 Package for GOES-16 ABI is currently being tested in-house. This software package was developed as part of an ongoing collaboration with the GOES-R Algorithm Integration Team (AIT) at NOAA, who are the maintainers of the core science software. The initial publicly released version of that software will generate a subset of the ABI Level 2 products using research implementations of the operational product algorithms.

A beta version of the Geostationary Cloud Algorithm Testbed (GEOCAT) Level 2 Package for Himawari-8 AHI was released in late 2016. The software package was developed in collaboration with the groups that maintain of the core GEOCAT software and science algorithms, led by Michael Pavolonis and Andrew Heidinger. The initial publicly released version will allow users to run advanced research versions of the GOES-R Level 2 algorithms on data from the Advanced Himawari Imager.

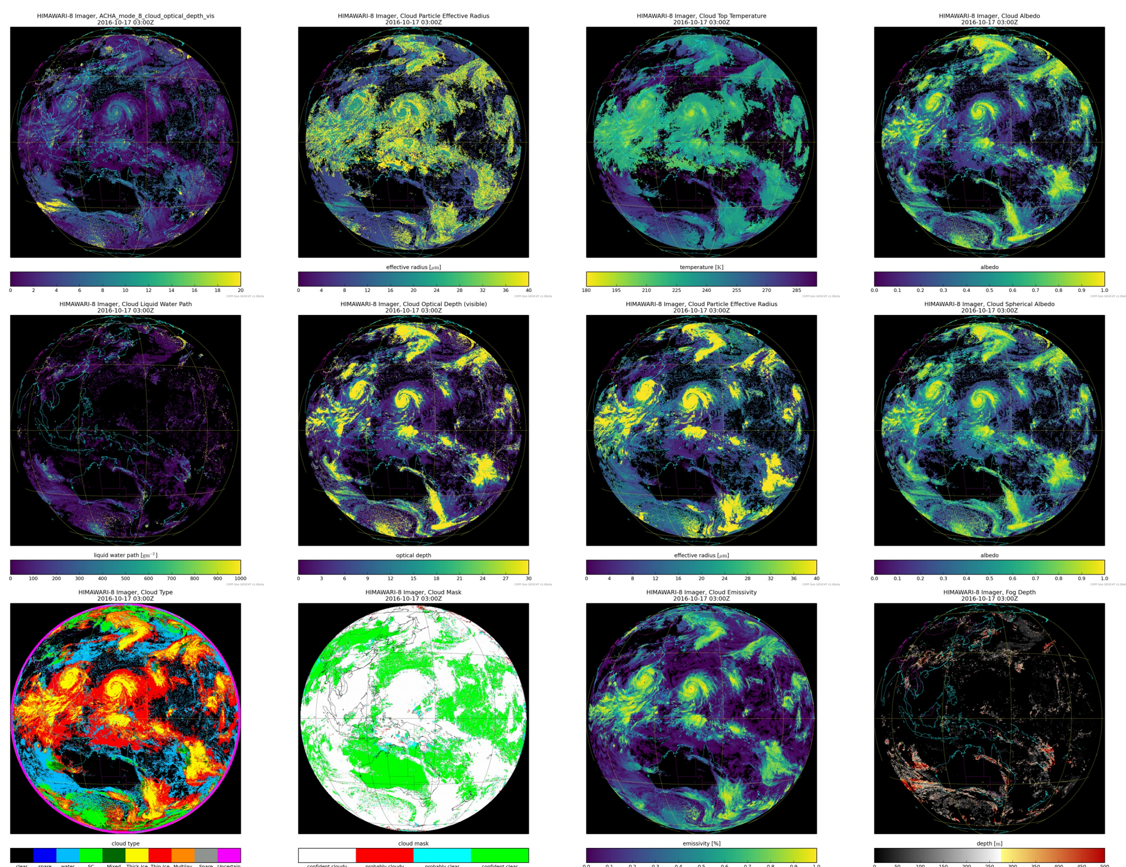


**Figure 62. Quicklook images showing examples of Level 2 products generated by running advanced GOES-R algorithms on Himawari-8 AHI data.**

***User support and outreach***

The CSPP Geo website and user forum have been maintained as the distribution point for software as well as the primary user resource to obtain system requirements, technical documentation and project news. Users contact our support group via email or via the user forum, and also interact with project personnel in telecons and in person at conferences. Additional outreach activities have included an invited workshop in South Korea for direct broadcast users from developing countries in the Asia Pacific region, sponsored by the Korea Meteorological Administration. We anticipate an increasing demand for user training in the GOES-16 era.

**Figure 63. CSPP training at the AOMSUC conference in October 2016.**

## 11. GOES-R Specific Mobile Apps

**CIMSS Task Leader: Sam Batzli**
**CIMSS Support Scientists: Dave Parker, Russ Dengel, Nick Bearson, Tommy Jasmin, Dave Santek**
**NOAA Collaborator: Jeff Key, Tim Schmit, Steve Goodman**
**Budget: $63,000**

**NOAA Long Term Goals:**

- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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
- Education and Outreach

## Objective
To bring GOES imagery and derived products to mobile devices for visualization.

## Project Overview
The launch of GOES-R has brought unprecedented quality and volume of geostationary satellite imagery to scientists and weather forecasters. All of these new products will be viewable in the RealEarth web browser and related mobile app. However, because of the profusion of GOES imagery and derived products, we are developing a dedicated, GOES-branded complimentary app specifically for GOES imagery and products, called "GOES App."

## Milestones with Summary of Accomplishments and Findings

### *Upgrading WxSat*
The RealEarth App was released to both the Android and iOS stores in the fall of 2016. Both have been met with enthusiasm with 6,690 downloads of the Android app and 18,900 downloads of the iOS app since release. All GOES products available in the RealEarth browser are available in these apps.

### *Infrastructure supplement and GOES Product Development*
The RealEarth team added a dedicated GOES server and VM to the network in support of this project. This allowed us to be among the very first to showcase GOES-16 non-operational imagery in near real-time for general public and science users. The response was overwhelmingly positive. In fact, at any given time, the new GOES-16 products are the most popular products of the 555 available in RealEarth (see Figure 64). RealEarth currently hosts 84 GOES-16 full-disk, CONUS, and Meso products with more on the way.

### *Dedicated GOES App Development*
Now that we have the infrastructure in place to handle GOES-16 and we have the mechanisms for putting that imagery into the RealEarth App, we are in the process of establishing the stand-alone iOS and Android dedicated GOES Apps. The GOES App(s) will include all the features of the RealEarth App(s) (such as pan and zoom, animation, user location identification, basemap, product search, and overlay of country outlines, but will provide a streamlined way to get immediately to the grouped and categorized imagery and products from the GOES legacy and GOES-16 systems.

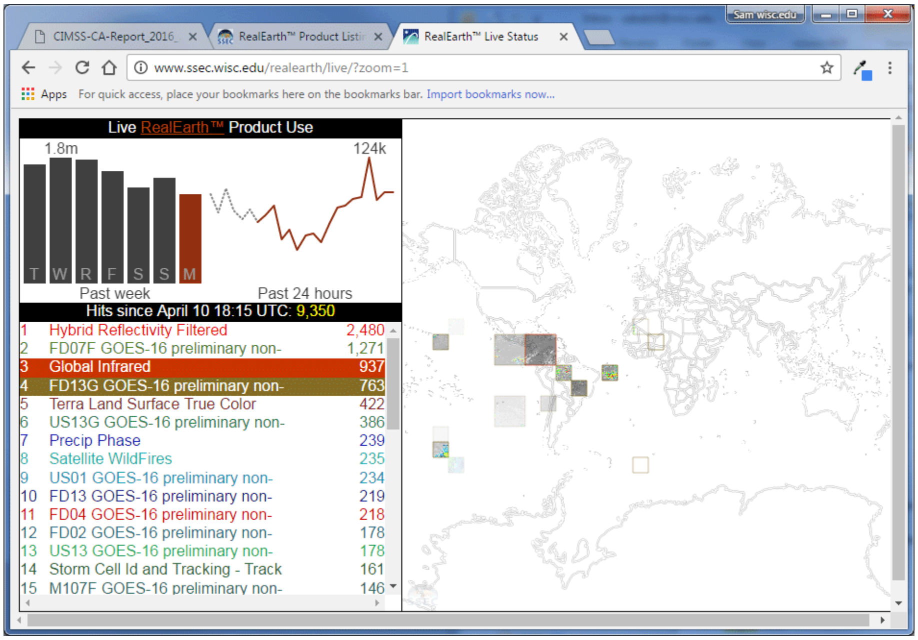



**Figure 64. This snapshot of RealEarth user activity shows that 9 of the most popular 15 products listed are GOES-16 products. Other popular products, such as "Satellite WildFires" often also include GOES data.**

## 12. CIMSS Support for GOES-R/JPSS Visiting Scientist: Development of Software to Display Winds Derived from Hurricanes in 3D

**CIMSS Task Leader: Chris Velden**
**NOAA Collaborator: Andy Heidinger**
**Budget: $7,500**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- 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

### Objective

To develop a first generation software tool that could interactively define vertical cross sections through a selected hurricane and plot available AMV and cloud property information on the chosen sections, along with coincident aircraft dropsonde information when available.

### Project Overview

Atmospheric motion vectors (AMVs) are now being routinely produced with higher quantity and quality than ever before. And these datasets will only become higher in spatiotemporal resolution when produced from GOES-R (-16). These 3-dimensional datasets are often plotted on 2-dimensional charts and crudely color-coded into layers by their respective height assignments. This presentation is acceptable in some applications. But for detailed diagnostic studies and to more carefully establish the validity of the assigned vector heights, it is desirable to have more flexible visualization options. Therefore, the primary goal of this project was to develop a software utility that could plot AMVs along with associated cloud properties in cross-section style, and eventually in 3-D (volume) type graphics if time permitted.

The specific vision for this tool is in applications to hurricane diagnostics. For example, the horizontal extent of storm outflow is normally well captured by 2-D plots of AMVs, but what is important to visualize and understand is the source of the outflow: Is it primarily emanating from tall eyewall convection near the heart of the hurricane, or from lower in altitude outer spiral bands? This distinction can be important for understanding hurricane intensity and structure changes.

To take a crack at this visualization tool, Dr. Timo Hanschmann from DWD in Germany visited CIMSS for 3 weeks in October. During Dr. Hanschmann's 3-week stay at CIMSS, about 2 weeks was devoted to this project with PI Velden. The remaining week was spent with Dr. Heidinger on other topics.

### Milestones with Summary of Accomplishments and Findings

After some discussion on the project needs and within the reasonable limits of the time given to work on it, the goal was established to develop a first generation software tool that could interactively define vertical cross sections through a selected hurricane and plot available AMV and cloud property information on the chosen sections, along with coincident aircraft dropsonde information when available. For example, these sections could transect the hurricane outflow areas where satellite-derived cloud top height and base along with AMVs could start to address the project scientific questions noted above.

Based on these goals, Dr. Hanschmann designed the visualization software and a graphical user interface (GUI), all written in the interactive data language IDL. The four input data sets are:

1. CLAVRx cloud information from GOES,
2. Center location of the hurricane from NHC Best Track data,
3. Dropsonde data from aircraft flying through the hurricane, and
4. AMV data from GOES to match the corresponding CLAVRx dataset.

The first data set comprises cloud microphysical and macrophysical properties, along with solar reflectance, thermal window brightness temperature, and water vapor absorption brightness temperature. These data have been gridded to a regular equal angle grid, from which the resolution can be selected in the GUI. The gridding is performed in order to ease the collocation and visualization of the different observations, and to speed up the processing time. The second data set is a table comprised of the latitudinal and longitudinal locations of the selected hurricane center over its full lifetime. The third data set are dropsonde profiles from a reconnaissance airplane flying over or through the hurricane. In our case example for Hurricane Joaquin, these dropsondes are available every few minutes on transect lines through the center of the storm each time the aircraft penetrated the core. The dropsonde vertical profiles of wind, temperature and moisture start at the aircraft flight level and continue down until splash into the ocean. The fourth data set is the AMV data. It is provided by CIMSS in ASCII format with latitude, longitude, pressure, wind direction, wind speed and quality information for each AMV. For the visualization and combination with other observations, the AMV data have been gridded to a regular equal angle grid. The grid resolution can be chosen in the GUI with the same buttons as the resolution for the CLAVRX data.

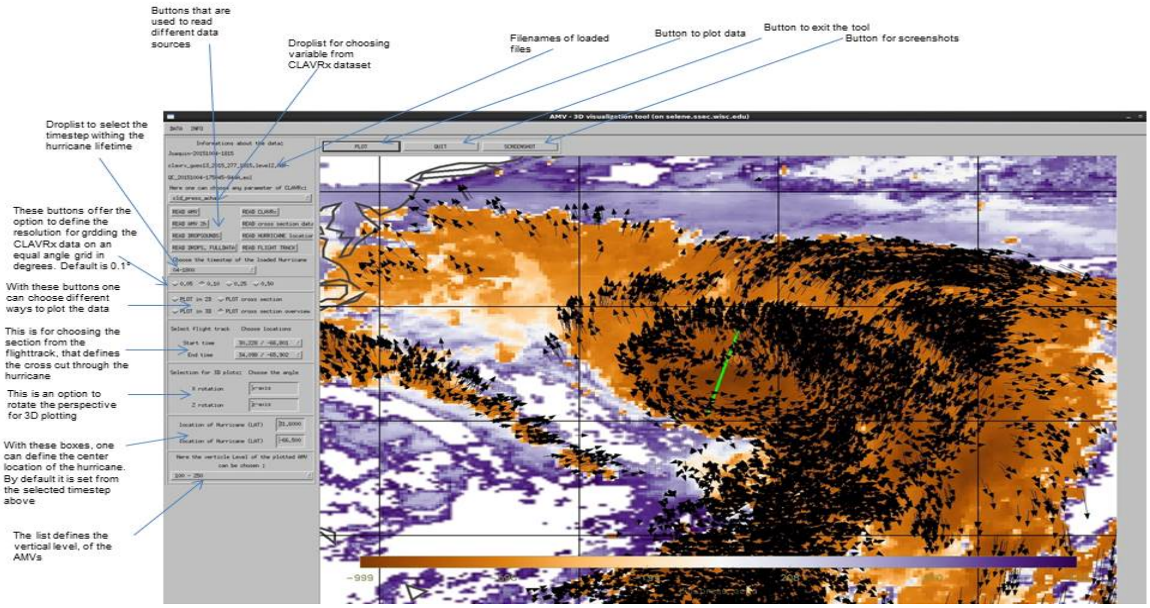



**Figure 65. Screenshot of the visualization software interface with explanation of the different buttons and drop lists. The scene in the window is a 2-d plot of upper-level AMVs (black arrows) over coincident CLAVRx cloud top pressures from GOES-East (high cloud in orange and low cloud in purple). The green line represents an aircraft transect through the core of Hurricane Joaquin (2015).**

Figure 65 shows the GUI in its final design. All visualizations can be selected by the buttons and the dropdown menus, enabling the user, for example, to select the time period and define the aircraft flight track and desired cross section. In the example graphic in Figure 65, Hurricane Joaquin (2015) is depicted, which serves as the testbed case for the software development. In the display, the CLAVRx cloud top pressure is plotted, but any other parameter available in the CLAVRx files can be used instead, such as cloud microphysics, brightness temperatures, or radiances. On the left side, a drop down list shows all available parameters and by clicking the mouse, any of them can be chosen. The black arrows, plotted over the top pressures, are the high-level AMV data for the vertical layer between 100 and 250 hPa. The green line crossing the storm center is the selected track for one defined part of the reconnaissance aircraft flight. The start and the end points of this track can be chosen in the GUI from dropdown lists.

The primary intent of the software is to enable the visualization of a vertical cross-section along the defined aircraft path. This can be selected by a button in the GUI called "plot cross section." The flight track locations, defined above, are used to define the extent of the cross section. CLAVRx and AMV data, collocated with the flight track, are plotted together along the flight track. An example is illustrated in Figure 66. The x-axis is along the flight track, and the y axis is the vertical dimension displayed in this case by the atmospheric pressure. Additionally, vertical profiles of dropsonde winds from the airplane along the track are plotted, so that all datasets can be matched and compared. From these views, the user can compare the AMV height assignments with collocated CLAVRx cloud top information and dropsonde wind validation data to assess their accuracy. In the Figure 66 example, the AMVs agree well with the dropsonde winds. These views complement the planar views to better allow diagnoses of flow fields as depicted by the AMVs.

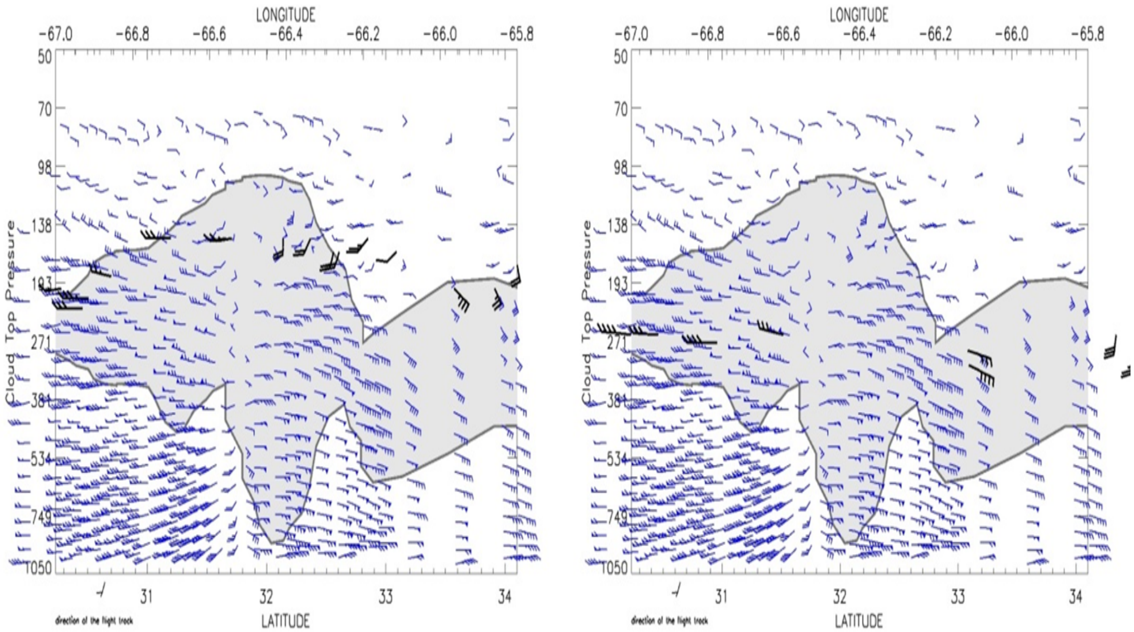



**Figure 66. Vertical cross section through Hurricane Joaquin (2015) along a selected aircraft transect. The black wind barbs show the coincident AMVs for a pre-selected height layer (left: between 100 - 250 hPa, right: between 250 and 350 hPa). The blue wind barbs show the coincident dropsonde vertical wind profiles, and the shaded gray area show the clouds defined by the CLAVRx cloud top and cloud base.**

In summary, an IDL-based software package designed to better visualize winds in hurricanes was developed. The software is primarily intended for the use of GOES satellite data. The code now resides with the CIMSS tropical cyclone group for use in diagnostic studies and to further develop the tool.

## 13. CIMSS Support to GOES-R Risk Reduction: GOES-R High Impact Weather Research Theme

**CIMSS Task Leader: Chris Schmidt**
**CIMSS Support Scientist: Allen Lenzen**
**NOAA Collaborator: Brad Pierce**
**Budget: $97,000**

**NOAA Long Term Goals:**

- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**

- Serve society's needs for weather and water
- 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
- Environmental Models and Data Assimilation

## Objective

To improve NWS WFO and IMET situational awareness during wildfire events.

## Project Overview

The CIMSS GOES-R High Impact Weather Research Theme focuses on two major high impact weather events: fires and severe storms. The objective of the fires component of the research is to improve NWS WFO and IMET situational awareness during wildfire events. The fires component has three sub-topics focusing on fire detection and characterization, smoke forecasting and data assimilation, and development of probabilistic estimates of lighting wildfire ignition sources. The severe storms component has two sub-topics focusing on convective and winter storms, and tropical cyclones. FY16 funding supported the Fires component of the GOES-R High Impact Weather Research Theme.

## Milestones with Summary of Accomplishments and Findings

The two major FY16 milestones for the Fire component of this project are noted below.

### *Improve NWS IMET and WFO situational awareness by developing a fire clustering algorithm to track fire behavior (movement and intensity)*

The GOES-R Fire Detection and Characterization Algorithm (FDCA) (aka WFABBA) calculates fire size, temperature, and fire radiative power (FRP), and produce a metadata mask describing the disposition of each pixel after the algorithm has run. The fire radiative power (FRP) is a readily understandable measure of fire intensity that can be used by IMETs. Many large fire events span several fire pixels in any given scan, and pixel-wise detection and characterization can produce an incomplete and confusing record of the fire's behavior. Initial work on cluster identification began at a reduced pace due to preparation for the launch and availability of data from GOES-16. The clustering algorithm will track a cluster's growth and movement, and must also account for times when the fire is not visible due to clouds or blockout zones. Initial work with Himawari-8 and GOES-16 shows that, due to remapping of the data, fires are more likely to be appear as clusters rather than discrete detections, even for smaller events. Clustering is also complicated on AHI and ABI due to a remapping artifact that causes colder pixels to appear near hot pixels.

### *Support NWS smoke forecasting and assimilation through prelaunch OSSE studies using synthetic ABI AOD retrievals and WFABBA FRP within HRRR-Smoke/GSI*

HRRR-Smoke forecasts issued over the continental USA at 4-km grid resolution are difficult to manage because of large file sizes and memory requirements. Preparatory work was conducted with WRF-Chem simulations over a domain that has similar extent at a 20 km grid resolution. 3D-Var and new components to Gridpoint Statistical Interpolation (GSI) are used to assimilate AOD derived from GOES-R observations. Community Radiative Transfer Model (CRTM) converted model species to simulated observations. CRTM relies on Goddard Chemistry Aerosol Radiation and Transport (GOCART) model, so GOCART smoke tracer species were projected. Two parallel series of WRF-chem simulations were used, one with GOCART aerosols and another with Smoke tracer (as in HRRR-Smoke). Daily, 24-hour issued at 18Z (the mid-time of

VIIRS passage over North America) were performed for 26 August to 5 September, 2016. Extensive forest fires were under way over the northwestern USA at that time.

A constrained least square procedure that relies on calculating weights that partition smoke to three GOCART species present in fires (black carbon - BC1, organic carbon – OC1, dust – P25) was developed. This allows optimal matching between GOCART and Smoke AOD such that differences are minimized and the sum of weights is equal to one. These weights will be applied to HRRR-Smoke simulations for the purpose of AOD assimilation using the CRTM/GSI.

Synthetic ABI AOD retrievals from the fourth GOES-R Data Operations Exercise (DOE-4) were available during this time from the GOES-R ground system. Figure 67shows the synthetic ABI AOD baseline algorithm (using synthetic ABI synthetic radiances) from DOE-4 compared to the forecasted AOD obtained from the real-time 8km WRF-Chem simulations that were used to generate the synthetic ABI radiances. The baseline AOD retrieval using synthetic ABI radiances showed artificially high AOD values over bright surfaces and was not suitable for the planned OSSE studies. Synthetic AOD replaced the model AOD within the DOE-4 retrieval files in our OSSE experiments.

In FY17 a clustering algorithm will be developed for real FDCA data, first to track the pixels and then to take characteristics of the fires and create representative values for the cluster. The next steps in the ABI AOD OSSE development are to generate background error covariance estimates for the Smoke tracers using the NMC method (Parrish and Derber, 1992) and conduct an OSSE during the August 26-September 05, 2016 timeframe, and to evaluate the impact of assimilating ABI AOD within the OSSE framework.

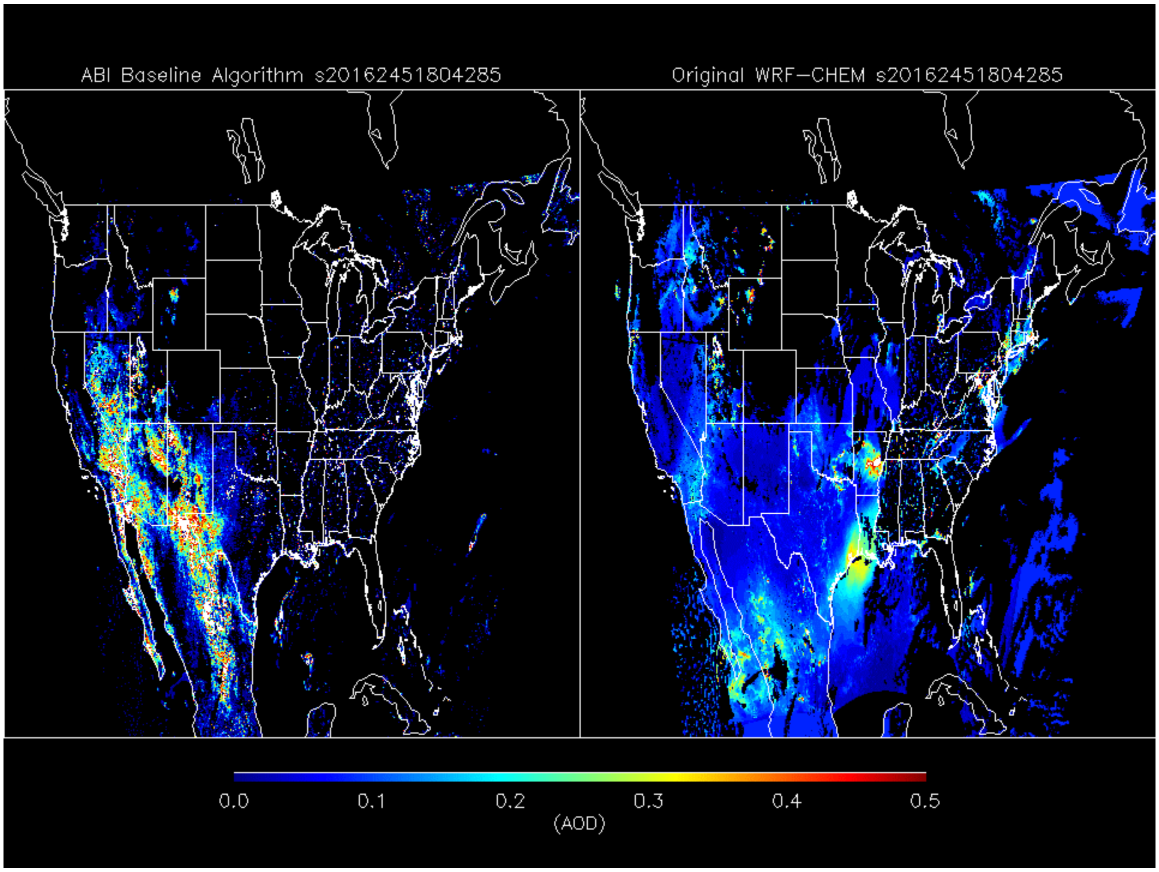



**Figure 67. Synthetic ABI AOD baseline retrievals from DOE-4 (left) versus actual AOD from 8km WRF-CHEM simulation used to generate proxy radiances for DOE-4 (right) at 18Z on September 01, 2016.**

## References

Parrish, D. F., and J. C. Derber, 1992: The national meteorological center's spectral statistical-interpolation analysis system. Mon. Wea. Rev.,120. 1747-1763.

## 14. JPSS Risk Reduction Algorithm Integration Team Midwest

**CIMSS Task Leader: R. Garcia**
**CIMSS Support Scientists: W. Straka, G. Martin**
**NOAA Collaborator: W. Wolf**
**Budget: $106,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- Provide critical support for the NOAA mission

### CIMSS Research Themes:

- Satellite Meteorology Research and Applications

### Objective
Provide integration and technical support for the integration of the Enterprise algorithms for JPSS.

### Project Overview
For GOES-R, a substantial number of algorithms have been researched, implemented and demonstrated for operational integration. As a risk reduction to JPSS, NOAA is selecting and applying compatible GOES-R algorithms to demonstrate pseudo-operational processing capability using JPSS sensor data, by adapting the NOAA SAPF implementation and science software. JPSS AIT Midwest is principally a programming and integration support group providing computing, coding and process expertise in order to bridge research to operations and preserve algorithm interoperability, to assist science teams in developing and adapting algorithms for JPSS and to prototype and develop common software facilities and infrastructure.

Activities included:
- Providing coding expertise, design input, and review for enhancements to AIT framework;
- Continuing development of algorithm testbed (Geocat) and common algorithm interface and infrastructure as needed to support SNPP / JPSS algorithms;
- Assisting in validation and verification of test products, including comparisons with IDPS products;
- Developing any required testing tool enhancements required to validate or verify SNPP products processed with adapted GOES-R algorithms; and
- Improving compatibility (algorithm APIs, libraries and components, toolsets) as needed between research, pseudo-operational, and IDPS operational systems.

### Summary of Accomplishments and Findings
- Integrated and verified updates to the CIMSS JPSS Enterprise algorithms to STAR Algorithm Processing Framework (SAPF) . This included all of the Cloud algorithms, Volcanic Ash, and several of the cryosphere algorithms for use with JPSS instrumentation.
- Successfully compiled and ran SAPF locally at CIMSS for use by JPSS algorithm developers; assisted scientists in performing integration and testing work on up-to-date SAPF code drops.
- Provided coding expertise, design input, and review for enhancements to SAPF.
- Continued development of algorithm testbed (Geocat) and common algorithm interface and infrastructure as needed to support SNPP / JPSS algorithms.
- Assisted in validation and verification of test products, including comparisons with IDPS products.

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

### 15.1 VIIRS Algorithm Development
**CIMSS Task Leader: Denis Botambekov**
**CIMSS Support Scientists: Andi Walther, Yue Li, Steve Wanzong**
**NOAA Collaborator: Andrew Heidinger NOAA/STAR/NESDIS**
**Budget: $160,000**

## NOAA Long Term Goals:
- Weather-Ready Nation

## NOAA Strategic Goals:
- 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

## Objective
Development and support of all cloud algorithms for JPSS is the main objective of this project.

## Project Overview
The team of scientist developed and supports two cloud masks for the JPSS: VIIRS Cloud Mask (VCM), which is operational right now, and is running at the IDPS NOAA, and Enterprise Cloud Mask (ECM), which should become an official product of VIIRS later this year, and will be run at the Framework NOAA. Both masks are using several tests to determine cloud occurrence at the each VIIRS pixel. The other cloud algorithms include AWG Cloud Height Algorithm (ACHA), Daytime and VIIRS Nighttime Lunar Cloud Optical and Microphysical Properties (DCOMP and NCOMP). There are different tools that are used to validate and tune both cloud masks, ACHA, DCOMP and NLCOMP. This is a collective effort and is coordinated with the other our colleagues from the Air Force Weather Agency (AFWA) in Omaha, Nebraska (Tom Kopp), NOAA STAR JPSS Algorithm Integration Team (AIT) (Walter Wolf), Cooperative Institute for Research in the Atmosphere (CIRA) (Steve Miller).

Tasks included:
- *Validation Tool Development*
  Our developed tools allow validating cloud algorithms globally and by individual granules.
- *NOAA/NASA Cloud Mask Comparison*
  Using our tools we are able to compare other developed cloud masks to the ECM and VCM. These are run at the CIMSS in Madison, Wisconsin (UW-Madison). The tools allow creating match-ups between ECM, VCM and MODIS (MYD35) cloud masks.
- *VIIRS Match-ups with CALIOP*
  Data from CALIPSO is considered as "truth", matching CALIOP data with VIIRS allow validating and tuning the algorithms. These tools run at the CIMSS in Madison, Wisconsin (UW-Madison). The identified errors lead to better understanding of cloud detection, and improving of the cloud masks and cloud properties products.

## Milestones with Summary of Accomplishments and Findings
The Block 2.0 is now operational in the IDPS and produces VCM mask. Recently the Cal/Val team was able to identify an error in the VCM ancillary input data. The daily snow/ice map wasn't correctly implemented over Southern Hemisphere. During the day VCM has the test to identify snow/ice pixels, but it is off during the night, and VCM totally rely on the ancillary input map. Plotting the ice/snow bit (Figure 68) from the test results over Antarctica it became obvious

of an error (a) because all South Pole was snow/ice free. Working closely with the Raytheon, AFWA and NOAA scientists an error was identified and fixed (b) in a timely manner.

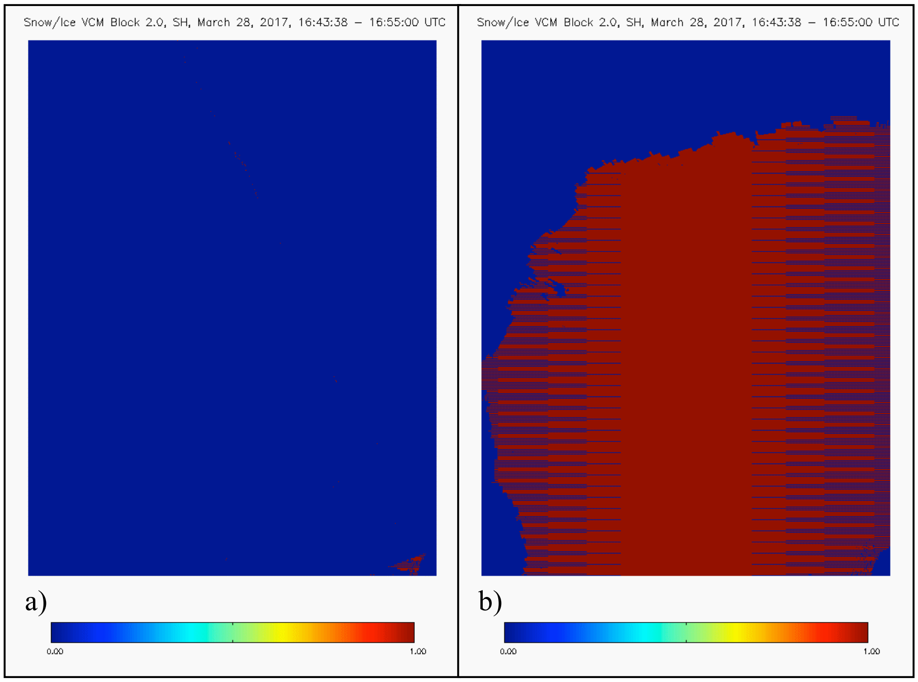



**Figure 68. Snow/Ice mask bit from VCM over Antarctica a) before and b) after an error fix.**

CIMSS cloud team creates daily images for two Long-Term Monitoring (LTM) websites: SSEC (http://cimss.ssec.wisc.edu/patmosx/VIIRS.html) and NOAA STAR LTM (http://www.star.nesdis.noaa.gov/jpss/EDRs/products_clouds.php). The SSEC webpage focuses only at three areas: North Pacific off the California Coast, USA and Brazil. For the NOAA STAR LTM CIMSS tools daily create global images of Enterprise Cloud Mask, Cloud Optical Depth, Cloud Top Temperature, and False Color RGB.

## 15.2 Software/Algorithm Integration and Testing

**CIMSS Task Leader: William Straka III**
**CIMSS Support Scientist: Jay Hoffman**
**NOAA Collaborators: Andrew Heidinger, Michael Pavolonis**
**Budget: $50,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

### Objective
Conduct software/algorithm integration and testing in support of cloud research for Suomi-NPP and JPSS.

### Project Overview
The NOAA NDE algorithms (enterprise cloud algorithms) are integrated into the STAR Algorithm Processing Framework (SAPF), which is the NDE equivalent of the IDPS. The CIMSS Cloud team views the ability to run the SAPF locally as a critical part of the development and maintenance tasks. The development and maintenance of bridge code allows algorithm tests in both the local processing framework (CLAVR-x) as well as the operational processing framework (SAPF). Being able to perform algorithm tests in multiple frameworks is a critical step in preserving product performance from research to operations.

### Summary of Accomplishments and Findings
The focus of the JPSS Cloud AWG this reporting period was maintaining and updating the various algorithms, validating the updated algorithms for Suomi-NPP and JPSS. The tasks for this project were to develop and integrate the Cloud Base and CCL algorithms in to the SAPF. In order to do this, new bridges must be developed for new algorithms, such as the evolution of CCL into a standalone algorithm. In addition, as algorithms evolve, new inputs and outputs may be developed - which would require the maintenance of the existing bridge/services modules for those algorithms.

In order to ensure the integrity of the integration of the cloud algorithms, as well as providing output in order to tune and maintain the algorithm, the Cloud team developed the ability to run the SAPF independently. This involved the installation of the latest versions of AIT Framework on local CIMSS machines and developing the infrastructure to process numerous days of granules through cluster processing. The amount of processing time, illustrated in Figure 69, decreases dramatically with increasing number of processing cores. To process a day of VIIRS data would take longer than a day if processed linearly, however process tens of granules simultaneously allows a day of VIIRS data to be processed in a fraction of an hour. This was needed in order to support both algorithm integration and validation efforts as well as the development of thresholds specific to the SAPF.

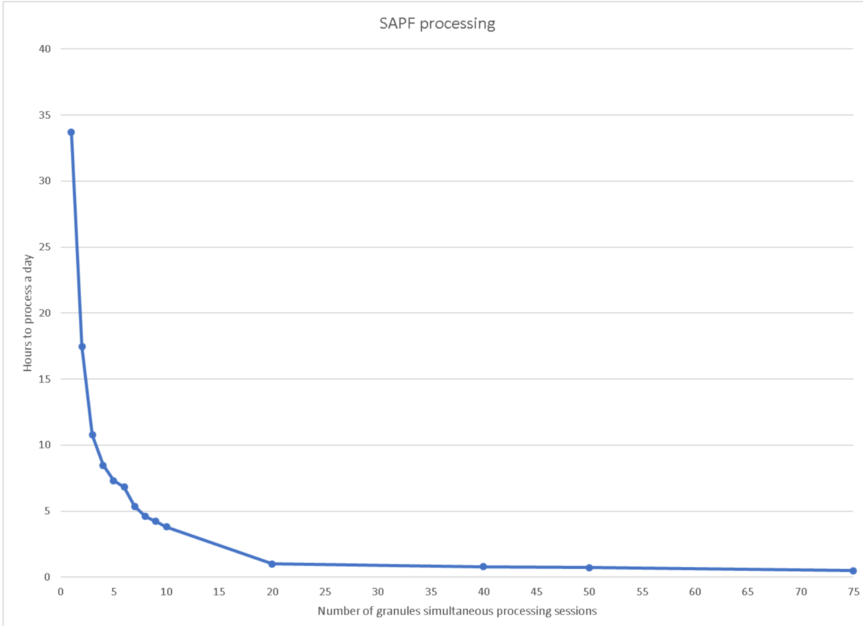



**Figure 69. Processing time in number of hours to process a day of VIIRS data as a function of processing cores.**

## 15.3 Algorithm Maintenance

**CIMSS Task Leader: William Straka III**
**CIMSS Support Scientists: Corey Calvert, Yue Li, Andi Walther, Pat Heck, Denis Botambekov, Steve Wanzong**
**NOAA Collaborators: Andrew Heidinger, Michael Pavolonis**
**Budget: $50,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- 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

### Objective

To maintain algorithms to insure that cloud products meet requirements.

### Project Overview

This project requires that cloud products are maintained to insure that they meet the requirements set in the JPSS L1RD. This includes retuning algorithms using a sufficient amount of data from the operational processing system (the SAPF), delivering updates of the science code as improvements are made, and delivering updated documentation to support NDE operations. In addition, supporting the JPSS EDR monitoring site, JPSS PG, CSPP, and participating in science and user interaction meetings is part of this task.

### Summary of Accomplishments and Findings

During this time period, the CIMSS Cloud team updated the cloud algorithms (Mask, type, height, base and COMP) twice. As part of this process, the statistics from the algorithm were compared to truth (ex. CALIOP) as well as to offline comparison with truth data. In Figure 70, statistics from the SAPF Cloud Top Height integration are compared against the offline (CLAVR-x) statistics with truth.

| CTH Statistics (VIIRS Clavr-x vs CALIPSO) | | | | | | |
|---|---|---|---|---|---|---|
| Type | Bias(km) | StanDev(km) | Corr | Counts | Within Specs - Accuracy | Within Specs - Precision |
| All clouds | 0.07 | 1.25 | 0.95 | 21071 | 78.8% | 79.0% |
| Water | 0.03 | 1.00 | 0.76 | 12097 | 84.9% | 85.0% |
| Ice | 0.11 | 152 | 0.86 | 8974 | 70.6% | 70.6% |

| CTH Statistics (VIIRS NDE 2.0 vs CALIPSO) | | | | | | |
|---|---|---|---|---|---|---|
| Type | Bias(km) | StanDev(km) | Corr | Counts | Within Specs - Accuracy | Within Specs - Precision |
| All clouds | -0.31 | 1.21 | 0.95 | 16956 | 78.7% | 79.2% |
| Water | -0.15 | 0.94 | 0.79 | 10229 | 85.9% | 86.3% |
| Ice | -0.54 | 1.50 | 0.84 | 6727 | 67.8% | 69.6% |

**Figure 70. CTH statistics from the CLAVR-x and SAPF verses CALIOP.**

As can be seen the statistics show close agreement between SAPF (NDE 2.0) and CLAVR-x (offline) tests. Further analysis shows that the algorithms have the same relative frequency for all cloud types (Figure 71).

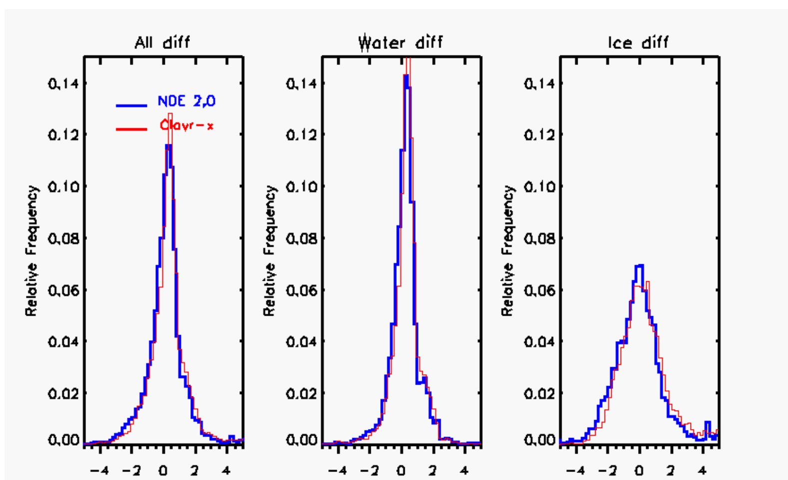



**Figure 71. Histogram Distribution of differences between VIIRS and CALIOP.**

In addition to the science code, updated ATBDs and lookup tables were delivered for algorithms which require sensor specific information.

### 15.4 Calibration and Validation
**CIMSS Task Leader: Denis Botambekov**
**CIMSS Support Scientists: Andi Walther, Yue Li, Steve Wanzong**
**NOAA Collaborator: Andrew Heidinger NOAA/STAR/NESDIS**
**Budget: $103,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

**Objective**
To validate and calibrate cloud algorithms ran on VIIRS data for JPSS is the main objective of this project.

**Project Overview**
The CIMSS cloud team has developed cloud algorithms that are official product of NOAA STAR. Cloud algorithms include Enterprise Cloud Mask (ECM), AWG Cloud Height Algorithm (ACHA), Daytime and Nighttime Lunar Cloud Optical and Microphysical Properties (DCOMP and NLCOMP). All these products are validated against other existing cloud algorithms. There are different tools that are used to validate and calibrate cloud algorithms. We work closely with the other colleges from the Air Force Weather Agency (AFWA) in Omaha, Nebraska (Tom Kopp), NOAA STAR JPSS Algorithm Integration Team (AIT) (Walter Wolf), Cooperative Institute for Research in the Atmosphere (CIRA) (Steve Miller).

Tasks include:
- *Validation Tool Development*
  Our developed tools allow validating all cloud algorithms globally and by individual granules.
- *Cloud Algorithms Comparison*
  Calibration and validation of our cloud algorithms is possible by comparing the results with the other developed algorithms. All the tools are run at the CIMSS in Madison, Wisconsin (UW-Madison). The tools allow creating match-ups between VIIRS and MODIS Aqua.
- *VIIRS Match-ups with CALIOP*
  Data from CALIPSO is considered as "truth", matching CALIOP data with VIIRS allow validating and calibrating the algorithms. These tools run at the CIMSS in Madison, Wisconsin (UW-Madison). The identified errors lead to better understanding of cloud detection, cloud optical properties and improving of the cloud algorithms.

**Milestones with Summary of Accomplishments and Findings**
CIMSS cloud team daily updates the Long-Term Monitoring (LTM) website, where VIIRS cloud algorithms results over North Pacific off the California Coast, USA and Brazil are compared to the MODIS-Aqua and AVHRR-NOAA19 (http://cimss.ssec.wisc.edu/patmosx/VIIRS.html). Figure 72 shows the time series of (a) 0.65 micron mean reflectance and (b) mean Cloud Optical Depth (COD) over 20x20 degree area in the North Pacific. Both VIIRS-NOAA and VIIRS-NASA COD results are higher than AVHRR-NOAA19 and MODIS-Aqua approximately on 2-4. It is believed that VIIRS M5 channel (0.65 micron) needs to be recalibrated, reducing reflectance

approximately on 5-6%, which will allow bringing COD from VIIRS to family. Our findings are confirmed by NASA NPP team.

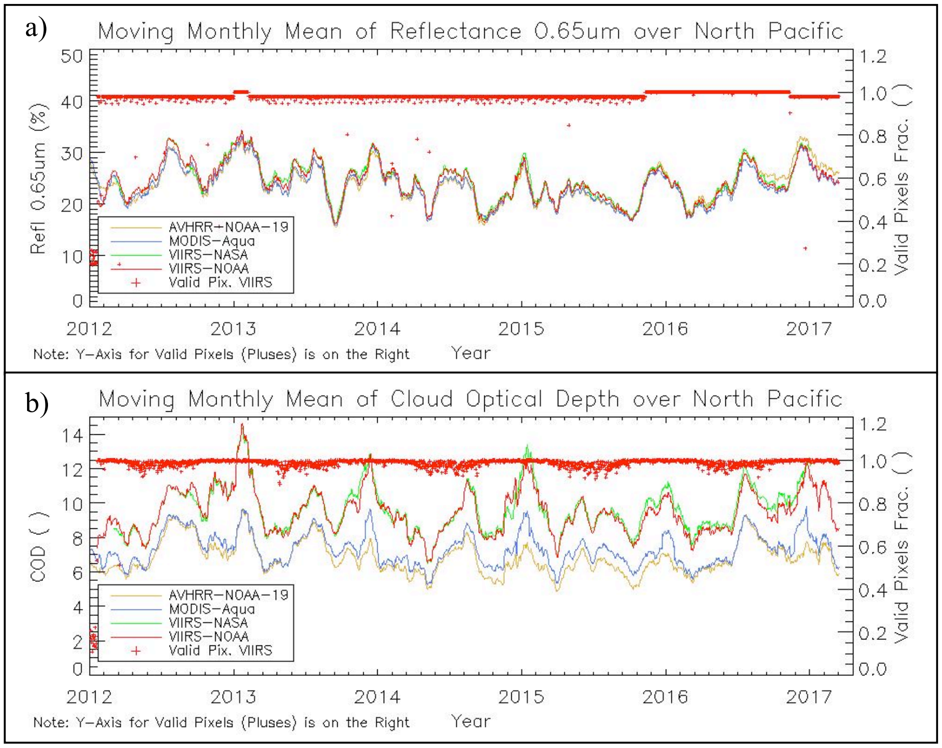



**Figure 72. Time series of a) mean 0.65 micron reflectance and b) mean Cloud Optical Depth over 20x20 degrees box in North Pacific.**

## Publications and Conference Reports

Andrew Heidinger presented "Update on PATMOS-X products" at the Global Space-based Inter-Calibration System (GSICS) conference 20-24 March 2017 in Madison, WI.

## 15.5 Long-Term Monitoring and Anomaly Resolution

**CIMSS Task Leader: Michael Foster**
**CIMSS Support Scientist: Denis Botambekov**
**NOAA Collaborator: Andrew Heidinger**
**Budget: $61,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- 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

### Objective
Our primary objective is to ensure the quality and consistency of the Suomi NPP and JPSS VIIRS-derived cloud products and radiances through long-term monitoring and comparison against other satellite-based cloud products.

### Project Overview
The basic goals of this project are as follows:
- Implement a complete processing of the global VIIRS record using the NOAA Enterprise algorithms in CLAVR-x;
- Generate these data and images and deliver them to STAR for use in the STAR JPSS Product monitoring site: (http://www.star.nesdis.noaa.gov/jpss/EDRs/products_clouds.php); and
- Establish an LTM site at CIMSS to monitor and validate VIIRS-derived cloud mask, cloud height, optical properties and valid pixel retrievals along with a method to monitor differences in calibration.

### Milestones with Summary of Accomplishments and Findings
Processing of the VIIRS data through CLAVR-x and delivery of data and imagery to STAR was accomplished during previous periods-of-performance, as was development of the webpage at (https://cimss.ssec.wisc.edu/patmosx/monitor.html). The goal of this site is monitoring the number of valid VIIRS pixels, validate against other cloud mask, height, and optical retrieval products, and assess the quality of clear-sky radiances. There are two primary plotting tools developed for this purpose. One uses a co-location tool to compare performance over a specified region. To date a region over the North Pacific has been used. We have now expanded to include regions over Brazil and North America. The second plotting tool generates a time series of multiple cloud products and radiances to assess stability and cyclical anomalies such as seasonal and inter-annual cycles. One area of interest among the data sets is the visible reflectance and subsequent optical properties. During this period of performance an alternative calibration was introduced from NASA and incorporated into the monitoring tool (See Figure 73).

