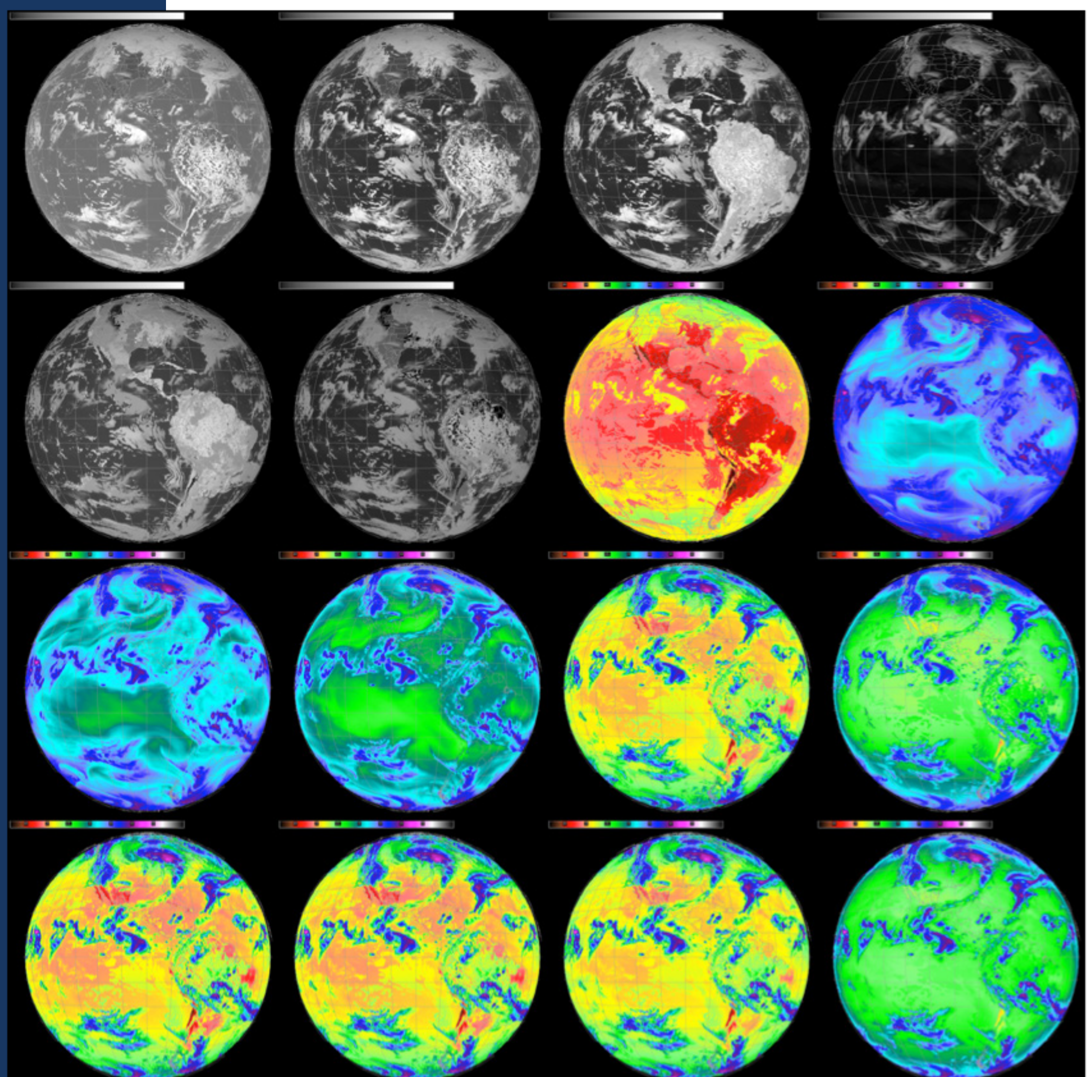
CIMSS Cooperative Agreement Annual Report

for the period
1 April 2015 to 31 March 2016



GOES-R ABI Simulated Radiances

Submitted by the
Cooperative Institute for
Meteorological Satellite Studies
University of Wisconsin-Madison
April 2016