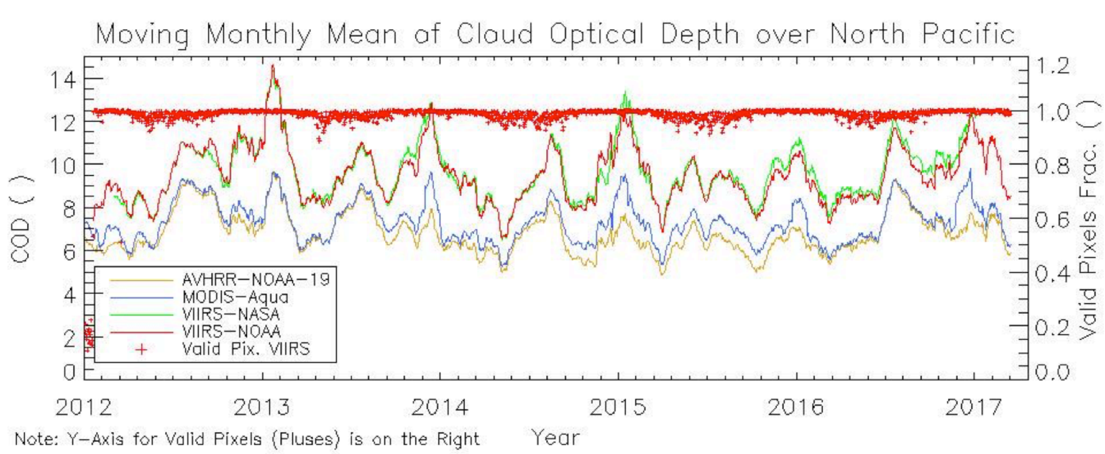



**Figure 73. Time series of cloud optical depth as retrieved using the DCOMP algorithm from AVHRR/NOAA-19 (yellow line), MODIS/Aqua (blue line), Suomi NPP/VIIRS using NASA calibration (green line), and Suomi NPP/VIIRS using NOAA calibration (red line). The fraction of valid VIIRS pixels are tracked using red plus symbols.**

Future work includes better characterization of the COD difference between AVHRR/MODIS and VIIRS.

## 15.6 McIDAS Support for VIIRS Imagery and Data Analysis
**Task Leaders: Tom Rink, Tommy Jasmin**
**NOAA Collaborator: Don Hillger (RAMMB/CIRA)**
**Budget: $40,000**

### NOAA Long Term Goals:
- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:
- 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
- Environmental Models and Data Assimilation
- Education and Outreach

### Objective
To support visualization and analysis of Suomi NPP and future JPSS data in McIDAS-V.

### Project Overview
SSEC/CIMSS has added support for visualization and analysis of Suomi NPP data in McIDAS-V. Code has been developed to support the VIIRS, CrIS, and ATMS instruments. A user interface was introduced allowing aggregation of multiple consecutive granules into a single data selection, greatly improving ease of use. In 2016 McIDAS-V was expanded to support NASA VIIRS L1B products from the Suomi NPP satellite in addition to the previously supported comparable NOAA products.

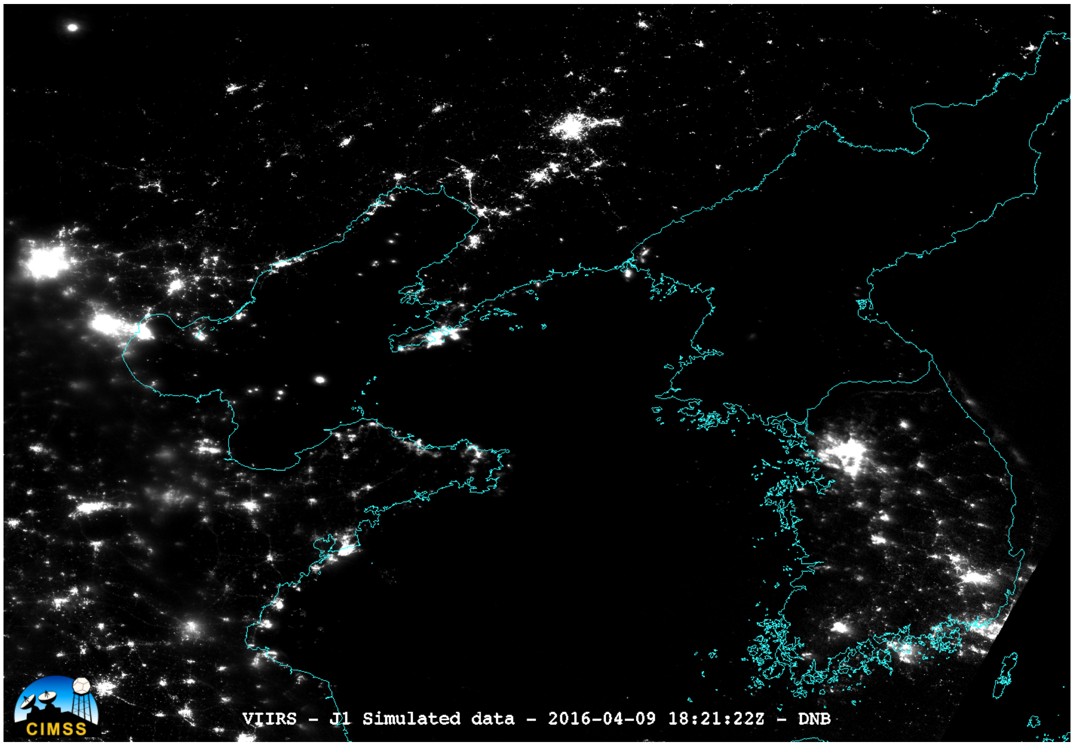



**Figure 74. Simulated J1 DNB data over the Yellow Sea, rendered in McIDAS-V.**

## Milestones with Summary of Accomplishments and Findings

With the launch of JPSS-1 coming late 2017, it will be vital to ensure McIDAS-V works with sample simulated JSPP VIIRS SDR and EDR data as it becomes available.

The primary VIIRS-related McIDAS-V goals for 2017 will include extensive testing and preparation for JPSS-1 and for future JPSS missions, as well as resolving outstanding high priority feature requests and bug reports in time for the next stable McIDAS-V release, version 1.7. Some of the tasks outlined below were originally scheduled for 2016, but were pre-empted by the unexpected transition from NOAA to NASA VIIRS data products, for which development support consumed much of the 2016 budget.

### *Additional Planned Development for 2017*

- *Improve data selection user interface for swath data*
  At present, it is very difficult to select an entire data granule or aggregation of data granules, and there is no option to specify a sample/stride for data. We will attempt to add these capabilities in 2017.
- *Continue scripting development to facilitate user-driven derived product creation and background processing*
  Several users, including members of the NESDIS/StAR VIIRS Imagery Team, have expressed a need to utilize McIDAS-V capabilities with VIIRS data in a background environment. For example, to access data, run processing algorithms, and create output products. SSEC will provide this functionality via the Jython scripting interface, which has been under active development the past three years.
- *Expand on I/O conversion options*
  At present, users can load Suomi NPP data and write KMZ (which can be loaded in for example Google Earth). Users have expressed interest in being able to write Satellite-CF compliant NetCDF files, and GeoTIFF files. As standards for satellite data are only now

emerging, swath data can be gridded and output using current CF standards. Explore using this process for volume visualization of CrIS retrievals.

- *Handle visualization of low-Earth orbit (granule-based) data crossing the 180-degree longitude line*
  Currently, McIDAS-V has issues with swath data that straddles the International Date Line. The problem typically manifests as small pieces of missing data in the display for these granules, and is a serious deficiency for McIDAS-V when working with data near the poles.

## 16. SSEC/CIMSS Research Tasks in Support of the Suomi NPP and Joint Polar Satellite System (JPSS) Sensor Data Records 2016

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

**CIMSS Task Leader: David Tobin**
**CIMSS Support Scientists: Hank Revercomb, Robert Knuteson, Joe Taylor, Daniel DeSlover, Lori Borg, Graeme Martin, Jon Gero**
**NOAA Collaborator: Yong Han**
**Budget: $670,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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

#### Objective

One of many objectives of this work was to develop and assess a calibration module to account for scene mirror induced polarization artifacts of the CrIS sensor.

#### Project Overview

For the past period of performance, efforts of this project have focused on following main areas:

1. Support of CrIS related reviews and meetings,
2. Continued Cal/Val analyses of the Suomi-NPP CrIS data,
3. CrIS SDR algorithm assessment and refinement,
4. Continued analysis of the JPSS-1 TVAC CrIS test data,
5. Involvement in the planning for early post-launch evaluation of JPSS-1 CrIS data, and
6. Involvement in pre-launch assessment of JPSS-2 CrIS test data

#### Milestones with Summary of Accomplishments and Findings

Detailed progress reports are provided to NOAA STAR each quarter for this project. Topics over the last year have included:

1. Evaluation of Spacecraft Level JPSS-1 RCRIS files,
2. Suomi-NPP FOV5 Cold Scene anomaly investigation,
3. Correction for CrIS on-board FIR non-cyclic convolution,
4. CrIS Interferogram Simulations and Self-Apodization correction evaluations,
5. Earth view Radiance Trending,
6. Analysis of Spacecraft Level JPSS-1 CrIS data,
7. Comparison of FIR Convolution Correction (FCC) methods,
8. CrIS Calibration Accuracy and its role as an Inter-calibration Reference,
9. S-NPP CrIS FOV5 Anamoly Diagnosis and Correction Assessment,
10. S-NPP CrIS Polarization Correction Assessment,
11. Development of an Interferogram Domain Self-apodization Correction for CrIS,
12. Understanding recent developments in CrIS radiance data assimilation,
13. Continued development and assessment of a new self-apodization correction for CrIS,
14. Clear sky observed minus calculated for spectral ringing assessment, and
15. CrIS highlighted at annual GSICS meeting.

Due to space limitations information on each topic is not included here. As one example, below is a summary of the polarization correction and assessment effort.

On 24 October Joe Taylor presented the results of an assessment of the candidate polarization correction for S-NPP CrIS. The assessment was very positive, with the correction showing relatively small effects in the LW and MW bands, and showing effects which are largely consistent with biases observed between IASI and CrIS in the SW band for cold scenes. An example result is shown in Figure 75 where current (without polarization correction) CrIS differences with respect to IASI from SNOs are compared to the candidate polarization correction for similar scenes.

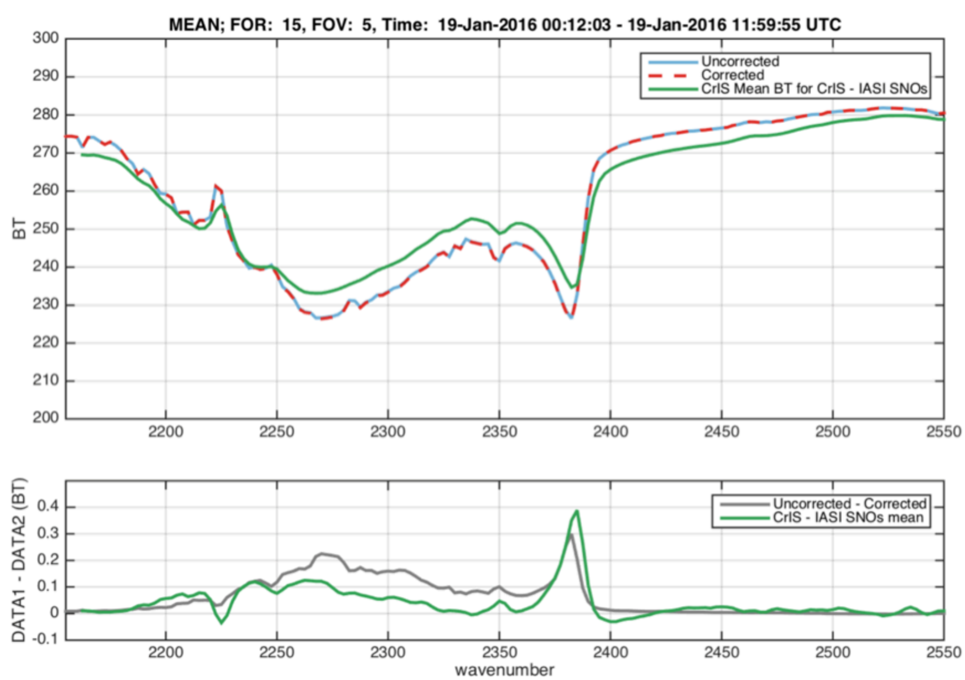



**Figure 75. Comparison of the candidate CrIS polarization correction with current (without polarization correction) IASI-CrIS differences.**

**Publications and Conference Reports**

Revercomb, H. E. et al., CrIS FOV-5 Artifact: Beamsplitter Channeling as a Possible Mechanism, CrIS SDR telecon, 16 March 2016.

Knuteson, R. O. et al., UW Comparison of CrIS Finite Impulse Response (FIR) Convolution Correction Methods, CrIS SDR telecon, 3 Aug 2016.

Tobin, D. C. et al., CrIS Calibration Accuracy and its role as an Inter-calibration Reference, CrIS SDR telecon, 17 Aug 2016.

Tobin, D. C., Hyperspectral Infrared Observations For Weather And Climate: Current Capabilities And Future Needs, 2016 International Radiation Symposium, April 2016.

DeSlover, Daniel; Knuteson, R.; Tobin, D. and Revercomb, H.. Detecting climate trends using AIRS, IASI and CrIS high spectral resolution brightness temperature spectra. Boston, MA, American Meteorological Society, 2017.

Deslover, Daniel H.; Nikolla, Ester; Knuteson, Robert O.; Revercomb, Henry E. and Tobin, David C.. Understanding climate trends using IR brightness temperature spectra from AIRS, IASI and CrIS. Washington, DC, American Geophysical Union, 2016.

Tobin, D. C. et al., CrIS Calibration Accuracy and its role as an Inter-calibration Reference, 2016 JPSS Science Teams Annual Meeting NOAA Center for Weather and Climate Prediction, College Park, MD August 2016.

Knuteson, R. O. et al., CrIS FOV5 BT Anomaly Revisited, CrIS SDR telecon, 31 Aug 2016.

Knuteson, R. O. et al., CrIS FOV5 BT Anomaly Root Cause and Correction, CrIS SDR telecon, 28 Sep 2016.

Taylor, J. K. et al., Preliminary assessment of polariza1on correc1on on Earth view data, CrIS SDR telecon, 24 Oct 2016.

Knuteson, R. O. et al., CrIS FOV5 BT Anomaly Preliminary Correction, CrIS SDR telecon, 7 Dec 2016.

Smith, W. L. et al., On the Dependence of Satellite Soundings on Instrument Field-of-View Size – A Study to Support Improvements in the CrIS Sensor Design, CrIS SDR telecon, 15 Feb 2017.

Revercomb, H. E. et al., CrIS Self-Apodization Correction: Basis for a new approach, CrIS SDR telecon, 15 Feb 2017.

## 16.2 VIIRS SDR Calibration/Validation
**CIMSS Task Leader: Chris Moeller**
**CIMSS Support Scientist: Jun Li**
**NOAA Collaborator: Changyong Cao**
**Budget: $154,771**

**NOAA Long Term Goals:**
- Climate Adaptation and Mitigation

**NOAA Strategic Goals:**
- Understand climate variability and change to enhance society's ability to plan and respond

**CIMSS Research Themes:**
- Satellite Sensors and Techniques

## Objective
This task strives to establish and maintain VIIRS instrument performance for all VIIRS sensors, utilizing pre-launch test characterization with on-orbit evaluation to optimize accuracy and precision of the SDR product.

## Project Overview
This task includes the following subtasks:

### *SNPP VIIRS On-Orbit SDR Performance Evaluation*
This subtask supports the ongoing application of a subset of VIIRS Cal/Val task tools at UW-Madison for SDR performance monitoring and review, including the use of VIIRS and CrIS matchups to identify VIIRS SDR bias dependence on cloud cover and earth surface type. This subtask contributes to investigations of known and revealed on-orbit performance issues and adjustments to the SDR calibration algorithm.

### *JPSS-1 VIIRS Preparation for Launch*
Through participation in the JPSS-1 pre-launch test program, UW-Madison has gained deep knowledge and insight into VIIRS performance. This expertise supports preparation for launch, including spectral characterization and SDR LUT development, and will also support on-orbit SDR assessment after the anticipated launch of JPSS-1 in Fall, 2017.

### *JPSS-2 VIIRS Pre-launch Performance Characterization*
Participation in the JPSS-2 VIIRS pre-launch test program is separately funded under the Flight Project; however pre-launch test data analysis supporting the launch readiness and the post-launch JPSS-2 SDR product performance is partially supported under this subtask

### *Support STAR and SDR Team Meetings and Activities*
UW-Madison is continuing participation on the VIIRS SDR Team, providing analyses on VIIRS SDR performance and participating in the review of all VIIRS performance issues.

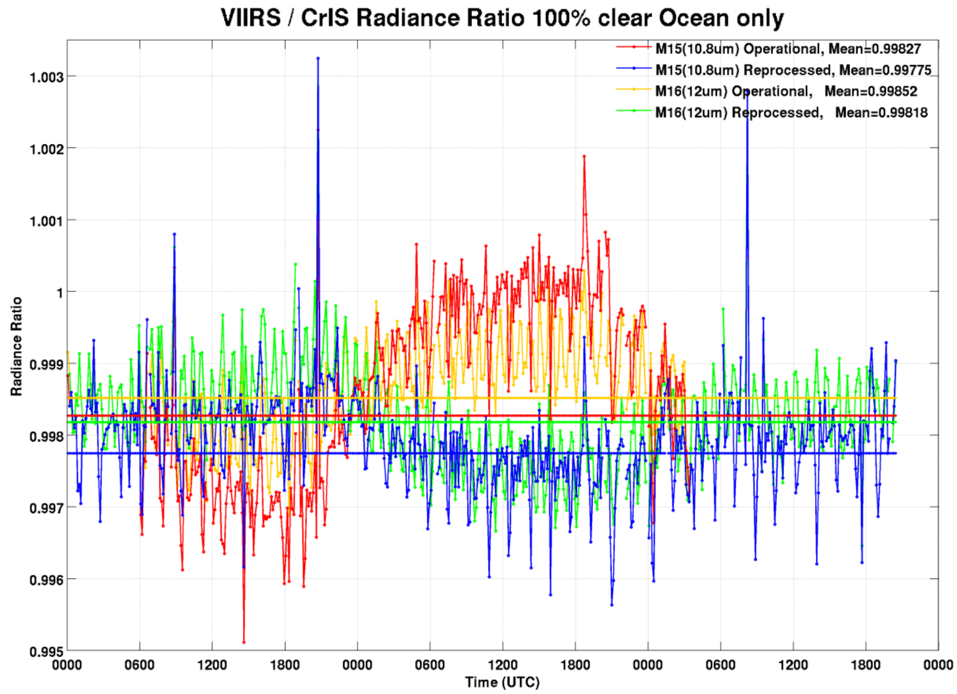



**Figure 76. The radiance ratio (VIIRS/CrIS) of operational M15 (red) and M16 (orange) data and reprocessed M15 (blue) and M16 (green) data spatially and temporally averaged over CrIS granules for Sept. 19-21, 2016.**

## Milestones with Summary of Accomplishments and Findings

### *SNPP VIIRS On-Orbit SDR Performance Evaluation*

Wisconsin has continued Cal/Val task activities including calculating bias (mean) and standard deviation (STD) of VIIRS-CrIS differences and VIIRS/CrIS radiance ratios as a function of cloud presence and surface type:

- For a three day period September 19-21, 2016, it is found that 1) The scene temperature has significant impact on both VIIRS bias and STD for each band tested; 2) CrIS subpixel cloud presence has substantial impact on STD, also impact on bias; 3) Local zenith angle has substantial impact on STD, but subtle impact on bias; and 4) As for surface type, the bias over ocean is smaller than other surface types for M13 and M15 brightness temperature. In extreme scene temperature cases, e.g., overcast deep convective cloud (DCC) or polar regions, larger differences are found between VIIRS and CrIS due to bias introduced by the cold scene temperatures.
- An analysis of September 19-21, 2016 warm-up/cool-down (WUCD) radiances not only shows the infrared bands' behavior responding to the on-orbit calibration exercise, but also proves its potential use for VIIRS calibration correction and product (e.g., SST) improvement. Figure 76 shows the radiance ratio (VIIRS/CrIS) time series of the operational M15 (red) and M16 (orange) data and the reprocessed M15 (blue) and M16 (green) data spatially and temporally averaged over CrIS granules. It is seen that the scene dependency in the radiance ratios was removed after applying a correction methodology developed by Cao et al. (2017). A manuscript (Gong et al., 2017) has been written for publishing on this item.
- In order to better detect deep convective clouds (DCCs), a brightness temperature difference to noise ratio (BNR) method using the difference between the water vapor absorption and IR window radiances is developed to assess the uncertainty of DCC identification for different instruments. If a pixel's BNR is larger than one, the signal is

stronger than noise, meaning that the pixel is part of the overshooting top of the DCC. The simulation shows that the high spectral resolution CrIS has better capability to detect DCCs than the VIIRS broadband IR imager. This finding supports VIIRS bias determination using DCC earth scenes by using collocated CrIS for DCC detection. More details can be found in Ai et al. (2017).

- Due to ongoing RTA mirror reflectance degradation, SNPP VIIRS band M6 shows increasing occurrences of earth scene radiances > 60 W/m2 sr um which causes them to be designated as saturated radiances in the SDR product. These designations are resulting in the loss of earth scene information in band M6. An adjustment upward of the saturated radiance threshold would restore the information content of these earth scenes.
- Band M6 reflectances show out-of-family behavior when M6 radiances are flagged as saturated based upon a data quality test. The reflectances for these occurrences are much too high, near 1.6. The behavior suggests that the SDR algorithm code is not properly handling the conversion of radiance to reflectance for those pixels that are flagged as saturated.

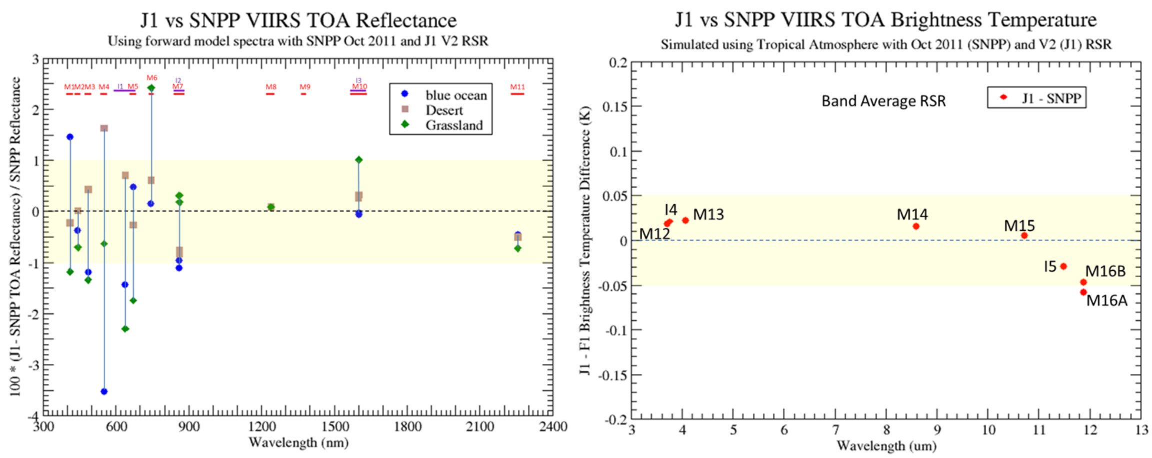



**Figure 77. Comparisons between JPSS-1 and SNPP VIIRS spectral influence on TOA Reflectance (left and TOA Brightness Temperature (right).**

### *JPSS-1 VIIRS Preparation for Launch*

The effort on JPSS-1 VIIRS has focused primarily on spectral considerations in preparation for the launch of JPSS-1 anticipated in September 2017.

- JPSS-1 VIIRS "at-launch" RSR were used with forward model output (desert, blue ocean, grassland) to compare spectrally driven differences in SNPP and JPSS-1 top of atmosphere (TOA) reflectance (Figure 77 left panel). Reflectance differences (relative to scene reflectance) exceed 1% in several VisNIR bands due to a redesign of the VisNIR focal plane for JPSS-1 which resulted in spectral position and shape changes to the RSR of those bands. Spectrally driven changes in SWIR band TOA reflectances are < 1%.
- JPSS-1 VIIRS "at-launch" TEB RSR have been used in a forward model (with standard tropical atmosphere) to simulate the influence of spectral differences between S-NPP and JPSS-1 VIIRS top-of-atmosphere brightness temperature. For all bands the two sensors agree within about 50 mK (Figure 77, right panel).
- Spectrally induced detector striping has been simulated for JPSS-1 VIIRS VisNIR and thermal bands using the "at-launch" RSR. Reflectance variation within all bands is less than 0.4% (relative to scene reflectance) and follows an expected pattern that is induced by the non-telecentric design of the VIIRS optics. Spectrally induced detector striping for

thermal is largest for bands I5 and M13 (about +/- 0.1 K). Other TEB are all less than +/- 0.05 K with the SST bands M15 and M16A,B coming in at less than +/- 0.02 K

- The JPSS-1 VIIRS "at-launch" RSR have been updated by the Version 2.1 RSR released along with supporting documentation on the password protected NASA eRooms at https://jpss-erooms.ndc.nasa.gov/eRoom/JPSSProgram/JPSSScience/0_8a7d8. The update includes a minor (0.7nm) adjustment to shorter wavelengths of the band M9 RSR spectral position. The RSR for all other bands is unchanged.
- The Version 2.1 JPSS-1 VIIRS RSR have been provided to update the "at-launch" JPSS-1 VIIRS RSR LUT in readiness of the SDR algorithm for the launch of JPSS-1.

### *JPSS-2 VIIRS Pre-launch Performance Characterization*

A first look at the JPSS-2 VIIRS spectral performance has been gained through GLAMR-based spectral measurements of the reflective solar bands (supported under the Flight Project). A review of these measurements provides the following insight:

- Modest spectral shape and position changes between J2 and J1 VIIRS RSR are present, most notably in bands M2, M4, M5, M8, and M9. These changes are attributable to new filter acquisitions for the VisNIR and SWIR focal planes.
- Out-of-band spectral leaks and crosstalk are evident in the measurements; however most of these features appear to be at or below similar features observed in JPSS-1 VIIRS.
- The first-time GLAMR-based measurements of SWIR bands have revealed evidence in bands M8 and M9 of modest electronic crosstalk.

## Publications and Conference Reports

Moeller, C., T. Schwarting, J. McIntire, and D. Moyer, "JPSS-1 VIIRS Version 2 At-launch Relative Spectral Response Characterization and Performance", *Proc. SPIE* 9972, Earth Observing Systems XXI, 997203 (September 19, 2016); doi:10.1117/12.2238050.

Ai, Y., W. Shi, Jun Li, T. Schmit, C. Cao, and W. Li, 2017: Deep convective cloud characterizations from both broadband and hyperspectral infrared sounder measurements, Journal of Geophysical Research – Atmospheres; 10.1002/2016JD025408.

Gong, X., Z. Li, J. Li, C. Moeller, C. Cao, and W. Wang, 2017: Validation of VIIRS with CrIS by taking into account the subpixel cloudiness and viewing geometry, Journal of Geophysical Research – Atmospheres (to be submitted).

Chris Moeller gave a presentation titled "J1 VIIRS RSR final release, comparison with SNPP and potential impacts" to the STAR JPSS-1 August 2016 Annual Science Team meeting in College Park, MD.

## References

Cao, C., W. Wang, S. Blonski, and B. Zhang, 2017: Radiometric traceability and bias correction 1 for the Suomi NPP VIIRS long-wave infrared channels during blackbody unsteady states, JGR-Atmospheres (submitted).

Gong, X., Z. Li, J. Li, C. Moeller, C. Cao, and W. Wang, 2017: Validation of VIIRS with CrIS by taking into account the subpixel cloudiness and viewing geometry, Journal of Geophysical Research – Atmospheres (to be submitted).

# 17. SSEC/CIMSS Research Tasks in Support of Suomi NPP and the Joint Polar Satellite System (JPSS) Sounds and Cryosphere Environmental Data Records (EDR)

## 17.1 CrIMSS EDR Cal/Val: ARM Site Support 2016

**CIMSS Task Leader: Lori Borg**
**CIMSS Support Scientists: David Tobin, Michelle Feltz**
**NOAA Collaborators: Tony Reale, Quanhua (Mark) Liu, Nicholas Nalli**
**Budget: $70,000**

### NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:

- 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

### Objective

Prepare for and conduct efforts for the critical validation of SNPP CrIS/ATMS atmospheric temperature and water vapor retrieved profiles.

### Project Overview

Given the high accuracy retrieval goals for the Suomi National Polar-orbiting Partnership (SNPP) Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) temperature and water vapor profiles careful and detailed validation using accurate and on-going validation data is required. The Atmospheric Radiation Measurement (ARM) program field sites provide such data. In this arrangement, radiosondes have been launched coincident with the SNPP satellite overpasses of the ARM sites located at Eastern North Atlantic (ENA), North Slope of Alaska (NSA), Southern Great Plains (SGP), and Tropical West Pacific at Manus (TWP). Combined with other ARM data, an assessment of the radiosonde data quality is performed and post-processing corrections are applied producing an ARM site best estimate (BE) product. This validation data set is a well-characterized ensemble of temperature and water vapor profiles, which is essential for assessment of the satellite products. Previously for AIRS and IASI, best estimates (BE) of the atmospheric state 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. Further science justification and details of the approach for this effort are described in detail in Tobin et al., 2006.

### Milestones with Summary of Accomplishments and Findings

Over the last year, this effort involved the continuing coordination of sonde launches at the Eastern North Atlantic (ENA), North Slope Alaska (NSA), and Southern Great Plains (SGP) ARM sites coincident with overpasses of the SNPP satellite. During Phase-4 of this effort, which ended in September 2016, 80/88/86 overpasses were targeted at the ENA/NSA/SGP sites respectively. Phase-5 of this effort began in October 2017 and will continue through the end of September 2017. See the table below for additional information on the sonde launch efforts during these phases. While this collaborative effort with ARM to target SNPP overpasses is coming to an end with Phase-5, future collaborative efforts are being proposed to be in place prior to JPSS-1 launch.

**Table 2. Sonde Launch Efforts: Phase-4 & Phase-5 through 1 April 2017. Overpass (OP) targeted with either Single radiosonde 15-min prior to OP or Dual radiosondes 45- and 5-min prior to OP.**

| Sonde Launch Efforts | | | | | | |
|---|---|---|---|---|---|---|
| **Phase** | **Site** | **Start** | **Stop** | **nOverPasses** | **nSingle** | **nDual** |
| **4** | ENA | Oct15 | Sep16 | 80 | 80 | -- |
| | NSA | | | 88 | 55 | 33 |
| | SGP | | | 86 | 16 | 70 |
| 5 | ENA | Oct16 | ongoing | 41 | 41 | -- |
| | NSA | | | 37 | 22 | 15 |
| | SGP | | | 43 | 27 | 16 |

In an effort to assess upper-tropospheric and lower-stratospheric temperatures, comparisons of the NOAA Unique Combined Atmospheric Processing System (NUCAPS) vertical temperature profile product were made to radiosonde, radio occultation (RO), and to other hyperspectral infrared sounder temperature products. When temperature averaging kernels (AKs) were applied, NUCAPS bias relative to radiosondes from 40-100 hPa was found to be under 0.5 K (with root mean square error under 1 K). When using RO as a common reference and AKs were applied, NUCAPS agreement with Infrared Atmospheric Sounding Interferometer (IASI) and Atmospheric Infrared Sounder (AIRS) operational temperature retrievals was found to be under 0.5 K. See Figure 78, which shows seasonal, zonal bias and RMS profiles for NUCAPS, AIRS, and IASI relative to RO using two different approaches to vertical averaging of the IR-RO profiles; including the application of averaging kernels and slab layering. A paper was recently submitted on this topic to the Journal of Geophysical Research - Atmospheres entitled "Assessment of NOAA NUCAPS Upper Air Temperature Profiles Using COSMIC GPS Radio Occultation and ARM Radiosondes" (M.L. Feltz, L. Borg, R.O. Knuteson, D. Tobin, H. Revercomb, and A. Gambacorta ).

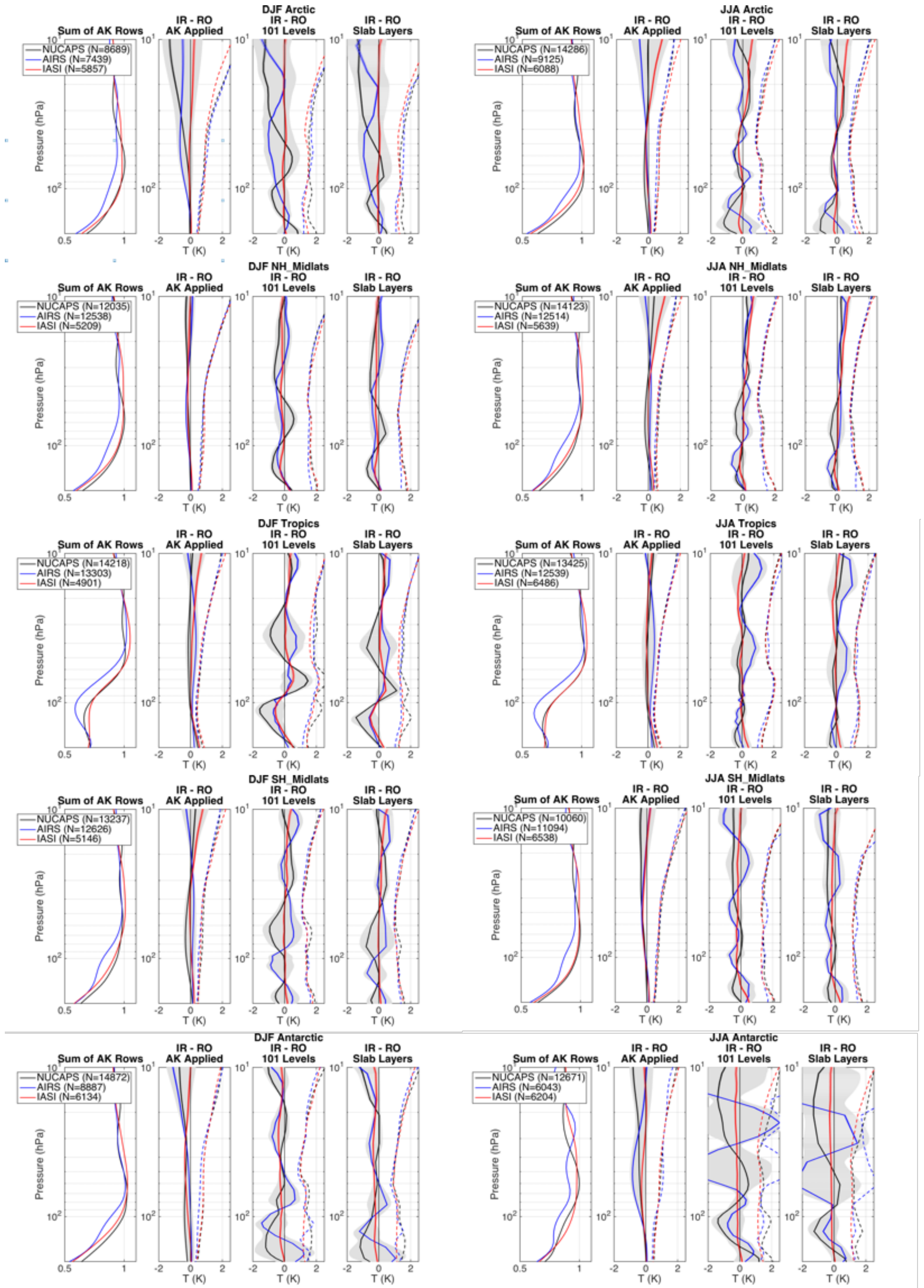


**Figure 78. Seasonal, zonal IR sounder minus COSMIC bias and RMS for NUCAPS, AIRS, and IASI. Average sum of AK rows (leftmost of four panel group), and IR-RO bias (solid) with 2 sigma uncertainty (dotted, considered negligible) and RMS (dashed) after AKs application (2nd leftmost), no vertical averaging (2nd rightmost), and ~1 km vertical degradation (rightmost) for 5 zonal regions for DJF (left column) and JJA (right column) seasons. Grey shading marks area under +/-2 standard deviations from the mean of the 3 IR sounder biases and provides a measure of the average IR sounder accuracy compared to COSMIC RO.**

### Publications and Conference Reports

Borg, Lori, and David Tobin, Michelle Feltz, Robert Knuteson, Tony Reale, Quanhua (Mark) Liu, Donna Holdridge, Jim Mather. *Using ARM data to provide atmospheric state best estimates for satellite retrieval validation.* Oral Presentation. ICM-8, 25-29 April 2016, Boulder, CO.

Borg, Lori, Tobin, D., Feltz, M., Knuteson, R., Reale, T., Liu, Q., Holdridge, D., and Mather, J. *S-NPP EDR Validation at ARM (GRUAN) Sites*. Oral Presentation. STAR JPSS Annual Science Team Meeting, 8-12 August 2016, College Park, MD.

Borg, Lori A. and M. L. Feltz, D. C. Tobin, R. O. Knuteson, T. Reale, D. J. Holdridge, J. H. Mather, and Q. Liu. *CrIMSS Temperature and Water Vapor Retrieval Validation Using ARM Site Atmospheric State Best Estimates and GPS RO COSMIC.* Poster. AMS - 21st Conference on Satellite Meteorology, 15-19 August 2016, Madison, WI.

### References

Tobin, D. C., H. E. Revercomb, R. O. Knuteson, B. M. Lesht, L. L. Strow, S. E. Hannon, W. F. Feltz, L. A. Moy, E. J. Fetzer, and T. S. Cress (2006), Atmospheric Radiation Measurement site atmospheric state best estimates for Atmospheric Infrared Sounder temperature and water vapor retrieval validation, *J. Geophys. Res.*, 111, D09S14, doi:10.1029/2005JD006103.

## 17.2 Science and Management Support for NPP VIIRS Snow and Ice EDRs in 2016

**CIMSS Task Leader: Yinghui Liu**
**CIMSS Support Scientists: Xuanji Wang, Richard Dworak**
**NOAA Collaborator: Jeffrey Key**
**Budget: $130,000**

### NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation
- Healthy Oceans

### NOAA Strategic Goals:

- 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

### Objective

To conduct research on sea ice concentration and sea ice age and thickness to provide science and management support for NPP VIIRS snow and ice EDRs.

### 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).

## Milestones with Summary of Accomplishments and Findings

### *Sea Ice concentration*

Work at CIMSS continues to obtain VIIRS SDRs, IPs, and EDRs automatically from the GRAVITE system, checking the quality of these SDRs and EDRs, and performing comparisons of these IPs and EDRs with all other available datasets, visually and quantitatively. 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 (SIC), 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.

The VIIRS ice concentration is derived using the NOAA's "Enterprise" algorithms. The VIIRS ice concentration algorithm classifies a pixel as ice or no-ice using a threshold method, and calculates the pixel ice concentration using a tie point approach, and generates ice concentration at VIIRS M-band resolution at 750 m at both daytime and nighttime. The NOAA's Interface Data Processing Segment (IDPS) and Enterprise ice concentration algorithms use different approaches for tie-point detection. The major differences are: 1) The Enterprise algorithm applies an Normalized Difference Snow Index (NDSI) based threshold to identify a first guess for ice covered pixels, then retrieves SIC using the tie-point information from the 0.64 µm reflectance band (daytime), followed by a final ice pixel identification refined by the retrieved ice concentration; 2) the IDPS ice concentration algorithm applies band weighted ice concentrations from multiple band tie point information with identification of ice covered pixels implicitly included in the tie point detection; 3) The Enterprise ice concentration has resolution of 750 m, and IDPS ice concentration has resolution of 375 m. Details of the VIIRS ice concentration Enterprise algorithm can be found in Liu et al. (2016).

The Enterprise ice concentration is validated using ice concentration derived from high-resolution imagery of Landsat 8, and from the Special Sensor Microwave Imager Sounder (SSMIS). All Landsat 8 scenes in 2013 and 2014 containing Arctic sea ice and that are 90% or more clear sky were obtained from the U.S. Geological Survey (USGS) data server. There are a total of 155

Landsat scenes, with a scene size of 170 km by 185 km collocated with VIIRS ice concentration products. For each scene, visible and thermal channel observations at 30 m spatial resolution are available from the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). Only daytime images are used because cloud OLI does not contain the split-window (11 and 12 μm) channels that needed for surface temperature retrieval and hence nighttime ice concentration estimates. Therefore, validation with Landsat is restricted to the months of February through October. Bias and root-mean-square error (RMSE) of ice concentration from VIIRS in comparison to Landsat 8 are calculated using the 155 collocated cases. The bias is defined as the average difference between observations of the two products. The RMSE is the square root of the mean squared difference of the two products. RMSE is also calculated with the bias removed, which is the square root of the average squared deviation of the errors from the mean error, or the standard deviation of the errors. Histograms of the differences between VIIRS and Landsat 8 ice concentration match-ups are shown in Figure 79 for all cases and for concentration bins of 15-30%, 30-50%, 50-70%, 70-90%, and 90-100%. Only cases (pixels) with ice concentration from both products higher than 15% are included. For over 2 million matched pairs, the VIIRS ice concentration shows an overall bias of -0.3% and an RMSE with the bias removed of 9.5% as shown in Table 3. The majority of the ice concentration differences (biases) have absolute values less than 10.0%.

A daily mean sea ice concentration product was also obtained from the Special Sensor Microwave Imager/Sounder (SSMIS) onboard the Defense Meteorological Satellite Program (DMSP) F17 satellite. The product has a 25 km resolution in a polar stereographic grid and is based on the NASA Team algorithm [20] from the Natiaonal Snow and Ice Data Center (NSIDC). Lastly, the NASA Team 2 sea ice concentration algorithm [15] was applied to AMSR2 cases in winter, spring, and summer for an additional comparison to VIIRS ice concentration. Results from comparisons with AMSR2 in January through August 2015, Arctic and Antarctic, show biases (accuracies) from 0.25 to 3.2%, and RMSE (precision) values in the range 8-20%.

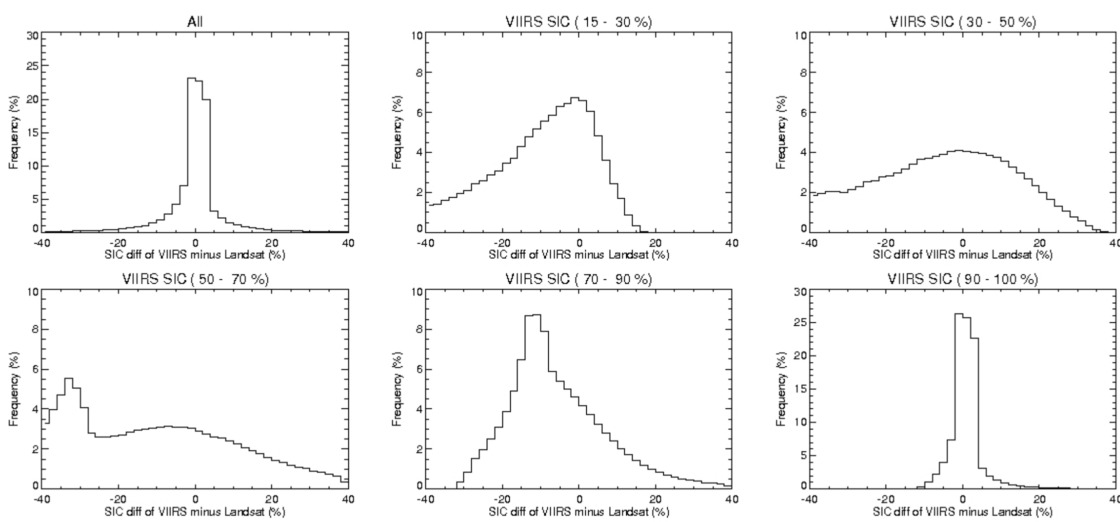



**Figure 79. Comparison of VIIRS minus Landsat ice concentrations for different concentration ranges/bins.**

**Table 3. Bias and RMSE with bias removed (precision) for comparisons of VIIRS minus Landsat ice concentrations for different concentration ranges/bins before and after tie point adjustment.**

| | Overall | VIIRS SIC 15-30% | VIIRS SIC 30-50% | VIIRS SIC 50-70% | VIIRS SIC 70-90% | VIIRS SIC 90-100% |
|---|---|---|---|---|---|---|
| | Bias /RMSE (%) | Bias /RMSE (%) | Bias /RMSE (%) | Bias /RMSE (%) | Bias /RMSE (%) | Bias /RMSE (%) |
| Without tie point adjustment | -0.3/9.5 | -15.6/20.4 | -16.9/26.0 | -11.7/22.6 | -4.8/14.4 | 0.9/6.4 |
| With tie point adjustment | 1.4/8.9 | -12.6/17.4 | -9.1/22.4 | -4.5/21.7 | 0.3/17.2 | 1.6/7.2 |

The 375m resolution VIIRS ice concentration from the IDPS algorithm is compared against estimates made from 2m DigitalGlobe (DG) WorldView-2 imagery and also against estimates created from 10cm Digital Mapping System (DMS) camera imagery. The 750m VIIRS ice concentraton from the Enterprise ice concentration algorithm is compared against DG imagery. The IDPS vs. DG comparisons reveal that, due to algorithm issues, many of the IDPS ice concentration retrievals were falsely assigned ice-free values when the pixel was clearly over ice. These false values increased the validation bias and RMS statistics. The IDPS vs. DMS comparisons were largely over ice-covered regions and did not demonstrate the false retrieval issue. The validation results show that products from both the IDPS and Enterprise algorithms were within or very close to the 10% accuracy (bias) specifications in both the non-melting and melting seasons, but only products from the Enterprise algorithm met the 25% specifications for the uncertainty (RMSE) (Baldwin et al., 2017).

### *Sea Ice Age and Thickness*

1. The Algorithm Theoretical Basis Documents (ATBD) of sea ice age/thickness was updated for JPSS project (March 2016).
2. The energy budget based algorithm (OTIM) of sea ice age and thickness estimation has been improved further with research code. The main improvements in the OTIM include the better estimation of residual heat flux with regression method, the addition of sea ice growth/melting-down process parameterization scheme, and the addition of sea ice dynamic process parameterization scheme. Those improvements were tested good, and ready to implement in the operational code soon.
3. Impact study was performed for the new calibration applied to SDR products, and the results show the impacts of new calibration on sea ice age and thickness are negligible, much smaller than the required accuracy.
4. Sea ice age and thickness products were validated good and meet the requirement with VIIRS data for JPSS project.
5. The OTIM retrieved near real-time Arctic and Antarctic sea ice thickness with Suomi NPP (S-NPP) VIIRS data were made available with research code, and available at https://stratus.ssec.wisc.edu/ice-products/anibrowser/ and will be added to the STAR LTM website in the near future (Figure 80).
6. The OTIM retrieved sea ice thickness products with AVHRR data was comprehensively and intensively compared with sea ice products from ICESat, CryoSat-2, SMOS, and IceBridge field campaign (Wang et al., 2016). The results show that OTIM retrieved sea

ice thickness product is superior to other satellite products in terms of IceBridge sea ice thickness products.

7. The comparison was also done between the OTIM retrieved sea ice thickness with S-NPP data and NASA IceBridge (aircraft lidar + snow radar) estimated sea ice thickness for the matched locations (S-NPP). The statistical results show good performance of the OTIM as listed in Table 4 below.

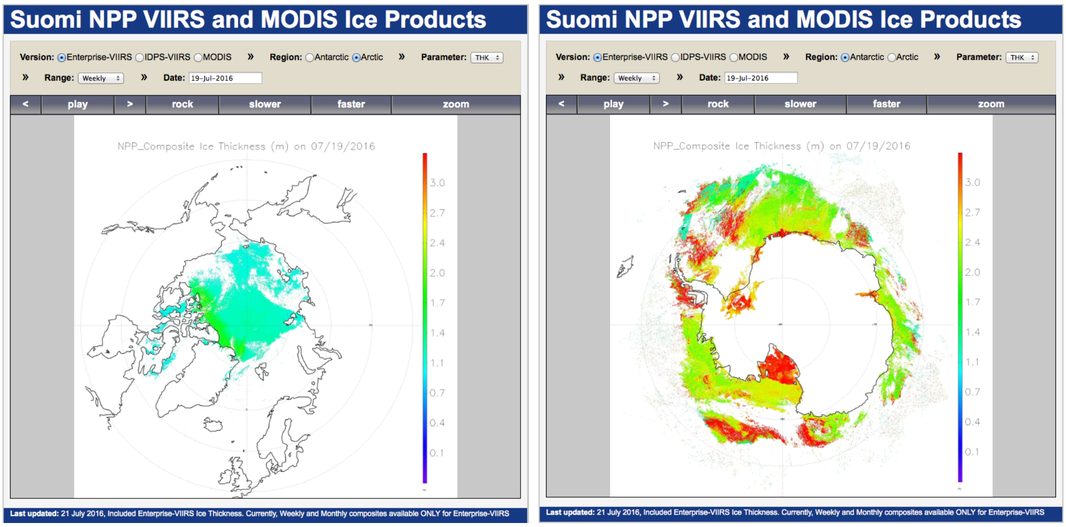



**Figure 80. Examples of OTIM retrieved near-real-time sea ice thickness products with Suomi NPP VIIRS data for the Arctic (left) and the Antarctic (right).**

**Table 4. Statistical results of the comparison in sea ice thickness between S-NPP and NASA IceBridge (aircraft lidar + snow radar) for matched locations (S-NPP pixels).**

| Case no | Date | S-NPP | | IceBridge | | S-NPP minus IceBridge | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | mean | STD | mean | STD | mean | STD | percent (%) | matched pixels |
| 1 | 2014.03.12 | 1.18 | 0.52 | 1.45 | 0.69 | -0.27 | 0.55 | -5.34 | 495 |
| 2 | 2014.03.13 | 2.48 | 0.55 | 2.24 | 0.52 | 0.24 | 0.55 | 16.49 | 438 |
| 3 | 2014.03.24 | 1.88 | 0.78 | 2.33 | 0.48 | -0.45 | 0.78 | -6.31 | 803 |
| 4 | 2014.03.31 | 2.28 | 0.21 | 2.56 | 0.35 | -0.28 | 0.43 | -8.97 | 37 |
| 5 | 2015.03.24 | 2.06 | 0.59 | 2.45 | 0.43 | -0.39 | 0.75 | -11.63 | 1050 |
| 6 | 2015.03.29 | 1.72 | 0.43 | 1.88 | 0.54 | -0.16 | 0.74 | -1.69 | 5153 |
| Average | | 1.93 | 0.50 | 2.15 | 0.50 | -0.22 | 0.63 | -2.91 | 7976 (total) |

## Publications

Liu, Y.; Key, J.; Mahoney, R. Sea and Freshwater Ice Concentration from VIIRS on Suomi NPP and the Future JPSS Satellites. *Remote Sens.* 2016, *8*, 523.

Baldwin. D., M. Schudi, F. Pacifici, and Y. Liu, Validation of Suomi-NPP VIIRS Sea Ice Concentration with Very High-Resolution Satellite and Airborne Camera Imagery. Journal of Photogrammetry and Remote Sensing, accept pending after minor revision.

Meier, W., J.S. Stewart, Y. Liu, J. Key, and J. Miller, An operational implementation of sea ice concentration and ice type characterization estimates from the AMSR2 sensor. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, in review.

Xuanji Wang, Jeffrey Key, Ron Kwok, Jinlun Zhang, 2016, Comparison of Sea Ice Thickness from Satellites, Aircraft, and PIOMAS Data, Remote Sens., Special Issue: Sea Ice Remote Sensing and Analysis, 2016, 8(9), 713; doi:10.3390/rs8090713.

## 18. CIMSS Participation in the JPSS Proving Ground/Risk Reduction Program for 2016

### 18.1 Advancing Hyperspectral Sounder Applications in the Direct-Broadcast Environment

**CIMSS Task Leader: Elisabeth Weisz**
**CIMSS Support Scientists: William L. Smith Sr., Rebecca Schultz, Kathy Strabala, Allen Huang**
**NOAA Collaborator: Mitch Goldberg**
**Budget: $120,000**

**NOAA Long Term Goals:**
- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**
- Serve society's needs for weather and water
- 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
- Environmental Models and Data Assimilation
- Education and Outreach

#### Objective
Our objective is to increase the utility of hyperspectral sounding data products in meteorological real-time operations and to serve the direct-broadcast (DB) community by making the best possible data products available.

#### Project Overview
We aim to characterize hyperspectral retrieval software that is currently available to the national and international direct-broadcast (DB) user community through the UW/CIMSS Community Satellite Processing Package (CSPP). The main differences between the UW/CIMSS Dual-Regression (DR) retrieval algorithm and the NOAA Unique Combined Atmospheric Processing System (NUCAPS) and their implications on product quality and performance for a variety of atmospheric conditions (including severe weather) are investigated. Our main goal is to promote

and enhance the use of hyperspectral satellite data products in meteorological and environmental real-time applications.

## Milestones with Summary of Accomplishments and Findings

Due to their high spectral resolution, hyperspectral infrared (IR) sounders on polar-orbiting satellites, such as AIRS (Atmospheric Infrared Sounder), IASI (Infrared Atmospheric Sounding Interferometer) and CrIS (Cross-track Infrared Sounder), provide critical information about the atmospheric vertical structure and composition. Weisz et al. (2015a) summarize the main differences between the Dual-Regression retrieval algorithm (Smith et al., 2012; Weisz et al., 2013) and NUCAPS (Gambacorta et al., 2013). Severe weather indices such as the Lifted Index (LI) and the Convective Available Potential Energy (CAPE) are measures of atmospheric stability and characterize atmospheric destabilization associated with the convective development of severe local storms. Derived from hyperspectral sounder temperature and humidity profiles, these indices provide additional diagnostic information to aid the NWS warning and decision-making process during severe weather events. Figure 81 shows LI derived from CrIS measurements on 11 May 2016, when a multi-day severe weather outbreak struck the Midwest and Southern Plains. Apart from differences in spatial resolution and retrieval yield related to algorithm differences (e.g., NUCAPS incorporates microwave data, which increases the retrieval yield but decreases the spatial resolution, whereas DR allows for more details in the products due its higher spatial resolution) the regions of intense severe weather are correctly detected by both methods with similar LI values.

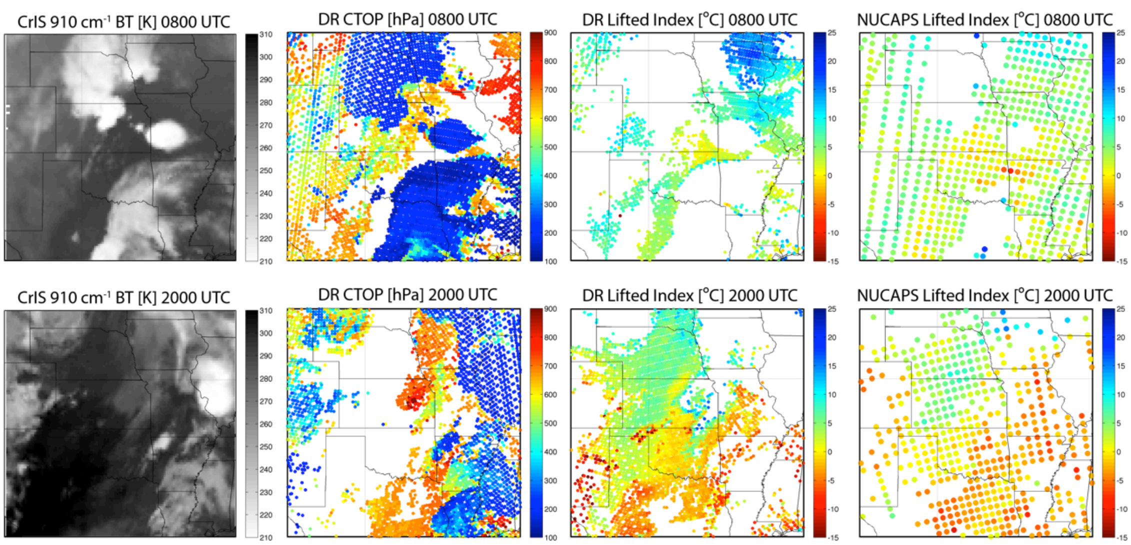



**Figure 81. CrIS Brightness Temperatures (BT) at a window channel, Dual-Regression (DR) retrieved cloud top pressures (CTOP) and Lifted Index (LI), and NUCAPS retrieved LI for the morning (top) and afternoon (bottom) S-NPP overpasses on 11 May 2016.**

Real-time weather applications, including severe-storm nowcasting, further benefit if the entire operational sounding capability is used (i.e., four polar-orbiting satellites carrying advanced sounders). Hence, valuable information can be extracted from a time sequence of hyperspectral retrievals derived from multiple instruments in consecutive orbits (Weisz et al., 2015b). This is illustrated in Figure 82, which shows the evolution of LI and CAPE, derived from AIRS, IASI and CrIS Dual-Regression atmospheric profile retrievals over a 24-hour period for the 24 August 2016 tornado outbreak across Indiana and Ohio. The most severe weather (tornado, high wind, hail) reports were observed around 1900 UTC.

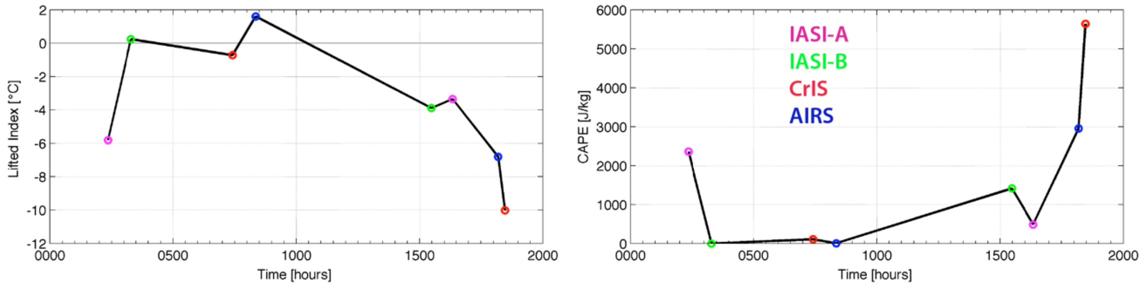



**Figure 82. 24-hour time-series of lifted index (left) and the convective potential available energy (right) derived from all operational hyperspectral sounders on 24 August 2016 (for one specific location near the Missouri/Arkansas state border).**

## Publications and Conference Reports

Smith, W. L., E. Weisz, B. Hoover, Making Satellite Retrievals Compatible with NWP Background Fields for NWP Data Assimilation, Joint 21st AMS Conference of Satellite Meteorology, 15-19 August 2016, Madison, Wisconsin, USA.

Weisz, E., W. L. Smith, R. Schultz, Enhancing Weather Monitoring and Forecasting with Polar-orbiting High Spectral Resolution Infrared Sounders, Joint 21st AMS Conference of Satellite Meteorology, 15-19 August 2016, Madison, Wisconsin, USA.

Schultz, R, B. A. Baum, E. Weisz, Investigation of favorable atmospheric conditions for PyroCb (Pyrocumulonimbus) events using Cross-track Infrared Sounder (CrIS) measurements and retrieval products. Joint 21st AMS Conference of Satellite Meteorology, 15-19 August 2016, Madison, Wisconsin, USA.

Smith, W. L., E. Weisz, B. Hoover, J. Li, and W. Cheng, "Vertical Structure De-Aliasing of Satellite Product Retrievals fro NWP Assimilation", EUMETSAT 2016 Meteorological Satellite Conference, 26-30 Sept 2016, Darmstadt, Germany.

Weisz, E., W. L. Smith, R. Schultz, K. Strabala, A. Huang, N. Smith, Leveraging Direct-Broadcast Hyperspectral Sounder Retrieval Data for Regional Weather Monitoring Applications, 2016 AGU Fall Meeting, 12-16 December 2016, San Francisco, California, USA.

Weisz, E., R. Schultz, W. L. Smith, K. Strabala, A. Huang, Expanding Existing Observations of the Pre-Storm Environment Using a Time-Series of High-Spectral Resolution Infrared Sounder Retrievals, 97th AMS Annual Meeting, 22-26 January 2017, Seattle, Washington, USA.

## References

Gambacorta, A., et al. (2013), The NOAA Unique CrIS/ATMS Processing System (NUCAPS): Algorithm Theoretical Basis Documentation, Version 1.0, NOAA Center for Weather and Climate Prediction (NCWCP), 5830 University Research Court 2nd Floor, Office 2684 College Park, MD 20740-3818, USA.

Smith, W. L., E. Weisz, S. Kirev, D. K. Zhou, Z. Li, and E. E. Borbas (2012), Dual-Regression Retrieval Algorithm for Real-Time Processing of Satellite Ultraspectral Radiances. *J. Appl. Meteor. Clim., 51*, Issue 8, 1455-1476.

Weisz, E., W. L. Smith, and Nadia Smith (2013), Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements. *Journal of Geophysical Research -Atmospheres*, 118, 6433-6443.

Weisz, E., W. L. Smith, N. Smith, (2015a) Assessing Hyperspectral Retrieval Algorithms and their Products for Use in Direct Broadcast Applications, 20th International TOVS Study Conference (ITSC-20) proceedings paper 3.03, 28 October - 3 November 2015, Lake Geneva, Wisconsin, USA.

Weisz, E., N. Smith, and W. L. Smith (2015b), The use of hyperspectral sounding information to monitor atmospheric tendencies leading to severe local storms. *Earth and Space Science*, 2.

## 18.2 Enhance the Utilization of Real Time JPSS Sounder Data in SDAT for Tropical Cyclone Forecast Application

**CIMSS Task Leader: Jun Li**
**CIMSS Support Scientists: Jinlong Li, Kevin Baggett, and Pei Wang**
**NOAA Collaborators: Mark DeMaria (NHC), John L. Beven (NHC), Vijay Tallapragada (EMC), Andrew Collard (EMC), and Tim Schmit (STAR)**
**Budget: $130,000**

### NOAA Long Term Goals:
- Weather-Ready Nation

### NOAA Strategic Goals:
- 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

### Objective
The objective is to use the NPP/JPSS sounder measurements for improving the prediction of tropical cyclone (TC) genesis and evolution.

### Project Overview
This is the second phase of our JPSS PGRR project and is the continuation of first phase project "Near real-time assimilation system development for improving tropical cyclone forecasts with NPP/JPSS sounder data" which ended in June 2015. The PI and the team propose to enhance the utilization of real time JPSS (Suomi NPP, JPSS1, JPSS2) sounder data in CIMSS Satellite Data Assimilation for Tropical storm forecast (SDAT) system (http://cimss.ssec.wisc.edu/sdat) while meeting the latency for tropical cyclone (TC) forecast application by increasing the model horizontal resolution, using TC vital observations to improve the hurricane location initialization, and implementing the latest version of Community Gridpoint Statistical Interpolation (GSI) data assimilation system. The community satellite processing package (CSPP) real time products from Space Science Engineering Center (SSEC), Miami, and Puerto Rico direct broadcast (DB) sites will be assimilated into SDAT after converted to BUFR format that GSI assimilation system uses.

The Cross-track Infrared Sounder (CrIS) data (radiances, cloud-cleared radiances, and soundings), along with the Advanced Technology Microwave Sounder (ATMS) will be the primary products from CSPP to be assimilated. SDAT will serve as the testbed to conduct research on improving the utilization of JPSS data, and the research topics include: better CrIS sub-pixel clear detection by using collocated high spatial resolution VIIRS cloud mask, which has been successfully demonstrated using AIRS/MODIS (Wang et al., 2014); CrIS radiance assimilation in cloudy regions; impact study on assimilating Unique CrIS/ATMS Processing System (NUCAPS) soundings and cloud-cleared radiances (CCRs), and impact study on assimilating the full spectral resolution CrIS water vapor absorption band radiances. The research progress will be implemented in SDAT for real time demonstration and TC forecast application. In addition, the research progress made with SDAT on JPSS sounder assimilation will also be tested with benchmark HWRF at STAR's supercomputer S4/Cardinal located at Space Science and Engineering Center (SSEC). CIMSS scientists will collaborate with Environmental Modeling Center (EMC) on possible transition of the research progress made by this project to operational HWRF.

CIMSS has been providing the SDAT forecast products in near real time (NRT) since September 2014 to ATCF (automatic tropical cyclone forecast) system that National Hurricane Center (NHC) uses. CIMSS scientists will collaborate with NHC on the application of SDAT products and get feedback/guidance from users for further improvement on JPSS sounder data assimilation and SDAT system.

## Summary of Accomplishments and Findings

### *SDAT Forecasts: Availability, Assessment, and Improvement*

The CIMSS real time Satellite Data Assimilation for Tropical storm forecasts (SDAT) continues to provide forecasts in Automated Tropical Cyclone Forecast (ATCF) in NRT to the end users. SDAT assimilates both U.S. GOES and POES data include the GOES Sounder radiances, AMSU-A (N15, N18, Metop-A, -B, Aqua), ATMS, CrIS (Suomi-NPP), AIRS (Aqua), IASI (Metop-A), and MHS (N18, Metop-a) radiances, and will also include AHI when data are available. In addition to assimilating radiances, the GOES Sounder real time total precipitable water (TPW) with GOES-R series legacy atmospheric profile (LAP) algorithm is also assimilated since October 2015. NOAA/NESDIS-funded Supercomputer for Satellite Simulations and Data Assimilation Studies (S4) (Boukabara et al., 2017, BAMS) located at UW-Madison's Space Science Engineering Center (SSEC) is used for running real time SDAT. A webpage has been preliminary designed for accessing the forecasts results: http://cimss.ssec.wisc.edu/sdat and the SDAT forecast products in ATCF are available in the following ftp site: ftp://rammftp.cira.colostate.edu/musgravek/SDAT/

The SDAT forecasts have been delivered in NRT every day to ATCF since September 2014, which means the end users can access SDAT products in their TC forecasts without causing extra efforts.

SDAT 2015 hurricane season evaluation was done by Dr. Mark DeMaria. SDAT forecasts provided by CIMSS from 2015 Atlantic season in ATCF format, 72 hr forecasts of track and intensity with 56 forecasts from 4 storms (Danny, Erika, Fred and Joaquin) are verified by NHC. Evaluation focused on the forecasts with relocation version. Homogeneous comparisons are conducted with subset of NHC's operational models, for example, tracks from HWRF, GFS (called AVNO), TVCN (consensus forecast), and intensities from Interpolated HWRF (HWFI), Interpolated GFDL (GHMI), SHIPS, LGEM, ICON (Consensus forecast) are used. Simple statistical model OCD5 used as baseline for skill evaluation, NHC verification rules are applied (cases must be tropical or subtropical to be included, must also have NHC Official Forecast (OFCL)). The verification metrics for track include Average Error, Skill relative to OCD5, for intensity include Average Error, Bias, Skill relative to OCD5.

It is found that SDAT track errors are comparable with NHC's best operational models, SDAT has large track skill compared with OCD5, but SDAT intensity errors are larger than NHC's best operational models, with very large low intensity bias at the initial stage. SDAT has little skill of intensity at early times, but some skill at 48 and 72 hr.

Recommendations made from NHC (Dr. Mark DeMaria) on SDAT include: Run to 126 hr if possible; Address latency using "interpolater"; See if SDAT adds to consensus track model skill; Large early intensity errors and large negative bias suggest initialization/spin up problems; Interpolator method may reduce large initial intensity errors; Provide forecasts for all TC cases if possible. CIMSS HIW team has taken actions to address those very valuable recommendations for 2016 hurricane season forecasts. The assessment on SDAT 2016 hurricane forecasts will also be conducted by Dr. DeMaria. SDAT can serve as research testbed to improve the utilization of satellite data in regional NWP, research progress from SDAT can be potentially transferred to operational NWP models such as HWRF and GFS.

***Evaluation of Imager-based CrIS cloud-cleared radiance (CCR) global dataset***

Following methodology developed by Li et al. (2005), the MODIS/AIRS cloud clearing procedure has been modified to apply to process the collocated VIIRS/CrIS. A global CrIS cloud-cleared radiance (CCR) dataset has been processed and provided to EMC for evaluation. Initial evaluation has been conducted by EMC (Drs. Andrew Collard and Haixia Liu) on CIMSS developed imager-based CrIS cloud-cleared radiance (CCR) global dataset in GFS.

Currently EMC is using background-based (BG-based) cloud-cleared CrIS radiances (CCRs) in GFS. The VIIRS-based CrIS CCRs and BG-based CrIS CCRs are evaluated against clear sky brightness temperature (BT) observations within the FORs (fields-of-regard), one CrIS FOR contains 3 by 3 CrIS fields-of-view (FOVs). Figure 83 shows the BT difference image between BTclr and BTccr within FORs (total 13198 FORs) for CrIS channel 150 with wavenumber of 743.125 $cm^{-1}$. The FORs (13198) with CCR FOVs provide much more coverage than those (9230) with only clear CrIS clear FOVs.

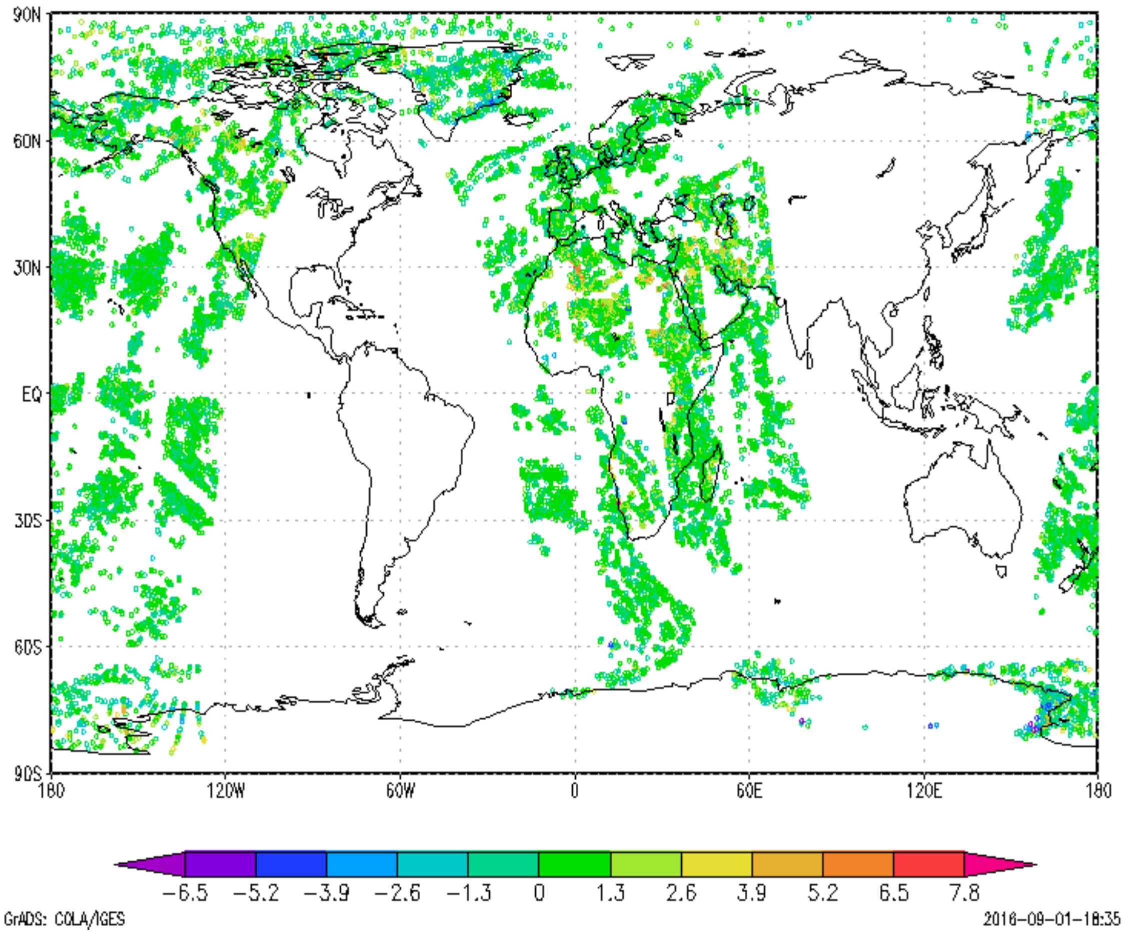



**Figure 83. The BT difference image between BTclr and BTccr within FORs (total 13198 FORs) for CrIS channel 150 with wavenumber of 743.125 cm$^{-1}$.**

Figure 84 shows the BT differences between CrIS CCRs (converted to BT) and clear sky BT observations. It can be seen that both VIIRS-based and BG-based CCRs have small differences in both CO2 absorption and window regions, but VIIRS-based CCRs and BG-based CCRs have different signs for bias (VIIRS-based CCRs have negative bias while BG-based CCRs have positive bias). There are total 3103 matched FORs that have both VIIRS-based CCRs and BG-based CCRs, but only 875 out of 3103 FORs have clear-sky FOVs flagged by the VIIRS cloud mask.

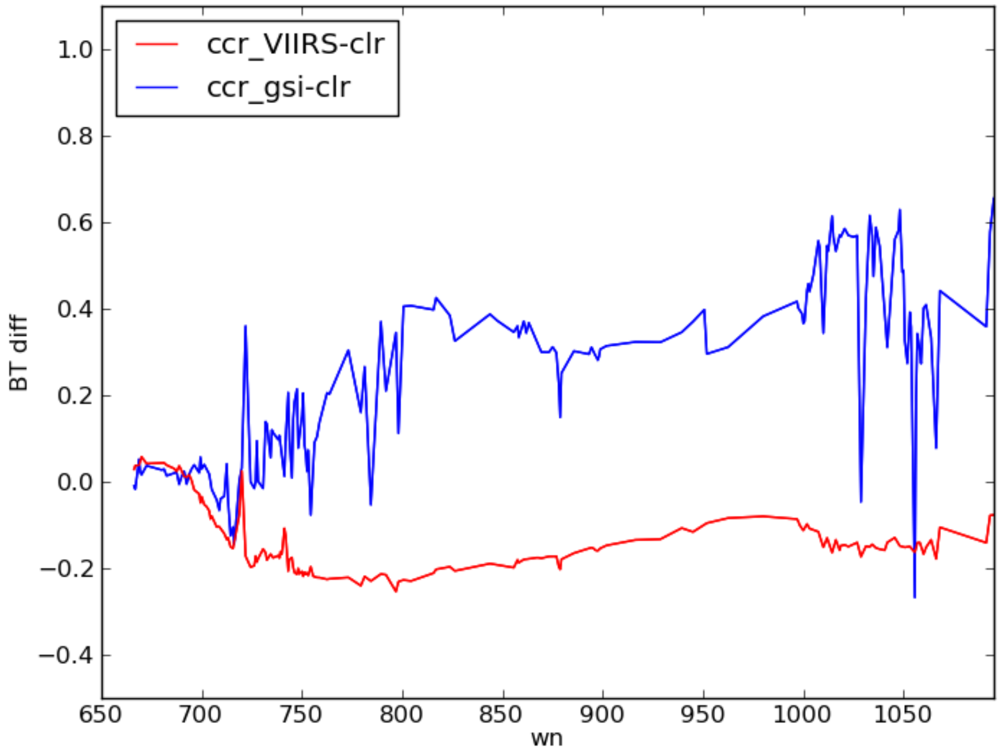



**Figure 84. The mean BT differences between CrIS CCRs (converted to BT) and clear sky BT observations.**

CrIS CCRs have been tested with SDAT, experiments shows that CrIS cloud-cleared radiances (CCRs) provided significant improvement on TC track forecasts in some particular situations. For example, in hurricane Joaquin (2015) forecast experiments, we found that many dynamic models predicted on 30 September and 01 October 2015 that the storm might turn to East Coast in a few days, but the hurricane went away from the coast to Atlantic Ocean. Experiments indicate significant improvement from CrIS CCR over CrIS original clear radiances detected by GSI on 120-hour forecasts started 18 UTC 30 Sept 2015 and 00 UTC 01 Oct 2015. Figure 85 shows the 120-hour forecasts started at 00 UCT 01 October 2015 from assimilating conventional data (GTS)+4AMSUA+ATMS+CrIS (blue) and GTS+4AMSUA+ATMS+CrIS_CCR (red) SDAT (blue), along with the best track (black) (upper middle panel). The coverage of clear CrIS detected by GSI system (lower left panel) and the coverage of CrIS CCR (lower right panel) for channel 130 with weighting peak around 750 hPa (upper right panel), are illustrated by overlaying on GOES 11 µm BT image.

This regional NWP experiments on CrIS CCRs are encouraging, further testing in GFS at EMC is ongoing.

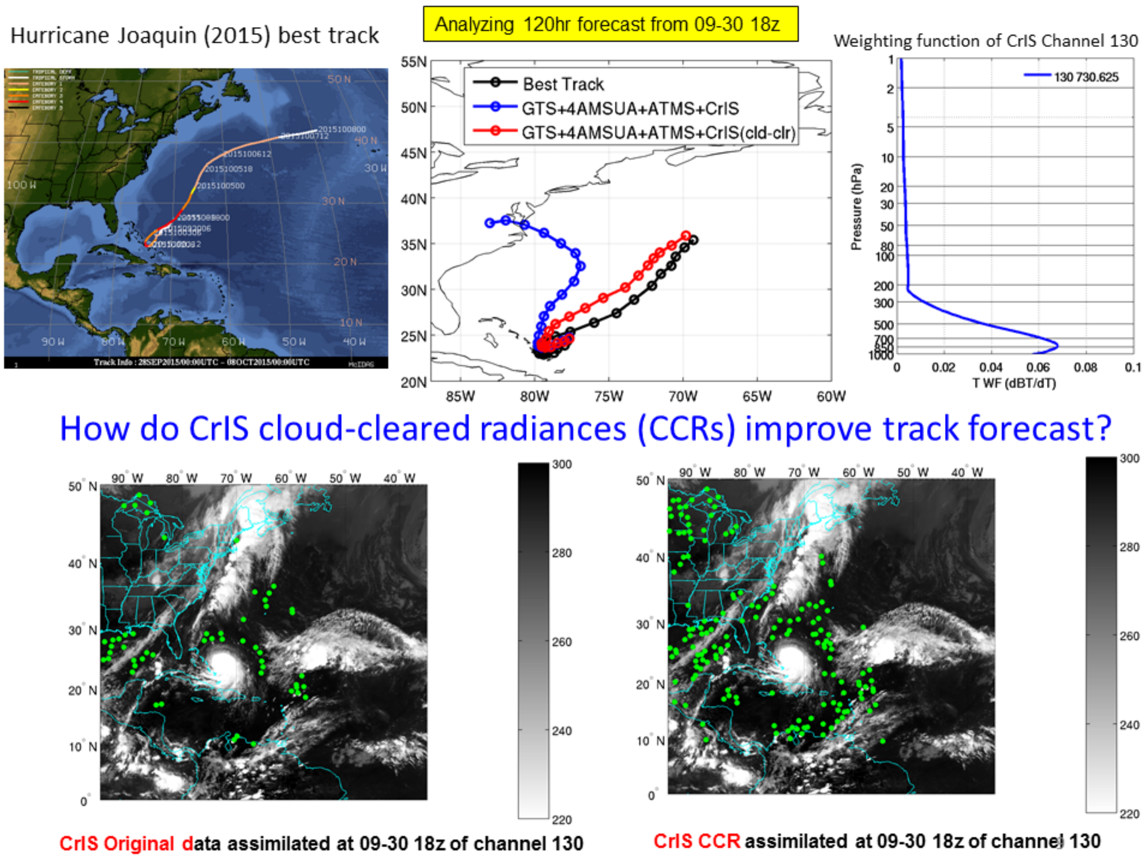



**Figure 85. The 120-hour forecasts started at 00 UTC 01 October 2015 from assimilating conventional data (GTS)+4AMSUA+ATMS+CrIS (blue) and GTS+4AMSUA+ATMS+CrIS_CCR (red) SDAT (blue), along with the best track (back) (upper middle panel). The coverage of clear CrIS detected by GSI system (lower left panel) and the coverage of CrIS CCR (lower right panel) for channel 130 with weighting peak around 750 hPa (upper right panel), are illustrated by overlaying on GOES 11 um BT image.**

### *HWRF Testing*

Following suggestions/guidance from Dr. Mitch Goldberg, the JPSS Program Scientist, and Dr. Mark DeMaria, NHC user and collaborator in this project, HWRF is tested at Operations-To-Research (O2R) environment on the Supercomputer for Satellite Simulations and data assimilation Studies (S4) (Boukabara et al., 2017) physically located at SSEC. The hwrf_v3.7a DTC version has been installed at S4 by Joint Center for Satellite Data Assimilation (JCSDA), and the preliminary document is also drafted. For successful using HWRF for CrIS radiance assimilation experiments, testing and benchmarking are needed at S4. The following tasks are tested:

1. Tested HWRF at S4, fix problems and make HWRF running;
2. Conducted case experiment, compare results from different settings of HWRF at S4; and
3. Developed script to make HWRF cycling running at S4.

The next step is to test the VIIRS-based CrIS CCR assimilation, and the CrIS clear sky radiance with VIIRS for cloud-detection, compare with SDAT and the operational HWRF. The purpose is to potentially transfer CIMSS research progress on CrIS radiance assimilation to operation HWRF.

**Publications and Conference Reports**

Ai, Y., J. Li, T. Schmit, and C. Cao, 2016: Deep Convective Cloud Characterizations from both Broadband Imager and Hyperspectral Infrared Sounder Measurements, Journal of Geophysical Research – Atmospheres (accepted).

Boukabara, S., T. Zhu, H. Tolman, S. Lord, S. Goodman, R. Atlas, M. Goldberg, T. Auligne, B. Pierce, L. Cucurull, M. Zupanski, M. Zhang, I. Moradi, J. Otkin, D. Santek, B. hoover, Z. Pu, X. Zhan, C. Hain, E. Kalnay, D. Hotta, S. Nolin, E. Bayler, A. Mehra, S. Casey, D. Lindsey, L. Grasso, V. Kumar, A. Powell, J. Xu, T. Greenwald, J. Zajia, Jun Li, Jinlong Li, B. Li, J. Liu, L. Fang, P. Wang, and T. Chen, 2016: S4: An O2R/R2O Infrastructure for Optimizing Satellite Data Utilization in NOAA Numerical Modeling Systems: A Step Toward Bridging the Gap between Research and Operations, Bulletin of American Meteorological Society, 97, 2359 - 2378.

Han, Hyojin, Jun Li, Mitch Goldberg, Pei Wang, Jinlong Li, Zhenglong Li, B.-J. Sohn, and Juan Li, 2016: Microwave sounder cloud detection using a collocated high resolution imager and its impact on radiance assimilation in tropical cyclone forecasts, Monthly Weather Review, 144, 3927 - 3959.

Li, J., et al., 2016: On the assimilation of satellite sounder data in cloudy skies in the numerical weather prediction models, Journal of Meteorological Research, 30, 169 - 182.
Li, J., 2016: Improving JPSS and GOES-R applications with CIMSS near real-time satellite data assimilation for tropical cyclone forecasts, feature article, JPSS.

Li, Jun, Pei Wang, Zhenglong Li and Mitch Goldberg, 2016: On the assimilation of hyperspectral infrared sounder radiances in cloudy skies in numerical weather prediction models – challenges and practical approaches, 7th Asia-Oceania/2nd AMS-Asia/2nd KMA Meteorological Satellite Users' Conference, 21 – 28 October 2016, Songdo, Incheon, Korea.

Wang P., J. Li, Z. Li, J. Li, A. Lim, T. J. Schmit and M. Goldberg, Improving assimilation of CrIS radiances under cloudy skies using collocated VIIRS data, 21st Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface, 97th AMS annual meeting, Seattle, WA, 22-26 January, 2017.

## 18.3 High Resolution Trajectory-Based Smoke Forecasts using VIIRS Aerosol Optical Depth and NUCAPS Carbon Monoxide Retrievals

**CIMSS Task Leader: James E Davies**
**CIMSS Support Scientists: Kathy Strabala, Russ Dengel**
**NOAA Collaborator: R. Bradley Pierce**
**Budget: $125,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

- Serve society's needs for weather and water

**CIMSS Research Themes:**

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

## Objective

This work addresses the need for low latency, web-based, high resolution forecasts of smoke dispersion for use by NWS Incident Meteorologists (IMET) to support on-site decision support services for fire incident management teams.

## Project Overview

This project supports the Fire and Smoke (F&S) and Sounding Applications (NUCAPS, Atmospheric Chemistry) Initiatives of the 2016 Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction (PGRR) Program by using Visible Infrared Imaging Radiometer Suite (VIIRS) Aerosol Optical Depth (AOD) and combined Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) NOAA-Unique CrIS-ATMS Processing System (NUCAPS) carbon monoxide (CO) retrievals to initialize trajectory-based, high spatial resolution North American smoke dispersion forecasts.

## Milestones with Summary of Accomplishments and Findings

### *Complete IDEA-I NAM 3km meteorological driver (High spatial resolution trajectory forecast capability) and IDEA-I VIIRS and NUCAPS ingest*

We conducted off-line testing of the use of high resolution (3km) NAM forecasts and full resolution (6km) VIIRS AOD EDR to initialize high resolution IDEA-I trajectory-based smoke forecasts during the Fort McMurray wild fire (Figure 86). A total of 4336 trajectories where initialized for this case and the 23 hour forecast illustrates how the smoke plume bifurcates with some of the smoke being transported to the south east over Wisconsin behind the low pressure system over Virginia and North Carolina and some of the smoke being transported to the north east and being entrained into a deep low pressure system over Hudson Bay. Ground based Aeronet measurements of smoke AOD confirm the predicted mid-tropospheric transport of a thin smoke plume from the Fort McMurray wildfire over Madison on May 5th, 2016 (Figure 87).

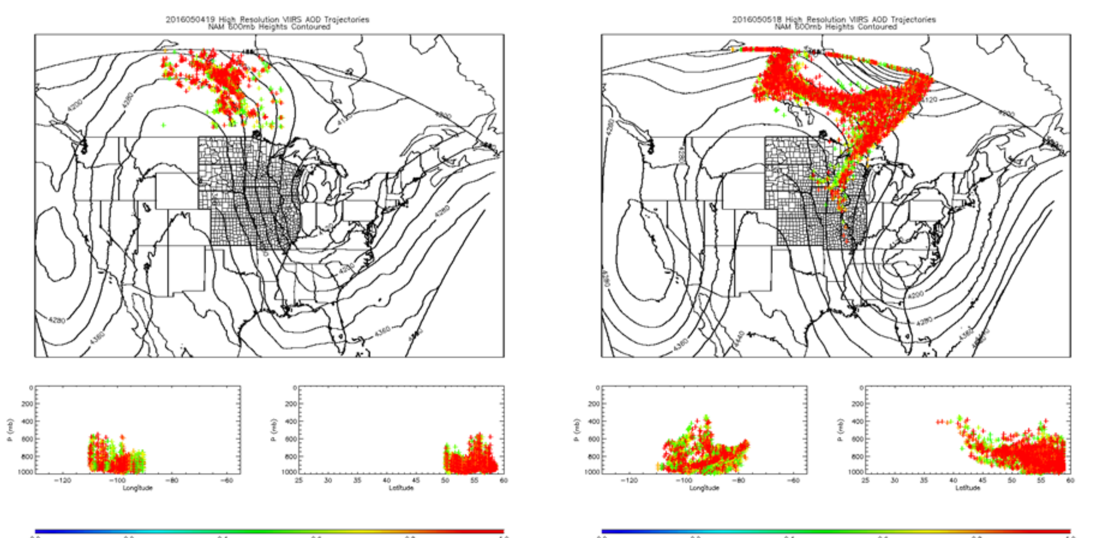



**Figure 86. Initial conditions (left) and 23 hour forecast (right) for May 04, 2016 NAM high resolution trajectory forecast of Fort McMurray wildfire. Trajectories are colored by their initial AOD. Cross-sections of trajectory longitude verses pressure (mb) and latitude verses pressure (mb) are shown below each map. NAM 600mb heights are contoured**

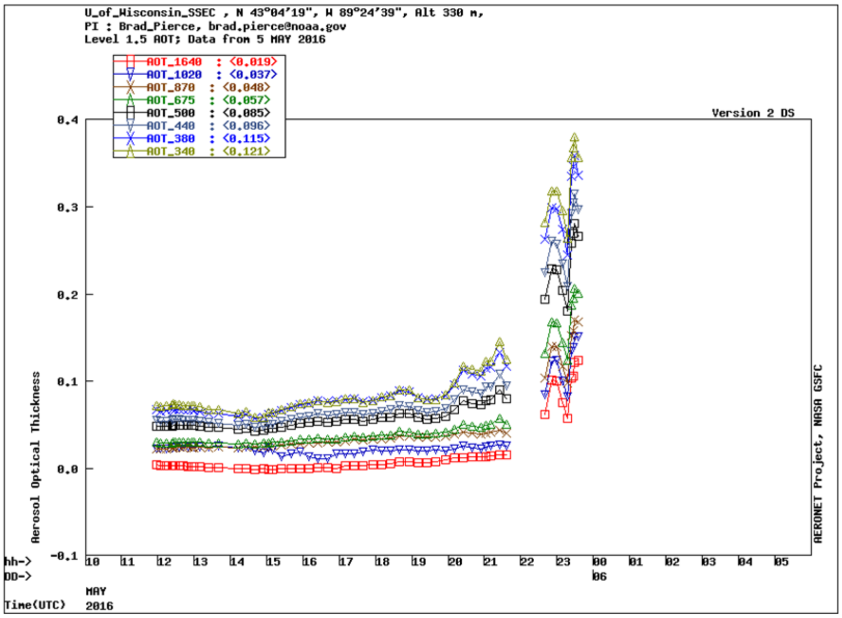



**Figure 87. Level 1.5 Aeronet observations of spectrally resolved AOT at the Madison, WI Aeronet site beginning at 10Z on May 05, 2016 and extending to 00Z on May 06, 2016.**

### *Release beta version of IDEA-I High Resolution*

A beta version of IDEA-I High Resolution that supports high resolution NAM VIIRS AOD trajectories for multiple, user defined domains was completed and is being evaluated internally prior to public release. Real-time demonstration of the use of the high resolution (4km) NAM forecasts and full resolution (6km) VIIRS AOD EDR to initialize high resolution IDEA-I trajectory-based smoke forecasts during the November 2016 wildfires within the Great Smoky Mountains National Park.

### Publications and Conference Reports

Briefed Western Region NWS on NAM high resolution trajectory-based smoke during the Fort McMurray wildfire during SOO Science Call webinar entitled "Update on Modeling Smoke/Air Chemistry Project" on May 25, 2016

"JPSS Observations of Intercontinental Pollution and Atmospheric River Transport Processes during the 2016 NOAA El Niño Rapid Response (ENRR) Field Campaign" presented at the 2016 AGU NOAA Booth

"High Resolution Trajectory-Based Smoke Forecasts Using VIIRS Aerosol Optical Depth and NUCAPS Carbon Monoxide Retrievals" during the Space-Based, Operational Global Earth Observations from Suomi National Polar-Orbiting Partnership (S-NPP), the Joint Polar Satellite System (JPSS) Session at the 2016 AGU

## 18.4 The Cold Air Aloft Aviation Hazard: Its Detection Using Observation from JPSS

**CIMSS Task Leaders: J. Davies, E. Weisz**
**CIMSS Support Scientists: Dave Hoese, Kathy Strabala**
**NOAA Collaborator: Kristine Nelson (NOAA/CWSU)**
**Budget: $63,050**

**NOAA Long Term Goals:**
- Weather-Ready Nation
- Resilient Coastal Communities and Economies

**NOAA Strategic Goals:**
- 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
- Environmental Models and Data Assimilation

## Objective
The primary objectives of this project are as follows:
1. Develop and disseminate gridded real-time CrIS/ATMS products through DB,
2. Generate new AWIPS II visualization capabilities with gridded products for 3-D visualization of CrIS/ATMS profile data,
3. Transition experimental product to Alaska CWSU and perform targeted assessment to determine operational utility of product for CAA forecast challenge, and
4. Identify and investigate other forecast challenges outside of CAA where similar visualizations may be beneficial.

## Project Overview
The NOAA/NWS CWSU in Anchorage, Alaska has forecast responsibilities for disseminating text-based products to pilots and airlines, which give guidance on the latitude/longitude bounds and vertical flight levels of these cold air aloft (hereafter CAA) regions where the air temperature is at or below -65$^{o}$C. Previously, forecasters at the CWSU would rely on a combination of isolated aircraft reports, a sparse network of radiosondes, and global model fields for identifying and characterizing these cold air hazards. However, these current datasets have proven spatially and vertically insufficient for the accurate characterization of the three-dimensional (3-D) nature of these CAA features. Forecasters have expressed an urgent need for additional data to be added to fill observational gaps and/or confirm information that is seen in models (i.e., to build confidence in numerical CAA predictions). One source of observations that has remained largely unused but promises to add great value is temperature soundings from hyperspectral infrared (IR) instruments onboard polar-orbiting satellites. Decision support systems have traditionally been used to visualize observations from space-based imagers as two-dimensional (2-D) surface plots (e.g., a cloud field). Satellite soundings, however, offer 3-D characterization of the atmosphere (latitude, longitude, and height) that can potentially improve forecasting skill in general and the characterization of these CAA regions specifically.

## Milestones with Summary of Accomplishments and Findings
1. *Develop and Disseminate Gridded CrIS/ATMS Products through Direct Broadcast*
   The Dual Regression Retrieval (DR) and Polar2Grid software tools have been available within CSPP for more than two years. At present, the DB site at GINA (U. Alaska) runs CSPP in real-time and disseminates products via File Transfer Protocol (FTP). NUCAPS, the NOAA operational CrIS/ATMS processing algorithm, was released within CSPP at

the end of February 2015. GINA receives CrIS/ATMS data from the S-NPP satellite via DB antennas at the University of Alaska campus in Fairbanks and at the NOAA Satellite and Information Service (NESDIS) Command and Data Acquisition Station at Gilmore Creek, Alaska. We successfully implemented the NUCAPS retrieval products at GINA by using the CSPP software to process the data and generate products depicting the CAA phenomenon in formats ready for ingest into AWIPS II.

CIMSS provided critical support for the adaptation of Polar2Grid software for use with the NUCAPS product. A list of accomplishments under the current funding period are provided below:

- This project funded new features, software bug fixes, and software maintenance in the form of testing, documentation, updating third-party libraries, and software packaging of official Polar2Grid releases.
- Initial work added ability to read NUCAPS retrieval NetCDF4 files via a NUCAPS "Reader".
- The Reader could produce Temperature (Temperature) and H2O Mixing Ratio (H2O_MR) data that was then resampled to a uniform grid and written to an HDF5 file via Polar2Grid.
- Resampling was done using a nearest neighbor resampling algorithm.
- HDF5 files were then used by SPORT to view the data in AWIPS and other tools.
- Feature: Ability to mask data below the surface pressure
- Feature: Ability to mask data based on NUCAPS quality flags
- Feature: Ability to specify which pressure levels to produce
- NUCAPS reading was a challenge for Polar2Grid as it was the first pressure-based products it had ever had to read.
- Second round of work added "Skin_Temperature", "Surface_Pressure", and "Topography" to produced output.
- The ability to turn off the above-mentioned masking functionality was also added.
- Additional work was done to add fields that may be used in the future.
- The NUCAPS functionality added to Polar2Grid was done so via the open source python library SatPy in collaboration with the PyTroll group. It can be accessed in SatPy using the reader name "nucaps".
- By adding the NUCAPS Reader to SatPy we benefit from many developers reviewing the code, more testers, more users, and reduced redundancy of code. We also benefit from any features or optimizations that may be contributed to the project; even when it isn't added specifically for the NUCAPS Reader.
- Polar2Grid and SatPy (as well as other PyTroll python packages) are hosted on the online project hosting service GitHub (github.com) and are available to the public.
- Funding was used to add "unit tests" to SatPy and Polar2Grid to help insure that changes to the software keep the NUCAPS functionality working as the software grows and new features get added. Unit tests are run automatically after ever change that is made to the software via the Continuous Integration service TravisCI (travis-ci.org).
- In addition to unit testing the SatPy package takes advantage of the Coveralls service (coveralls.io) to report on how much of the code is being actively tested. It reports this as a percentage of code lines "touched" during testing. This helps to inform the development team and users of the stability of the SatPy project. Since SatPy is a rather new project every new test helps.
- The SatPy python library is available to python developers via the PyPI (Python Package Index) (https://pypi.python.org/pypi/satpy). This allows for easy installation for

any developers familiar with the Python programming language.
- SatPy and Polar2Grid are written in the Python programming language with command line helper scripts written in bash. They both take advantage of third-party libraries like NumPy and SciPy for fast calculations as well as some custom code written in the Cython programming language to produce C/C++ code for the best performance in key areas of the processing.

Related links:
https://github.com/davidh-ssec/polar2grid
https://github.com/pytroll/satpy
https://travis-ci.org/davidh-ssec/polar2grid
https://travis-ci.org/pytroll/satpy
https://coveralls.io/github/pytroll/satpy

2. *Generate AWIPS II visualization capabilities for 3-D CrIS/ATMS profile data*
Examples of the a high impact CAA event that was well captured by Gridded NUCAPS in AWIPS II is shown in Figure 88 and Figure 89. Figures provided by B. Zavodsky (SPORT).