University of Wisconsin–Madison

Cooperative Institute for
Meteorological Satellite Studies (CIMSS)

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

Cooperative Agreement Annual Report

for the period
1 April 2015 to 31 March 2016
Cooperative Agreement Number: NA10NES4400013

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 2015 to 31 March 2016

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Director, CIMSS

Wayne Feltz
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I. Director's Executive Summary

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) is a collaborative partnership between the National Oceanic and Atmospheric Administration (NOAA) and the University of Wisconsin–Madison (UW–Madison) that has and continues to provide outstanding benefits to the atmospheric science community and to the nation through improved use of remote sensing measurements for weather prediction, climate analysis and monitoring environmental conditions. Under the auspices of CIMSS, scientists from NOAA/NESDIS and the UW–Madison Space Science and Engineering Center (SSEC) have a formal basis for ongoing collaborative research efforts. CIMSS scientists work closely with the NOAA/NESDIS Advanced Satellite Product Branch (ASPB) stationed at the UW–Madison campus. This collaboration includes a scientist from the National Climate Data Center (NCDC), who joined the NOAA NESDIS employees stationed at CIMSS.

As demonstrated by this annual report, CIMSS continues to excel at meeting the three components of its mission statement. We will briefly describe examples relevant to NOAA that demonstrate how CIMSS personnel, in collaboration with ASPB and others, are meeting our mission goals. Details on individual projects are provided later in the report; here we only refer to a few relevant examples.

1. Foster collaborative research between NOAA and UW–Madison in those aspects of atmospheric and earth science that exploit the use of satellite technology.

The first part of the CIMSS mission is to foster collaborative research. One metric of success is to quantify the number of collaborative publications in general, and those with NOAA employees in particular. CIMSS continues to publish more than 40% of its peer reviewed papers with NOAA co-authors (see Appendix 2), indicating the strong collaborations between the two organizations. CIMSS Scientists work with NOAA NESDIS ASPB scientists in support of the quality-assurance of the current and future GOES observations. This diagnostic or 'science support' has included issues such as: stray light corrections, electronic side switch monitoring, Sounder short-wave noise, Sounder filter wheel issues, imager co-registration and other issues.

Another assessment strategy that CIMSS is meeting its goals is our ability to work with NOAA in transferring research to NOAA operations. We have over two dozen research algorithms that have been moved from our research community at CIMSS to NOAA operations. In preparation for the GOES-R era, CIMSS is involved in the development of many of the GOES-R algorithms, including cloud properties, atmospheric motion vectors, volcanic ash and SO2, hurricane intensity, fire and hot spots, fog and low clouds. Preparing forecasters for new data analysis methods is also a goal of CIMSS. In preparation for the GOES-R launch, 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. CIMSS works closely with the GOES-R Data Operations Support Team (DOST), the AWG Algorithm Integration Team (AIT), and the NWS to provide real-time simulated ABI data in GOES-R ReBroadcast (GRB) form for ground system testing, algorithm testing within the AIT Framework through comparison with products produced at CIMSS using GEOCAT (e.g., cloud properties, legacy sounding retrievals, aerosol properties, total column ozone, and fire detection), and for display within AWIPS II for testing and user preparedness.

CIMSS scientists collaborate with ASPB scientists in assessing new and current satellite instruments, continuing a tradition of over 35 years. The GOES-14 satellite was operated in Super Rapid Scan Operation for GOES-R (SRSOR) mode on several days during 2015 for the purpose of demonstrating the value of high temporal observations (1-minute intervals) from GOES which will become available regularly with GOES-R. Some of this data is being combined with radar and lightning observations for detailed studies of severe thunderstorms. As another example, an improved Atmospheric Motion Vector (AMV) product was developed for the GOES-R Advanced Baseline Imager (ABI) using a new tracking algorithm. This new tracking algorithm has been demonstrated to significantly improve the slow speed bias inherent in the AMVs derived from previous algorithms. This significant reduction in the speed bias of the AMVs could benefit Numerical Weather Prediction (NWP) by improving the analyses and the accuracy of NWP forecasts. NOAA's AWG utilizes the CIMSS developed 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.