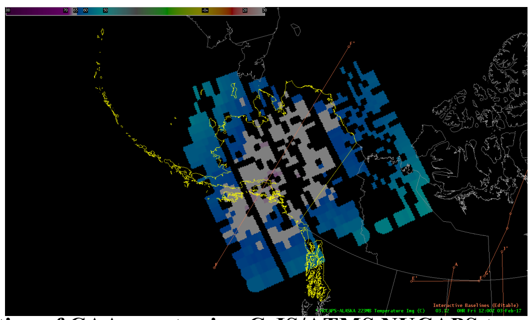


**Figure 88. AWIPS II visualization of CAA event using CrIS/ATMS NUCAPS temperature profiles at the 223 mb level at 1200 UTC on 2 February 2017 over Alaska.**

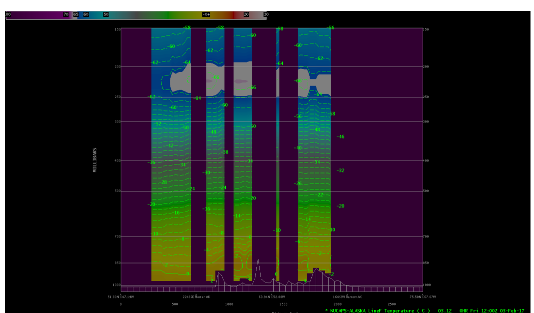


**Figure 89. Figure 1 AWIPS II visualization of CAA event using CrIS/ATMS NUCAPS temperature profiles as a vertical cross-section at 1200 UTC on 2 February 2017 over Alaska.**

3. *Transition experimental product to Alaska CWSU and perform targeted assessment to determine operational utility of product for CAA forecast challenge.*
In progress under SPORT leadership.
4. *Identify and investigate other forecast challenges outside of CAA where similar visualizations may be beneficial.*
In progress under SPORT leadership.

## References

Gambacorta, A, 2014: *The NOAA Unique CrIS/ATMS Processing System (NUCAPS): Algorithm Theoretical Basis Documentation*, NOAA/NESDIS/STAR, 72 pp.

Jedlovec, G., 2013: Transitioning Research Satellite Data to the Operational Weather Community: The SPoRT Paradigm. *IEEE Geoscience and Remote Sensing Magazine*, 1, 62.

## 18.5 A Fused SO2 Analysis from JPSS

**CIMSS Task Leader: John Cintineo**
**CIMSS Support Scientist: Justin Sieglaff**
**NOAA Collaborator: Mike Pavolonis**
**Budget: $65,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- Serve society's needs for weather and water
- 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

### Objective

Fusing SO2 detection capabilities from VIIRS, CrIS, and OMPS to create an integrated SO2 analysis product from JPSS.

### Project Overview

$SO_2$ is an abundant volcanic gas that is hazardous to human health, infrastructure and the environment, and is often a very effective tracer for volcanic ash, which is a major aviation hazard. In addition, regular monitoring of volcanic $SO_2$ emissions can help scientists better characterize volcanic unrest, forecast eruption, and assess the climate impacts of very large eruptions. Despite the importance of $SO_2$ monitoring, JPSS is severely underutilized for this application, and the existing single sensor JPSS $SO_2$ products from the Ozone Mapping Profiler Suite (OMPS) and the Cross-track Infrared Sounder (CrIS) have several important limitations. This research is a step in the direction of creating a far more capable fused $SO_2$ product suite using the Visible Infrared Imaging Radiometer Suite (VIIRS), CrIS, and OMPS. Users will benefit from the strengths of three sensors integrated into a single coherent product line, eliminating the need to try to manually blend all of the "stove piped" information. This work utilizes OMPS and CrIS to mathematically constrain the retrieval of $SO_2$ properties (detection, loading, and height) derived from VIIRS. Thus, the final products from this research will exhibit the spatial resolution of VIIRS and accuracy consistent with the products derived from the hyperspectral measurements. The resulting product can provide timely and relevant information to users to help monitor eruption cloud motion and mitigate potential aviation and/or ash-fall hazards. The primary users for the proposed products are Volcanic Ash Advisory Centers (VAACs), Meteorological Watch Offices (MWOs), volcano observatories (including the USGS Alaska Volcano Observatory (AVO)), the Air Force Weather Agency (AFWA), and the Icelandic Met Office (IMO). Based on our experiences with volcanic ash products, we expect additional operational and research-focused users from the international community to also be interested in these products

## Milestones with Summary of Accomplishments and Findings

- The Bayesian classifier that is used to compute the pixel-level $SO_2$ probability from VIIRS infrared measurements has been implemented (see Figure 28) and evaluated using VIIRS $SO_2$ probability results (see top panel of Figure 29).
- The object portion of the Spectrally Enhanced Cloud Objects (SECO) method for VIIRS $SO_2$ detection has been advanced.
- Progress has been made in modifying GEOCAT/VOLCAT software to process CrIS in tandem with VIIRS.

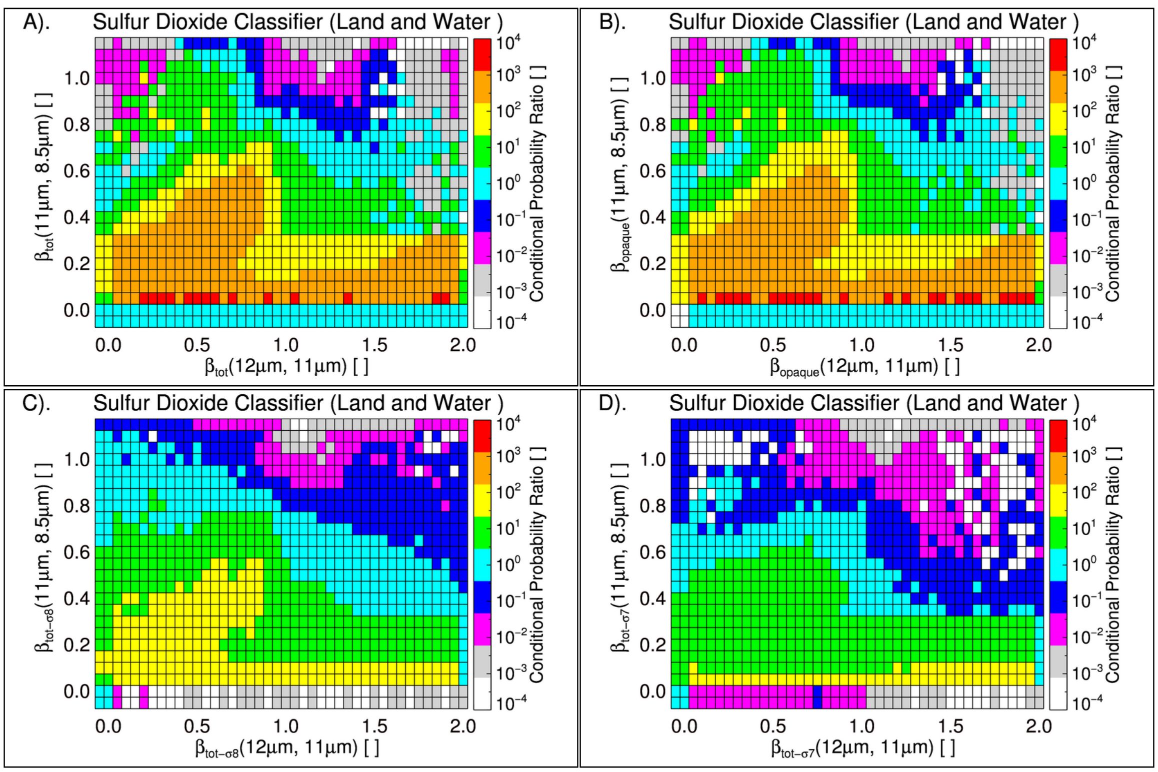
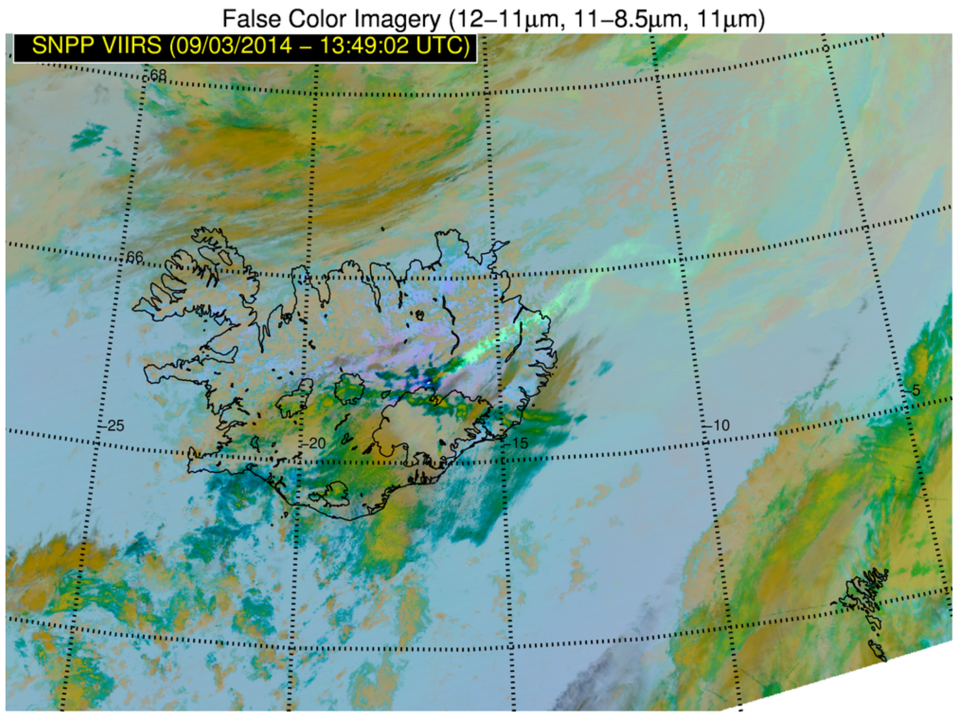
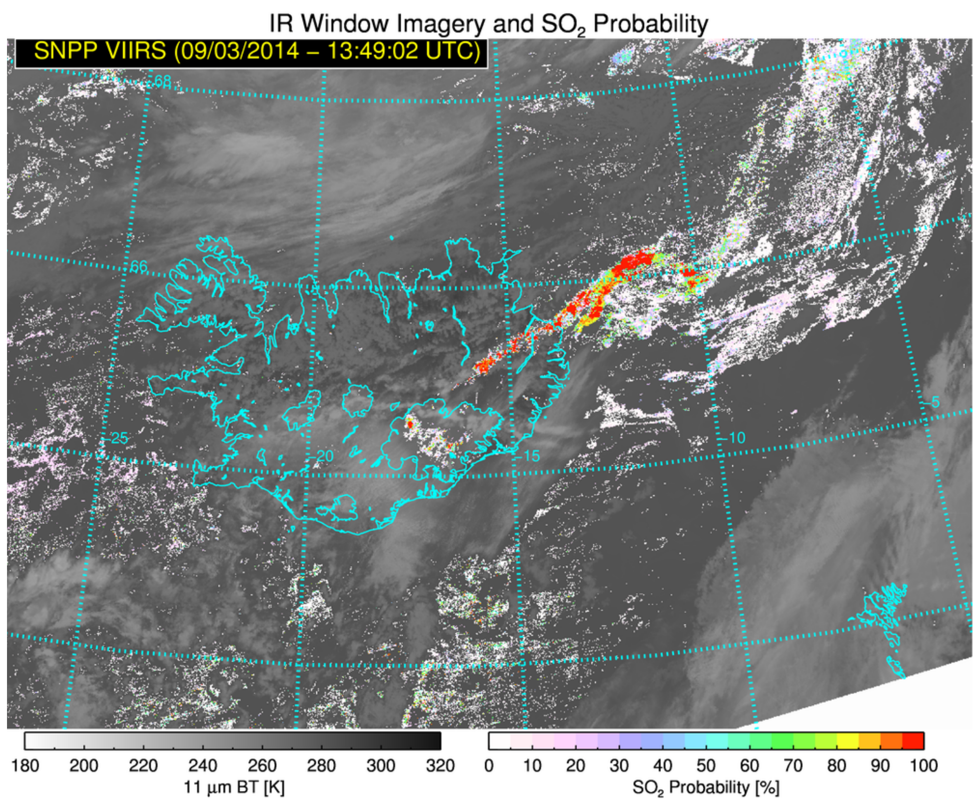



**Figure 90. The ratio of the $SO_2$ class conditional probability to the class conditional probability of all other features is shown as a function of four multivariate spectral classifiers. The cyan through red portion of the color scheme indicates that the class conditional probability of $SO_2$ is greater than the class conditional probability of all non-$SO_2$ features for that histogram bin. A). $\beta_{tot}$(12µm, 11µm) vs. $\beta_{tot}$(11µm, 8.5µm), B). $\beta_{opaque}$(12µm, 11µm) vs. $\beta_{opaque}$(11µm, 8.5µm), C). $\beta_{tot\_\sigma8}$(12µm, 11µm) vs. $\beta_{tot\_\sigma8}$(11µm, 8.5µm), D). $\beta_{tot\_\sigma7}$(12µm, 11µm) vs. $\beta_{tot\_\sigma7}$(11µm, 8.5µm). These β-based predictors are explained in greater detail in Pavolonis et al. (2015a).**


False Color Imagery (12–11μm, 11–8.5μm, 11μm)
SNPP VIIRS (09/03/2014 – 13:49:02 UTC)
68
66
-25
-20
-15
-10
-5


IR Window Imagery and SO2 Probability
SNPP VIIRS (09/03/2014 – 13:49:02 UTC)
68
66
-25
-20
-15
-10
-5
180 200 220 240 260 280 300 320
11 μm BT [K]
0 10 20 30 40 50 60 70 80 90 100
SO2 Probability [%]

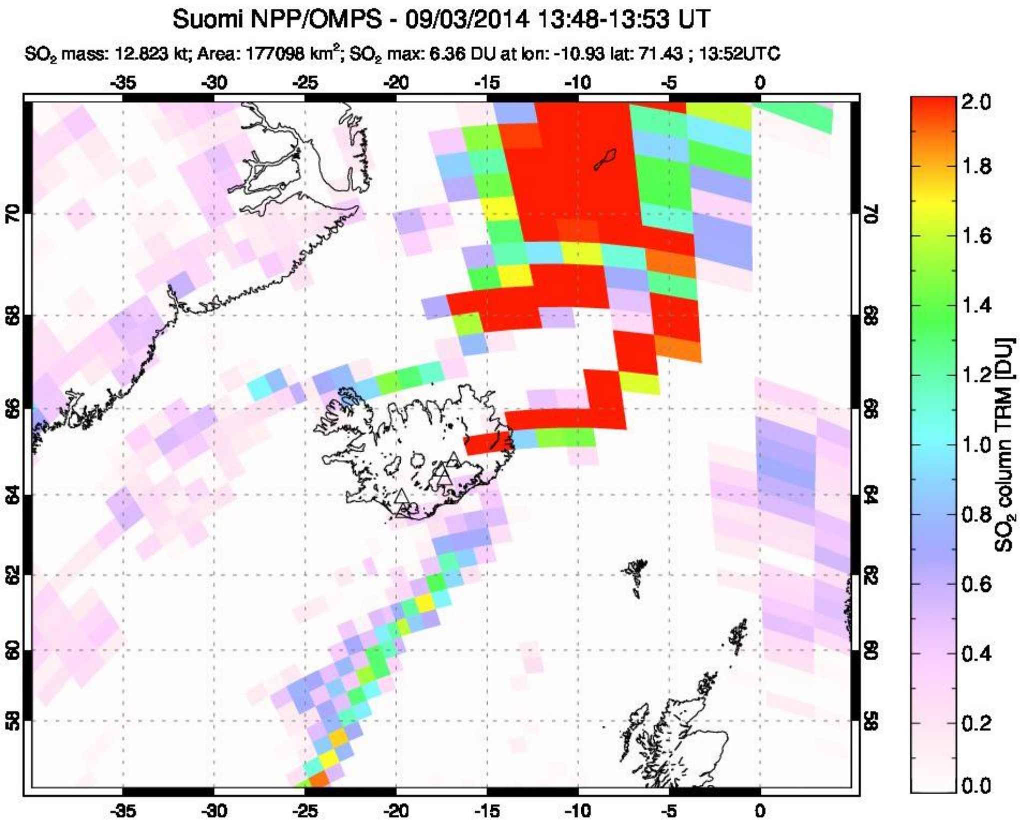



**Figure 91. A VIIRS false color image from 13:49 UTC on September 3, 2014 is shown in the top panel. The VIIRS image is centered on Iceland where the Bárdarbunga Holuhraun lava field was producing significant $SO_2$ emissions. Large concentrations of $SO_2$ will appear green in the false color image. The corresponding VIIRS $SO_2$ probability is shown in the center panel, where only probabilities greater than 1% are imaged (the M15 brightness temperature is shown elsewhere). The bottom panel shows the OMPS $SO_2$ loading derived using the NASA algorithm. The $SO_2$ probability field is generally consistent with the false imagery and the OMPS $SO_2$ analysis.**

## References

Pavolonis, M.J. and A. Parker, 2010: GOES-R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document for $SO_2$ Detection, http://www.goes-r.gov/products/ATBDs/option2/Aviation_SO2_v1.0_no_color.pdf.

Pavolonis, M. J., 2010: Advances in Extracting Cloud Composition Information from Spaceborne Infrared Radiances-A Robust Alternative to Brightness Temperatures. Part I: Theory. *Journal of Applied Meteorology and Climatology,* **49**, doi:10.1175/2010JAMC2433.1.

Pavolonis, M. J., J. Sieglaff, and J. Cintineo (2015a), Spectrally Enhanced Cloud Objects (SECO): A Generalized Framework for Automated Detection of Volcanic Ash and Dust Clouds using Passive Satellite Measurements, Part I: Multispectral Analysis, *J. Geophys. Res. Atmos*., 120, doi:10.1002/2014JD022968.

Pavolonis, M. J., J. Sieglaff, and J. Cintineo (2015b), Spectrally Enhanced Cloud Objects (SECO): A Generalized Framework for Automated Detection of Volcanic Ash and Dust Clouds using Passive Satellite Measurements, Part II: Cloud Object Analysis and Global Application, *J. Geophys. Res. Atmos*., 120, doi:10.1002/2014JD022969.

# 19. CIMSS Participation in the 2016 JPSS Directed Risk Reduction Program

## 19.1 Addressing NWS Desires for Cloud Cover Layers (CCL) and Sky Cover Products using VIIRS and CrIS

**CIMSS Task Leader: Steve Wanzong**
**CIMSS Support Scientists: Yue Li, Andi Walther, and Steve Wanzong**
**NOAA Collaborator: Andrew Heidinger**
**Budget: $30,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

### Objective
Apply the CCL product to SNPP/VIIRS, and extend the VIIRS cloud products to use a combined VIIRS + CrIS level1b dataset.

### Project Overview
Due to budget constraints, several GOES-R ABI products were reclassified from "baseline" to "future capability". Cloud Cover Layer is one such product. In 2014, the NWS Operational Algorithm Team (NOAT) selected five future capability GOES-R ABI products to be transitioned to operations. Included are Cloud Cover Layer (CCL), Aerosol Particle Size, Ice Concentration, Ice Age/Thickness, and Ice Motion.

While this NOAT request was directed for GOES-R, these products have been successfully generated by applying the same algorithm to the SNPP/VIIRS sensor relevant to the OCONUS region. The VIIRS cloud information could provide complementary cloud type and emissivity input to the currently geostationary-only sky cover product, particularly for Alaska.

The current NOAT guidance is that CCL should report 6 cloud fractions at predefined flight levels (FLs), including the total cloud fraction. These 5 levels are surface to FL050 (where FL050 stands for 5 kft), FL050 to FL100, FL100 to FL180, FL180 to FL240, and FL240 to the top of the atmosphere (TOA). Additionally, convective and super-cooled cloud fraction needs to be assessed.

### Milestones with Summary of Accomplishments and Findings
The CCL code has been updated following the NOAT requirements. The 3-layer CCL software has been re-written to provide 6 cloud fractions at predefined flight levels (FLs), including the total cloud fraction. Cloud top properties derived from the AWG Cloud Height Algorithm (ACHA) is converted to FL altitudes, and then used to compute cloud fraction at the predefined

FLs. The four-level enterprise cloud mask from the GOES-R (adapted to JPSS) and cloud probability for JPSS are used in the computation. Cloud base height is not utilized in this update. Figure 92 shows an example of total (column-integrated) cloud fraction and layered cloud fractions for each of the 5 layers at a horizontal resolution of 10 km. By separating the layered fractions from the total cloud fraction, for this example, mostly upper level clouds contribute to the total. However, at the edge of the scan, lower level clouds dominate. Note that once cloud base height is considered (future work), the information can be used to enhance the cloud fractions inferred at lower levels in the profile obscured by cloud top. This additional information holds value to the aviation community.

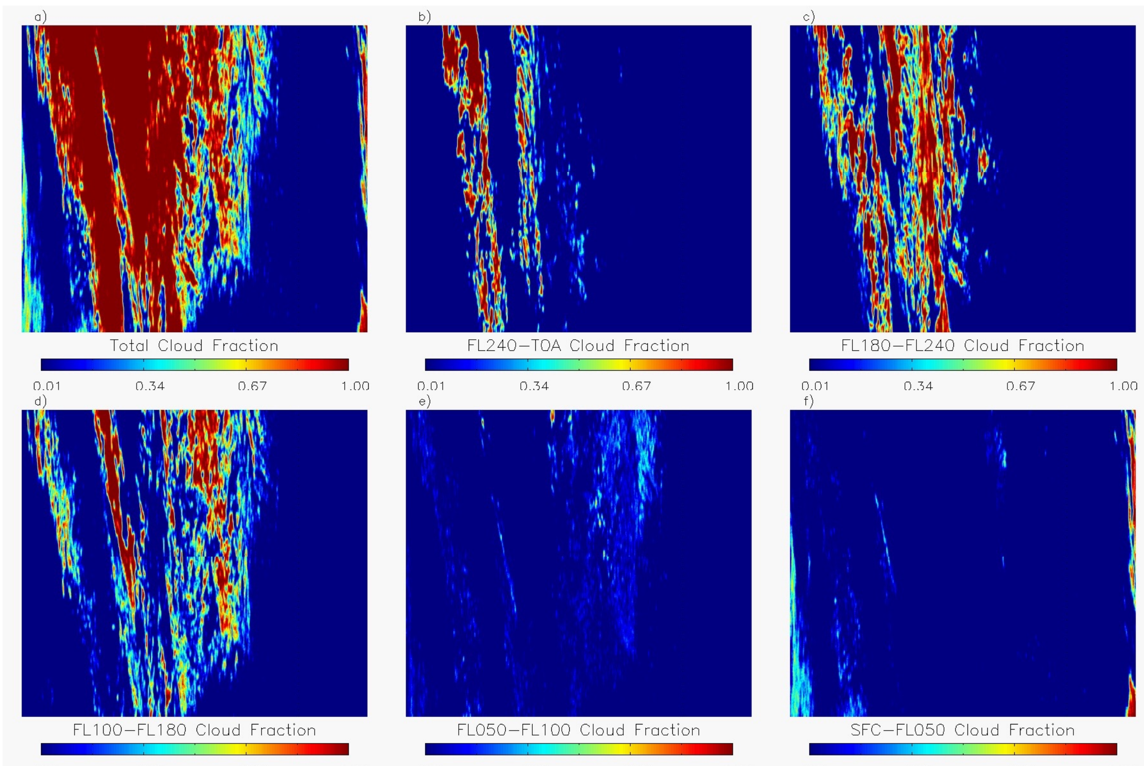



**Figure 92. VIIRS granule on September 27, 2013 at 2014 UTC shows a) total cloud fraction, and cloud fractions for b) FL240-TOA, c) FL180-FL240, d) FL100-FL180, e) FL050-FL100, and f) SFC-FL050.**

VIIRS is not alone on S-NPP or JPSS, it flies next to the CrIS hyperspectral IR sounder, which provides high resolution measurements throughout the IR absorption bands. A stable version of the merged JPSS + CrIS files is nearing completion. The cloud team software has been prototyped on test files and will be ready to evaluate this data once the merged Leve1b files become available.

The NOAT guidance also emphasized the importance of the sky cover product. While a sky cover product was originally calculated based on cloud emissivity and cloud transmission from geostationary imagers for the contiguous United States and Hawaii, the climate and latitude of Alaska presents challenges for the computation of cloud products and sky cover that may be uniquely addressed with VIIRS and CrIS data from the NPP satellite and JPSS, and the proposed advancements in the cloud products from these sensors. Test data, available through a local McIDAS ADDE server was made available to the CIMSS Sky Cover Team. Their evaluation is still a work in progress. Real time JPSS cloud products from the Madison DB (CONUS) and Fairbanks DB (OCONUS) is being produced in near real-time at CIMSS. These two data sets will be made available to the Sky Cover team for inclusion into Sky Cover once their initial evaluation is complete.

## 19.2 Strengthening TPW Visualization in the OCONUS Domain with JPSS Data Products

**CIMSS Task Leader: Anthony Wimmers**
**CIMSS Support Scientists: Christopher Velden, Jordan Gerth**
**NOAA Collaborators: Bill Ward, Carven Scott, Kennard Kasper, Xiwu Zhan**
**Budget: $106,520**

**NOAA Long Term Goals:**

- Weather-Ready Nation
- Healthy Oceans
- Resilient Coastal Communities and Economies

**NOAA Strategic Goals:**

- Serve society's needs for weather and water
- 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
- Environmental Models and Data Assimilation
- Education and Outreach

### Objective

To produce an enhanced, state-of-the-art visualization (morphed animation) of total precipitable water (TPW) that incorporates JPSS retrievals to ensure the product's viability far into the future, delivered over AWIPS, and ready to be incorporated as a major enhancement to NOAA's operational capabilities.

### Project Overview

Precipitable water is a quasi-conservative satellite-retrieved quantity that is uniquely suited for observation with advection from model winds over several hours. We can exploit this behavior of precipitable water to take retrievals from polar-orbiting satellites and combine them into a natural, fluid, high temporal-resolution representation of global total-column water vapor. A prior algorithm ('MIMIC-TPW version 1') used this approach to produce accurate, over-ocean visualization of TPW at hourly intervals. That product has been valuable for OCONUS stakeholders forecasting tropical weather, atmospheric rivers and aerosol transport. However, for expediency, the algorithm utilized only TPW retrievals from SSMI/SSMIS sources, and this limited the product to using older retrieval methods and left the product highly vulnerable to future data outages.

The current project replaces the previous version of MIMIC-TPW, and primarily uses TPW retrievals from ATMS and AMSU/MHS sounders from existing platforms. It uses the latest

MIRS retrieval system, and also uses entirely new code for rapid processing and more robust trajectory calculations. New algorithm development is also directed toward compatibility with NOAA's current operational Blended TPW product, so that a succeeding iteration of work can more easily leverage from the two systems.

## Milestones with Summary of Accomplishments and Findings

The past twelve months have been directed toward applying the innovations developed in the previous year (rapid, accurate trajectory calculation and optimal compositing of cross-track scan swaths, for example) toward a new real-time morphological composite system. The new product suite is online and stable, and has a growing user base. The major milestones from this past year are as follows:

### *Extending MIMIC-TPW domain to 70N-70S latitude and adding a "North Pacific" domain to the web products*

Rather than extending the domain poleward to 70N-70S, we were successful in producing a fluid, morphed composite product that is **fully global**. Because the MIRS ver.11 retrieval of TPW is valid over all surfaces, and because our new advection scheme works at all latitudes, we were able to exceed the original goal of displaying the product over any areas of liquid water surrounding Alaska. Instead, the product includes Alaska itself and all surrounding areas during all seasons (Figure 93).

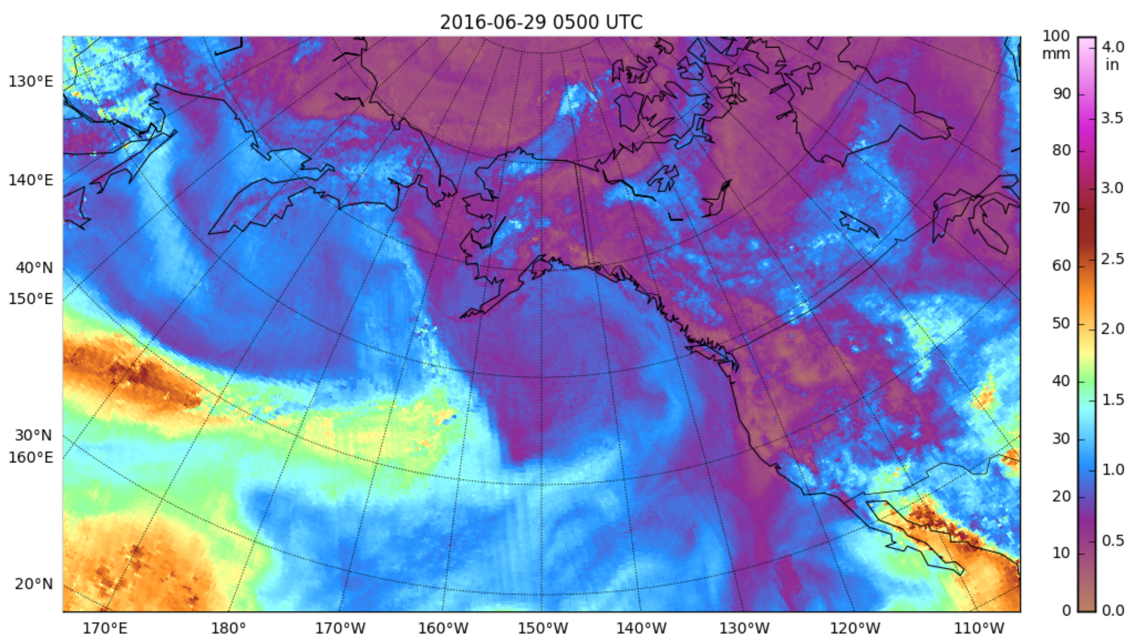



**Figure 93. Morphed composite product for the North Pacific domain (29 June 2016, 0500 UTC), available in real-time online.**

### *Setting up a publically available website for the updated MIMIC-TPW product*

We have completed the public website for the new MIMIC-TPW product, hosted at SSEC/CIMSS at http://tropic.ssec.wisc.edu/real-time/mtpw2 (or Google 'CIMSS tpw2'). The site includes a dropdown menu to view the product in multiple domains; options for animated gifs or a controllable Javascript image animation; diagnostic imagery to view the impact of satellite source, scan angle, or advection time; an image archive; and instructions for new users. An example of the diagnostic imagery in the product website is shown in Figure 94.

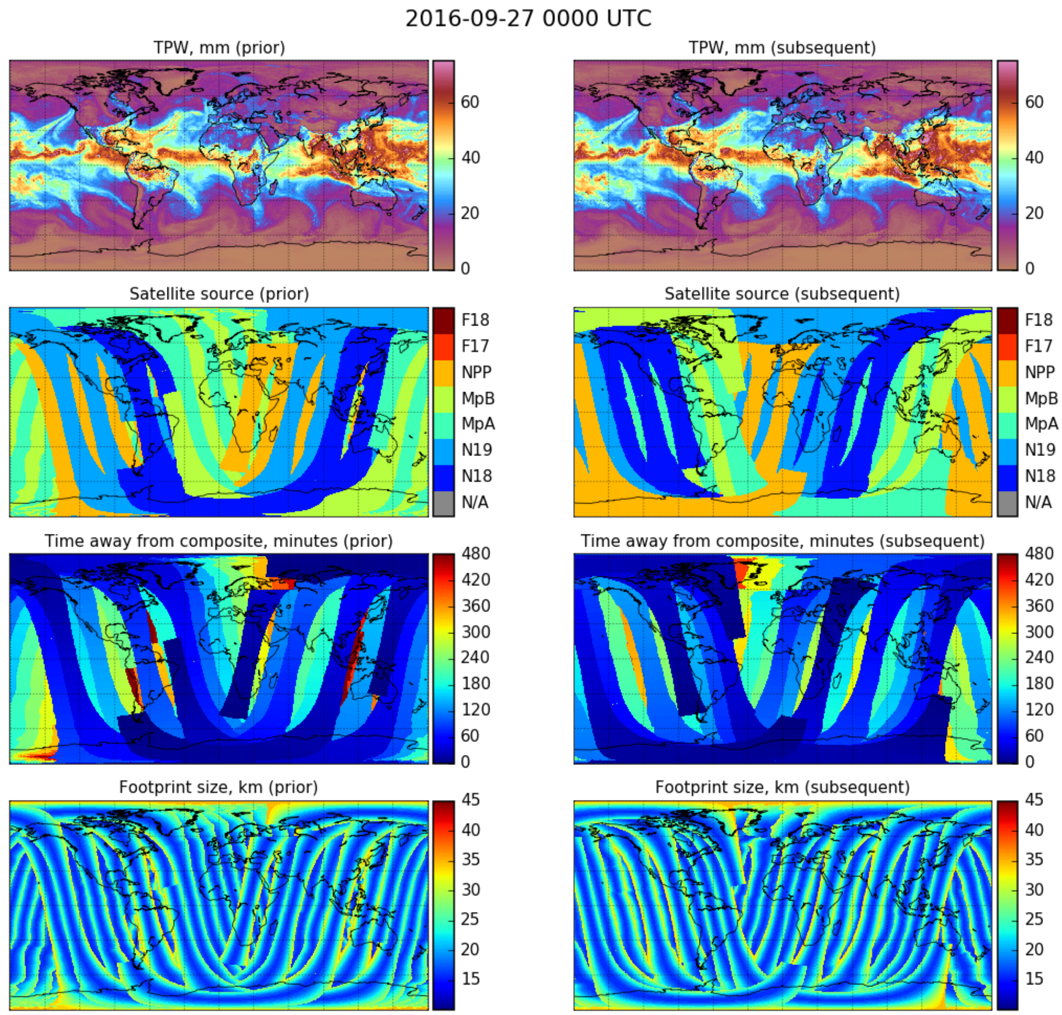



**Figure 94. Example of an online diagnostic product for MIMIC-TPW ver. 2.**

### *Setting up a new AWIPS data product for real-time demonstration*

The MIMIC-TPW2 product is now staged on an AWIPS server at SSEC. Jordan Gerth has added this product to the Honolulu forecast office, which serves as a template for setup at other WFOs.

### *Engagement with operational partners*

We have been in contact with our WFO partners and receiving feedback on the new website and the AWIPS product. This has been especially important for prioritizing future improvements. In addition, at the 2017 AMS Annual conference we met with several new users of the MIMIC-TPW2 product, including two representatives of the Advanced Hydrological Prediction Service in Anchorage, Alaska. They stated that they use the product every day for synoptic situational awareness of flooding potential in Alaska. We have also submitted an abstract for a presentation at the 2017 National Weather Association meeting in order to spread the word of this product to the broader user community.

### Publications and Conference Reports

Wimmers, Anthony, Chris Velden, Jordan Gerth, Bill Ward, Carven Scott, Kennard Kasper, Xiwu Zhan, 2016: MIMIC-TPW 2.0: Global morphological compositing of TPW for JPSS using the MIRS retrieval, STAR JPSS 2016 Annual Science Team Meeting, College Park, Maryland.

Wimmers, Anthony, C. Velden, A. Heidinger, 2016: Advancements in Morphological Compositing of Polar-Orbiting Satellite Imagery, American Meteorological Society Joint 21st Satellite Meteorology, Oceanography and Climatology Conference and 20th Conference on Air-Sea Interaction, Madison, Wisconsin.

## 19.3 Application of JPSS Imagers and Sounders to Tropical Cyclone Track and Intensity Forecasting
**CIMSS Task Leader: Chris Velden**
**CIMSS Support Scientist: Derrick Herndon**
**NOAA Collaborator: Mark DeMaria**
**Budget: $95,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

### Objective
Demonstrate an innovative satellite-based consensus approach that provides superior estimates of tropical cyclone intensity.

### Project Overview
The goals of this study are to 1) integrate previously successful research on developing objective methods to derive the intensity of tropical cyclones (TCs) from multi-spectral satellite sources (Leo and Geo), and 2) demonstrate an innovative satellite-based consensus approach that employs cross-method information sharing and performance analysis to weight the consensus member estimates and ultimately provide superior estimates of TC intensity. The outcome of this work will fuse TC intensity estimates derived by proven methods from ATMS, AMSU, SSMIS and GOES/GOES-R to yield improved TC intensity analyses that will benefit operational forecasts from the National Hurricane Center, the Central Pacific Hurricane Center, and the Joint Typhoon Warning Center. They will also benefit the initialization of operational hurricane forecast models such as the HWRF run at NCEP/EMC. The research community will benefit from the improved records of TC intensity through more reliable trend analyses for climate change studies.

### Milestones with Summary of Accomplishments and Findings

1. A final analysis of SATCON performance during the 2016 season was conducted. During this process it was discovered that a change to a new source for eye size information (a new version of ARCHER) lead to some erroneous eye size values. The values were 10 km too large, which caused some of the large weak bias and high RMSE for SSMIS and ATMS. All of the SSMIS and ATMS cases impacted were re-processed and the resulting RMSE has been reduced. The resulting errors for SATCON are also slightly reduced through the improved member inputs as well as the eye size bias correction applied to the

final SATCON estimate of maximum sustained wind (Vmax). See Table 1 below for the latest statistical analysis of SATCON.

There was some initial concern that the weights used for SSMIS may need to be changed due to noise issues in F-17 channel 4. However, an analysis of 2006-2016 F-17 cases reveals that errors are not significantly different than the broader sample of cases including F-16, F-18 and F-19. This indicates that the mitigation of the noise in the algorithm is currently sufficient thus no changes to the SATCON weights are required at this time. F-17 is currently the only SSMIS sounder and will continue to be monitored for stability.

2. CIMSS is now in receipt of the CIRA ATMS intensity estimates for 2012-2016. Error analysis and testing of the CIRA ATMS estimates as an additional member in SATCON are underway.

**Table 5. SATCON 2006-2015 performance. Simple average is a straight average of all members and acts as a benchmark for the weighted consensus. Validation is aircraft ground truth in Atl, EPac and CPac.**

| N= 4097 | SATCON | Simple Avg | ADT | AMSU | SSMIS/ATMS |
|---|---|---|---|---|---|
| Bias (kts) | -0.2 | -2.7 | -1.6 | -4.4 | -2.2 |
| Abs Error | 7.2 | 7.3 | 10.0 | 9.8 | 8.6 |
| RMSE | 9.1 | 9.3 | 12.8 | 12.6 | 11.2 |

## 19.4 Further Development of the VIIRS Nighttime Lunar Reflectance-Derived Cloud Properties and the Demonstration of their use for Precipitation and Icing Applications

**CIMSS Task Leader: Andi Walther**
**CIMSS Support Scientist: Samantha Tushaus**
**NOAA Collaborator: Andrew Heidinger**
**Budget: $35,000**

### NOAA Long Term Goals:
- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:
- 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

### Objective
This project aims to extend the developments of VIIRS Nighttime Lunar reflectance-derived cloud products to meteorological applications

## Project Overview

The primary goal of this project is to continue advancing the use of the DNB lunar reflectance and the associated quantitative cloud property retrievals. Capitalizing on this unique and unprecedented capability, we use these cloud properties to develop proof-of-concept nocturnal precipitation and icing threat applications. This new source of nighttime information holds important value to NWP applications in high-latitude regions challenged by extensive nighttime periods, such as Alaska. These cloud properties can be incorporated into the official NOAA precipitation and icing applications in the future.

In support of this effort, we will conduct research in the following core elements:

- Further improvements and refinements to a lunar reflectance based nighttime cloud optical retrieval scheme;
- Use lunar reflectance for improved cloud cover and cloud type retrievals at night;
- Show the consistency of these products to the daytime equivalent;
- Explore application of the retrieved nocturnal cloud products to precipitation and ice threat products, yielding new capabilities for these operationally important products; and
- Introduce the retrievals to operational and quasi-operational environment CSPP, NOAA framework and CLAVR-x.

## Milestones with Summary of Accomplishments and Findings

1. We focused in this period on completing the development of the stand-alone VIS/IR precipitation retrieval. We successfully **implemented** rain rate retrieval **in CLAVR-x** software scheme.
2. We **refined lunar irradiance** model according advice by Steve Miller (CIRA).
3. We started the **development of hybrid retrieval** merging VIIRS data with ATMS observations. This combined visible/IR approach with Microwave measurements will combine high spatial resolution of VIIRS with the more physical approach of ATMS. Image below illustrates the matching technique and gives an exemplarily visualization of rain rate from MW and from VIS/NIR.

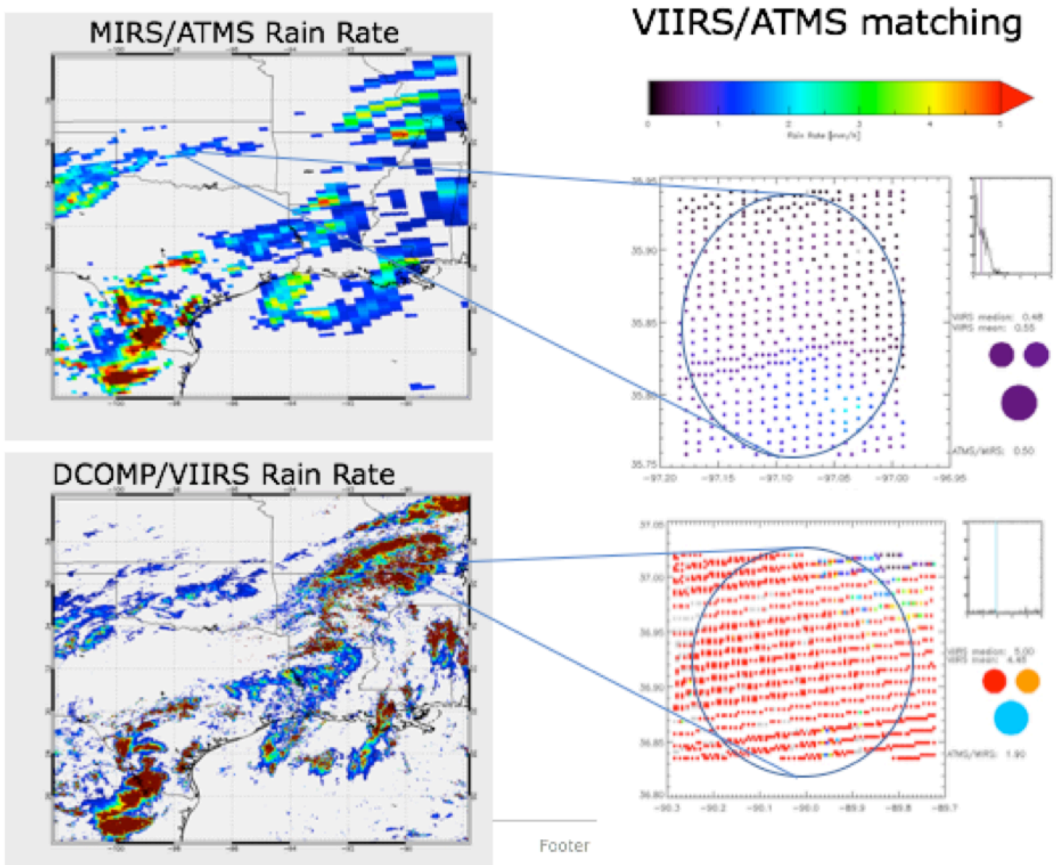



**Figure 95. Illustration of pixel matching of ATMS pixels with VIIRS.**

### Publications and Conference Reports

Andi Walther presented the combined rainrate algorithm during the AMS conference in Seattle in January 2017.

## 19.5 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 Task Leader: Ralph A. Petersen**
**CIMSS Support Scientists: Lee Cronce and Richard Dworak**
**NOAA Collaborators: William Line and Carven Scott**
**Budget: $100,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

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

**CIMSS Research Themes:**

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

## Objective

In coordination with the National Weather Service (NWS) Alaska Region (AR), increase the operational utility of Low Earth Orbit (LEO) soundings to forecasters in analyses and short-range forecasts using an approach that helps fill the large data gaps that exist between the sparse conventional and radar sites and periodic POES observations.

## Project Overview

This project is working toward increasing the operational utility of LEO satellite soundings to forecasters and helping fill the large data gaps that exist between the sparse conventional observations, radar sites and successive LEO orbits near AR. AR relies heavily on satellite in the forecast process and is unique within the NWS in its reliance on LEO observations, including JPSS. At these latitudes, LEO systems provide sufficient temporal and spatial coverage to provide frequently updated observations. Thus many science and/or technological advances need to integrate LEO satellite information within their solutions. The high repeat cycle also allows adaption of applications similar to those developed for GOES sounder data over the CONUS.

Specific objectives include: 1) assess and validate various LEO sounder moisture products for use in very-short-range forecasting, 2) test the impact of LEO-retrieval based NearCasts on improving very-short-range forecast products specifically designed for AR forecasting needs, and 3) determine the optimal information contained in both hyperspectral and microwave LEO moisture retrievals using a variety of algorithms. A test version of the NearCast system is running in regularly over the AR. Real-time data access delays have limited operational product delivery. Efforts to reduce data latency and expand areal coverage have forced the project to gather centrally produced retrievals from AWIPS, CLASS, and NESDIS.

## Milestones with Summary of Accomplishments and Findings

During the past year, we have continued to perform activities that need to be completed prior to final field testing, primarily addressing a number of data-flow issues. The real-time data access problems, which have dominated our activities, now seem to have been resolved. During the period when the data access problems were being resolved by NESDIS, the spending rate has been much smaller than planned. As such, substantial funding remains for the final year of the originally defined effort.

Improved treatment of quality control flags has resolved the vast majority of data consistency issues noted between successive NUCAPS data passes and along the pass limbs noted in the past report. Data are now being ingested and processed in real-time using sources of centrally produced retrievals available via AWIPS and special CLASS arrangements developed by NESDIS. Plans are in place to incorporate UW retrievals above cloud tops in areas covered only by NUCAPS microwave retrievals. NearCast outputs are available both in web displays and GRIB-II formats, which have been successfully ingested into AWIPS.

Prior to real-time testing, new "Introduction to NearCasts" training materials have been developed and independently reviewed by EUMETSAT. CIMSS also developed a new web display tool to help forecasters distinguish between IR and microwave sources of information in NearCasts (See Figure 96). If these tools prove useful, similar capabilities could be explored within AWIPS.

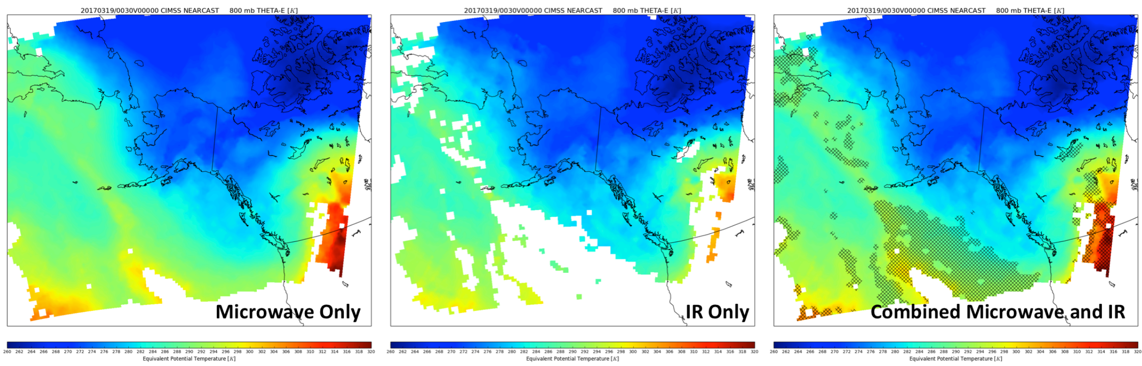



**Figure 96. Examples of NearCast analysis displays using 9 hours of retrievals from CrIS and IASI for equivalent potential temperature at 800 hPa over northeastern Alaska and northern Canada) valid at 0030 UTC on 19 March 2017. Left panel used microwave retrievals only, center panel used IR retrievals only and right panel used both microwave and IR retrievals, with hatching used to denote areas where microwave data were only available. NearCast analysis procedures time adjust earlier retrievals to time/locations of last observations, thereby filling data gaps and regions between successive satellite observation swaths. Note clear differentiation of cold/dry air (blue) near Seattle from warmer/moister air to north and south. Inclusion of hatching allows forecasters to easily differentiate between areas where high-vertical-resolution IR soundings are available for further study from those with only lower-vertical-resolution microwave data.**

### Publications and Conference Reports:

Petersen, R. A, L. M. Cronce, W. E. Line, T. August and T. Hultberg, 2016: Increasing the utility of real-time IASI moisture and temperature soundings in very-short-range forecasting. 4th EUMETSAT IASI (Infrared Atmospheric Sounding Interferometer) Conference, Antibes Juan-les-Pins, France.

## 20. CIMSS Support to Acquire Polar Satellite Antenna Radome for the National Weather Service in Guam

**CIMSS Task Leaders: Jordan Gerth and Liam Gumley**

**NOAA Collaborators: Brian Gockel, National Weather Service Office of Observations; and Bill Ward, National Weather Service Pacific Region Headquarters**

**Budget: $51,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

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

### CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Education and Outreach

### Objective

CIMSS partnered with NOAA to install and operate a polar-orbiting satellite direct broadcast satellite data reception station at the National Weather Service (NWS) forecast office in Guam to (a) acquire real-time visible, infrared, and microwave satellite imagery, (b) serve that satellite imagery and related derived products to NWS meteorologists in Guam, (c) acquire and process infrared and microwave sounder data from polar-orbiting meteorological satellites, and (d) deliver the resulting products to NOAA with low latency for assimilation in numerical weather prediction (NWP) models. The National Environmental Satellite, Data, and Information Service (NESDIS) granted the primary cost for the antenna to CIMSS in the previous budget year. The NWS funded this follow-on project for a radome, to protect the antenna from strong typhoon winds, and a full-height equipment rack, to sit adjacent to the Himawari racks in the forecast office.

## Project Overview

CIMSS worked with the National Weather Service (NWS) Office of Observations and Pacific Region Headquarters to procure and install a polar-orbiting satellite direct broadcast reception station in Guam for the benefit of the NWS forecast office there, and to provide real-time advanced infrared and microwave sounder data to NOAA National Centers for Environmental Prediction (NCEP) Environmental Modeling Center (EMC) for timely assimilation into their operational numerical models. It is anticipated that the antenna will capture important information about the structure and intensity of tropical cyclones that often impact Guam, and are otherwise commonly found in the adjacent western Pacific Ocean.

The NWS has demonstrated significant benefits of polar-satellite imagery and products in the forecast decision-making process, particularly in geographic areas that geostationary weather satellites do not serve well (e.g., Alaska), or in situations where geostationary satellite data do not provide sufficient spatial or spectral information. For this purpose, advanced imagery and products from polar-orbiting satellites have provided new information to NWS forecasters to help with situational awareness. The newest United States polar-orbiting satellite, the Suomi National Polar-orbiting Partnership (NPP) satellite hosts the Visible Infrared Imaging Radiometer Suite (VIIRS) and Advanced Technology Microwave Sounder (ATMS). The VIIRS and ATMS instruments provides a rich source of new data for the NWS to apply to the operational weather forecast and analysis process. For example, NWS meteorologists in Hawaii have applied the VIIRS Day/Night Band (DNB) to detect low cloud at night, helping to detect the center of circulation for sheared tropical cyclones. The combination of imagery from Suomi NPP, Metop-A/B, NOAA-18/19, and Terra/Aqua, among others, and the upcoming Joint Polar Satellite System (JPSS), means that data from at least seven satellites are able to cumulatively provide satisfactory temporal coverage for weather operations. The NWS Guam reception station provides imagery and higher-level products (e.g., sea surface temperature) from all these satellites with low latency and high reliability.

NCEP EMC use of advanced infrared and microwave sounder data over North America and adjacent oceans in numerical model data assimilation was previously limited because of the latency of the products in relation to the arrival deadlines for assimilation. The Guam antenna will deliver infrared and microwave sounder data to NCEP with the lowest latency possible, via the reception and processing of data received via direct broadcast. The goal is to reduce latency for advanced infrared and microwave sounder data to less than 15 minutes.

**Figure 97. Taken shortly following installation, this photograph shows the radome on the antenna pad. The antenna is inside. The antenna dish is three meters (9.8 feet) wide. The radome is measures approximately 18 feet in diameter, and is capable of withstanding winds up to 190 miles/hour.**

### Milestones with Summary of Accomplishments and Findings

The antenna, equipment rack, and radome, shown in Figure 97, were installed on the property of NWS Guam in February 2017. The antenna is currently functional, tracking polar-orbiting satellites, and providing data to the NWS Guam Advanced Weather Interactive Processing System (AWIPS) for operational meteorologists to use in the weather analysis and forecast process. Updates to the direct broadcast processing system (DBPS) connected to the antenna, bringing additional capabilities, are slated to occur during the remainder of 2017. The DBPS runs the Community Satellite Processing Package (CSPP).

## 21. The Development of the High Performance JPSS Analysis Facility for Instrument Impacts on Requirements (JAFIR)

**CIMSS Task Leader: Allen Huang**
**CIMSS Support Scientists: Agnes Lim, Mat Gunshor, Zhenglong Li, Hong Zhang**
**Budget:$161,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- Provide critical support for the NOAA mission

### CIMSS Research Themes:

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

## Objective
Evaluating the impact on forecasts from improved spatial resolution of field-of-view size (FOV) for CrIS and potential VIIRS instrument waiver analyses.

## Project Overview
This project consists of two tasks. The first is to evaluate the impact on forecast models from improved spatial resolution for CrIS and the second is to assist the science teams in assessment of instrument waivers on products for. For Task 1, reduced errors in the initial conditions and improved forecast models have led to steady improvements of forecast skill in the past three decades. Some of the reductions in initial condition errors come from increases in the quality and quantity of satellite observations. The spatial resolution of satellite observations must increase to maintain its positive influence on forecast skill as Numerical Weather Prediction (NWP) Centers move to higher resolution forecast models. Increasing the spatial resolution of satellite observations provide a higher probability that the observation is cloud free and decreasing spatial inhomogeneity in satellite observations is crucial for satellite radiance assimilation. This project supports the National Oceanic and Atmospheric Administration's Joint Polar Satellite System (NOAA/JPSS) Program in planning for the next generation hyperspectral sounder where the forecast impact due to FOV size of the hyperspectral infrared sounder such as Cross-track Infrared Sounder CrIS instrument on NWP will be assessed.

The NOAA National Centers for Environmental Prediction's (NCEP) Global Data Assimilation system/Global Forecast System (GDAS/GFS) will be used. The forecast impact of the CrIS sensor with a smaller FOV will be assed in the presence of the existing observing network to assess. Impact assessment will be performed in a simulated environment, also known as an Observing System Simulation Experiment (OSSE). Forecasts from two different scenarios will be compared to access the forecast performance. The primary difference between these two scenarios will be the FOV size of CrIS observations. One scenario assimilates CrIS observations at the current spatial resolution whereas the other assimilates CrIS observations at half the current spatial resolution.

The second task proposed under this project was to continue the design and implementation of an analysis facility for VIIRS instrument waivers. The JPSS Analysis Facility for Instrument Impacts on Requirements (JAFIIR) project has been designed to conduct sensor modeling, measurement simulation, EDR algorithm adaptation and VIIRS instrument impact assessments on system requirements. This task follows the successful GOES-R Analysis Facility for Instrument Impacts on Requirements project (GOES-R AWG GRAFIIR).

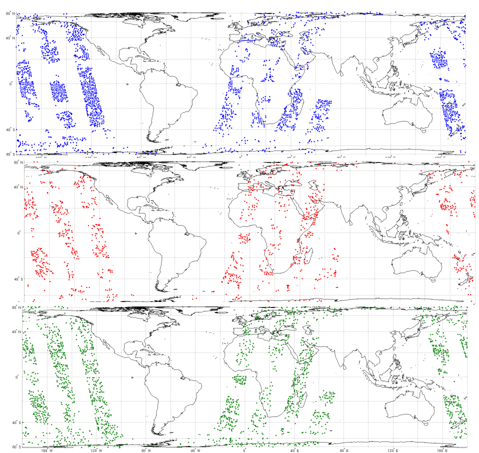
The JAFIIR system leverages efforts from project activities of 1) GOES-R AWG GRAFIIR, 2) Community Satellite Processing Package (CSPP), 3) NPP proving ground, 4) VIIRS and CrIS calibration/validation, and 5) LEO Cloud Algorithm Testbed (LEOCAT).

## Milestones with Summary of Accomplishments and Findings
Calibration of the OSSE was the main focus for Task 1. It was realized after the first set of calibration experiments that prior to tuning the variance between real and OSSE, the number of observations used per type must be tuned. Satellite infrared radiance observations was the observation type whose number being assimilated differed significantly between real and OSSE. Numerous experiments were conducted at reduced resolution to adjust the threshold that defines an observation being clear. Once the threshold had been determined, the full resolution global model was run to ensure that the threshold still holds (Figure 98). The second part of the

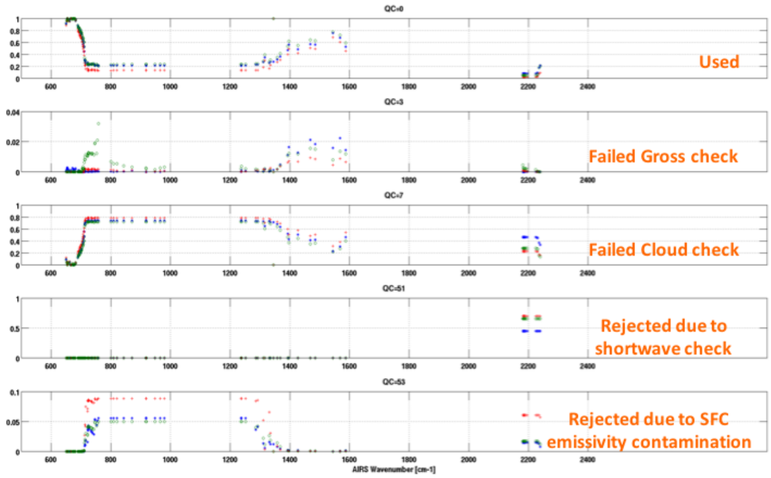
calibration was to tuned the variance of each observation type to be similar to the real world. A three-week experiment was run and variance calculation indicated that a significant number of observation type/level could not be adjusted because the scaling factor retrieved was negative. Long discussions were engaged with NOAA and NASA GMAO OSSE team and found that the noise addition utility wasn't formulated correctly. Revision of the utility was conducted and further split the calibration steps. Three iterations of calibration had been conducted so far and variances of OSSE are moving towards that of real world. However, more iterations are still necessary.

GSI code modification to read in all 36 FOVs was conducted in parallel to calibration experiments. Trial experiment show that modifications made indicate that GSI can handle this significant increase in the number of CrIS observations and minimization performance did not seem to be degraded. Longer experiment at reduced resolution are currently underway to further test the code before it is used to run the forecast impact experiments. Figure 99 shows the progress of OSSE to date.

Task 2 milestones, related to JPSS waiver activity, were to attend JPS waiver meetings via telephone and web-meeting software, to collaborate with JPSS science teams on implementation and interpretation of algorithm outputs during waiver analysis, and to follow CSPP software development to acquire up-to-date SDR and EDR packages. There was no JPSS waiver activity during the reporting period. CSPP software development has continued and the JAFIIR team continued to maintain their software and tools in the event of a waiver request.



(a)




(b)

**Figure 98. Assimilation cycle centered at 00z on 2 May 2006. Red represent real would. Blue indicates OSSE before tuning and green indicates OSSE after tuning. (a) Location of observations assimilated for a 6 hour window for AIRS channel 295 @ 734.15cm$^{-1}$ or 13.6um which peaks at 840 hPa, (b) Ratio of use/rejected to total observation count considered for all AIRS used channels.**

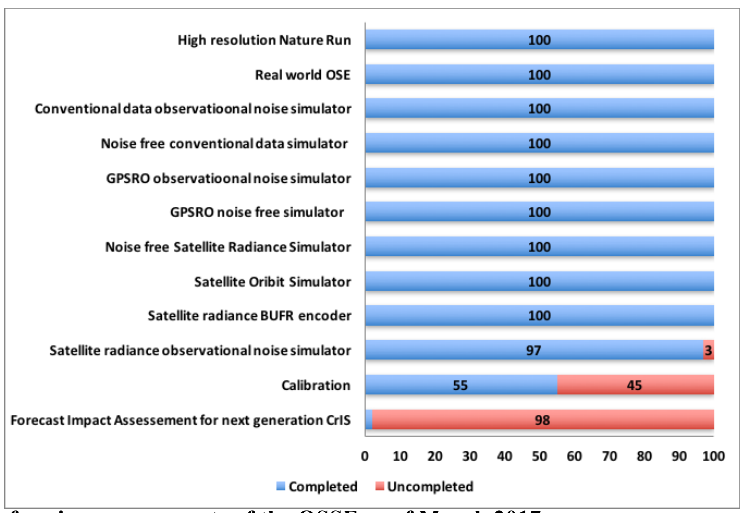



**Figure 99. Progress of various components of the OSSE as of March 2017.**

## Publications and Conference Reports

Lim, Agnes; Li, Z.; Jung, J. A.; Huang, A.; Woolen, J.; Quinn, G.; Nagle, F. W.; Healy, S. B.; Otkin, J. A.; Goldberg, M. and Atlas, R. **Impact analysis of LEO hyperspectral sensor IFOV size on the next generation high-resolution NWP model forecast performance**., Joint 21st Satellite Meteorology, Oceanography and Climatology Conference and 20th Conference on Air-Sea Interaction, Madison WI, 2016

Lim, Agnes; Huang A.; Jung, J. A.; Li, Z.; Woollen, J.; Quinn, G.; Nagle, F. W.; Healy, S. B.; Otkin, J. A.; Goldberg, M. and Atlas, R. **Analysis of CrIS FOV sizes on the next generation high-resolution NWP model forecast performance through an OSSE**. Boston, MA, American Meteorological Society, 2017

# 22. CIMSS Support to the Development of a Community Satellite Processing Package (CSPP) for Suomi NPP/JPSS Real Time Regional Applications for 2016

## 22.1 CSPP Software Enhancement and Support

**CIMSS Task Leader: Liam Gumley**
**CIMSS Support Scientists: Kathy Strabala, Jessica Braun, Nick Bearson, Geoff Cureton, James Davies, Scott Mindock, Graeme Martin, Ray Garcia**
**NOAA Collaborator: Mitch Goldberg**
**Budget: $317,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

### Objective
To continue to support and update existing capabilities and add new capabilities of the Community Satellite Processing Package (CSPP) for imager and sounder data received via direct broadcast from polar orbiting satellites including primary satellite Suomi NPP, but also the NOAA-18/19, Metop-A/B, and Terra/Aqua satellites. A particular focus is the release of NOAA-developed algorithms and software for creating products from these satellites.

### 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 Level 2 products, and is optimized for real-time processing and regional applications. The CSPP software has the following capabilities:
- Ingest CCSDS packet files from VIIRS, CrIS, ATMS and NPP spacecraft diary;
- Create SDR, EDR, and Level 2 products for VIIRS, CrIS, and ATMS;
- Produce SDR output files in the HDF5 formats defined by the JPSS Common Data Format Control Books;
- Retrieve all required dynamic non-spacecraft ancillary data automatically;
- Run natively on 64-bit Intel Linux host platforms;
- Run on Microsoft Windows and Apple OS X platforms via a Virtual Appliance;
- Allow the end user to customize which EDR products are created;
- Provide a simple algorithm chaining capability to run algorithms in sequence;

- Provide detailed logs of all processing operations and give clear indications of where and when failures occur;
- Provide products optimized for NWS which are AWIPS and/or NOAA NextGen compatible; and
- Provide value-added products for end users that are not part of the JPSS operational suite, such as images in KML format for Google Earth; Night Fog Detection; Volcanic Ash; and Aviation Safety products.

## Milestones with Summary of Accomplishments and Findings

CSPP updates during the reporting period included:

- **June 2, 2016** (CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software Version 2.2 Patch)
  This patch is required to install on top of CSPP Version 2.2 to correct software bugs that include ATMS orbit number calculation and to allow users to correctly set the external ancillary data environment variable JPSS_REMOTE_ANC_DIR for CrIS SDR.
- **February 8, 2017** (CSPP Advanced Clear-Sky Processor for Oceans (ACSPO) Software Patch Version 1.1.2)
  Patch required for use of an update to the Canadian Meteorological Center (CMC) gridded SST dynamic ancillary data files. A change to the main ACSPO run script and ancillary fetching logic is required in the form of a patch to the Version 1.1 software.
- **March 3, 2017** (CSPP International ATOVS Processing Package (IAPP) Software Version 1.1)
  Updated release of the IAPP software that retrieves vertical profiles of temperature, moisture and other parameters from input NOAA-15, 16, 18 and 19 and Metop-A and B HIRS, AMSU-A and MHS Infrared and Microwave Sounders. This update includes improved quality checking and logging, and removes the use of AMSU Channel 15 on Metop-B because of channel failure.
- The CSPP LEO team tested and benchmarked several versions of the CSPP SDR v3.0 beta software based on ADL Bock 2.0. Comparisons of the SDR products against the corresponding IDPS granules were performed to validate the content and the format of the SDR products created by the new SDR software.
- CIMSS/SSEC developed and released an update package to support the leap second insertion on January 1, 2017. The patch automatically scanned the host computer and updated all instances of the leap second file found within any installed instances of CSPP software.
- CIMSS/SSEC implemented limb correction for ATMS imagery in the Polar2Grid software, and deployed the software at DB stations including SSEC, AOML, and HCC.
- CIMSS/SSEC accepted delivery of a NOAA VIIRS wildfire detection software package and worked on adapting and documenting it for CSPP release in 2Q 2017.
- CIMSS/SSEC started an automated ingest system for SNPP VIIRS calibration lookup tables from NOAA.
- CIMSS/SSEC provided prompt user support to CSPP LEO users from Sweden, Finland, NAVO, NRL Stennis, EUMETSAT, Meteo France, Met Office, Slovakia, Russia, Australia, Taiwan, UAF/GINA, and Canada.

## Publications and Conference Reports

Liam Gumley attended the NOAA JPSS OCONUS meeting in Hawaii in June 2016.

Kathy Strabala, Dave Hoese, and Allen Huang attended the NASA Direct Readout Meeting in Valldolid, Spain in July 2016.

Scott Mindock attended the NOAA JPSS Science Team meeting in College Park MD, in July 2017.

The CSPP LEO team presented 8 posters at the AMS Satellite Meteorology Conference in Madison, WI in August 2016.

Liam Gumley attended the WMO DBnet Coordination group meeting in Geneva, Switzerland in September 2016.

## 22.2 Product Processing System for Real-Time Data over North America

**CIMSS Task Leaders: Allen Huang (PI), Liam Gumley (PM)**
**CIMSS Support Scientists: Jessica Braun, Kathy Strabala, Bruce Flynn**
**NOAA Collaborator: Mitch Goldberg**
**Budget: $75,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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

### Objective

The objective is to ingest, process and distribute near real-time polar-orbiting satellite data from Suomi NPP, Aqua, Terra, NOAA 18/19 and Metop A/B from Direct Broadcast stations across North America and make the data available to NWS and the public.

### Project Overview

The Direct Broadcast group at CIMSS/SSEC has been ingesting and processing direct broadcast data from over 15 antennas stationed across North America. The processing systems use the Community Satellite Processing Package (CSPP) and International MODIS/AIRS Processing Package (IMAPP) suite of software packages to create Level 1 and Level 2 products in near real-time.

The Aqua and Terra processing uses a merged pass system, implementing an overpass prediction method to merge collocated Level 0 PDS files ingested from multiple DB sites. The resulting PDS files have more extensive coverage and high quality of data as the majority of dropouts and bad packets are removed.

VIIRS and MODIS data is distributed to the National Weather Service (NWS) in near real-time for use within the Advanced Weather Interactive Processing System (AWIPS) system. MODIS data is also provided to NOAA CoastWatch. High resolution true color and false color imagery over the Contiguous United States is provided on our MODIS Today page (http://ge.ssec.wisc.edu/modis-today/).

## Milestones with Summary of Accomplishments and Findings

- Implementation of all CSPP software packages on our operational direct broadcast processing servers including NOAA/NESDIS Operational Cloud Processing System (CLAVR-x) Version 2.0, the International ATOVS Processing Package (IAPP) Retrieval Software Version 1.1 and the Polar2Grid Reprojection Software Version 2.1. Data and products are distributed freely in near-real time on public ftp sites.
- Updated Terra and Aqua MODIS processing to use the Collect 6 MODIS algorithms from NASA.
    - The Collect 6 package provides improvements and updates to Level 2 products.
- Added Terra and Aqua MODIS data from Geographic Information Network of Alaska (GINA) to the merged pass system.
    - The resulting merged passes processed at SSEC are longer, have more consistent coverage, and are of better quality. We have found that the addition of this merged process has not heavily impacted latency in our distribution to AWIPS as 95% of the data is processed and distributed in approximately 34 minutes following the end of the pass.

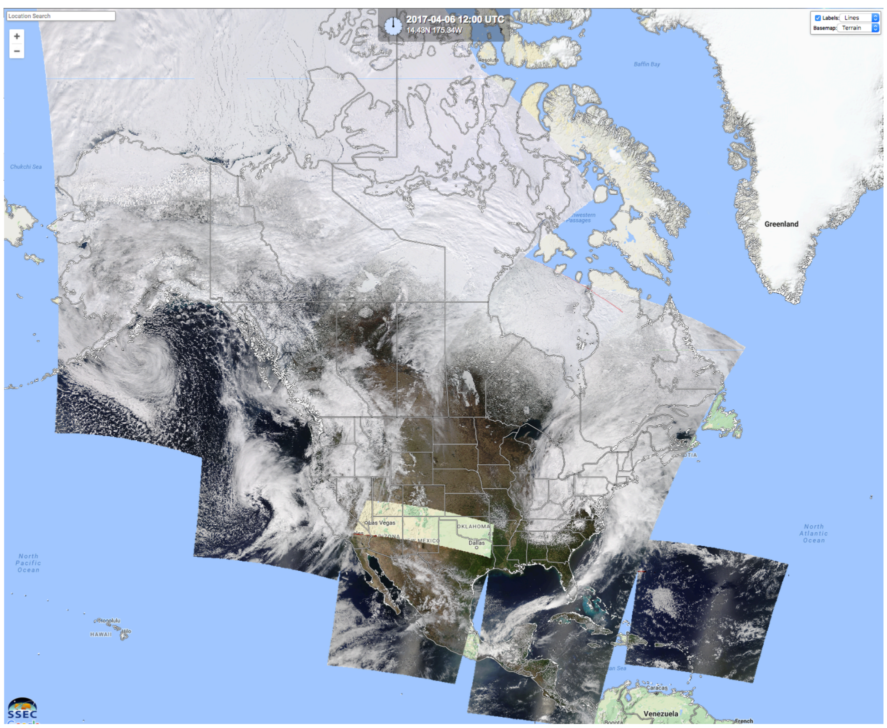



**Figure 100. Terra MODIS True Color Composite image from April 6, 2017 showing the extended coverage across North America.**

- Started the development of a VIIRS Today page to provide additional imagery to the general public.
    - We have found that the MODIS Today page receives heavy traffic from NWS offices and the general public. Images from MODIS Today are often seen across social media via Facebook and Twitter. Information regarding snow cover, smoke from fires, foliage coloring, and ice coverage over lakes has been discussed with reference to MODIS Today.

- Started the development of expanding the merged pass system to include Level 0 data from additional sensors, starting with the VIIRS, CrIS, and ATMS instruments on Suomi NPP. Data from additional polar-orbiting satellites is planned to follow.

## 22.3 Enhancement of CSPP Polar2Grid Software for Real-Time Imagery Delivery to the National Weather Service

**CIMSS Task Leader: Kathleen Strabala**
**CIMSS Support Scientists: David Hoese, Jordan Gerth, Lee Cronce**
**NOAA Collaborator: Mitch Goldberg**
**Budget: $100,000**

**NOAA Long Term Goals:**
- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**
- Serve society's needs for weather and water
- 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
- Education and Outreach

### Objective
The objective for this work is to expand and enhance support for polar orbiter satellite data and products delivered to the National Weather Service (NWS) from locally acquired data in real-time for operational use through the Community Satellite Processing Package (CSPP) Polar2Grid software.

### Project Overview
The aim of the Community Satellite Processing Package (CSPP) is to facilitate the use of Direct Broadcast (DB) polar orbiter satellite data by global environmental decision makers. Polar2Grid (P2G) is part of the CSPP software suite designed to make it easy for users to make high quality reprojected satellite product images. The target user group is the US National Weather Service. Polar2Grid is the software that enables delivery of S-NPP real-time products to NWS Forecast Offices and Regional Centers. Polar2Grid allows conversion from swath formats to AWIPS projection grids and formats for display at the NWS in real time. Polar2Grid is used by all of the groups delivering real time data to the NWS, including CIMSS/SSEC, GINA/UAF, and SPORT/MSFC. Specifically, the goals for P2G are to expand the suite of products supported to include microwave imagery and products, ACSPO Sea Surface Temperatures, CLAVRx cloud products, VIIRS active fire overlays and support for JPSS-1 VIIRS.

**Milestones with Summary of Accomplishments and Findings**

Support for the direct broadcast Advanced Microwave Scanning Radiometer 2 (AMSR2) instrument onboard the GCOMW1 satellite has been added to P2G Version 2.1. This version includes the capability to reproject and reformat AMSR2 direct broadcast Level 1B data for the 36.5 and 89 GHz spectral regions.

Using the P2G AMSR2 reader, end users can create reprojections from provided static grids (include AWIPS grids), dynamic grids, user defined grids as well as select the output format they prefer, including AWIPS NetCDF, Binary, GeoTIFF and HDF5. In addition, specialized scaling and color tables can be invoked when working with AMSR2 brightness temperatures, that allow output images to be created that are identical to those posted by the Naval Research Lab (NRL) on their tropical cyclone page. This capability has been used to support the National Hurricane Center (NHC) during the tropical cyclone 2016 season by posting storm centered images acquired and processed at NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) in real-time to a web direct broadcast image browser

P2G version 2.1 also adds support for microwave product imagery from a number of satellite/sensors combinations created by the NOAA CSPP Microwave Integrated Retrieval System (MIRS) software including S-NPP ATMS, NOAA-18 and -19 AMSU-A and MHS, and Metop-A and -B AMSU-A and MHS direct broadcast. P2G can create a standard set of MIRS reprojections in support of all of the instruments listed above. These standard products include rain rate, sea ice, snow cover, total precipitable water vapor, snow water equivalence and 90 GHz brightness temperatures.

Additional support is available for the S-NPP ATMS instrument for all 22 spectral bands including limb correction. The limb correction algorithm was provided by Kexin Zhang of NOAA STAR, and is applied as part of the MIRS ATMS P2G execution.

Using the P2G MIRS reader, end users can create reprojections from provided static grids (include AWIPS grids), dynamic grids, user defined grids as well as select the output format they prefer, including AWIPS NetCDF, Binary, GeoTIFF and HDF5.

The CSPP MIRS products are being evaluated for operational use by the NWS in the Alaska region. They are especially useful to high latitude users where the number of polar orbiter observations is high, and geostationary satellite instrument Fields-of-View (FOV) are large. Figure 101 is an AWIPS display of the MIRS AMSU Snow Water Equivalence (SWE) product created from data acquired at the Geographic Information Network of Alaska (GINA) and reprojected/reformatted using the CSPP P2G software.

Work has begun on P2G support for the CSPP Advanced Clear-Sky Processor for Oceans Sea Surface Temperature (SST) products. ACSPO supports a number of satellites and instruments including S-NPP VIIRS, Aqua and Terra MODIS and NOAA and Metop AVHRR. This well validated, high spatial resolution software is expected to provide more and better SST retrievals for NWS forecasters including those offices surrounding the Great Lakes, where local observations are scarce.

Work has also begun on completing the remaining Polar2Grid tasks including adding support for VIIRS Active Fires as well as NOAA CSPP Clouds from AVHRR Extended (CLAVR-x) products in AWIPS. To facilitate the completion of the tasks, CIMSS personnel are traveling to Alaska in May, 2017, to work directly with all three regional forecast offices to assist in the technical and practical use of the CSPP Polar2Grid products, as well as to learn how the products can and are used in operational environmental monitoring and forecasting.

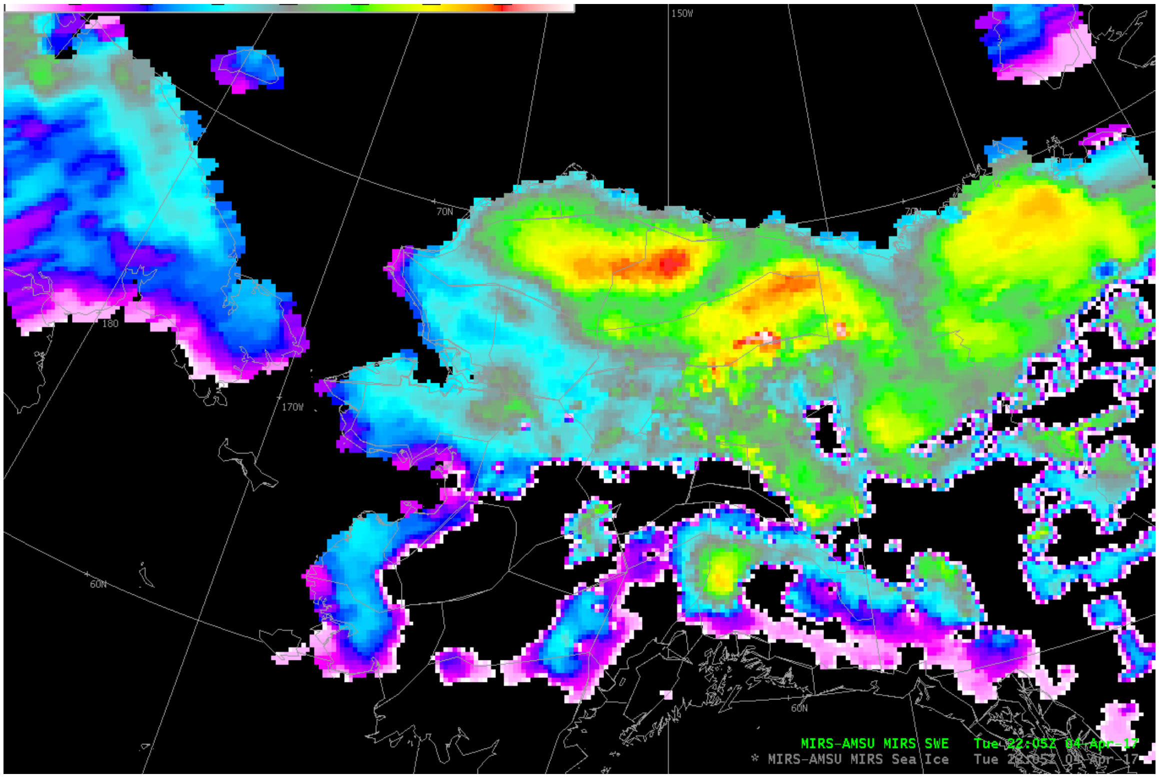



**Figure 101. AWIPS display of the AMSU MIRS Snow Water Equivalence (SWE) product from an overpass acquired on 4 April 2017, 22:05 UTC.**

### Publications and Conference Reports

David Hoese: Community Satellite Tools – Polar2Grid. Oral presentation made at the NASA Direct Readout Conference (NDRC-9), Valladolid, Spain, 21-24 June 2016.

David Hoese and M. Raspaud: SatPy – A Python Library for Weather Satellite Imagery. Poster presented at the NASA Direct Readout Conference (NDRC-9), Valladolid, Spain, 21-24 June 2016.

David Hoese and K. Strabala: Polar2Grid: Reprojecting Satellite Data Made Easy. Poster presented at the American Meteorological Society Joint 21st Satellite Meteorology, Oceanography and Climatology Conference and 20th Conference on Air-Sea Interaction, 15-19 August 2016, Madison, Wisconsin.

David Hoese and K. Strabala: Polar2Grid 2.0: Reprojecting Satellite Data Made Easy. Poster presentation at the American Geographical Union (AGU) Fall Meeting, 12-16 December 2016, San Francisco, California.

## 23. CIMSS Support to the JPSS Algorithm Development Library Team for 2016

### CIMSS Task Leader: Liam Gumley

### CIMSS Support Scientists: Scott Mindock, Ray Garcia, Graeme Martin

**NOAA Collaborator: Paul Meade**
**Budget: $370,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

**Objective**
SSEC/CIMSS supports the JPSS Project by providing a public release point for the Algorithm Development Library, ensuring that all users inside and outside JPSS have access to the latest version of ADL and can downloads, install, and run the ADL system.

**Project Overview**
SSEC supports the JPSS project as a member of the Algorithm Development Library (ADL) Team by:
- Acting as the release point for ADL to the JPSS user community,
- Maintaining the ADL Website and User Forum,
- Providing user support for installing and operating ADL,
- Providing training material and courses for end users of ADL,
- Developing a Docker-based distribution of ADL,
- Developing an ingest and pre-processing capability for dynamic ancillary data in ADL,
- Verify compatibility with RDRs from Direct Broadcast sources,
- Check compatibility of Direct Broadcast produced SDRs with the corresponding IDPS SDRs, and
- Verify 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.

**Milestones with Summary of Accomplishments and Findings**
CIMSS/SSEC continued to receive, build, and test ADL Block 2.0 versions from Raytheon (Block 2.0 versions 18, 19, 20, 21, 22, 23), and posted the DVD contents and build instructions on the JPSS ADL website at https://jpss.ssec.wisc.edu/. The builds were completed in both OVIRT-managed virtual machines, and in Docker images. CIMSS/SSEC worked with end users at NRL Stennis and NAVO to build the ADL SDR software from source code in their closed environments.

To assist with IDPS Block 2.0 testing, CIMSS/SSEC was able to build and use ADL Block 2.0 v23 to process
- ATMS SDR from SNPP on-orbit, SNPP Block 2.0 test data, and JPSS-1 Block 2.0 test data;

- CrIS SDR from SNPP on-orbit, SNPP Block 2.0 test data, and JPSS-1 Block 2.0 test data (full spectral resolution and normal spectral resolution); and
- VIIRS SDR from SNPP on-orbit, SNPP Block 2.0 test data, and JPSS-1 Block 2.0 test data.

CIMSS/SSEC developed a workflow to allow the DBMS used internally by ADL for Block 2.0 to be shipped to users in a pre-populated format, along with tools to safely update the database after installation at customer sites when (a) new lookup tables are downloaded, and (b) when new ancillary TLE, polar wander, and VIIRS RSB AUTOCAL files are obtained.

CIMSS/SSEC continued to operate a real-time ancillary data ingest and distribution site to provide a one-stop shop for ADL users to obtain the ancillary data needed to run SDR and EDR algorithms. The website is available at http://jpssdb.ssec.wisc.edu/ancillary/

Files distributed include:
- GFS model grib2 forecast files,
- GDAS model grib2 analysis files,
- NISE Snow and Ice Extent HDF4 files,
- NAAPS aerosol forecast grib2 files,
- Polar Wander blob and ascii files,
- TLE internal text and ascii files, and
- LUTs needed for SDR processing.

## 24. CIMSS Support to JPSS VIIRS Derived Winds Validation and Science for 2016

**CIMSS Task Leader: David Santek**
**CIMSS Support Scientist: Steve Wanzong**
**NOAA Collaborators: Jeff Key, Jaime Daniels**
**Budget: $37,000**

### NOAA Long Term Goals:
- Weather-Ready Nation

### NOAA Strategic Goals
- 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

### Objective
To provide validation and science support for the current S-NPP polar winds product and prepare for the launch of the first JPSS satellite in 2017.

### Project Overview
The VIIRS polar winds product is currently operational for the Suomi National Polar-orbiting Partnership (S-NPP) satellite and provides wind speed, direction, and pressure of cloud-tracked features at high latitudes. These winds have been produced operationally by NESDIS since May

2014 and are also being distributed via the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) EUMETCast broadcast. The VIIRS winds are being assimilated in the Naval Research Lab's (NRL) Atmospheric Variational Data Assimilation System - Accelerated Representer (NAVDAS-AR) and are currently being monitored in NCEP's pre-operational version of the Global Data Assimilation System/Global Forecast System GDAS/GFS. They are also used by some numerical weather prediction centers abroad.

The objective of this project is to assess the quality of the operational S-NPP VIIRS winds and to prepare for the long-term monitoring and validation of VIIRS winds from the first Joint Polar Satellite System (JPSS) satellite (JPSS-1) and beyond.

## Milestones with Summary of Accomplishments and Findings

VIIRS Polar Winds Validated Maturity Review: A JPSS Validated Maturity Review was held on 18 October 2015 for GCOM Day-1 products, MIRS products, Green Vegetation Fraction, VIIRS Polar Winds, the Vegetation Health Index Suite, and NUCAPS Outgoing Longwave Radiation (OLR) and the CrIS Ozone Profile. The VIIRS Polar Winds were presented, with in-depth assessments of product performance relative to the system requirements in the Level-1 Requirements Document (L1RD) and the JPSS Requirements Document (JERD). The polar winds product was accepted as being at the "Validated" maturity stage.

Product monitoring and maintenance: In March 2017 it was discovered that the operational VIIRS Cloud Mask (VCM) was using an incorrect snow/ice mask in the Southern Hemisphere. CIMSS participated in evaluating the impact of this VCM problem on the VIIRS polar winds. After comparisons to MODIS and AVHRR winds, and before-after comparisons employing a potential fix to the VCM proposed by Raytheon, it was concluded that the impact on the VIIRS winds product was minimal.

New product ideas: The current polar winds products from the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Advanced Very High Resolution Radiometer (AVHRR) use three successive orbits (100-minute time step) from a single satellite to derive the cloud motion. Since JPSS-1 will be in a similar orbit as S-NPP, but delayed by ½ orbit in time, there is an opportunity to track clouds from alternating satellite passes. This will reduce the time interval between images to approximately 50 minutes, which will result in a reduced latency in product availability and higher quality winds due to the shorter time interval for tracking.

The JPSS-1/S-NPP orbit configuration is similar to the Metop-A/-B, so we have the ability to test the alternating satellites using Metop as a proxy. Figure 102 shows the mixed-satellite tracking (left) and the traditional single-satellite tracking (right) for AVHRR on board the Metop satellites. Generally, the winds are in reasonable agreement, however, the mixed-satellite mode has increased coverage (white circles), that extends further equatorward to the high mid-latitudes (not shown).

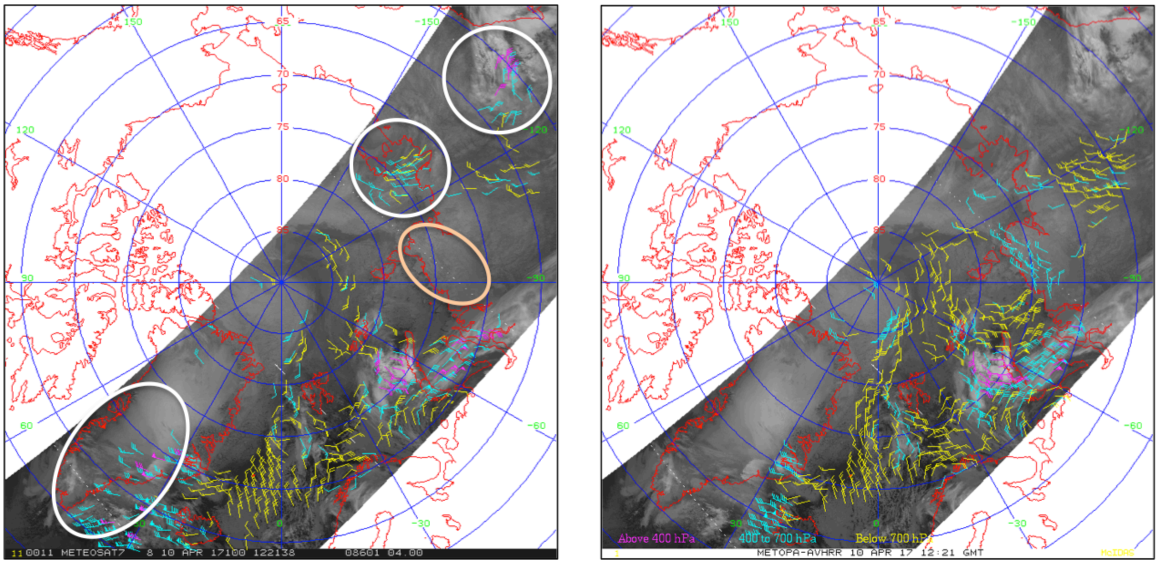



**Figure 102. Metop polar winds from alternating Metop-A and Metop-B passes (left) and three successive Metop-A passes (right) on 10 April 2017 at 1221 UTC. Colors represent the height of the wind vectors: Yellow (1000 to 700 hPa), cyan (700 to 400 hPa), magenta (about 400 hPa). The white circles denote regions where the mixed-satellite passes retrieved additional winds over the single-satellite mode. The orange circle is a region where fewer winds were retrieved, due to a missing scan of Metop-B IR data.**

In preparation for JPSS-1, we will process additional cases of mixed-satellite tracking using the Metop satellites and develop tools to quantify the differences and comparisons to 'truth', such as radiosondes.

## 25. Implementation of GCOM-W1 AMSR2 Snow Products

**CIMSS Task Leader: Yong-Keun Lee**
**NOAA and other collaborators: Jeffrey R. Key and Cezar Kongoli (CICS)**
**Budget: $55,000**

**NOAA Long Term Goals:**

- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**

- Serve society's needs for weather and water
- 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
- Environmental Models and Data Assimilation
- Education and Outreach

## Objective

The objectives of this project include continuous testing and validation of the snow algorithm and routine snow product generation with AMSR2 data. The selected heritage algorithms are being modified as necessary.

## Project Overview

Snow is one of the most dynamic hydrological variables on the Earth's surface and the cryospheric component with the largest seasonal variation in spatial extent. It also plays a key role in the global energy and water budget. Since microwave radiation is unhindered by darkness and clouds and penetrates a deeper layer of snow cover at certain frequencies, satellite passive microwave measurements have been used to detect snow cover and snow depth globally in nearly all weather conditions. The Advanced Microwave Scanning Radiometer 2 (AMSR2) instrument launched on the Japan Aerospace Exploration Agency (JAXA) Global Change Observation Mission 1st – Water "SHIZUKU" (GCOM-W1) satellite. 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). Ice Characterization includes ice "age" (ice free, first-year, and multiyear ice) and ice concentration. 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 testing and validation of the snow algorithm and routine snow product generation with AMSR2 data. The algorithms are being modified as necessary.

## Milestones with Summary of Accomplishments and Findings

The suite of AMSR2 algorithms developed for the retrieval of snow cover and snow depth is comprised of well-established methods is now being used operationally by NOAA. 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.

Accomplishments for this project year include setting up the automatic analysis system of the AMSR2 snow cover detection. Figure 103 shows the daily comparison of the retrieved AMSR2 snow cover detection with IMS snow products between Nov. 2016 and Feb. 2017 using the automatic analysis system.

During the next project year we will further refine the snow detection, snow depth methodologies and snow water equivalent algorithm.

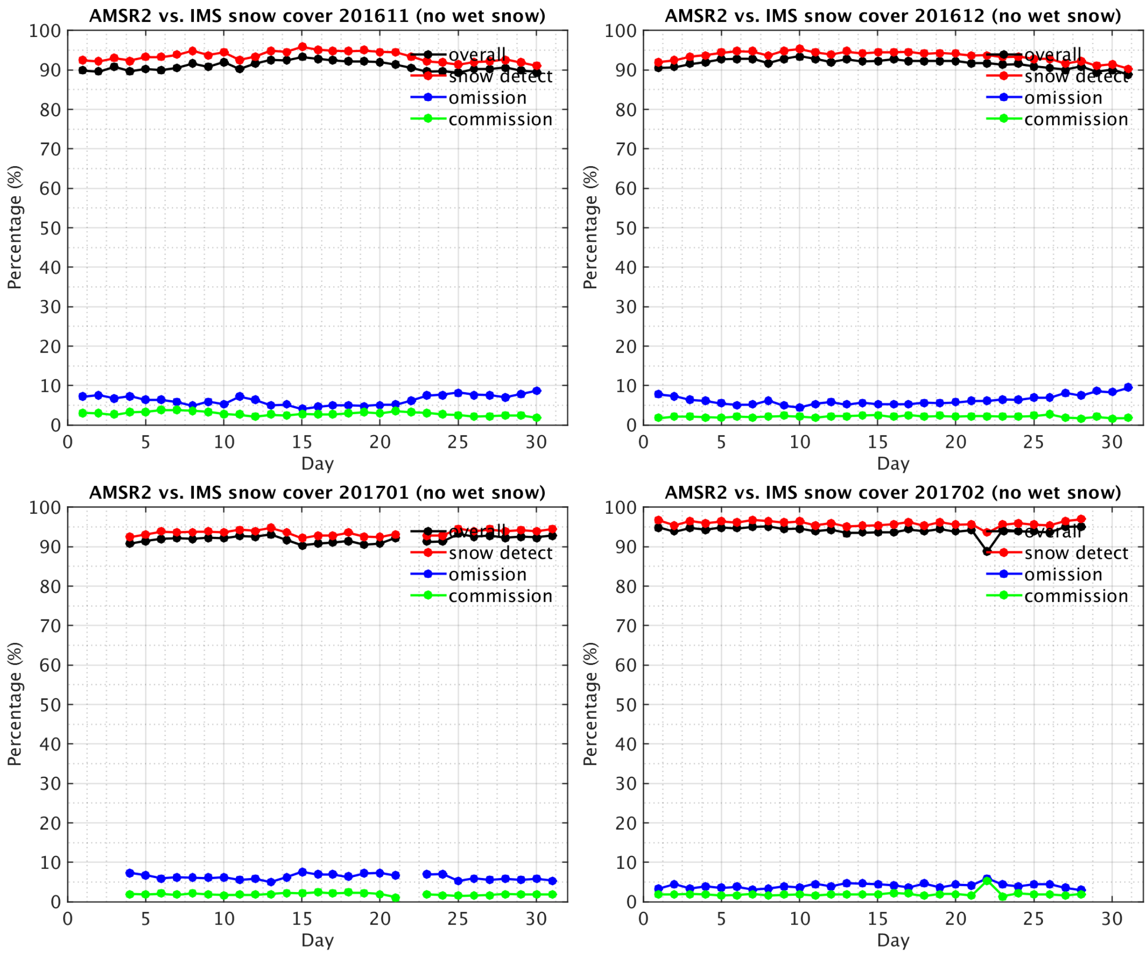



**Figure 103. Daily comparison of AMSR2 snow cover detection with IMS snow products between Nov. 2016 and Feb. 2017.**

## Publications and Conference Reports

Lee, Y.-K., C. Kongoli, and J. R. Key, 2016: "Snow products from the Global Change Observation Mission (GCOM) AMSR2 measurement", The 2016 European Space Agency Living Planet Symposium, 9-13, May. Prague, Czech Republic.

## References

Brown, R. D. and P. W. Mote, (2009), The Response of Northern Hemisphere Snow Cover to a Changing Climate. *J. Climate* 22, 2124–2145.

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.

Lee, Y.-K., C. Kongoli, and J. R. Key, (2015), An in-depth evaluation of heritage algorithms for snow cover and snow depth using AMSR-E and AMSR2 measurements, *J. Atmos. Oceanic Technol*., 32, 2319-2336. doi: 10.1175/JTECH-D-15-0100.1.

Sturm, M, J. Holmgren, and G. E. Liston, (1995), A seasonal snow cover classification system for local to global applications, *J. Climate*, 8, 1261-1283.

## 26. CIMSS Support to In Pursuit of the Shadows: VIIRS Day/Night Band Research Enabling Scientific Advances and Expanded Operational Awareness of the Nocturnal Environment for 2016-2017

**CIMSS Task Leader: William Straka III**
**NOAA Collaborator: Dan Lindsey (NOAA/NESDIS/STAR/RAMMB)**
**Budget: $12,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- 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

### Objective

The overarching goal of this project is to integrate 'low-light visible thinking' into the minds of the operational forecaster, providing familiarity with the new technology, and a new empowerment to forecasters as they contend with longstanding challenges of nocturnal environmental characterization.

### Project Overview

This research spans essential DNB tool development, novel user applications, instrument stewardship, and foundational research. Key components of this research at CIMSS are listed below.

#### *DNB Applications*

CIMSS will provide the DNB imagery, along with the information on the location of the imagery to aid in the explorations of new nocturnal applications, focusing on events outside of the CONUS and Alaska regions. These include disaster monitoring, (anthropogenic light changes), Cryospheric Applications (snow cover, sea ice), visibility hazards (fog, fires/smoke, dust, ash), and tropical cyclones (exposed low-level circulation)

#### *Sensor Performance & Preparation for J1*

Participation in ongoing Cal/Val Team discussions, Technical Interchange Meetings, test/evaluate potential software solutions, and support studies concerning DNB data quality on J1 and beyond.

### *Scientific Exploration Studies*

We propose to expand the horizons of science by researching the information content present the DNB nightglow observations. This work will include the analysis and interpretation of gravity waves occurring globally as observed via specially scaled DNB nightglow imagery during the new-moon phase. We will also continue the search for widespread 'milky sea' marine bioluminescent events via strategic monitoring of historically active locations in Southwest Asia and Indonesia.

### Summary of Accomplishments and Findings

From power outages in Syria to typhoons in the Pacific and wildfires in North America, there were plenty of examples of applications that were found for the Day Night Band. Some of the most prominent of these were the wildfires in the United States and Canada in the spring of 2016. As part of aiding and exploring new applications, images from significant events were shared with stakeholders and forecasters both thought the JPSS Satellite Liaison and though social media. In turn, occasionally, these some forecasters and stakeholders shared these images with the public to create awareness about significant events. One such example is shown in Figure 104, where the NWS San Francisco/Monterey NWS WFO chose to share and image which was provided to the JPSS Liaison at CSU.

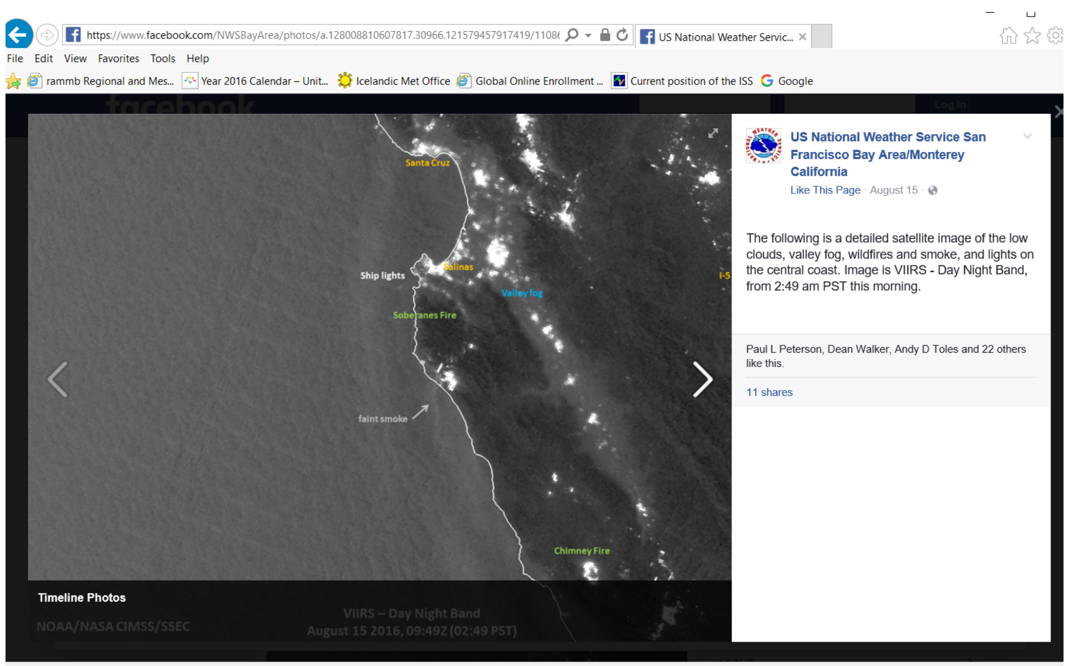



**Figure 104. DNB satellite image of Santa Cruz, California, coastline depicting low clouds, valley fog, wildfires and smoke, and lights on the central coast,. Image is VIIRS - Day Night Band, from 15 August 2016 at 9:49 UTC.**

In addition to fires, there were several super typhoons which allowed for observations unique to VIIRS. One such case is show below in Figure 105, which is of Super Typhoon Meranti on 12 September, 2016. In this case, the DNB allowed for observations of gravity waves in two completely different parts of the atmosphere, the troposphere and the mesosphere. Such observations, along with those from other sensors, can help link the transfer of energy throughout the atmosphere.

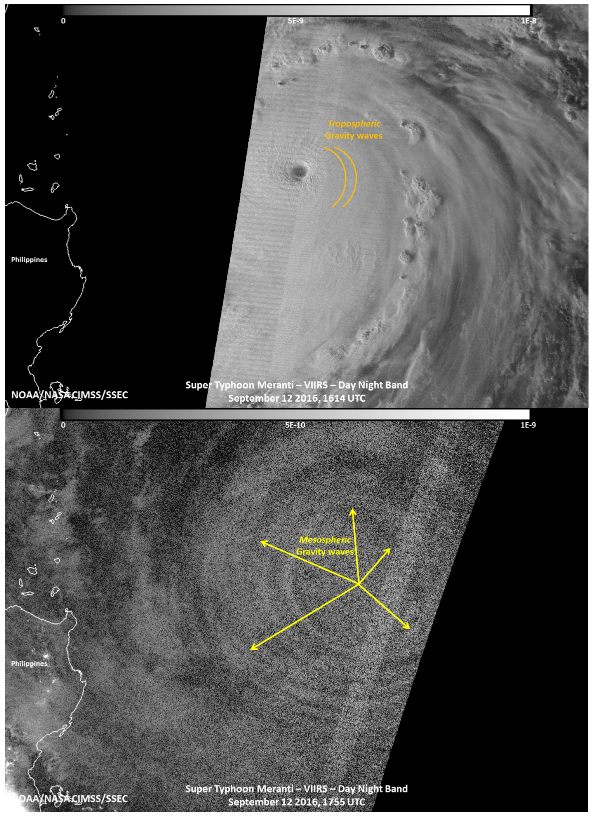



**Figure 105. Super Typhoon Meranti on 12 September, 2016. The first pass at 1614Z allowed for nighttime observations of tropospheric gravity waves, while the next pass was moon-less and allowed for observations of mesospheric gravity waves.**

In addition to finding cases, as part of the EUMETSAT Visiting Scientist Program, William Straka visited the EUMETSAT Headquarters in the week of September 19-23, 2016 and gave a presentation on a overview of the Day and Night Band. Several questions related to the exciting discovery of mesospheric gravity waves detected by the DNB on moonless nights as well as several other applications were discussed after the seminar was given.

Finally, as part of the preparation for JPSS-1, CIRA and CIMSS have been participating in discussions surrounding J1 underlap issue. It is our hope is to gain sufficient understanding to evaluate the issue on real DNB data from J1 when it becomes available and conduct an assessment of impacts at that time.

## Publications and Conference Reports

Straka, W. C. III; Miller, S. D; Seaman, C. J.; Lindsey, D.T, Torres, J;. and Stevens, E. Usage of the VIIRS Day Night Band As an Operational Tool. Annual Symposium on Future Operational Environmental Satellite Systems, 13th, Seattle, WA, 23-27 January 2017. American Meteorological Society.

Lai, C., J. Yue; J. Xu; W. Straka III; S. D. Miller; X. Liu, 2017: Suomi NPP VIIRS/DNB imagery of nightglow gravity waves from various sources over China. Advances in Space Research, 59(8), 1951-1961, doi.org/10.1016/j.asr.2017.01.041, Manuscript Number: ASR-D-16-00683R1; Section: EM -Earth Magnetosphere/Upper Atmosphere.

Hillger, D., T. Kopp, C. J. Seaman, S. D. Miller, D. Lindsey, E. Stevens, J. Solbrig, W. Straka III, M. Kreller, A. Kuciauskas, and A. Terborg, 2016: User Validation of VIIRS Satellite Imagery. Remote Sensing 2016, 8, 11;

NOAA Booth talk – AMS 2017

## 27. Support CIMSS JPSS and AWIPS II OCONUS Satellite Liaison

**CIMSS Task Leader: Jordan Gerth**
**NOAA Collaborator: Bill Ward and Eric Lau, National Weather Service Pacific Region Headquarters**
**Budget: $200,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

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

### CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Education and Outreach

### Objective

This project entails a designated scientist focusing on improving NOAA's research to operations (R2O) mechanisms and maximizing the operational value of geostationary and polar-orbiting satellite data and research products, particularly through activities centered on National Weather Service (NWS) weather forecast offices to improve services in states and territories beyond the contiguous United States, particularly Hawaii. The scientist serves in a wide array of relevant and related roles: as a satellite liaison, R2O consultant, software engineer, subject-matter expert, trainer for primarily operational meteorologists, and atmospheric and oceanic sciences researcher.

### Project Overview

The Outside CONtiguous United States (OCONUS) satellite scientist serves four primary functions beyond his capacity as a satellite meteorologist and remote sensing scientist for National Weather Service (NWS) forecast offices in the states of Alaska and Hawaii, and the territories of Guam, American Samoa, and Puerto Rico. First, the scientist is a software developer and technical consultant, focusing on Advanced Weather Interactive Processing System (AWIPS) and the NWS technical infrastructure, including networking, data flow, and antenna systems, to assure satellite imagery and products are making it to the field and meeting the needs of operational meteorologists throughout the United States. Second, the scientist is a coordinator of regional satellite proving ground and related activities, including the visiting scientist program in NWS Pacific Region, which introduces new capabilities of OCONUS value to the relevant field offices. Third, the scientist is a liaison for meteorologists and office management in NWS Pacific Region and NWS Alaska Region to assist in the development and delivery of training and addressing specific questions about the capabilities of current and future meteorological satellites, particularly the Geostationary Operational Environmental Satellite R-Series (GOES-R) and Joint Polar Satellite System (JPSS). Fourth, the scientist is a consultant to the Chair of the NWS Operational Advisory Team (NOAT) for recommending and implementing satellite proving ground and training initiatives.

### Milestones with Summary of Accomplishments and Findings

The scientist funded under this project:

- ensures that meteorologists in the OCONUS achieve optimal learning on the use of satellite imagery and products in daily operations;
- conducts scientific investigations and serves as the coordinator for demonstrating JPSS-related science products in NWS Pacific Region and NWS Alaska Region operations;
- integrates GOES-R, Himawari, JPSS, and Global Change Observation Mission (GCOM) imagery and science products into AWIPS II; and
- acts as a technical coordinator and AWIPS II developer for GOES-R and JPSS proving ground partners.

The major milestones and related accomplishments between 1 April 2016 and 31 March 2017 are indicative of the value of this project. Specifically, the scientist:

- worked with the Community Satellite Processing Package (CSPP) package development team to establish output formats that are compatible with AWIPS, and conducted related testing;
- configured AWIPS at the NWS forecast office in San Juan, Puerto Rico, to receive and display Suomi National Polar-orbiting Partnership (NPP) and other polar-orbiting satellite imagery collected from a new L/X-band antenna in Miami, Florida;
- configured AWIPS at the NWS Pacific Region Headquarters (PRH) and Honolulu Forecast Office (HFO) to display Himawari and other satellite imagery at the highest spatial, spectral, and temporal resolution available, with Eric Lau;
- coordinated a data flow architecture to optimize the transmission of satellite imagery and products to, from, and across NWS PRH;
- served as part of the Satellite Enhancement Team (SET) to ensure that "day one" visualization of imagery from GOES-R, and related training containing imagery examples, is satisfactory;
- conducted independent research related to human perception of colors and visualizing multi-spectral composite imagery;
- participated in the Satellite Training Advisory Team (STAT) to recommend foundational course content and subsequent applications-centric training materials for all NWS meteorologists related to GOES-R;
- began coordinating nationwide NWS training activities related to JPSS;
- held the June 2016 OCONUS meeting in Honolulu, Hawaii;
- led and contributed to JPSS training events, such as short courses, at annual meetings of the American Meteorological Society and National Weather Association;
- maintained the L/X-band antenna at Honolulu Community College and assured that imagery and products from the antenna system were available to NWS PRH and HFO; and
- supported the JPSS initiatives and other satellite liaisons in NWS Alaska Region.

The scientist attended the following meetings during the award period:

- Satellite Proving Ground and User Readiness Meeting (Norman, Oklahoma),
- American Meteorological Society Satellite Meteorology Conference (Madison, Wisconsin),
- National Weather Association Annual Meeting (Norfolk, Virginia),
- Asia/Oceania Meteorological Satellite Users' Conference (Incheon, South Korea), and
- American Meteorological Society Annual Meeting (Seattle, Washington).

**Publications and Conference Reports**

The success story of Himawari-8: Does R2O really mean "Risks to Overcome"?
Talk, American Meteorological Society 21st Conference on Satellite Meteorology—Potential of New Generation Satellite Systems Part II (Madison, Wisconsin)
https://ams.confex.com/ams/97Annual/webprogram/Paper305295.html
August 17, 2016

Visualizing multi-spectral satellite imagery in different color spaces
Talk, American Meteorological Society 21st Conference on Satellite Meteorology—Research and Operational Satellite Data Applications for Weather, Ocean, and Climate Monitoring and Forecasting Part I (Madison, Wisconsin)
https://ams.confex.com/ams/97Annual/webprogram/Paper305295.html
August 18, 2016

## 28. CIMSS Support to JPSS Field Terminal Segment (FTS) Tasks 2016

### 28.1 CSPP SDR to support Block 2.0 IDPS SDR processing for SNPP and JPSS

**CIMSS Task Leader: Liam Gumley**
**CIMSS Support Scientists: Scott Mindock, Graeme Martin, Ray Garcia, Kathy Strabala, Jessica Braun**
**NOAA Collaborator: Mitch Goldberg**
**Budget: $337,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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

**Objective**

The goal of this project is to provide the JPSS Sensor Data Record (SDR) software to the public in the form of (a) buildable and executable binaries in the Algorithm Development Library (ADL) environment, and (b) value-added software as part of the Community Satellite Processing Package (CSPP) for easy-to-use processing of data received from SNPP and JPSS satellites in direct broadcast mode.

**Project Overview**

CIMSS/SSEC supports JPSS FTS by providing algorithm and software integration services to enable users to integrate IDPS SDR algorithms into their local processing systems through the development of user-friendly software packages. The support from the JPSS Program for the development and maintenance of these software packages will demonstrate the ability to create ready-to-use products from the HRD link and provide risk reduction effort at a minimal cost. CIMSS/SSEC will provide software packages, supporting ancillary data, documentation and training, end user support, and value added products and software as part of this effort.

CIMSS/SSEC will acquire and process HRD from SNPP and JPSS using its existing 2.4-meter X/L-band antenna system to track the quality of the HRD transmission and monitor the validity of the products created from the HRD broadcast.

## Milestones with Summary of Accomplishments and Findings

The CSPP SDR software package is based on the Algorithm Development Library (ADL) software developed by Raytheon for the JPSS Project. ADL allows the operational processing algorithms for Suomi NPP to run without modification in a Linux environment. SSEC has packaged the ADL versions of the Suomi NPP algorithms so they can 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 SNPP SDR products is IDPS HDF5.

In June 2016 a patch was released for CSPP SDR v2.2 to correct the following problems:

- Corrected a bug which caused the ATMS orbit number to always be 00001;
- Corrected a bug in the CrIS SDR software which did not allow users to set the JPSS_REMOTE_ANC_DIR environment variable for that instrument; and
- Fixed a problem in calculating the orbit number for VIIRS, CrIS and ATMS passes that span the equator.

In December 2016 a patch was released for CSPP SDR v2.2 to update the leap seconds file, which was required because of the leap second insertion on January 1, 2017.

CIMSS/SSEC ingested all required ancillary data for the VIIRS, CrIS, and ATMS SDRs and to make them available for download to users of the CSPP SDR software. End users are able to run an automated script that will check for new LUTs on the CIMSS/SSEC FTP site, and if necessary download, unpack, and install the LUTs without user intervention. CIMSS/SSEC obtained the LUTs from the JPSS Common CM and from the NASA Land SIPS for this purpose. In particular, the VIIRS RSB AUTOCAL files were retrieved daily and posted for CSPP SDR users to download, enabling them to keep up to date with trends in VIIRS RSB performance.

In February 2017 CIMSS/SSEC released a beta version of the CSPP SDR software based on ADL Block 2.0 to the global DBNet community in order to maintain compatibility with the ATMS SDR data coming from IDPS as a result of the switch to Block 2.0. As a result, all DBNet operators supplying ATMS SDR data with low latency in BUFR format (EUMETSAT, Meteo France, Met Office, SSEC) were able to make the transition to Block 2.0 ATMS SDR calibration with no interruption in service.

During the reporting period CIMSS/SSEC continued to process real-time SNPP direct broadcast data over CONUS and provided the products to National Weather Service forecast offices for display in AWIPS2. Imagery products visible and infrared single channels, true color and false color imagery, and Day/night band imagery with several enhancements.

During the reporting period CIMSS/SSEC presented a training workshop titled “2016 Mayagüez Puerto Rico Polar Orbiter Workshop: Satellite Direct Broadcast in Support of Real-Time Environmental Applications” at the University of Puerto Rico at Mayagüez from 26-29 April, 2016. The workshop ran for 3.5 days and included lectures and laboratory sessions on SNPP VIIRS and EOS MODIS real-time processing, software, products, and applications. On the final day students presented summaries of a short research topic they investigated during the workshop.

During the reporting period CIMSS/SSEC presented a training workshop titled "CSPP LEO and GEO real-time products and applications" in conjunction with the AOMSUC 2016 Conference in Seoul, Korea from October 21-28, 2016. The workshop ran for 3 days and included lectures and laboratory sessions on real-time SNPP VIIRS products, applications, and software installation and operation.

During the reporting period CIMSS/SSEC presented a training workshop titled "CSPP LEO real-time products and applications" at Moscow State University from 28-30 November, 2016. The workshop ran for 3 days and included lectures and laboratory sessions focusing on SNPP VIIRS products and applications. On the third day the students gave short briefings on a subject of interest which they investigated during the workshop.

## 28.2 Real time processing of VIIRS River Flood and River Ice Products
**CIMSS Task Leader: Jay Hoffman**
**CIMSS Support Scientists: David Santek, Russell Dengel**
**Budget: $48,000**

### NOAA Long Term Goals:
- Weather-Ready Nation

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

### Objective
Evaluation and maintenance of the routine generation of the GMU flood and CCNY ice products at CIMSS.

### Project Overview
CIMSS hosts a river ice product developed at City College of New York (CCNY) and a river flood product developed at George Mason University (GMU), both product algorithms are derived from VIIRS. The GMU product provides an estimate of flooding water fractions, regions of ice, cloud, snow cover, and shadows. The CCNY algorithm produces an enhanced river ice mapping product with river ice location, extent, and concentration. Products are generated with direct broadcast VIIRS data in near real-time and sent to AWIPS and for those without access to AWIPS - SSEC's RealEarth Web Map Service.

The success of the product has sparked interest from several river forecast centers (APRFC, NERFC, MBRFC, and WGRFC). These products could be useful to other institutions that monitor river ice and flooding conditions, especially in mid- and high-latitude locations.

### Milestones with Summary of Accomplishments and Findings

#### *Maintenance of CCNY's river ice algorithm*
The CIMSS CSPP team is generating this product routinely and providing it to NWS River Forecast Centers (RFC). During the reporting period, CCNY delivered two product updates to

CIMSS. In addition to the legacy ice extent mask, with the first update (version 3.1), an ice classification product began providing ice concentration to the nearest 10%. A second update (version 3.2) is in the process of being tested and will add several new rivers to the coverage domain as well as add a cloud shadow category. The product has run routinely at CIMSS and Geographic Network of Alaska (GINA). The CCNY river ice product is available in AWIPS and RealEarth

### *Maintenance of GMU's river flood algorithm*

The product river flood product continues to running routinely at CIMSS. A product update was installed in the Alaska region to provide some experimental off-shore (ice) coverage. In preparation for the next generation of product, a 30m resolution product scene was displayed in RealEarth. In response to feedback from river forecast center offices, the product domain was expanded to include the entire CONUS plus Alaska (Figure 106).

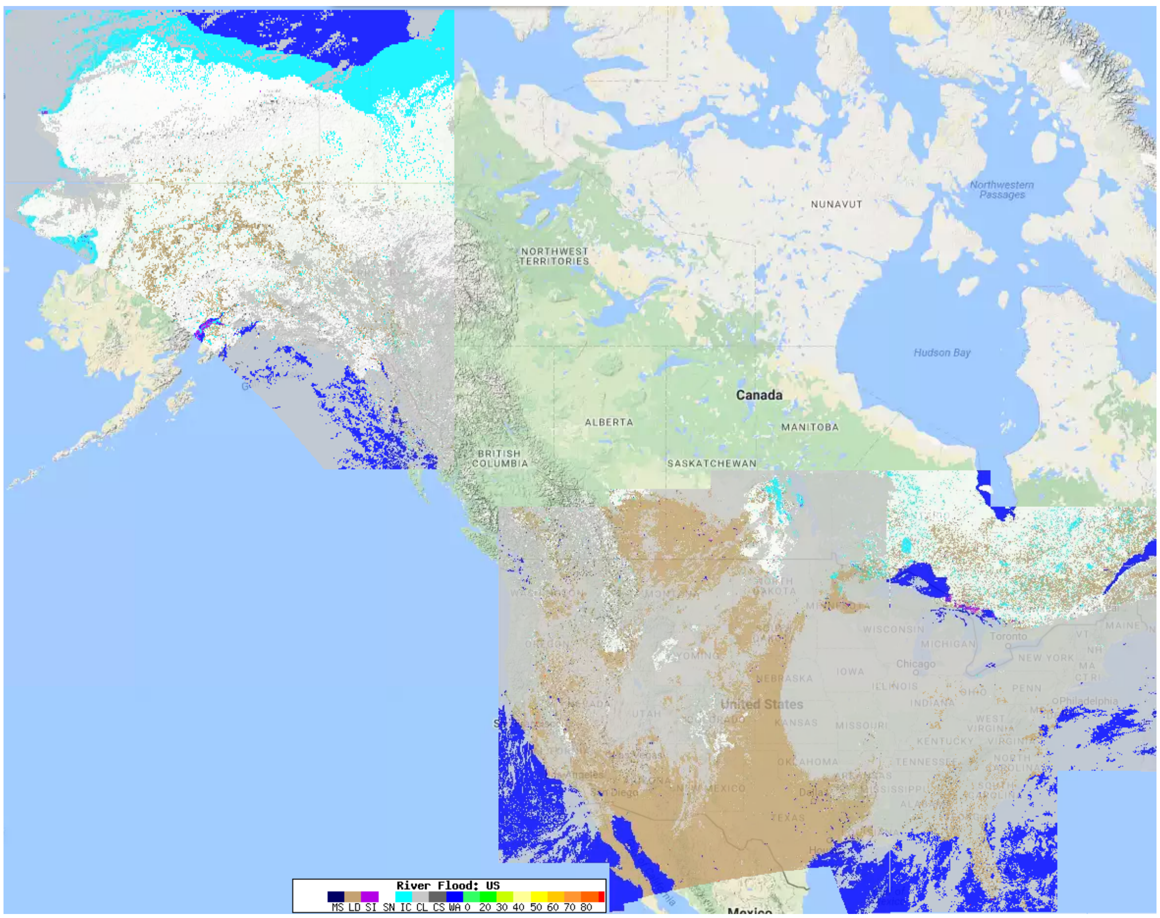



**Figure 106. RealEarth screen capture showing example coverage of VIIRS River Flood product**

## Publications and Conference Reports

DeWeese, M., D. Sun, S. Li, J. Hoffman, D. Santek (2016). A Case Study of the 2015-16 Mississippi River Basin Flood Using Suomi-NPP VIIRS Flood Products. National Weather Association 41st Annual Meeting, Norfolk, VA, 10-15 September 2016.

Li,S., D. Sun, M. Goldberg, B. Sjoberg, D. Santek, J. Hoffman, M. DeWeese, P. Restrepo, S. Lindsey, E. Holloway (in review). Automatic near Real-Time Flood Detection using Suomi-NPP/VIIRS Data. *Remote Sens. Environ.*

### References

Chaouch, N., M. Temimi, P. Romanov, R. Cabrera, G. Mckillop, R. Khanbilvardi. (2014). An Automated Algorithm for the Monitoring of River Ice over the Susquehanna River Basin using MODIS data. *Hydrol. Process.*. **28**, Issue: 1, 62-73.

Li, S., D. Sun, M. Goldberg, A. Stefanidis (2013). Derivation of 30-m-resolution Water Maps from TERRA/MODIS and SRTM. *Remote Sens. Environ.***134**, 417–430.

## 28.3 Real Time Display of JPSS Datasets in Real Earth (ISEE)

**CIMSS Task Leader: Sam Batzli**
**CIMSS Support Scientists: Dave Parker, Russ Dengel, Nick Bearson, Tommy Jasmin, Dave Santek**
**NOAA Collaborator: Mitch Goldberg**
**Budget: $96,000**

### NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:

- 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
- Education and Outreach

### Objective

To extend the awareness, knowledge, and understanding of the societal value of JPSS satellites.

### Project Overview

ISEE is a web page and native mobile app that will monitor environmental events and conditions observed by S-NPP/JPSS satellites in near real-time, based on user-defined locations and subjects. The app will notify the user of a noteworthy event, display it on their mobile device, and extend a social media capability for sharing the discovered event with Twitter, Facebook, Email, or others.

### Milestones with Summary of Accomplishments and Findings

In addition to the five year-one milestones previously reported on, the RealEarth team accomplished the following in year-two:

- *Add additional products*
  ISEE now includes several new S-NPP and/or blended products: Satellite Wild Fires, River Ice and Flooding, Cryosphere (Sea Ice Concentration), Fractional Snow Cover, Aerosol Optical Depth, Cloud Optical Thickness, Total Precipitable Water (from Tony Wimmers).

- *Incorporate suggested changes in Apps*
  The ISEE app now has a login capability that allows users to synchronize their user-defined notifications with the browser version of ISEE. The means that if a user defines a geolocation polygon for a specific product (Satellite Wildfires) in either the App or the browser, that "notification" setting will appear in the manager under user settings in both the App and the browser. The RealEarth/ISEE team is working to improve the user-notification experience to limit false alarms or missed reports. Users now have the ability to set the sensitivity of satellite derived values that trigger alerts/notifications (see Figure 107).
- *Harden the Apps as needed*
  Hardening the Apps is ongoing and part of the development process. The entire RealEarth system now runs under "secure http" or "https." This encrypts the logins required in Milestone 2 above.
- *Prepare Apps for iOS/Android Stores*
  Ongoing work with both the browser and mobile devices is preparing the Apps for the App stores.

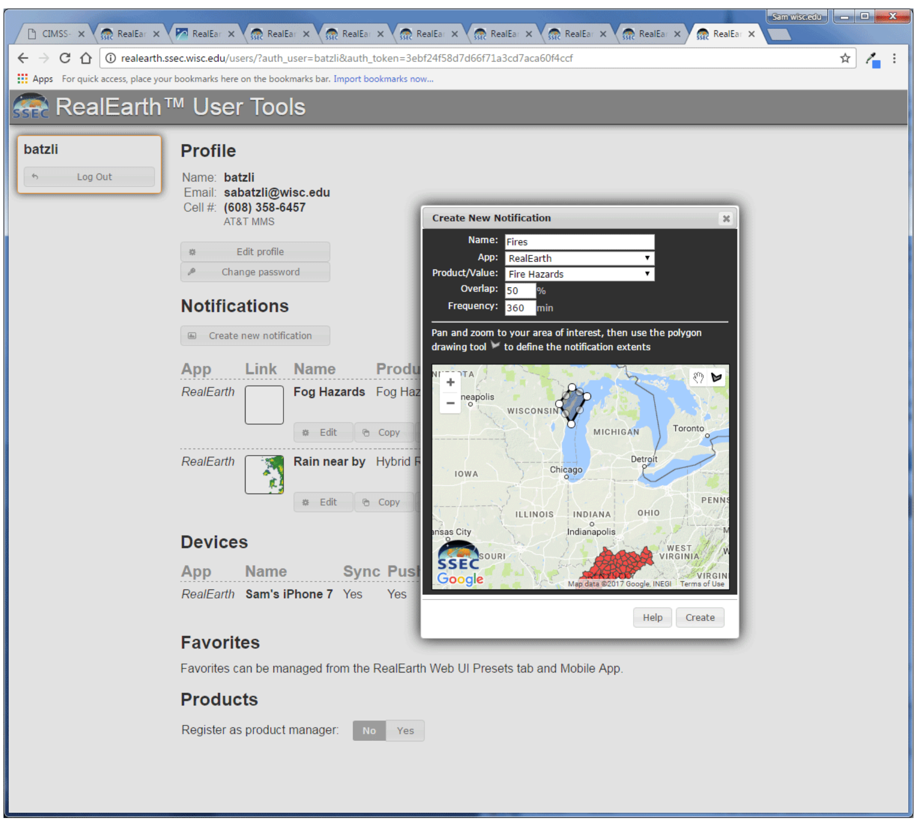



**Figure 107. RealEarth/ISEE developers have created user-defined notifications that synchronize between the browser and mobile device versions of RealEarth and ISEE. Users can define notifications on a specific product in either place then Tweet or share the resulting alert.**

## Publications and Conference Reports

RealEarth/ISEE participated in the JPSS Short Course at AMS in Seattle Saturday, January 21, 2017. On Monday, January 23, 2017 Batzli presented "RealEarth: Access to Real-time and Archive Satellite Data and Derived Products."

## 29. CIMSS Participation in the Evaluation on the Alternative of Advanced IR and MW Sounders with CIRAS and MicroMAS-2 for Weather Forecasting through OSSE

**CIMSS Task Leaders: Jun Li, Zhenglong Li**
**CIMSS Support Scientists: Pei Wang, Agnes Lim, Jinlong Li, Federick W Nagle**
**NOAA Collaborators: Timothy Schmit, NOAA/NESDIS/STAR, Robert Atlas, NOAA/AOML, Sid Boukabara, NOAA/NESDIS/STAR, and John Pereira, NOAA/NESDIS/OPPA**
**Budget: $193,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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
- Environmental Models and Data Assimilation

### Objective
The objective is to use quick regional OSSE (r-OSSE) to explore the value added impact from CubeSat-based microwave and infrared sounders on local severe storm forecast.

### Project Overview
The main focus on this project is for CIMSS to participate in the evaluation on the alternative of microwave (MW) and advanced Infrared (IR) sounders with Micro-sized Microwave Atmospheric Satellite-2 (MicroMAS-2) and CubeSat Infrared Atmospheric Sounder (CIRAS) for weather forecasting through quick regional Observing System Simulation Experiment (OSSE). The CIMSS scientists will focus on two tasks: 1) conducting CIRAS impact study with quick regional OSSE, and 2) conducting MicroMAS-2 impact study with quick regional OSSE. The ultimate goal is to understand the alternative of advanced infrared and microwave sounders from cubesat observing systems, with different orbit configurations, for NWP applications, in mitigating the loss of one or more of the existing polar orbiting advanced IR sounders. Under this proposal, CIMSS will continue to collaborate with NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML) and the Joint Center for Satellite Data Assimilation (JCSDA) for simulation, validation, assimilation and impact studies; CIMSS will also collaborate with Jet Propulsion Laboratory (JPL) and Lincoln Laboratory (LL) of Massachusetts Institute of Technology (MIT) on instrument specifications in this OSSE studies.

### Milestones with Summary of Accomplishments and Findings

#### *Orbit simulator*
An orbit simulator was developed to simulate any satellite orbit. Given the inputs of satellite altitude, inclination, right ascension of the ascending node (RAAN), hour angle of the satellite from the sun, swath, field of view size, angular speed etc, it is capable of accurately predicting

needed orbital information for synthetic observation simulations, including geolocation, satellite geometry, solar geometry, time and etc (Nagle and Holz 2009). Figure 108 shows the simulated orbits for CIRAS and MicroMAS-2 in three different orbits.

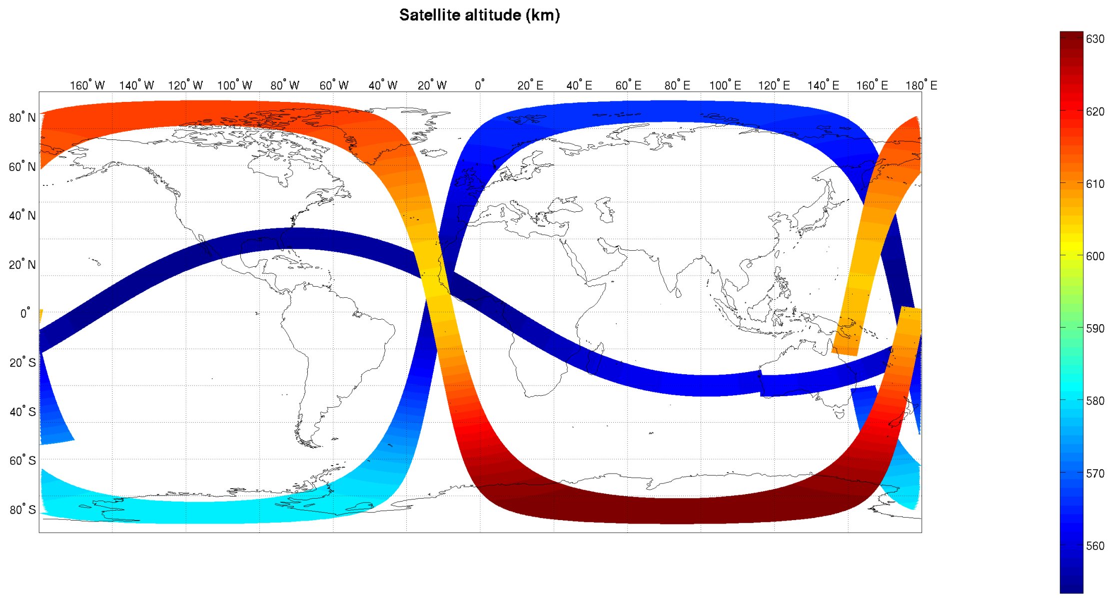



**Figure 108. Simulated satellite altitude (km) of MicroMAS-2 and CIRAS in different orbits, the polar orbits for MicroMAS-2 (blue) and CIRAS (Red), and the tropical orbit (inclination of 30 degree) for MicroMAS-2 (blue).**

### *Synthetic radiance simulator*

Based on the orbit simulator, a radiance simulator was developed to simulate synthetic satellite radiances with the WRF Nature Run (NR), either ARM or NMM. For a given orbit, the simulator will search two nearest times of NRs (one before and one after the satellite observation time), and performs temporal/spatial interpolation of variables needed for radiance simulation to satellite FOVs. The Community Radiative Transfer Model (CRTM, Tong Zhu and Sid Boukabara) team have developed and delivered the optical depth in pressure space (ODPS) coefficients for both CIRAS and MicroMAS-2 based on spectral response function provided by JPL and Lincoln Lab. CIMSS has also developed a pressure layer fast algorithm for atmospheric transmittances (PFAAST) coupled with the fast single layer cloud model (Wei et al., 2004; Li et al., 2017) for CIRAS (ongoing for clears sky MicroMAS-2). Comparison between CRTM and CIRAS shows excellent agreement (Figure 109) for one randomly chosen atmospheric profile. Since CIRAS has a spectral resolution of 0.6 - 1 $cm^{-1}$, worse than IASI's 0.25 $cm^{-1}$, it is not able to capture the fine absorption lines as IASI. Both CRTM and PFAAST do not have NonLocal Thermodynamic Equilibrium (NLTE).

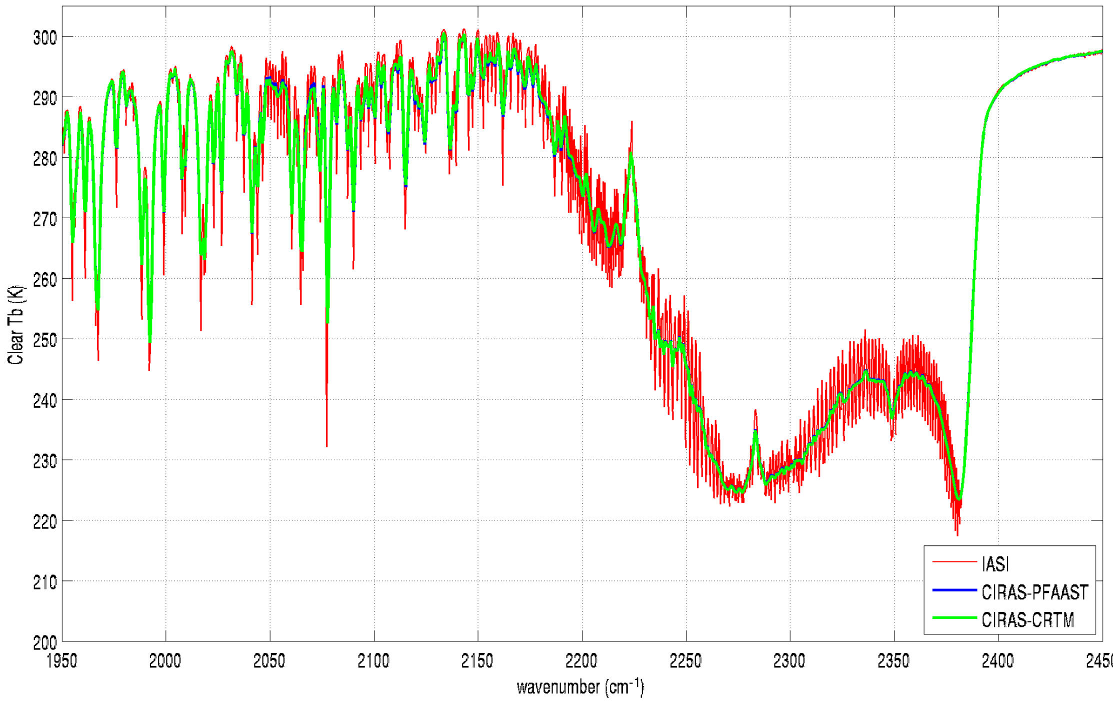



**Figure 109. Comparison of simulated CIRAS brightness temperature from (green) CRTM and (blue) PFAAST along with (red) IASI from PFAAST.**

### *Impact study on local severe storms from MicroMAS-2*

The WRF-NMM is used to generate high spatial resolution (2 km) NR for local severe storms from 00 - 15 UTC on May 27, 2006. The initialization and boundary conditions come from the global OSSE analysis using GFS by Lim (2017), which uses the Goddard Earth Observing System Model, Version 5 (GEOS-5) Nature Run (G5NR, Gelaro et al., 2014) as the NR. The purpose is to study whether MicroMAS-2 can mitigate the loss of ATMS from Suomi-NPP and future JPSS satellites. Since GSI does not have the capability to assimilate MicroMAS-2, its radiances are converted to ATMS through a linear regression; only the 11 ATMS channels that are well predicted by this conversion are directly assimilated. Since ATMS has 22 channels, much more than 12 channels from MicroMAS-2, the information loss due to conversion should be little. The control run-1 (CNTL1) assimilates existing observations of radiosonde, AMSU-A and IASI on Metop-b, representing the baseline of the study. The control run-2 (CNTL2) add ATMS on top of CNTL1, representing the target of the study. Three orbits of MicroMAS-2 are studied: 1030 AM, 130 PM (same as ATMS), and 430 PM. The evaluation focuses on precipitation forecast. The Equitable Threat Score (ETS) are shown in Figure 110. These results show that a) single MicroMAS-2 may slightly improve precipitation forecast, but not for heavy precipitation, and b) 3 MicroMAS-2 (1030 AM, 130 PM and 430 PM) together are more promising: on par with ATMS for heavy precipitation, less so for light precipitation.

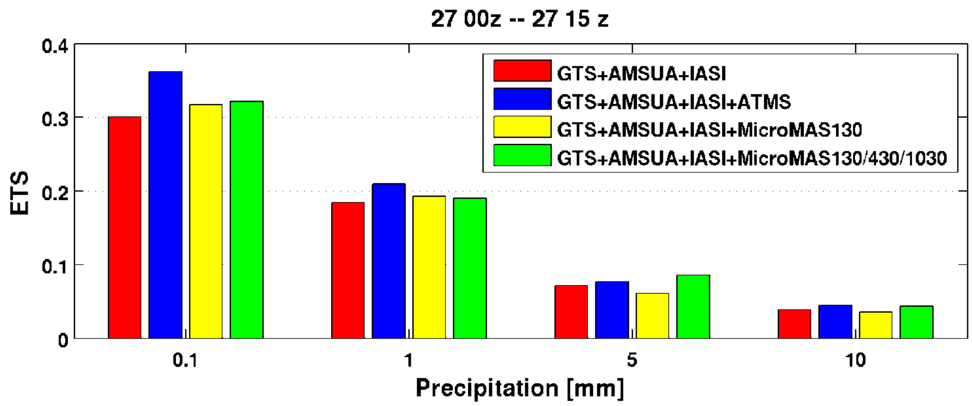



**Figure 110. ETS scores from different experiments. 1 mm means all precipitations equal or larger to 1 mm are used to calculate the ETS.**

### *Impact study on local severe storms from CIRAS*

Since no existing hyperspectral sounders have similar spectral coverage as CIRAS that is currently assimilated into GSI, profile retrieval assimilation is preferred to show CIRAS impact. While this is an ongoing effort, CIMSS has finished the following tasks for both CIRAS and CrIS: orbit simulation, radiance simulation, sounding retrievals, conversion to PREPBUFR, and impact experiments. The analysis of the impact studies are ongoing and will be shown in the annual report near the end of the project.

## Publications and Conference Reports

Li, Zhenglong; Li, J.; Wang, P.; Lim, A.; Schmit, T. J.; Li, J.; Nagle, F. W.; Atlas, R.; Boukabara, S. A.; Pagano, T.; Blackwell, W. J. and Pereira, J. Quick regional OSSEs on Cubesat based IR/MW sounders on local severe storm forecasts. Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface, 21st, Seattle, WA, 21-26 January 2017. American Meteorological Society, Boston, MA, 2017.

Li, Jun, Zhenglong Li, Pei Wang, Timothy Schmit, Wenguang Bai, and Robert Atlas, 2017: An efficient radiative transfer model for hyperspectral IR radiance simulation and applications under cloudy sky conditions, Journal Geophysical Research – Atmospheres (submitted).

## References

Gelaro, R.; Putman, W.M.; Pawson, S.; Draper, C.; Molod, A.; Norris, P.M.; Ott, L.; Prive, N.; Reale, O.; Achuthavarier, D.; et al. Evaluation of the 7-km GEOS-5 Nature Run; Technical Report Series on Global Modeling and Data Assimilation 36; NASA Global Modeling and Assimilation Office: Greenbelt, MD, USA, 2014.

Lim, Agnes; Li, Z.; Jung, J. A.; Huang, A.; Woollen, J.; Nagle, F. W.; Quinn, G.; Healy, S. B.; Otkin, J.; Goldberg, M. D. and Atlas, R. Impact analysis of LEO hyperspectral sensor Ifov size on the next generation high-resolution NWP model forecast performance. Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface, 21st, Seattle, WA, 21-26 January 2017. American Meteorological Society, Boston, MA, 2017.

Nagle, F. W., and R. E. Holz (2009), Computationally efficient methods of collocating satellite, aircraft, and ground observations, J. Atmos. Oceanic Technol., 26, 1585–1595, doi:10.1175/2008JTECHA1189.1.

Wei, H., P. Yang, J. Li, B. B. Baum, H.-L. Huang, S. Platnick, Y. Hu, and L. Strow (2004), Retrieval of semitransparent ice cloud optical thickness from Atmospheric Infrared Sounder (AIRS) measurements, IEEE Trans. Geosci. Remote Sens., 42, 2254– 2267.

## 31. CIMSS Support to NPP and JPSS Data Assimilation Improvements and Data Denial Experiments

**CIMSS Task Leader: James Jung**
**NOAA Collaborators: Mitch Goldberg, John Derber, Dennis Keyser, Walter Wolf**
**Budget: $219,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- 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
- Environmental Models and Data Assimilation

### Objective

Improve the use of CrIS on SNPP and prepare for CrIS on JPSS-1 in the NOAA/NCEP Global Forecast System

### Project Overview

This project proposed to continue to focus on testing and incorporating data assimilation technique improvements to National Centers for Environmental Prediction (NCEP) Global Data Assimilation System / Global Forecast System (GDAS/GFS) for the Joint Polar Satellite System/National Polar-orbiting Partnership (JPSS/NPP) Cross-track Infrared Sounder (CrIS) full spectral resolution CrIS-FSR data and follow-on CrIS sensors. These improvements include software modifications to improve the impact CrIS has on the global forecast as well as improve memory and run-time efficiency within NCEP's operational constraints. This project also proposed to make modifications to the NCEP GDAS/GFS to use satellite data from the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Advanced Retransmission Service (EARS) / Direct Readout And Relay System (RARS) and the Direct Broadcast data available from the Space Science and Engineering Center (SSEC) at the University of Wisconsin.

### Milestones with Summary of Accomplishments and Findings

#### *Revise CrIS channel selection used by NCEP's GDAS/GFS*

When the radiances from certain instruments, like CrIS and the Infrared Atmospheric Sounding Interferometer (IASI), are apodized, their channel errors become correlated with neighboring channels. Various Numerical Weather Prediction Centers are moving toward using channel correlation matrices to characterize these channel inter-dependencies and to more effectively use various channels in their assimilation systems. Most Numerical Weather Prediction Centers are showing modest forecast skill improvements by doing this. NCEP/EMC is also moving in this direction and is requesting channel correlation matrices also be included with any future CrIS-FSR work. As such, I have been working with NCEP/EMC to generate this matrix. Several modifications to the matrix generation software as well as two different techniques were investigated. Figure 111 is the CrIS-FSR correlation matrix derived from the technique NCEP/EMC is currently using.

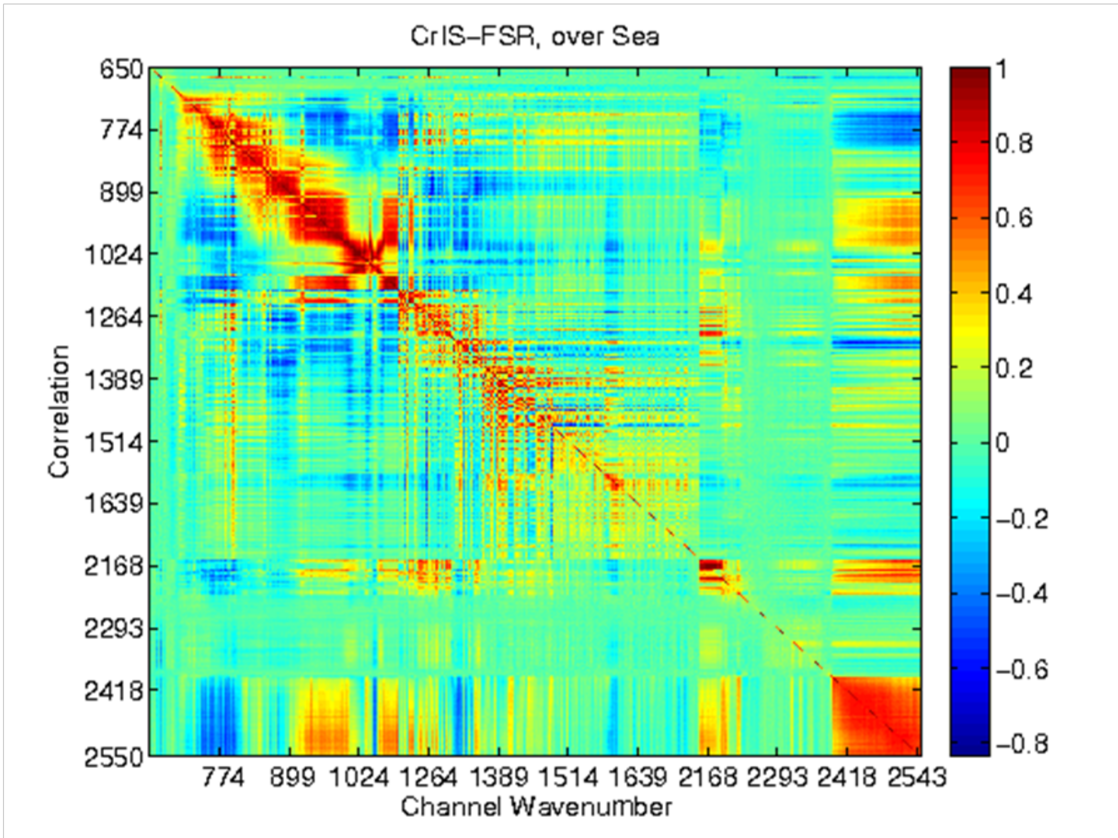



**Figure 111. Channel correlation matrix for CrIS-FSR. This matrix is used by the GSI to account for various channel cross-correlations. Using this matrix allows for better characterization of each channel and more optimal use. Courtesy of Kristen Bathmann.**

A two month experiment was conducted using the current CrIS operational configuration (82 temperature channels) and compared against an experiment using 204 temperature channels with the CrIS channel correlation matrix. The assimilation weights and quality control parameters were adjusted in the 204 channel experiment to be consistent with using the channel correlation matrix. Some forecast skill results of this season long test are shown in Figure 112. This test is only a proof of concept and a starting point to verify further improvements in generating the channel correlation matrix and optimizing the channel selection. Considerable work is still needed before it is ready for NCEP/EMC implementation testing.

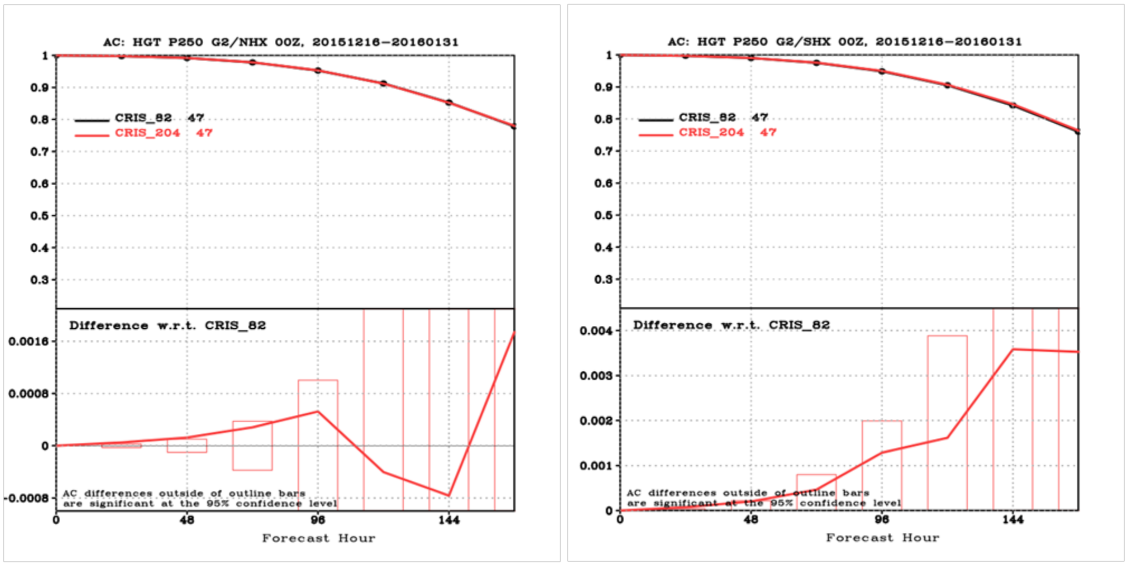



**Figure 112. Standard anomaly correlation die-off curves of 250 hPa geopotential heights for the Northern (left) and Southern (right) hemispheres during Dec 2015 – Jan 2016. Values greater than zero in the lower panels imply improved forecast skill. These curves show marginal improvements in forecast skill from adding the CrIS-FSR correlation matrix and more, potentially correlated, channels.**

### *Modify NCEP's GSI to use EARS/RARS and Direct Broadcast data*

Software modifications in the NCEP's Gridpoint Statistical Interpolation (GSI) to use the EARS/RARS and the Direct Broadcast data available from the Space Science and Engineering Center (SSEC) at the University of Wisconsin are complete. The GSI software modifications have passed the NCEP/EMC internal and external reviews and are now available to all developers. The Advanced Microwave Sounding Unit (AMSU), Microwave Humidity Sensor (MHS), High-resolution Infrared Radiation Sounder (HIRS), Advanced Technology Microwave Sounder (ATMS), IASI, and CrIS instruments are now supported. More sites are expected to participate in EARS/RARS or the SSEC Direct Broadcast improving data coverage in low latency weather forecast models. EARS/RARS and SSEC Direct Broadcast data from ATMS, CrIS, IASI, and AMSU are in the current NCEP GDAS/GFS implementation parallel tests.

Microwave data from the RARS/EARS and DB sites contain antenna corrections. The Community Radiative Transfer Model (CRTM) contains a subroutine to remove these antenna corrections for anyone wanting to use the un-corrected values. Inconsistencies were discovered in the removal of the antenna corrections. These are now fixed. The brightness temperatures from RARS/EARS and DB for all the current AMSU and MHS sensors, after the antenna corrections are removed, have been verified to be consistent with data from NESDIS Operations to within 0.01K.

## 31. CIMSS Cal/Val Activities in Support of the Calibration Working Group

**CIMSS Task Leader: Mathew Gunshor**
**CIMSS Support Scientist: James P. Nelson III**
**NOAA Collaborator: Timothy J. Schmit**
**Budget: $96,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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

### Objective
CIMSS supports the GOES-R Calibration Working Group (CWG) activities with the current operational GOES series, future GOES-R series, and Himawari-8 Imager data, especially in the area of data quality impacts on users.

### Project Overview
CIMSS proposed to assist the GOES-R CWG in preparing for the GOES-R era. Experience with the current GOES-series on science checkouts and radiance quality assurance, as well as involvement on the GOES-R AWG developing a system for analyzing ABI product output, has been valuable to the CWG. CIMSS proposed to report to the CWG on issues affecting current GOES radiance quality. Knowledge gained from monitoring current GOES can be applied to GOES-R. The GOES-R program moved from pre-launch to post-launch test during this year. CIMSS also proposed to continue to provide assistance to CWG analyzing JMA's AHI calibration and navigation.

### Milestones with Summary of Accomplishments and Findings
The proposed tasks for FY16 were as follows:
1. Assist CWG in analysis of calibration issues and their effects on products.
    - Supporting L1b calibration and ensuring ABI data quality.
    - Analyzing the impact of L1b issues on L2 products
    - Preparing for ABI PLT/PLPT.
    - Initial on-orbit analysis / starting ABI PLT/PLPT.
2. Assist CWG in analysis of calibration and navigation on JMA's AHI.
    - Support GOES-R CVCT INR efforts.
3. Report on issues addressed by CIMSS that affect current GOES radiance quality.
4. Attend regular CWG telecons, reporting on findings when appropriate.
    - Report pertinent activities to the CWG weeklies.

CIMSS provided meaningful feedback to the CWG on all tasks through attendance at CWG meetings, via the weekly CWG reports, and via E-Mail with CWG members. Some of the specific issues addressed by CIMSS include:
- Reviewed the procedure for data quality flag (DQF) determination for ABI L1b. Provided feedback to CWG.
- Reviewed PUG Version D.2 (L1b PUG & L2 PUG)
    - Comments were returned to Americo Allegrino in AWG (Excel spreadsheet template).
    - Some calibration information missing from the PUGs for VIS/NIR bands (no E_Sun or solar constant values listed for information necessary for converting radiance to reflectance factor).
    - The system is still using old mock SRFs.

- Reviewed DO3.0b patch ground system output data for proper conversions from L1b radiances to L2 Cloud and Moisture Imagery Product (Brightness temperatures and reflectance factors).
    - Comments were returned to Americo Allegrino in AWG (combination of Powerpoint and Word).
    - Raised several concerns about the L2 files, including Means being incorrect and the files are still being truncated at 173.15 K for each band, instead of having consistent values between radiance and later physical units.
    - Conversion from radiance to reflectance factor seems to be very accurate, with machine-precision level differences (e-06) between our calculations and the file contents.
    - Conversion from radiance to brightness temperature is not as accurate as machine precision differences (e-06), with differences in the hundredths of degrees K (order of 0.01). These differences are not worrisome scientifically for products, but nonetheless raise the question of if the conversion is being done properly.
        - Prior tests of conversion between Radiance and Brightness Temperature between our team and the AIT yielded differences on the order of 0.000001 K.
        - Possible errors are introduced due to scaling to store as integers, but we have not quantified that amount of error.
- Visualized ABI Thermal Vacuum (TVAC) data and shared images with CWG.
- AHI eclipse has a negative impact on the satellite winds product and this impact was shown to CWG.
- Stray light mitigation strategy for ABI does not prevent all stay-light during satellite eclipse from impacting both VIS/NIR bands and the 3.9um band as well.

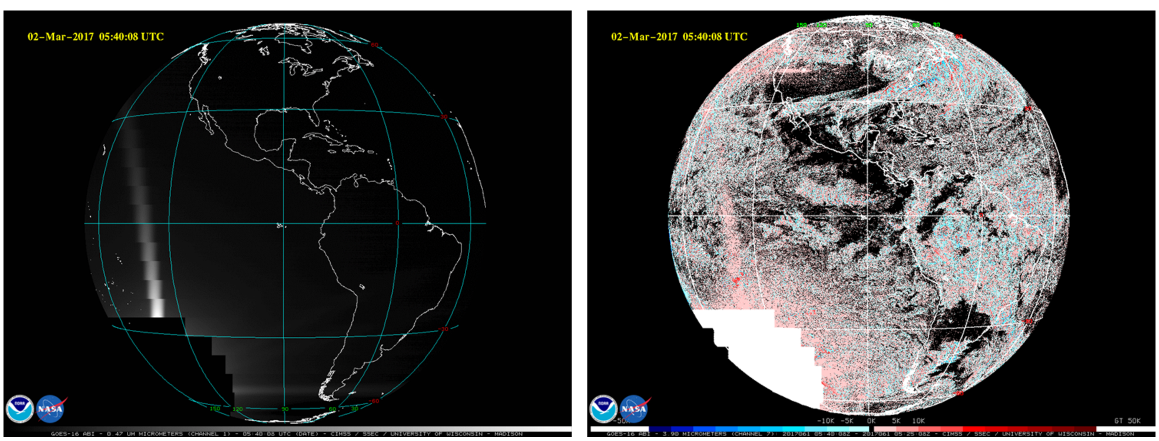



**Figure 113. GOES-16 ABI band 1 (0.47um) from 02-Mar-2017 05:40:08UTC during eclipse season, with solar avoidance region in lower left (on left) and band 07 (3.9um) difference image with subsequent image in time on right, which shows the impact of stray light in the shortwave IR band is evident beyond the solar avoidance zone removed from the imagery.**

## Publications and Conference Reports

Nelson, James P. III; Feltz, J. M.; Bah, K.; Gunshor, M. M. and Schmit, T. J. GOES-R imagery: Readiness and quality assurance. Conference on Satellite Meteorology, Oceanography and Climatology, 21st, Madison, WI, 15-19 August 2016. American Meteorological Society, Boston, MA, 2016 (Poster).

## 32. CIMSS Support to GOES-R Calibration/Validation Deployment Support For Scanning HIS (S-HIS)

**CIMSS Task Leaders: Joe Taylor, David Tobin**
**CIMSS Support Scientists: Hank Revercomb, Ray Garcia, David Hoese, Fred Best, Mark Mulligan, Nick Ciganovich**
**NOAA Collaborators: Steve Goodman, Frank Padula, Aaron Pearlman**
**Budget: $85,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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 Sensors and Techniques

### Objective
The primary objective of this project is radiometric calibration validation of the GOES-16 ABI instrument via intercomparison with the high altitude S-HIS sensor. The S-HIS will be deployed on the NASA ER-2.

### Project Overview
GOES-16 is conducting a calibration and validation field campaign in 2017. This funding will be used to deploy UW-Madison SSEC Scanning High resolution Infrared Sounder (S-HIS) on the ER-2 aircraft. Additional FY17 and FY18 funds are expected to provide further support for the field campaign and associated analyses. Routine instrument maintenance and field deployment preparation were the primary activities in Year 1.

### Milestones with Summary of Accomplishments and Findings
- Pre-mission end-to-end radiometric calibration verification of the S-HIS was completed at the SSEC.
- Pre-mission instrument maintenance and preparation was completed.
- The S-HIS personnel field campaign schedule was drafted, and on-site and remote support needs were identified and scheduled.
- The field campaign instrument integration to the aircraft was completed.
- Phase 1 science flights were conducted from NASA Armstrong and preliminary analysis was initiated.
- Mission planning support was provided throughout the contract period.

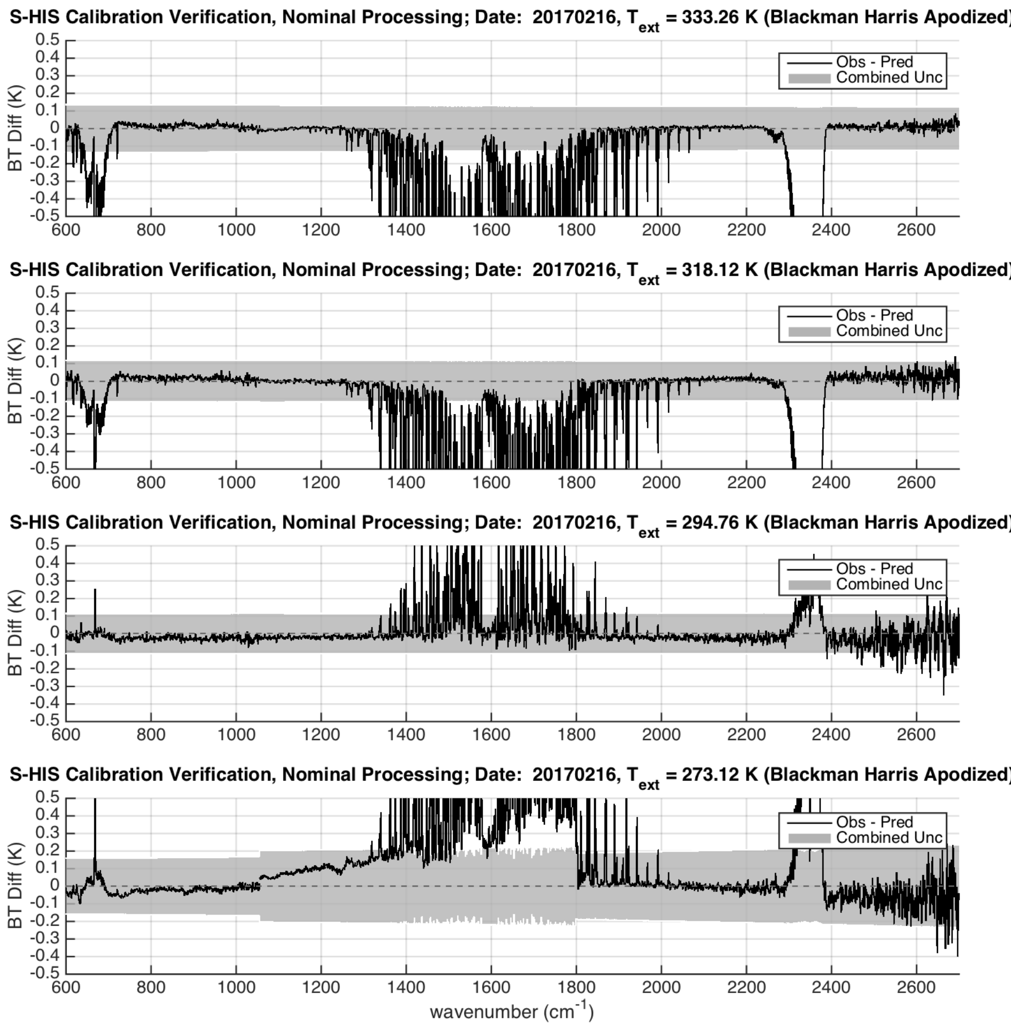



**Figure 114. Pre-mission S-HIS end-to-end radiometric calibration results (2017-02-16). Data is acquired for external blackbody temperatures of 333K (top panel), 318K (2nd panel), ambient (3rd panel), and an Ice Bath Blackbody (bottom panel). Observed – Predicted brightness temperature residuals are indicated here. Atmospheric emission/absorption is not included in the predicted BT (i.e., no LBLRTM).**

## 33. UW Scanning-HIS Participation in the NPP/JPSS Aircraft Field Campaigns

**CIMSS Task Leaders: Joe Taylor, David Tobin**

**CIMSS Support Scientists: Hank Revercomb, Ray Garcia, David Hoese, Fred Best, Aronne Merrelli**

**NOAA Collaborator: Mitch Goldberg**

**Budget: $200,000**

### NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

**NOAA Strategic Goals:**
- 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
- Education and Outreach

## Objective
The primary goal of this project is to assess the SNPP CrIS sensor radiometric calibration and environmental product retrieval quality for polar conditions using comparisons with the S-HIS high altitude sensor.

## Project Overview
The second Suomi NPP dedicated airborne calibration validation campaign was conducted in March 2015. The campaign was conducted out of Keflavik, Iceland with high altitude under-flights of the Suomi-NPP, METOP-A, METOP-B, and NASA Aqua satellites on the NASA ER-2 over the Greenland ice sheet.

## Milestones with Summary of Accomplishments and Findings
- S-HIS calibrated spectral radiances were approved for public distribution. The quality control and assessment of S-HIS calibrated spectral radiances was completed and the data was made available for public distribution. Preliminary data was made available to collaborators during the field campaign.
- S-HIS Dual Regression temperature and relative humidity retrievals were approved for public distribution. The quality control and assessment of S-HIS retrievals was completed and the data was made available for public distribution. Preliminary data was made available to collaborators during the field campaign.
- Calibration-validation analyses of the satellite observations with respect to the S-HIS were completed, with emphasis on the radiometric calibration uncertainty assessment of CrIS. Double obs – calc (DOMC) analyses were completed for all CrIS under-flights that had satisfactory scene conditions and aircraft to satellite coincidence.

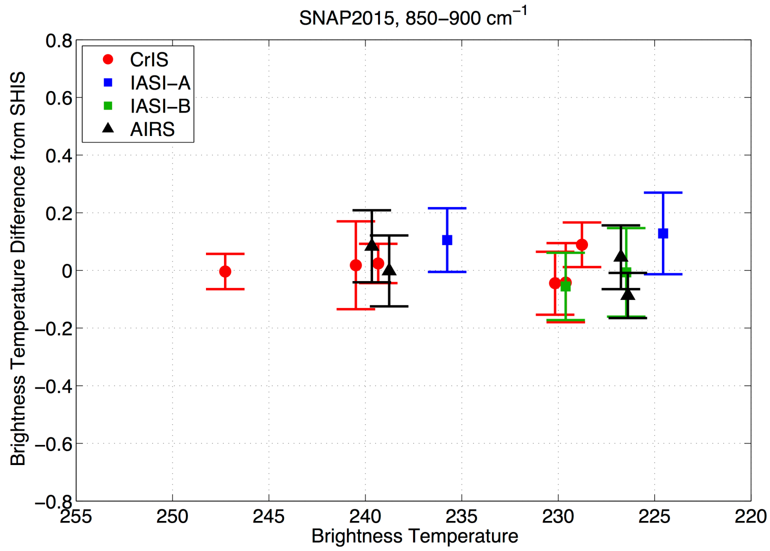



**Figure 115. 850 - 900 cm-1 (LW window) direct radiance comparisons (no DOMC) of CrIS, IASI, and AIRS with respect to S-HIS.**

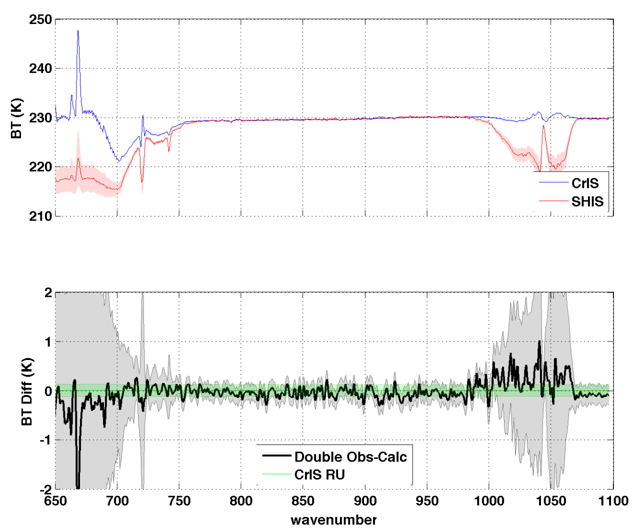



**Figure 116. DOMC example, 2015-03-29 flight. LW observed brightness temperature for CrIS and S-HIS (top panel) and DOMC with radiometric uncertainty (bottom panel).**

## Publications and Conference Reports

Taylor, Joe K., et al. "Calibration Validation Of The Cross-track Infrared Sounder (CrIS) With The Aircraft Based Scanning High-resolution Interferometer Sounder (S-HIS)." EUMETSAT Meteorological Satellite Conference 2016.

Taylor, Joe K., et al. "Calibration Validation Of The Cross-track Infrared Sounder (CrIS) With The Aircraft Based Scanning High-resolution Interferometer Sounder (S-HIS)." International Radiation Symposium 2016.

Taylor, Joe K., et al. "Cold Scene Calibration Validation Of The Cross-track Infrared Sounder (CrIS) With The Aircraft Based Scanning High-resolution Interferometer Sounder (S-HIS)." 2017 AMS Annual Meeting.

## 34. CIMSS Participation in Sensing Hazards with Operational Unmanned Technology (SHOUT)

**CIMSS Task Leader: Chris Velden**
**CIMSS Support Scientists: Derrick Herndon, Sarah Griffin**
**NOAA Collaborator: Gary Wick (ESRL)**
**Budget: $75,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

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

**CIMSS Research Themes:**

- Satellite Meteorology Research and Applications

### Objective

Provide tailored satellite data and products for weather hazard avoidance during SHOUT Global Hawk science and data collection missions.

### Project Overview

The CIMSS team has a strong history of supporting scientific field campaigns with crucial meteorological satellite data and tailored products. The expertise extends into developing, interpreting and utilizing these satellite products to support research aircraft hazard avoidance, as well as general mission support and research analyses. The PI and his team have participated in many recent projects, including NASA's HS3 field campaign that also utilized the Global Hawk. Many of these were in very successful collaborations with NOAA and NESDIS. We have been asked by NOAA to collaborate and provide support for the SHOUT program. This field campaign will operate at times in a tough environment for aircraft reconnaissance, and the over-ocean nature will mean that real-time satellite data/products from a variety of platforms will be crucial to mission planning and safety. CIMSS will provide these satellite data in a timely manner to the project, and tailore the derived products to fit the needs of SHOUT.

### Milestones with Summary of Accomplishments and Findings

The SHOUT field campaign ran from Aug-Sept. 2016, encompassing many science missions with the Global Hawk. Since the primary targets of these missions were tropical cyclones, the airplane was operating in conditions that posed unique challenges in many ways. Remote-sensing imagery and derived products were crucial to successful mission planning, decision-making, and execution, and the CIMSS team made this data available to the mission operations center in real time from multiple satellite platforms, tailored specifically to the SHOUT region of interest.

CIMSS scientists also brought their expertise to the operations center, providing product training and also as mission support scientists. The CIMSS PI has extensive experience supporting field projects, and has often collaborated with NOAA in support of mission and forecast operations. Satellite data product development and interpretation added a key element to the mission planning through the CIMSS team expertise in this area. Examples of specific real-time CIMSS tailored satellite products made available for the field campaign were:

- High-density wind vectors from GOES processed at hourly intervals;
- Diagnostic fields (shear, divergence, vorticity) from these wind vector fields;
- Cloud-Top Heights using latest NESDIS algorithms;
- Overshooting Tops identification; and
- TPW analyses using the CIMSS MIMIC algorithm (continuously updating with seamless animation).

Specific tasks accomplished were:

- Provided 24/7 support of CIMSS satellite-derived products for real-time use during the field campaign missions;
- Derived meteorological variables from satellite data to help meet mission requirements and the research goals of SHOUT; and
- Participated in the SHOUT planning meetings

## 35. CIMSS Support for Aura Chemical Reanalysis in Support of Air Quality Applications (NASA)

**CIMSS Task Leader: Allen Lenzen**
**CIMSS Support Scientist: Monica Harkey**
**NOAA Collaborator: R. Bradley Pierce (NOAA/NESDIS)**
**Budget: $133,000**

### NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:

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

### CIMSS Research Themes:

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

### Objective

Provide the air quality community with a multi-year global chemical and aerosol reanalysis using NASA Aura and A-Train measurements.

### Project Overview

This task focuses on providing the air quality community with a multi-year global chemical and aerosol reanalysis using NASA Aura and A-Train measurements. The reanalysis is conducted using the Real-time Air Quality Modeling System (RAQMS) [Pierce et al., 2007] coupled with the NOAA operational Grid point Statistical Interpolation (GSI) three dimensional variational (3D-Var) analysis system. We also conduct regional chemical data assimilation experiments using the US Environmental Protection Agency (EPA) Community Multi-scale Air Quality (CMAQ) model and the NASA Ozone Monitoring Instrument (OMI) tropospheric $NO_2$ column retrievals to quantify the influences of changes in $NO_x$ ($NO_2$+NO) emissions on US air quality during the Aura period.

## Milestones with Summary of Accomplishments and Findings

- Developed approach to use RAQMS NOx emission sensitivity experiments and RAQMS/GSI OMI NO2 data assimilation to adjust the 2010 global Hemispheric Transport of Air Pollution (HTAP) monthly NO2 emissions.
- Developed an approach to use the adjusted HTAP NO2 emissions and multiple linear regression of OMI urban NO2 trends to generate 2005-2015 global NO2 HTAP emissions.
- Conducted July 2011 CMAQ NOx emissions sensitivity studies for generation of regional background error covariances and adjustment of US EPA National Emission Inventory (NEI) 2011 NOx emissions using CMAQ/GSI OMI NO2 assimilation experiments.
- Conducted 2010 RAQMS/GSI data denial studies for MODIS Aerosol Optical Depth (AOD) and AIRS Carbon Monoxide (CO) and OMI NO2 retrievals.

The AIRS CO observation operator was implemented within GSI and assimilation experiments were conducted to optimize the AIRS CO profile assimilation. The implementation built upon the GMAO MOPITT DA implementation, but we found that the strategy for the tangent linear observation operator had to be changed to account for the CO kernel operating on logarithms of CO rather than on CO itself.

The adjustment of NEI 2011 NO2 emissions for use in CMAQ was done in three steps. First, 15 percent NO2 emission perturbation CMAQ experiments were used to compute the monthly mean NO2 Jacobian (normalized delta-emissions/normalized delta-NO2) following (Lamsal, et al., 2011). Second monthly mean tropospheric NO2 analysis increments are computed from the CMAQ/ GSI NO2 assimilation (used to define the normalized delta-NO2). Third, the delta_NO2 from OMI NO2 DA and Jacobian from the NO2 emissions perturbation experiment are used to adjust the apriori NEI 2011 NO2 emissions. Figure 117 shows the resulting emission adjustment (apriori-adjusted).

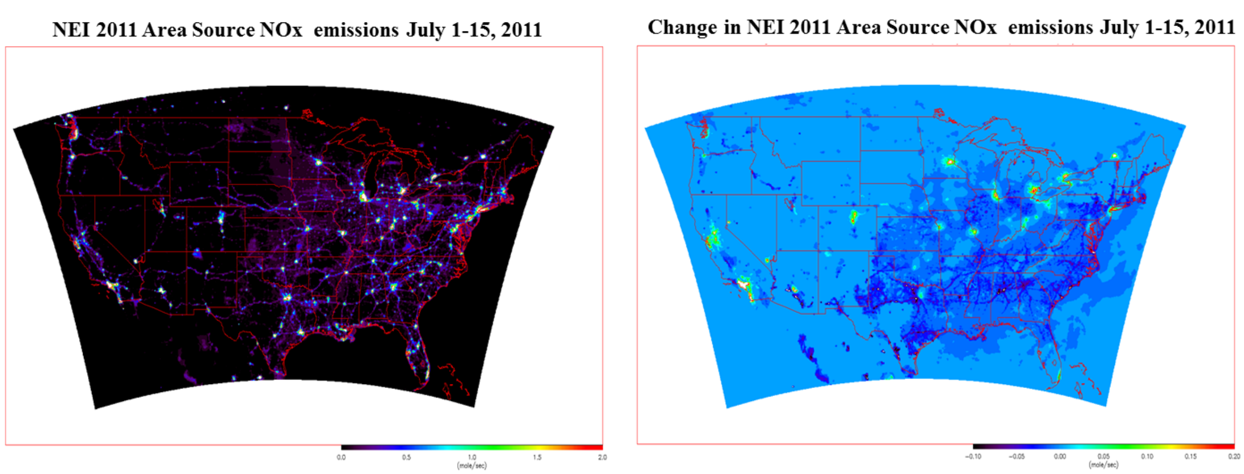



**Figure 117. US EPA National Emission Inventory (NEI) 2011 *apriori* area source NOx emissions (left panel, mole/sec) and change (apriori-adjusted) in area source NOx emissions (right panel, mole/sec) from CMAQ/GSI OMI NO2 data assimilation experiments for July 1-15, 2011.**

### Publications and Conference Reports
"Aura Chemical Reanalysis in support Air Quality Applications" presented at the NASA Health and Air Quality Applications Program Review, September 20-21, 2016, Ashville, NC

"Off-line constraints on NEI2011 NOx emissions using CMAQ/GSI/OMI Tropospheric NO2 Data Assimilation" presented at the NASA Health and Air Quality Applied Science Team (HAQAST) Meeting, February 27-March 01, 2017, University of Washington, Seattle, WA

### References
Lamsal, L. N., et al. (2011), Application of satellite observations for timely updates to global anthropogenic NOx emission inventories, Geophys.Res.Lett.,38,L05810,doi:10.1029/2010GL046476.

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.

## 36. CIMSS Support to Develop the Satellite Information Familiarization Tool to Support the National Weather Service Training Program
**CIMSS Task Leader: Jordan Gerth**
**CIMSS Support Scientists: Ray Garcia, Dave Hoese, Scott Lindstrom, and Kathy Strabala**
**NOAA Collaborators: Tim Schmit, National Environmental Satellite, Data, and Information Service Advanced Satellite Products Branch; and Bill Ward, National Weather Service Pacific Region Headquarters**
**Budget: $125,000**

### NOAA Long Term Goals:
- Weather-Ready Nation

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

### CIMSS Research Themes:
- Satellite Meteorology Research and Applications
- Education and Outreach

### Objective
This project continued the delivery of Satellite Information Familiarization Tool (SIFT) releases and furthered software feature development to align with the NWS operational meteorologist training program for new-generation geostationary weather satellites. The highest priority was to adapt SIFT to handle imagery from the Geostationary Operational Environmental Satellite R-Series (GOES-R), and enhance software performance pursuant to that task.

### Project Overview
The Satellite Information Familiarization Tool, or SIFT, is a meteorological satellite imagery visualization software application with a graphical user interface designed at the University of Wisconsin to run on mid-range consumer grade computers and notebooks. Windows, Mac, and

some Linux operating systems are supported. The National Weather Service (NWS) originally funded the development of SIFT for use as a training application for Himawari-8 imagery at the forecast office in Guam, but SIFT is envisioned as fulfilling a role as the primary learning software for use during the foundational training exercises on the new-generation geostationary weather satellites as part of the formal NWS training program on the Geostationary Operational Environmental Satellite R-Series (GOES-R). This project continued the development of SIFT to support NWS operational meteorologists as the primary users during the implementation of the training program.

## Milestones with Summary of Accomplishments and Findings

The current release of SIFT is version 0.9.1. In addition to visualizing imagery from the GOES-R Advanced Baseline Imager (ABI) and incorporating performance improvements related to loading high spatial resolution imagery, software development work conducted under this project led to the implementation of the ability for users to specify, and display data on, Lambert Conformal and geostationary satellite projections, in order to support users over the contiguous United States.

The following improvements are forthcoming in subsequent releases.

- An improved user interface for selecting multiple bands for multiple times will be implemented in the form of a new window that allows individual band and time range selection within a base data directory, without needing the user to specify individual filenames. This interface will also estimate load time and warn of potential performance issues if the user attempts to select a large subset of case data.
- The ability to save and load the state of the workbench will allow users to load a case by selecting one state file, and allowing that file to be easily shared and modified between users. This will ensure that users are able to load a case identically to how it was intended for use with the training material. The advantage is that training lessons can incorporate this state file for users to automatically load SIFT and the exercise data without selecting individual files for different bands and times.
- Supporting baseline satellite products and other data types, such as gridded binary (GRIB) model data, will provide users with an ability to correlate spatial patterns and values of various meteorological datasets and parameters, especially when overlaying satellite imagery.

This project also assisted NWS training divisions and funded partners who have incorporated SIFT, or plan to, into training exercises so that there is no degradation in the user experience.

## Publications and Conference Reports

Visualizing new-generation geostationary satellite imagery with SIFT
Talk, Asia/Oceania Meteorological Satellite Users' Conference—Application of satellite data to weather analysis and disaster monitoring (Incheon, South Korea)http://cimss.ssec.wisc.edu/~jordang/photos/slider/aomsuc7_jg.html
October 26, 2016

Visualizing new-generation geostationary satellite imagery with SIFT
Talk, American Meteorological Society Annual Meeting—13th Symposium on New Generation Operational Environmental Satellite Systems (Seattle, Washington)https://ams.confex.com/ams/97Annual/webprogram/Paper305295.html
January 23, 2017

## 37. CIMSS Support to Modernize VISITView to HTML5

**CIMSS Task Leader: Scott Lindstrom**
**CIMSS Support Scientist: Tommy Jasmin**
**NOAA Collaborators: Anthony Mostek, Bill Ward**
**Budget: $156,000**

### NOAA Long Term Goals:
- Weather-Ready Nation

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

### CIMSS Research Themes:
- Satellite Meteorology Research and Applications
- Education and Outreach

### Objective
VISITview client software has been encoded in HTML5, replacing earlier versions that relied on Java.

### Project Overview
VISITview is a software package that allows collaboration over the internet. The original incantation of VISITview was cast in Java, a software package that because of security vulnerabilities is increasingly difficult to use. Certain web browsers, for example, prohibit it as a plug-in.

### Milestones with Summary of Accomplishments and Findings
Underlying communication establishing contact with the server has been created in HTML5 and WebSockets. A large subset of the VISITview functionality similarly has been translated to HTML5. Extensive further development and testing to expand the capabilities in HTML5 to match those in the Java client is ongoing.

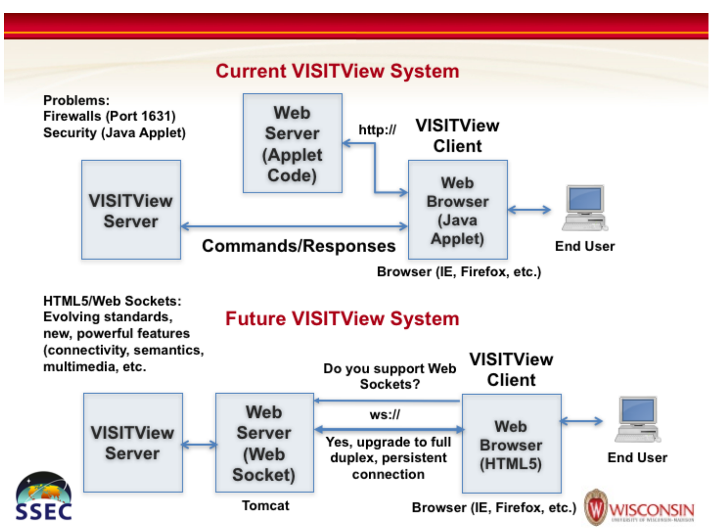



**Figure 118. Flow Chart for old VISITview (top) and Future VISITview (Bottom).**

## 38. CIMSS Support to Conduct Workshops on the Advanced Baseline Imager (ABI) to National Weather Service Science and Operations Officers (NWS SOOs)

**CIMSS Task Leader: Jordan Gerth**
**CIMSS Support Scientists: Scott Lindstrom and Kathy Strabala**
**NOAA Collaborators: Tim Schmit, National Environmental Satellite, Data, and Information Service Advanced Satellite Products Branch; and Bill Ward, National Weather Service Pacific Region Headquarters**
**Budget: $226,000**

**NOAA Long Term Goals:**
- Weather-Ready Nation

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

**CIMSS Research Themes:**
- Satellite Meteorology Research and Applications
- Education and Outreach

### Objective
Seven similar training workshops on the Geostationary Operational Environmental Satellite R-Series (GOES-R) were held to prepare National Weather Service Science and Operations Officers (NWS SOOs) for the likely operational applications of imagery from the Advanced Baseline Imager (ABI). The format of each three-day workshop was designed to maximize learning through interaction with case data, expert instructors, and operational peers.

### Project Overview
Under this project, a series of seven instructor-led training workshops on the Advanced Baseline Imager (ABI), were held at the National Weather Service (NWS) Training Center in Kansas City, Missouri. The workshop established a critical core competency amongst NWS Science and Operations Officers (SOOs) and other designees for using and applying Geostationary Operational Environmental Satellite R-Series (GOES-R) imagery in the weather analysis and forecast process as part of operational duties. A team of two instructors from CIMSS, or an instructor from CIMSS accompanied by a subject-matter expert from the NOAA NESDIS Advanced Satellite Products Branch (ASPB), traveled to Kansas City for each of the seven three-day workshops held between November 2016 and March 2017. With up to two dozen students in each course, there were around 150 meteorologists and hydrologists trained in total. The majority of the workshop time was spent with participants working in groups of two or three on notebook computers that ran visualization software, the Satellite Information Familiarization Tool (SIFT), specifically developed for this and similar workshops held previously. Updates to SIFT were made during the workshop series timeframe and deployed between workshops to add functionality and improve the user experience.

Following successful completion of each workshop, participant SOOs and others gained capacity to reach their staff with important information about the ABI's characteristics, operational applications for its imagery, and the relevance of radiation science to interpreting that imagery for short-term weather analysis and forecast challenges.

**Milestones with Summary of Accomplishments and Findings**

Each workshop started with a review of concepts that were introduced in the online satellite foundational course for GOES-R, a requirement for most NWS operational staff. This provided a baseline for which to assess student learning. To reinforce important ideas, on the second and third days of the workshop, students were asked to share a concept that they learned with the class, or a prospective "takeaway" application. Following each day of the workshop, students had an opportunity to provide anonymous feedback via a web form. In general, feedback was positive and constructive. Such written feedback, combined with additional interactions with the participants, provided thoughts on how to update training content for subsequent workshops to increase its effectiveness and relevance. For example, the SOOs sought more concise reference materials for selecting ABI bands to apply in scenarios based on prospective simplified uses. Once ABI imagery was available, lab materials were updated to incorporate examples relevant to the contiguous United States that are more relatable to the operational environment. This case data was made available to the field subsequently.

The first day covered the science of remote sensing with weather satellites, specifically:

- Core knowledge, such as the introduction to the GOES-R weather instruments, including a summary of major concepts in radiation science and changes from the current imagery (spatial, spectral, temporal, and bit depth characteristics); and
- Weighting functions and tri-band composite imagery (e.g., RGBs) and how to use those effectively and efficiently to complement single band imagery.

The second day emphasized meteorology skills for analyzing satellite imagery, covering:

- Methods for identifying, tracking, and corroborating vorticity maxima and minima, and other atmospheric features, from discrete convective cells to mesoscale convective systems, with numerical weather prediction analyses; and
- Roles for satellite imagery in the weather forecast and warning process.

On the third day, CIMSS instructors assisted with lab activities and provided instructional assistance as students engaged in small groups with NWS facilitation.

## 39. ABI Short Courses (CIMSS Support to GOES-R Program)

**CIMSS Task Leader: Mathew M. Gunshor**
**CIMSS Support Scientists: Jordan Gerth, Scott Lindstrom, Chris Schmidt**
**NOAA Collaborator: Timothy J. Schmit**
**Budget: $57,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

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

**CIMSS Research Themes:**

- Education and Outreach

### Objective
Present day-long short courses to introduce the GOES-R series primarily at conferences, such as the AMS annual and broadcast meteorology conferences.

### Project Overview
This report is for the 2nd year of a project that spans 3-years for CIMSS to support the GOES-R program's plan to attend multiple American Meteorological Society (AMS), and other, conferences to provide training on uses of GOES-R, primarily the Advanced Baseline Imager (ABI). This year CIMSS supported GOES-R short courses at the AMS 44th Conference on Broadcast Meteorology (in Austin, TX, 14 June 2016), at the GOES-R Teacher's Workshop (in Cocoa Beach, FL,18 November, 2016) just prior to the GOES-R launch, and the 97th AMS Annual Meeting (in Seattle, WA, 22 January 2017). In addition, the team presented a short course to the students in the Atmospheric and Oceanic Sciences (AOS) department at the University of Wisconsin-Madison on May 18, 2016. In preparation for each short course, the instructors prepare presentations and engaging hands-on material to present to the students. Whenever possible, material is tailored to the audience. While AMS annual meetings have a fairly general meteorological audience, a teacher's workshop or a broadcaster meeting have audiences with a more specific focus. Presentations can also be tailored for geography and the instructors try to make use of case studies that are recent had a local impact when possible.

### Milestones with Summary of Accomplishments and Findings
- Organized and presented "AOSS Short Course: GOES-R ABI Preview for Students" on May 18, 2016 in Madison, WI.
    - Meteorology students in the Atmospheric and Oceanic Science (AOS) department at UW-Madison requested a day-long workshop and we used this as an opportunity to practice for the upcoming broadcaster conference.
    - This event was in a computer lab in our building, so we were able to make use of the instructional tool SIFT (the development of which is under another project at CIMSS) and provided the students with a more rigorous satellite meteorology lab than we would a general audience at an AMS meeting.
- Helped to organize and presented "GOES-R Preview for Broadcasters" on June 14, 2016 preceding the 44th AMS Conference on Broadcast Meteorology in Austin, Texas.
    - Prepared hands-on and presentation material that included latest GOES-14 1-minute scans and case studies that from the southern US.
    - Invited and coordinated with the lunch-time speaker, Troy Kimmel.
    - Presentation and hands-on topics included the The GOES-R Advanced Baseline Imager (ABI): Capabilities, products, and concept of operations; Hands-on exercise showcasing ABI's 16 channels with improved spatial resolution, temporal refresh rate, and RGB products; Geostationary Lightning Mapper (GLM) capabilities and forecast applications; Hands-on exercise: Case studies using GLM as a tool for severe thunderstorm warnings; GOES-R derived products used in the Proving Ground; and Hands-on exercises using GOES-R derived products.
- Presented at the "GOES-R Launch Workshop for G6-12 Teachers" on 18 November, 2016 in Cocoa Beach, FL on November 18, 2016.
    - Presentations were: Satellite 101 & GOES-R overview; and GOES-R webapps & activities.
- Helped to organize and presented "GOES-R Preview for all GOES Users" on January 22, 2017 at the 97th AMS Annual Meeting in Seattle, WA.

- Updated presentations and hands-on material.
- Presentations were: The GOES-R Advanced Baseline Imager (ABI) Capabilities, Products, and Concept of Operations; Hands-On Exercise Showcasing ABI's 16 Channels with Improved Spatial Resolution, Temporal Refresh Rate, and RGB Products; Hands-On Exercise: Case Studies using GLM as a Tool for Severe Thunderstorm Warnings; Introduction to Derived GOES-R Products used in the GOES-R Satellite Proving Ground; and Hands-On Exercise: Case Studies demonstrating Use of Derived GOES-R Products in Severe Weather Situations.

There are a number of webapps that were developed and hosted at CIMSS which are used in hands-on exercises to highlight the spectral, temporal, and spatial improvements of the GOES-R series over the previous GOES: http://cimss.ssec.wisc.edu/education/apps/

Students attending the full short course at an AMS meeting receive a certificate of completion and are asked to fill out a short survey to provide feedback to the instructors. The feedback is used to improve future presentations of the course. While most of the feedback is very positive, occasionally there is useful information on how to improve. The most common complaint is that too much information is presented in one day. Since the short course usually includes the ABI and GLM, as well as space-weather instruments, it is difficult to go into any depth on any topics.

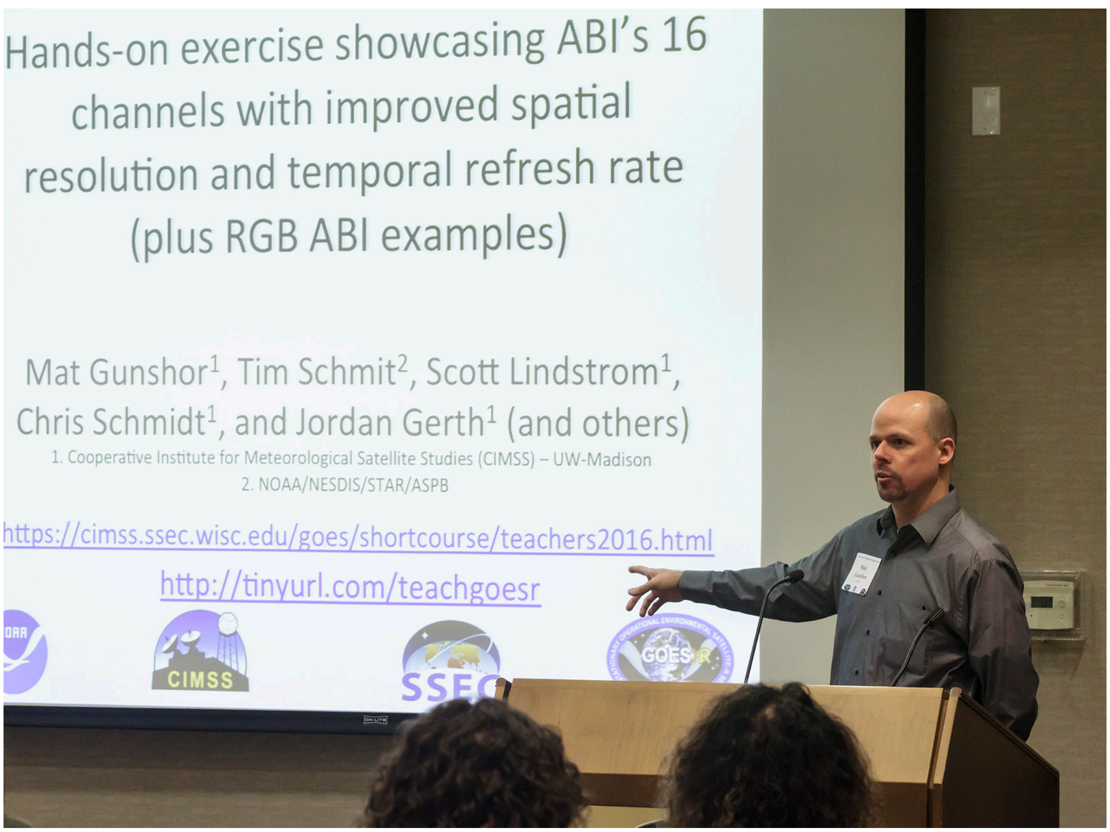



**Figure 119. Mat Gunshor of CIMSS presenting "Hands-on exercises" at the GOES-R Launch Workshop for G6-12 Teachers in Cocoa Beach, FL (November 18, 2016).**

## Publications and Conference Reports

Lindstrom, Scott S.; Schmit, T. J.; Gerth, J. J.; Gunshor, M. M.; Mooney, M. and Whittaker, T. M. Hands-on activities designed to familiarize National Weather Service forecasters with data

from ABI on GOES-R and AHI on Himawari-8. Conference on Environmental Information Processing Technologies, 33rd, and Symposium on Education, 26th, Seattle, WA, 21-26 January 2017. American Meteorological Society, Boston, MA, 2017, abstract only; Abstract TJ2.6.

Gunshor, Mathew M.; Schmit, T. J.; Gerth, J. J.; Lindstrom, S. S.; Schmidt, C.; Strabala, K. I. and Bachmeier, A. S. Helping prepare users for the GOES-R series. Conference on Satellite Meteorology, Oceanography and Climatology, 21st, Madison, WI, 15-19 August 2016. American Meteorological Society, Boston, MA, 2016, poster; Abstract 104.

## 40. CIMSS Research Activities in the VISIT program of 2016

**CIMSS Task Leader: Scott Lindstrom**
**CIMSS Support Scientist: Scott Bachmeier**
**NOAA Collaborators: Tim Schmit, Anthony Mostek, Brian Motta, Ross van Til**
**Budget: $153,000**

### NOAA Long Term Goals:

- Weather-Ready Nation

### NOAA Strategic Goals:

- 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
- Education and Outreach

### Objective

VISIT (Virtual Institute for Satellite Integration Training) work at CIMSS focused in 2016-2017 on the development of short training modules to improve forecaster knowledge of satellite capabilities.

### Project Overview

VISIT supported training activities designed to champion the used of Satellite Data in National Weather Service forecast offices. In 2016-2017, this included the development of 12 Foundational Courses for the GOES-R Series of satellites; these modules, required of all National Weather Service Forecasters, are part of a suite of nearly 40 training modules that were placed in the Department of Commerce Learning Center. VISIT supported Live teletraining to individual forecast offices on recently-developed satellite-focused training modules. VISIT supported "Satellite Chat" webinars that discussed recent weather events as viewed from the satellite perspective.

### Milestones with Summary of Accomplishments and Findings

VISIT support led to the development of 12 Foundational Courses for the GOES-R Series of satellites: "Basic operation of GOES-R Satellites," "Multi-Channel Interpretation Approaches (SIFT)," "Baseline Products: Aerosols," "Baseline Products: Clouds and Microphysics," "Baseline Products: Fire characterization, including land surface," "Baseline Products: Stability Indices and legacy profiles," "Baseline Products: Derived Motion Winds," "Baseline Products: Volcanic Ash," "Fog/Low Clouds Formation and Dissipation," "Cyclogenesis: PV Concepts" and

"Cyclogenesis: TROWAL Formation." This is required training for all NWS Forecasters, and the modules have been uploaded – with quizzes – into the Department of Commerce Learning Management System (LMS). This is part of a suite of ~40 training modules to introduce forecasters to the data from ABI and GLM on the GOES-R Series of satellites.

VISIT also supported multiple live teletrainings (using VISITview software) to National Weather Service Forecast Offices on the following topics: "NOAA/CIMSS ProbSevere," "GOES-R Fog/Low Stratus Products," "NUCAPS Soundings in AWIPS," "Mesoscale Convective Vortices," "TROWAL Identification," and "Interpreting Satellite Signatures." CIMSS also participated in near-monthly "Satellite Chats," 30-minute discussions of recent weather events as viewed from GOES-13/GOES-14/GOES-15 and starting in March 2017, GOES-16. These webinars used GoToMeeting.

The VISIT Teletraining modules "TROWAL Identification" and "Mesoscale Convective Vortices" were both updated and shortened.

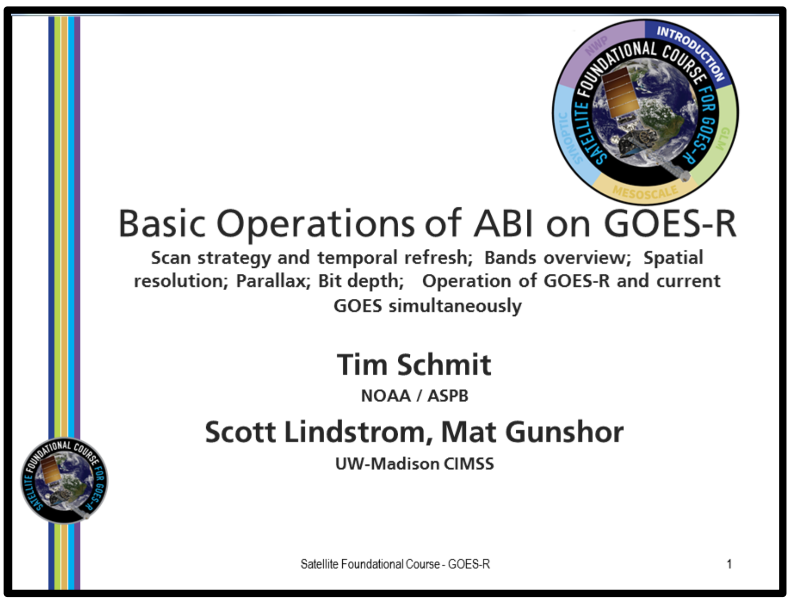



**Figure 120. Front Page of Satellite Foundational Course for GOES-R Module on ABI Operations on GOES-R.**

### Publications and Conference Reports

Lindley, T. T., A. R. Anderson, V. N. Mahale, T. S. Curl, W. E. Line, S. S. Lindstrom and A. S. Bachmeier, 2016: Wildfire Detection Notifications for Impact-based Decision Support Services in Oklahoma Using Geostationary Super Rapid Scan Satellite Imagery, *J. Operational Meteor.,* **4**(14), 182-191, doi: http://dx.doi.org/10.15191/nwajon.2016.0414

Ward, B., and co-authors, 2017: The Satellite Foundational Course for GOES-R: A Collection of Lessons to Prepare National Weather Service Forecasters for GOES-R, 13th Annual Symposium on New Generation Operational Environmental Satellite Systems, American Meteorological Society, Seattle, WA, 22-26 January 2017.

Lindstrom, Scott S., T. J. Schmit, J. J. Gerth, M. M. Gunshor, M. Mooney, and T. M. Whittaker, 2017: Hands-on Activities Designed to Familiarize National Weather Service Forecasters with Data from ABI on GOES-R and AHI on Himawari-8, 26th Symposium on Education; and the

33rd Conference on Environmental Information Processing Technologies, American Meteorological Society, Seattle, WA, 22-26 January 2017.

Connell, B. H, and co-authors, 2017: Satellite User Readiness Through Training: VISIT, SHyMet, WMO VLab and Liaisons, 13th Annual Symposium on New Generation Operational Environmental Satellite Systems, American Meteorological Society, Seattle, WA, 22-26 January 2017.

Schmit, Timothy J, M. M. Gunshor, R. B. Pierce, J. J. Gerth, S. S. Lindstrom, J. M. Daniels, and S. J. Goodman, 2016: Getting Ready for the Advanced Baseline Imager (ABI) on the GOES-R series, Oral Presentation at 21st Conference on Satellite Meteorology, American Meteorological Society, Madison WI, 15-19 August 2016.

Gunshor, M., T. J. Schmit, J. J. Gerth, S. S. Lindstrom, C. Schmidt, K. I. Strabala, and A. S. Bachmeier, 2016: Helping Prepare Users for the GOES-R Series, Poster Presentation at 21st Conference on Satellite Meteorology, American Meteorological Society, Madison WI, 15-19 August 2016.

Connell, B., D. Bikos, E. Szoke, S. Bachmeier, S. Lindstrom, A. Mostek, B. C. Motta, L. Veeck, and J. Torres, 2016: Satellite User Readiness through Training: VISIT, SHyMet, WMO VLab and a Liaison, Poster Presentation at 21st Conference on Satellite Meteorology, American Meteorological Society, Madison WI, 15-19 August 2016.

## 41. CIMSS Support for Participation in WMO 6th Workshop on the Impact of Various Observing Systems on NWP

**CIMSS Project Lead: Ralph A. Petersen**
**Budget: $12,000**

**NOAA Long Term Goals:**

- Weather-Ready Nation

**NOAA Strategic Goals:**

- 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

### Objective

To provide travel support to make presentation at WMO 6th Workshop on the Impact of Various Observing Systems on NWP in Shanghai, China in May 2016. Presentation shares work accomplished at CIMSS from earlier and ongoing AMDAR data assimilation studies funding by NOAA.

### Project Overview

This funding augmentation provided travel support to allow Dr. Ralph Petersen to make a presentation at the WMO 6th Workshop on the Impact of Various Observing Systems on NWP in Shanghai, China in May 2016. The presentation shared information with the global data assimilation community about work accomplished at CIMSS from earlier AMDAR-WVSS data assimilation studies funding by NOAA through Hurricane Sandy Supplement, as well as plans/results from a separate ongoing project. The presentation expanded on work by Petersen et al., 2016 and Hoover et al., 2016. It supported the expanded global use WMO-endorsed AMDAR-WVSS observations, as well as expansion of the global fleet of commercial aircraft providing those data. Results showed not only the positive forecast impacts in the GFS out to 66 hours and in extreme moisture events, but also the potential economic benefit of these data when used as supplement to (or replacements for) RAOB data at sites with sufficient observations. Based on these results, WVSS-II water vapor data were implemented in GFS in spring 2016.

## Milestones with Summary of Accomplishments and Findings

During the past year, a presentation was prepared and presented at the WMO 6th Workshop on the Impact of Various Observing Systems on NWP in Shanghai, China in May 2016. In addition to inclusion in the summary provided on the WMO web site, the presentation was also summarized in two articles included in the WMO'S AMDAR Newsletter.

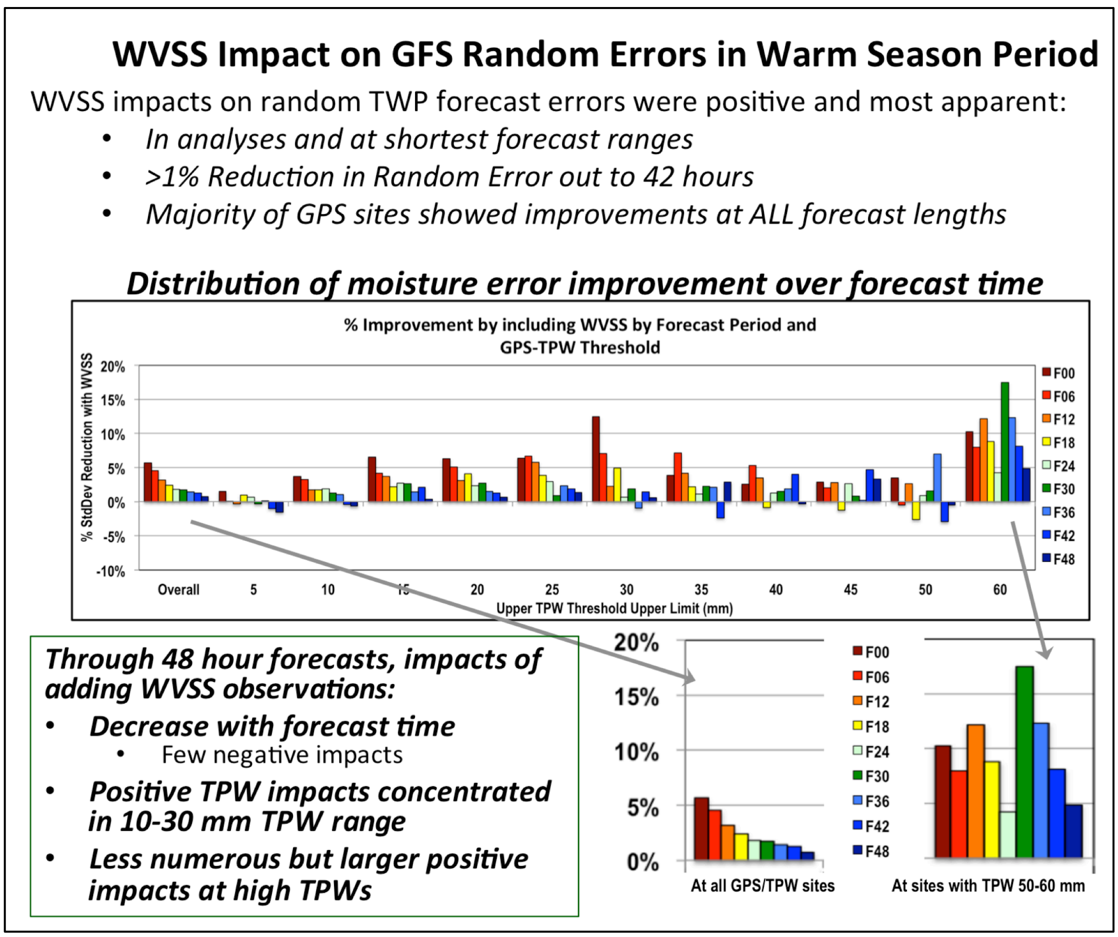



**Figure 121. Specific GFS forecast impacts on 0-48 hour Total Precipitable Water forecasts attributable to the use of WVSS-II profile observations. See figure for details.**

## Publications and Conference Reports

Petersen, R. A, B. Hoover, A-S Daloz, P. Pauley and N. Baker, 2016: Impact Tests of Aircraft Moisture Observations in Several Global-Scale NWP systems. *6th Workshop on the Impact of Various Observing Systems on NWP*, Shanghai, China, WMO, https://www.wmo.int/pages/prog/www/WIGOSWIS/reports/6NWP_Shanghai2016/Session-1/1.15.pptx.

Petersen, R. A, 2016: Improvements in Operational NWP from AMDAR Water Vapor - Part 1: Overall Model Impacts. WMO *AMDAR Newsletter*, #12, October 2016.

Petersen, R. A, 2017: Improvements in Operational NWP from AMDAR Water Vapor - Part 2: U.S. WAFS Model impacts. In press, WMO *AMDAR Newsletter*, # 13, April 2017.

### References

Hoover, B. T. Hoover, D. A. Santek, A-S Daloz, Y. Zhong, R. Dworak, R. A. Petersen and Andrew Collard, 2015: Forecast Impact of Assimilating Aircraft WVSS-II Water Vapor Mixing Ratio Observations in the Global Data Assimilation System (GDAS). In revision for *Wea. Forecasting.*

Petersen, R. A., L. Cronce, R. Mamrosh, R. Baker and P. Pauley: On the impact and future benefits of AMDAR observations in operational forecasting - Part 2: Water Vapor Observations. *Bull. Amer. Meteor. Soc.*, 97, 2117-2133.

## 42. GOES-R Education Proving Ground

**CIMSS Task Leader: Margaret Mooney**
**CIMSS Support Scientist: Mat Gunshor and Rick Kohrs**
**NOAA Collaborators: Tim Schmit and Steve Goodman**
**Budget: $53,520**

### NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

### NOAA Strategic Goals:

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

### CIMSS Research Themes:

- Education and Outreach

### Objective

The GOES-R Education Proving Ground (http://cimss.ssec.wisc.edu/education/goesr/) features the design and development of pre- and post-launch lesson plans and activities for G6-12 teachers and students to ensure that the education community is "launch ready" for new satellite imagery and improved products available in the GOES-R era.

### Project Overview

A key element of this effort is a core group of educators working with Education and Outreach staff at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) in close coordination with NOAA scientists at the Advanced Satellite Products Branch (ASPB) and members of GOES-R Algorithm Working Group at CIMSS.

### Milestones with Summary of Accomplishments and Findings

This was a watershed year for the GOES-R Proving Ground due to the historic November launch of the GOES-R satellite. By leveraging long-standing connections with six core educators, science centers, and a year-long collaboration with three dozen science teachers from thirteen states and Puerto Rico, the GOES-R Education Proving Ground was able to reach well over eleven thousand students, parents, educators colleagues, and science center visitors.

CIMSS and ASPB had been collaborating with the six core teachers to develop webapps and lessons plans that demonstrate the advancements with the Advanced Baseline Imager (ABI) and the Geostationary Lightning Mapper (GLM). Just prior to 2016, the Proving Ground expanded from six teachers to thirty, adding a few more in the spring as interest grew. These educators all agreed to attend four informational webinars and share the webapps, lessons plans and their new knowledge with students and colleagues. And share they did. When queried after the launch, participating teachers reported reaching an average of 150 students in the spring semester and another 150 during the fall! Some reported less but a few reported far more; based on the commonly reported average, this effort reached nine thousand students.

One of the core educators, Vicky Gorman[1], took a leadership role in 2016 and provided planning input for the November teacher workshop. Ms. Gorman also developed a "Countdown to Launch' calendar (http://cimss.ssec.wisc.edu/education/goesr/CountdownCalendarFINAL.pdf ) with daily suggestions to promote GOES-R during the month leading up to launch. She presented the calendar activities in a fall webinar.


**Figure 122. Countdown Calendar, available on-line at http://cimss.ssec.wisc.edu/education/goesr/CountdownCalendarFINAL.pdf**

GOES-R T-shirts were distributed to participating teachers and most wore them every Friday during the month leading up to launch, prompting many discussions with colleagues, students and parents. Some teachers tweeted pictures of themselves in their GOES-R T-shirts.

[1] Ms. Gorman received the Presidential Awards for Excellence in Mathematics and Science Teaching (PAEMST) in 2016, the highest recognition awarded to K-12 STEM teachers in the United States. https://recognition.paemst.org/finalist_profile/4611

Kennedy Space Center (KSC) capped the launch workshop at fifty and it filled up fast. And although fifty teachers registered, multiple launch delays whittled this number down to twenty-three attending, traveling from 10 different states and Puerto Rico. In the end, KSC could not accommodate our group so the first day involved professional development off-site culminating in a NOAA mission briefing at KSC. The workshop included presentations by each of the core teachers and an inspiring overview by NOAA ASPB scientist Tim Schmit, whose contagious excitement set the bar for an amazing STEM experience. The full agenda is on-line at http://cimss.ssec.wisc.edu/education/goesr/workshop.html.

On launch day, a sunny Saturday, teachers enjoyed exploring KSC on their own, before boarding buses to watch the launch from the Saturn V viewing complex. It was the chance of a lifetime, and everyone was genuinely enthusiastic about sharing the experience with his or her students and promoting GOES-R capabilities. It is worth noting that half of the workshop attendees were from Florida and not previously part of the Education Proving Ground, extending the reach of this project even further. Several Florida teachers brought family members to the launch (see Figure 1 in Section 2 for scenes from the GOES-R Teacher Workshop at the launch).

CIMSS has also been producing content for NOAA's Science On a Sphere® (SOS) for over a decade and in 2016 published "Weather Satellites – past, present and future" which spans satellite history from Sputnik to GOES-R. (http://sphere.ssec.wisc.edu/weathersatellites/) The satellite movie debuted at the American Meteorology Society (AMS) 21st Satellite Meteorology, Oceanography and Climatology Conference in Madison during the month of August in an exhibit room at the conference center.

The Education Proving Ground leveraged this SOS content by collaborating with two science centers to help get the word out about GOES-R: the Aldo Leopold Nature Center (ALNC) in Monona, Wisconsin and the James E. Richmond Science Center in Waldorf, Maryland.

ALNC offered "Weather Satellites" public programming throughout the month of October (http://aldoleopoldnaturecenter.org/event/october-weather-satellites-2-2/) specifically incorporating information and media related to the GOES-R satellite November launch. Special programming for young children and the general public included weather satellite imagery generated at CIMSS/SSEC displayed on their Science On a Sphere system, "Create a Satellite" activity stations, GOES-R promotional flyers, a raffle of GOES-R t-shirts and gear, and more. ALNC reported an estimated reach in excess of one thousand visitors.

The James E. Richmond Science Center (JRSC) and Charles County Public Schools were pleased to collaborate with CIMSS/SSEC to promote the launch of the long-awaited GOES-R satellite. As part of their efforts to promote GOES-R, JRSC added a satellite meteorology focus to their previously scheduled Flight Night event in November, including a GOES-R t-shirt drawing, building and launching rockets, GOES-R flyer distribution, and playing the GOES-R/Satellite NOAA Science On a Sphere movie. During the October and November planetarium shows, they made special announcements regarding GOES-R, including a custom-designed GOES-R 360° panoramic image in the 60-feet diameter digital dome planetarium and theater. The Charles County Public Schools communications department also distributed a press release regarding the launch and the Education Workshop that three teachers and one JRSC staff person were to attend, which was picked up by at least one media site. JRSC counted 866 visitors at their in-house GOES-R events during the fall of 2016, and they continued to distribute GOES-R flyers at monthly planetarium events into the spring of 2017.

Combining student reach from teachers in the Education Proving Ground with students reached by teachers attending the launch workshop and parents and colleagues and visitors to science centers, a conservative estimate of 11,000 people can be attributed to this effort. This number rises when considering the multiplier effects of social media.

The GOES-R Education Proving Ground continues to send regular email communications to educators sharing GOES-16 news and imagery. CIMSS will continue to leverage on-going relationships with science centers, the SOS Network, GOES-R teachers, and all educators, to promote the entire GOES-R series.

**Publications, Reports, Presentations**

Mooney, M., Schmit, T. J., & Gunshor, M., Galvanizing Excitement Around GOES-R with Science Teachers, Science Centers and TV Broadcasters. Seattle, WA, 22-26 January 2017. American Meteorological Society, Boston, MA, 2017

Schmit, T. J., Gunshor, M., R. B. Pierce, R., Daniels, J., Goodman, S., The Advanced Baseline Imager (ABI) on the GOES-R series. Seattle, WA, 22-26 January 2017. American Meteorological Society, Boston, MA, 2017

Gorman, Victoria, GOES-R Education Proving Ground and Teachers Workshop Report, Seattle, WA, 22-26 January 2017. American Meteorological Society, Boston, MA, 2017

# Appendix 1: List of Awards to Staff Members

**2017**

**Hank Revercomb**: Fellow of the AMS, for "outstanding contributions to advance the atmospheric and related sciences, technologies, applications"
**David Tobin**: 2017 Chancellor's Award for Excellence in Research
**Pei Wang**: The Chinese-American Oceanic and Atmospheric Association Dissertation Award

**2016**

**Kaba Bah, James Davies, Tom Greenwald, Matt Gunshor, Allen Huang, Allen Lenzen, Jason Otkin, Marek Rogal, and Todd Schaack**: NOAA-CIMSS Collaboration Award: "For their efforts in developing the capability to generate real-time GOES-R ABI proxy data for use in the GOES-R ground segment testing"
**Michelle Feltz**: UW-Madison Department of Atmospheric and Oceanic Sciences Lettau Award for outstanding master's thesis titled, "Guidance for atmospheric temperature products: Comparing cosmic radio occultation and AIRS hyperspectral infrared sounder data"
**Jim Kossin**: AMS Journal of Climate Editor's Award, "for careful, thoughtful, and insightful reviews that significantly improved the quality of manuscripts"
**Jim Kossin**: NOAA NCEI Special Act Award for "research-to-operations work with the National Hurricane Center"
**Jun Li**: UW-Madison Distinguished Scientist
**Leigh Orf**: IDC High Performance Computing Excellence Award, for the computational project, "Unlocking the Mysteries of the Most Violent Tornadoes"
**Michael Pavolonis**: AAS Earth Science and Applications Award, "For developing cutting-edge methods to convert satellite data into actionable information for mitigating hazards caused by volcanic eruptions and severe convection"
**Brad Pierce**: NOAA Administrator's Award for "for providing robust, real-time, simulated data of the next generation geostationary satellite imagers, reducing risk in post-launch operations"
**William L. Smith**: AIAA Losey Atmospheric Sciences Award for "visionary and pioneering hyperspectral resolution sounding techniques"
Jing Zheng, **Jun Li, Timothy J. Schmit, Jinlong Li**, and Zhiquan Liu: 2017 Esteemed Paper Prize for "The impact of AIRS atmospheric temperature and moisture profiles on hurricane forecasts: Ike (2008) and Irene (2011)" by Advances in Atmospheric Sciences

# Appendix 2: Publications Summary

**Table 1** below indicates the number of reviewed and non-reviewed papers that include a CIMSS or ASPB scientist as first author during the period 2014-2016. Two additional columns show lead authorship of NOAA scientists outside of ASPB or lead authors from other institutions or organizations. When summed, peer reviewed totals for each year (in Table 1) will equal peer reviewed totals in Table 3, a longitudinal graphic.

**Table 2** below shows collaborations on papers between or among Institute, ASPB and NOAA authors outside of ASPB. Because there may be many collaborators on a given paper, the by-year totals in Table 2 will not match the actual published paper totals in Table 1 (or in Table 3); they will be greater.

A bibliography of Advanced Satellite Products Branch (ASPB) publications is available at:
http://library.ssec.wisc.edu/research_Resources/bibliographies/aspb

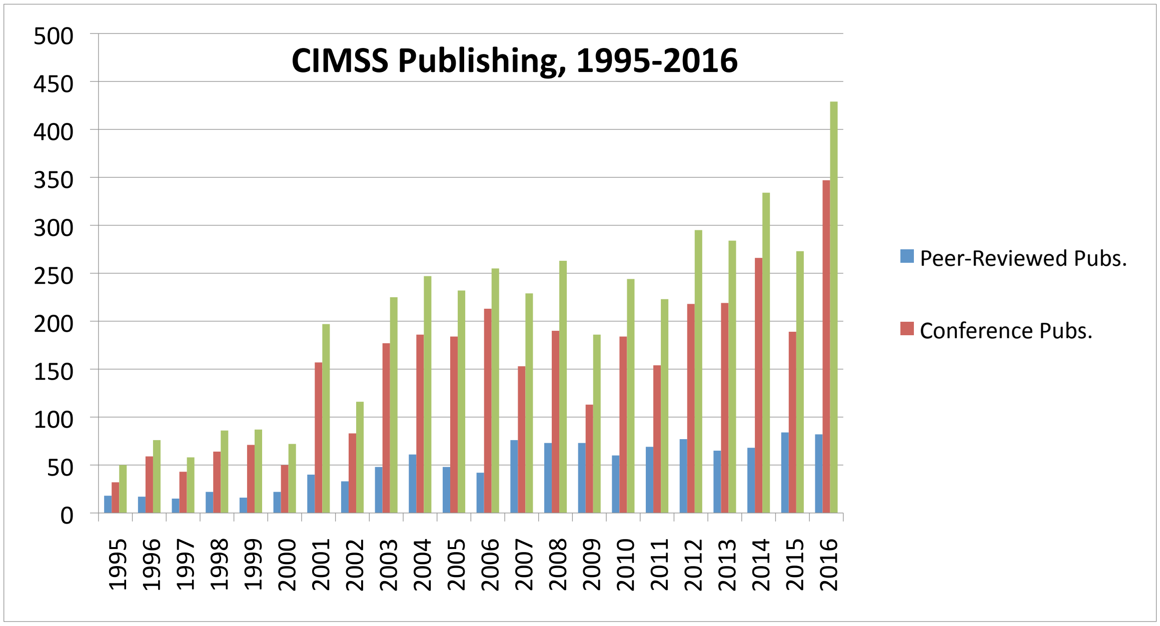
**Table 1.** Totals of Peer Reviewed and Non Peer Reviewed journal articles having CIMSS, ASPB, NOAA or Other lead authors, 2014-2016.

| | Inst Lead | | | ASPB Lead | | | NOAA Lead | | | Other Lead | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** |
| **Peer Reviewed** | 21 | 20 | 30 | 1 | 4 | 2 | 4 | 10 | 13 | 42 | 50 | 37 |
| **Non Peer Reviewed** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 2.** Peer Reviewed and Non Peer Reviewed journal articles having one or more CIMSS, ASPB, or NOAA co-authors, 2014-2016.

| | Institute Co-Author | | | ASPB Co-Author | | | NOAA Co-Author | | |
|---|---|---|---|---|---|---|---|---|---|
| | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** |
| **Peer Reviewed** | 91 | 99 | 121 | 17 | 27 | 24 | 23 | 64 | 54 |
| **Non Peer Reviewed** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 3.** CIMSS Publishing History, showing peer reviewed and conference publications for the period 1995-2016.



# Appendix 3: Employee Support Documentation

| Personnel | | | | |
|---|---|---|---|---|
| Category | Number | B.S. | M.S. | Ph.D. |
| Research Scientist | 7 | 0 | 2 | 5 |
| Visiting Scientist | 0 | 0 | 0 | 0 |
| Postdoctoral Fellow | 0 | 0 | 0 | 0 |
| Research Support Staff | 45 | 3 | 30 | 12 |
| Administrative | 0 | 0 | 0 | 0 |
| **Total** (≥ 50% Support) | 52 | 3 | 32 | 17 |
| Undergraduate Students | 16 | | | |
| Graduate Students | 6 | 3 | 3 | |
| Employees that received <50% NOAA Funding (not including students) | 58 | 9 | 22 | 26 |
| Located at Lab (include name of lab) | 1 AWC,<br>1 NCWCP | | | |
| Obtained NOAA employment within the last year | | | | |

# Appendix 4: Research Topics of Current CIMSS Graduate Students and Post-Doctors

## NOAA Funded Graduate Students

***Coda Phillips***
The High Spectral Resolution Lidar (HSRL) was developed at SSEC and has the capability to make precise measurements of aerosols and clouds. I have been learning the trade of hand-calibrating the output with the goal of producing a high quality dataset from the KORUS-AQ mission in Seoul. Once the dataset is available we may begin asking questions about the vertical distribution of aerosols, sources and trajectories of aerosols, and their effects on cloud formation and lifecycle.

***Pei Wang***
Ph.D. research focuses on the assimilation of the Cross-track Infrared Sounder (CrIS) data and its impact on hurricane forecast in regional NWP model. CrIS is onboard the Suomi National Polar-Orbiting Operational Environmental Satellite System Preparatory Project satellite (S-NPP) and the Joint Polar Satellite System (JPSS). To reduce the cloud contamination for CrIS assimilation, the collocated high resolution cloud mask from the Visible Infrared Imaging Radiometer Suite (VIIRS) is used to help CrIS cloud detection. The cloud contamination is reduced with the collocated VIIRS cloud mask, which improves the analysis fields and the track forecast of Hurricane Joaquin (2015). The cloud-clearing method is to get the equivalent clear radiances under partially cloudy regions. The assimilation of cloud-cleared radiances is an alternative way to assimilate the thermodynamic and hydrometric information under partially cloudy regions. The assimilation of cloud-cleared CrIS radiances data need to be further studied in the future.

***Charles White***
M.S. Thesis: “Spatial and Temporal Variability of Satellite Derived Lake Surface Temperature and Regional Cloud Properties.” A multi-year lake-surface temperature (LST) time series over the North American Great Lakes was constructed from NOAA’s Advanced Very High Resolution Radiometer (AVHRR) dataset. The time series was cloud-cleared and LSTs determined using the NOAA Pathfinder Atmospheres Extended (PATMOS-x) climate dataset and the Clouds from AVHRR Extended System (CLAVR-x). Results show strong spatial heterogeneity in the LST trends both within each lake and between lakes. A significant coastal upwelling signal can also be identified from the time series. The spatially varying temperature trends can have impacts on the habitable zones of freshwater species and facilitate the spread of invasive species. Additionally, trends in remotely-sensed cloud properties over the lakes and in the surrounding region will be identified and compared in the context of the spatially and temporally varying LST."

***Skylar S. Williams***
M.S. Title: “Validation of Water Vapor Measurements from Commercial Aircraft across the CONUS using Radiosondes.” With the addition of the Water Vapor Sensing System II (WVSS-II) on a number of commercial aircraft, water vapor measurements are added to the already present measurements of pressure, temperature, and wind. This allows for a full thermodynamic profile to be created whenever WVSS-II equipped aircraft take off and land, becoming a way to fill the spatial and temporal gaps present within upper air observations. Radiosonde-based validation of the WVSS-II has been limited to short-term field studies in climatologically similar

regions, which limits understanding of its performance in different environments. In the present study, the WVSS-II is compared to operational NWS radiosondes throughout the continental United States, enabling sensor validation in all seasons and multiple climate regimes. Locational and seasonal biases are explored, and the performance of the sensor in both high and low water vapor environments is determined. Characterizing potential biases in the WVSS-II dataset will improve data assimilation processes of this data into numerical weather prediction models and create confidence for both governmental and aviation forecasters regardless of location or time of year.

***Feng Zhu***

Ph.D. research topic is high temporal resolution geostationary satellite data assimilation for tropical storms, aiming at better utilizing the satellite observations to improve the forecast of tropical storms. One part of my research is evaluating and quantifying the impact of potential high temporal resolution geostationary satellite data sets on tropical cyclone (TC) forecasting with the method of observation system simulation experiments (OSSE). I am also working on developing a new method of tropical cyclone relocation to improve the initialization of TC and, meanwhile, to evaluate the impact of relocation on satellite data assimilation. Additionally, an independent research topic regarding the atmospheric system as a dynamical system, investigating the relationship between initial error, model error, and forecast error from both theoretical and practical sides. Conducting ideal experiments with toy models such as Lorenz63 and Lorenz96, and realistic experiments with WRF/GSI system, with the method of data assimilation and OSSE.

**Students Funded on other projects than NOAA**

***Kai-Wei Chang***

Ph.D. Thesis title: "Multi-sensor Ice Cloud Retrievals." Accurate satellite retrievals of ice clouds are crucial for understanding their role in climate and the water cycle. The suite of active and passive sensors in the A-Train constellation offers collocated observations that are well-constrained for cloud retrievals. To take full advantage of these observations, we perform channel selection using information content to select the bands from the AIRS and MODIS passive sensors that are optimal for retrieving key ice cloud properties. The channel selection is done in preparation for developing a joint retrieval that combines AIRS and MODIS observations with active observations from CloudSat and CALIPSO in order to take advantage of the co-located observations provided by the A-Train satellites. This retrieval is expected to provide accurate estimate of ice cloud properties, which are crucial for studying cloud processes and their role in climate.

***David Loveless***

M.S. Title: "Composite Analysis of Atmospheric Bores during PECAN Observed by Ground-Based Profiling Systems." Atmospheric bores are a type of gravity wave that commonly form as a result of the interaction between a stable layer and thunderstorm outflow. Bores propagate ahead of the thunderstorm outflow, along the interface between the stable surface layer and the free troposphere. Atmospheric bores were a focal point of the Plains Elevated Convection at Night (PECAN) field campaign, which took place during the summer of 2015. Atmospheric Emitted Radiance Interferometers (AERI) collocated with radar wind profilers or Doppler lidars were deployed at fixed locations and with two mobile units during PECAN, forming an integrated sounding array. Combined, these instruments observe thermodynamic and kinematic profiles within the boundary layer. While most previous observational studies have focused on a single bore in the context of a case study, the PECAN dataset provides a unique opportunity to construct a composite analysis of atmospheric bores in order to understand the typical boundary layer changes that occur with a bore passage. By gaining an understanding of how the boundary layer tends to change during bore passages, the potential role of atmospheric bores in nocturnal convective initiation can be described. The composite mean displays maximum parcel displacements on the order of 700 m. Convective Inhibition (CIN) and the Level of Free Convection (LFC) is shown to decrease with the bore passage, while Convective Available Potential Energy (CAPE) is shown to decrease. Results suggest that bores increase the potential for convective initiation in the post-bore environment, but may cause convection to be less intense than if convection occurred in a pre-bore environment.

***Marian Mateling***
M.S. title: "Spaceborne Snowfall Retrievals: Information gained from Day 1 GPM GPROF Empirical Databases" This research compares multiple independent global snowfall datasets (e.g., CloudSat, ERA-Interim, GPM) to identify global snowfall characteristics based on environmental and cloud macrophysical properties, illustrate regional biases - and possible causes for these biases - within the independent snowfall datasets, and highlight certain regions or snowfall modes that may be challenging for the Global Precipitation Measurement (GPM) Goddard Profiling (GPROF) precipitation retrieval algorithm due to inherent GPM observational limitations. Results from this research will be used to quantify global snowfall and improve multi-sensor spaceborne snowfall retrievals.

***Jacob Miller***
M.S. Research topic: This research is looking at the temporal and spatial extent of Arctic Leads, located north of Alaska. This is done by using MODIS retrieved data in an algorithm to detect the cloud cover, and find open "windows" with no clouds. In these windows another algorithm determines the coverage of ice and the orientation and width of leads based off a 95% threshold, which is then mapped, and later to be projected back on to a common grid. Currently the research involves case studies covering the time from Feb-April on selected years, in order to further improve/test the algorithms and research hypothesis.

***Keiko Yamamoto***
M.S. Title: "Dust Detection Using IR Channels of Himawari-8" The main focus of this research is to detect dust over land and ocean all day. The previous research showed that it is possible to detect dust using 8 µm, 11 µm and 12 µm channels over land; however, these channels alone cannot detect dust over ocean. If visible or near infra-red channels are used, it can detect dust quite well over land and ocean during daytime but the accuracy drops drastically during nighttime. In this study, 8.6 µm, 10.4 µm, 11.2 µm, and 12.4 µm channels on Himawari-8 are used, and a new algorithm for dust detection was developed. There are still noise especially during nighttime; however, the new algorithm improved the accuracy of dust detection over land and ocean, and during both daytime and nighttime.

# Appendix 5: Visitors at CIMSS 2015-2016 (visits of 3 days or more and key visitors)

| | |
|---|---|
| Yufei **Ai** | Peking University, China |
| Zhou **Bing** | Beijing Climate Center, National Climate Center, China Meteorological Agency |
| Tiziana **Cherubini** | Dept of Meteorology, University of Hawaii at Manoa |
| Luh-Hsiang **Chi** | Meteorological Satellite Center, Central Weather Bureau |
| Josh **Cossuth** | Naval Research Lab-Monterey |
| Jeff **Craven** | Scientific Services Division Chief, National Weather Service Central Region |
| Capt. Brian **DeCicco** | Typhoon Duty Officer, Joint Typhoon Warning Center, Honolulu, HI |
| John **Gagan** | Science and Operations Officer, National Weather Service, Milwaukee/Sullivan |
| Iliana **Genkova** | NOAA/NCEP/EMC |
| Xinya **Gong** | Institute of Atmospheric Physics, China |
| Steve **Goodman** | GOES-R Program Scientist, |
| Hyojin **Han** | Korea Meteorological Administration |
| Timo **Hanschmann** | German Meteorological Office |
| Steve **Hentz** | Lead Meteorologist, National Weather Service, Milwaukee/Sullivan |
| Andy **Heymsfield** | Senior Scientist, Mesoscale and Microscale Meteorology Laboratory, NCAR |
| Satya **Kalluri** | Chief, NOAA/NESDIS/STAR Cooperative Research Program |
| Wen **Liu** | Xi'an Institute of Optics and Precision Mechanics of Chinese Academy of Science (CAS) |
| Qingqing **Lyu** | National Satellite Meteorology Center, China Meteorological Agency |
| Jeremy **Mathis** | PMEL/OERD Division Leader, NOAA Arctic Research Program |
| Matt **Sitkowski** | Producer, Wx Geeks, Weather Channel |
| Rolf **Stuhlmann** | Geo Programme Scientist, EUMETSAT |
| Marouane **Temimi** | Assoc. Professor, Masdar Institute of Science and Technology, United Arab Emirates |
| Stephen **Tjemkes** | Remote Sensing Scientist, EUMETSAT |
| Louis **Uccellini** | Director, NOAA/National Weather Service |
| Michaela **Valachova** | Charles University in Prague, Czech Republic |
| Lu **Wang** | Chengdu University of Technology |

| | |
|---|---|
| Jerry **Wiedenfeld** | Information Technology Officer, National Weather Service, Milwaukee/Sullivan |
| Xifeng **Yao** | Harbin Engineering University |
| Johannes **Yimam** | Texas A&M |
| Nie **Yu** | Beijing Climate Center, National Climate Center, China Meteorological Agency |
| Cong **Zhou** | East China Normal University |
| Lin **Zhu** | China Meteorological Agency, National Satellite Meteorological Center |

# Appendix 6: List of Staff/Students hired by NOAA in the past years

**None.**

# Appendix 7: CIMSS Board of Directors and Science Council

## CIMSS Board of Directors

The Board of Directors will consist of senior employees from NOAA and UW-Madison. The Board of Directors shall review the policies, research themes, and priorities of CIMSS, including budget and scientific activities and will also provide for the periodic external review of the scientific activities of CIMSS. The Director of CIMSS or his/her designee shall serve as a non-voting member of the Board of Directors. The NESDIS Cooperative Research Program Director will serve as a special advisor to the Council in an *ex officio* status. Current Board of Directors members include:

| | |
|---|---|
| Marsha Mailick | Associate Vice Chancellor for Research and Graduate Education, UW–Madison |
| W. Paul Menzel | Interim Director, CIMSS, UW–Madison |
| Steve Ackerman | Interim Director, SSEC, UW–Madison |
| Greg Tripoli | Chair, Department of Atmospheric and Oceanic Sciences, UW-Madison |
| Steven Volz | Assistant Administrator for Satellite and Information Services, NOAA/NESDIS |
| Harry Cikanek | Director, Center for Satellite Applications and Research, NOAA/NESDIS |
| Jeff Key | Chief, Advanced Satellite Products Branch, NOAA/NESDIS |
| Jack A. Kaye | Associate Director for Research, NASA |
| Peter Hildebrand | Director, Earth-Sun Exploration Division of the Sciences and Exploration Directorate, NASA Goddard Space Flight Center |
| David F. Young | Director, Science Directorate, NASA Langley Research Center |

## CIMSS Science Advisory Council

The Science Council will advise the CIMSS Director in establishing the broad scientific content of CIMSS programs, promoting cooperation among CIMSS, NOAA, NASA and other agencies, maintaining high scientific and professional standards, and preparing reports of CIMSS activities. All Science Advisory Council members shall be recommended and selected by the Director of CIMSS, in consultation with the Board of Directors. In addition the Executive Director of SSEC or designee shall be a Council member. Council members shall serve three-year terms. Reappointment is possible for additional three-year terms pending approval by the Board. The number of Council members shall be set by the Board, provided the number of University members equal the total number of agency members. The Director of CIMSS will serve as the Chairperson of the Council. The NESDIS Cooperative Research Program Director will serve as a special advisor to the Council in an *ex officio* status. Science Council members include:

| | |
|---|---|
| Allen Huang | Distinguished Scientist, CIMSS, UW–Madison |
| Chris Velden | Senior Scientist, CIMSS, UW–Madison |
| Trina McMahon | Professor, College of Engineering, UW–Madison |
| Annemarie Schneider | Professor, SAGE, UW–Madison |
| Tristan L'Ecuyer | Professor, UW-Madison Atmospheric and Oceanic Sciences |
| Chris Kummerow | Professor, Department of Atmospheric Science, Colorado State University |
| Steve Goodman | GOES-R Program Scientist, NOAA/NESDIS/ORA |
| Satya Kalluri | Chief, Atmospheric Research and Applications Division, NOAA/NESDIS/ORA |

| | |
|---|---|
| Steve Platnick | Aqua Deputy Project Scientist, EOS Senior Project Scientist (acting), NASA Goddard Space Flight Center |
| Pat Minnis | Senior Research Scientist, NASA Langley Research Center |

# Appendix 8: CIMSS Publications, 2014-2017

## CIMSS Peer-Reviewed Publications, 2014-17

**2017: In Press, Accepted, or In Review**

Doyle, James D., Moskaitis, Jon, Feldmeier, Joel, Ferek, Ronald, Beaubien, Mark, Bell, Cecil, Daniel, Creasey, Robert, Durna, Patrick, Elsberry, russ, Komaromi, Will, Molinari, John, Ryglicki, David, Stern, Daniel, Velden, Chris, et al, 2017. A view of tropical cyclones from above: The Tropical Cyclone Intensity (TCI) Experiment. Bulletin of the American Meteorological Society, accepted for publication.

Hoover, B., Santek, D., Daloz, A.S., Zhong, Y., Dworak, R., and Peterson, R.A., 2017. Forecast impact of assimilating WVSS-II water vapor mixing ratio observations in the global data assimilation system (GDAS). Weather and Forecasting, accepted for publication.

Jang, Hyun-Sung, Sohn, B.J., Chun, Hyoung-Wook, Li, Jun, and Weisz, Elisabeth, 2017. Improved AIRS temperature and moisture soundings with local a priori information for the 1DVAR. Journal o Atmospheric and Oceanic Technology, in press.

Lee, yong-Keun, Li, Jun, Li, Zhenglong, and Schmit, Tim, 2017. Atmospheric temporal variations in the pre-landfall environment of Typhoon Nangka (2015) observed by the Himawari-8 AHI. Asia-Pacific Journal of Atmospheric Sciences, in press.

Poli, Paul, Dee, Dick P., Saunders, roger, John, Viju O., Rayer, Peter, Schulz, Jorg, Holmlund, Kenneth, Coppens, Dorothee, Klaes, Johnson, James E., Esfandiari, Asghar E., Gerasimov, Irina V., Zamkoff, Emily B., Al-Jazrawi, Atheer, F., Santek, David, et al, 2017. Recent advances in satellite data rescue. Bulletin of the American Meteorological Society, early online release: http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-15-00194.1

Robers, R., Aberson, S., Bell, M., Cecil, D., Doyle, J., Kimberlain, T., Morgerman, J., Shay, L., and Velden, C., 2017. Re-writing the tropical record books: The extraordinary intensification of Hurricane Patricia (2015). Bulletin of the American Meteorological Society, accepted for publication.

Velden, C., Lewis, W.E., Bresky, W., Stettner, D., Daniels, J., and Wanzong, S., 2017. Assimilation of high-resolution satellite-derived atmospheric motion vectors: Impact on HWRF forecasts of trpical cyclone track and intensity. Monthly Weather Review, 145, 1107-1125, 1107–1125, doi: 10.1175/MWR-D-16-0229.1.

**2017**

Ai, Y., Li, J., Shi, W., Schmit, T.J., Cao, C., and Li, W., 2017. Deep convective cloud characterizations from both broadband imager and hyperspectral infrared sounder measurements. Journal of Geophysical Research-Atmospheres, 122(3): 1700-1712.

Chai, T., Crawford, A., Stunder, B., Pavolonis, M.J., Draxler, R., and Stein, A., 2017. Improving volcanic ash predictions with the HYSPLIT dispersion model by assimilating MODIS satellite retrievals. Atmospheric Chemistry and Physics, 17(4), 2865-2879.

Feng, L., Hu, C., Barnes, B.B., Mannino, A., Heidinger, A.K., Strabala, K., and Iraci, L.T., 2017. Cloud and sun-glint statistics derived from GOES and MODIS observations over the Intra-Americas Sea for GEO-CAPE mission planning. Journal of Geophysical Research-Atmospheres, 122(3): 1725-1745.

Griffin, S.M., Otkin, J.A., Rozoff, C.M., Sieglaff, J.M., Cronce, L.M., and Alexander, C.R., 2017. Methods for comparing simulated and observed satellite infrared brightness temperatures and what do they tell us? Weather and Forecasting, 32(1): 5-25.

Heymsfield, A., Kramer, M., Wood, N.B., Gettelman, A., Field, P.R., and Liu, G., 2017. Dependence of the ice water content and snowfall rate on temperature, globally: Comparison of in situ observations, satellite active remote sensing retrievals, and global climate model simulations. Journal of Applied Meteorology and Climatology, 56(1): 189–215.

Huang, M., Huang, B., and Huang, H.-L.A., 2017. Parallel construction of the WRF Pleim-Xiu land surface scheme with Intel Many Integrated Core (MIC) architecture. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 10(4): 1239-1246.

Jones, T.A., Koch, S., and Li, Z., 2017. Assimilating synthetic hyperspectral sounder temperature and humidity retrievals to improve severe weather forecasts. Atmospheric Research, 186(1): 9-25.

Kim, M., Kim, H.M., Kim, J.W., Ki, S.-M., Velden, C., and Hoover, B., 2017. Effect of enhanced satellite-derived Atmospheric Motion Vectors on numerical weather prediction in East Asia using an adjoint-based observation impact method. Weather and Forecasting, 32(2): 579–594.

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Langford, A.O., Alvarex, R.J.I., Brioude, J., Fine, R., Gustin, M.S., Lin, M.Y. , Marchbanks, R.D., Pierce, R.B., Sandberg, S.P., Senff, C.J., Weickmann, A.M., and Williams, E.J., 2017. Entrainment of stratospheric air and Asian pollution by the convective boundary layer in the southwestern US. Journal of Geophysical Research-Atmospheres, 122(2): 1312-1337.

Mueller, K.J., Wu, D.L., Lorvath, A., Jovanovic, V.M., Muller, J.-P., De Girolamo, L., Garay, M.J., Diner, D.J., Moroney, C.M., and Wanzong, S., 2017. Assessment of MISR Cloud Motion Vectors (CMVs) relative to GOES and MODIS Atmospheric Motion Vectors (AMVs). Journal of Applied Meteorology and Climatology, 56(3): 555-572.

Noh, Y.-J., Forsythe, J.M., Miller, S.D., Seaman, C.J., Li, Y., Heidinger, A.W., Lindsey, D.T., Rogers, M.A., and Partain, P.T., 2017. Cloud-based height estimation from VIIRS. Part II: A statistical algorithm based on A-train satellite data. Journal of Atmospheric and Oceanic Technology, 34(3): 585-598.

Palerme, C., Genthon, C., Claud, C., Kay, J.E., Wood, N.B., and L'Ecuyer, T., 2017. Evaluation of current and projected Antarctic precipitation in CMIP5 models. Climate Dynamics, 48(1): 225-239.

Pan, L.L., Atlas, E.L., Salawitch, R.J., Honomichl, S.B., Bresch, J.F., Randel, W.J., Apel, E.C., Hornbrook, R.S., Weinheimer, A.J., Anderson, C.D., Andrews, S.J., Baidar, S., Beaton, S.P., Campos, T.L., Carpenter, L.J., Chen, D., Dix, B., Donets, V., Hall, S.R., Hanisco, T.F., Homeyer, C.R., Huey, L.G., Jensen, J.B., Kaser, L., Kinnison, D.E., Koenig, T.K., Lamarque, J.-F., Liu, C., Luo, J., Luo, Z.J., Montzka, D.D., Nicely, J.M., Pierce, R.B., Riemer, D.D., Robinson, T., Romashkin, P., Saiz-Lopez, A., Schauffler, S., Shieh, O., Stell, M.H., Ullmann, K., Vaughan, G., Volkamer, R., and Wolfe, G., 2017. The Convective Transport of Active Species in the Tropics (CONTRAST) experiment. Bulletin of the American Meteorological Society, 90(1): 106–128.

Platnick, S., Meyer, K.G., King, M.D., Wind, G., Amarasinghe, Marchant, B., Arnold, G.T., Zhang, Z., Hubanks, P.A., Holz, R.E., Yang, P., Ridgway, W.L., and Riedi, J., 2017. The MODIS cloud optical and microphysical products: Collection 6 updates and examples from Terra and Aqua. IEEE Transactions on Geoscience and Remote Sensing, 55(1): 502-525.

Seaman, C.J., Noh, Y.-J., Miller, S.D., Heidinger, A.K., and Lindsey, D.T., 2017. Cloud-based height estimation from VIIRS. Part I: Operational algorithm validation against CloudSat. Journal of Atmospheric and Oceanic Technology, 34(3): 567-583.

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**2016**

Anderson, D.C., Nicely, J.M., Salawitch, R.J., Canty, T.P., Dickerson, R.R., Hanisco, T.F., Wolfe, G.M., Apel, E.C., Atlas, E., Bannan, T., Bauguitte, S., Blake, N.J., Bresch, J.F., Campos, T.L., Carpenter, L.J., Cohen, M.D., Evans, M., Fernandex, R.P., Kahn, B.H., Kinnison, D.E., Hall, S.R., Harris, N.R.P., Hornbrook, R.S., Lamarque, J.-F., Le Breton, M., Lee, J.D., Percival, C., Pfister, L., Pierce, R.B., Piemer, D.D., Saiz-Lopez, A., Stunder, B.J.B., Thompson, A.M., Ullmann, K., Vaughan, A., and Weinheimer, A.J., 2016. A pervasive role for biomass burning in tropical high ozone/low water structures. Nature Communications, doi:10.1038/ncomms10267.

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Baylon, P.M., Jeffe, D.A., Pierce, R.B., and Gustin, M.S., 2016. Interannual variability in baseline ozone and its relationship to surface ozone in the western US. Environmental Science and Technology, 50(6): 2994-3001.

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Brunner, J., Pierce, R.B., and Lenzen, A., 2016. Development and validation of satellite-based estimates of surface visibility. Atmospheric Measurement Techniques, 9(2): 409-422.

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Christensen, M.W., Behrangi, A., L'Ecuyer, T.S., Wood, N.B., Lebsock, M.D., and Stephens, G.L., 2016. Arctic observation and reanalysis integrated system: A new data product for validation and climate study. Bulletin of the American Meteorological Society, 97(6): 907-915.

Cintineo, R.M., Otkin, J.A., Jones, T.A., Koch, S., and Stensrud, D.J., 2016. Assimilation of synthetic GOES-R ABI infrared brightness temperatures and WSR-88D radar observations in a high-resolution OSSE. Monthly Weather Review, 144(9): 3159-3180.

Crawford, A.M., Stunder, B.J.B., Ngan, F., and Pavolonis, M.J., 2016. Initializing HYSPLIT with satellite observations of volcanic ash: A case study of the 2008 Kasatochi eruption. Journal of Geophysical Research-Atmospheres, 121(18): 10786-10803.

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Gao, L., Li, J., Chen, L., Zhang, L., and Heidinger, A.K., 2016. Retrieval and validation of atmospheric aerosol optical depth from AVHRR over China. IEEE Transactions on Geoscience and Remote Sensing, 54(11): 6280-6291.

Grasso, L., Lindsey, D.T., Seaman, C.J., Stocks, B., and Rabin, R.M., 2016. Satellite observations of plume-like streaks in a cloud field in Canada. Pure and Applied Geophysics, 173(9): 3103-3110.

Gravelle, C.M., Mecikalski, J.R., Line, W.E., Bedka, K.M., Petersen, R.A., Sieglaff, J.M., Stano, G.T., and Goodman, S.J., 2016. Demonstration of a GOES-R satellite convective toolkit to "bridge the gap" between severe weather watches and warnings: An example from the 20 May 2013 Moore, Oklahoma, tornado outbreak. Bulletin of the American Meteorological Society, 97(1): 69-84.

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Griffin, S.M., Bedka, K.M., and Velden, C.S., 2016. A method for calculating the height of overshooting convective cloud tops using satellite-based IR imager and CloudSat cloud profiling radar observations. Journal of Applied Meteorology and Climatology, 55(2): 479-491.

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Heidinger, A., Foster, M., Botambekov, D., Hiley, M., Walther, A., and Li, Y., 2016. Using the NASA EOS A-train to probe the performance of the NOAA PATMOS-x cloud fraction CDR. Remote Sensing, 8(6): doi:10.3390/rs8060511.

Herring, S.C., Hoell, A., Hoerling, M.P., Kossin, J.P., Schreck, C.J.I., and Stott, P.A., 2016. Explaining extreme events of 2015 from a climate perspective: Introduction to explaining extreme events of 2015 from a climate perspective. Bulletin of the American Meteorological Society, 97(12): S1-S3.

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