CIMSS also has a long collaboration with NOAA scientist in conducting research and developing applications with NOAA's polar orbiting platforms. NOAA and NASA support several CIMSS projects that make use of instruments on the Suomi NPP platform. There are many activities, as described in the following sections, where NOAA support is provided to CIMSS researchers to support the JPSS program. JPSS risk-reduction activities seek to realize the full potential of VIIRS through innovative research and algorithm development. The notional beneficiaries of this research are many-varied and include all downstream developers of EDRs reliant on accurate nighttime cloud masking, the operational end-users of these VIIRS EDR products (e.g., forecasters), the climate research making use of VIIRS information, distillers of this information in connection with IGPCC, and ultimately policy makers. Monitoring of the cryosphere, and in particular Earth's snow cover, is among the primary applications of polar orbiting satellites. CIMSS, in collaboration with ASPB scientists assessing the suitability of heritage snow algorithms, algorithm selection/implementation with AMSR2 data.

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.

CIMSS and ASPB have a strong national and international reputations for quality and collaborative work, which enables us to be a center of excellence in the general field of satellite remote sensing. Examples supporting this statement follow and are more fully documented in the research summary overviews.

CIMSS is active in the international effort to calibrate the world's environmental satellites: Global Space-based Intercalibration System (GSICS). The primary goal of GSICS is to improve the use of space-based global observations for weather, climate and environmental applications through operational inter-calibration of the space component of the WMO Global Observing System (GOS) and Global Earth Observing System of Systems (GEOSS). CIMSS is an active partner with NOAA on this endeavor and much of the methodology developed at CIMSS was adopted by the international GSICS team. CIMSS scientists are working on making the SDRs the highest quality possible for weather and climate applications.

CIMSS continues to support NOAA's objective of improved weather forecasting through data assimilation. We are working with personnel from the Atmospheric Infrared Sounder (AIRS) Science Team, the National Center for Environmental Prediction (NCEP), the National

Environmental Satellite, Data and Information Service (NESDIS) and others in developing techniques to assimilate Suomi NPP CrIS, AIRS and the Infrared Atmospheric Sounding Interferometer (IASI) water vapor radiances. Observing System Experiments (OSEs) are used to quantify the contributions to the forecast made by SNPP/JPSS satellite data.

CIMSS is collaborating with the National Severe Storms Laboratory (NSSL) and the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) at the University of Oklahoma, on Observing System Simulation Experiments (OSSEs) to assess the potential for satellite observations to improve the characterization of storms within model analyses and forecasts.

Working closely with ASPB, CIMSS is producing high quality proxy ABI data sets derived from NWP model simulations. Synthetic ABI baseline products (including 16-band imagery) are generated in near-real-time over CONUS using the Joint Center for Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model (CRTM) and model output from the WRF-Chem/RAQMS system.

UW–Madison has a long and positive reputation for satellite data distribution. Organizations throughout the world make use of the UW–Madison developed The Community Satellite Processing Package (CSPP), which 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. In addition to providing access to the data, the package also supports analysis and visualization. A particular focus is the newest release of NOAA-developed algorithms and software for creating products from these satellites.

The Pathfinder Atmospheres Extended (PATMOS-x) is a NOAA/NESDIS climate dataset generated in partnership with CIMSS. PATMOS-x was selected as one of the first three Climate Data Records (CDR) to become operational CDRs at the National Climatic Data Center (NCDC). The NCDC Climate Data Record Program is also supporting CIMSS and ASPB scientists to lead of a multi-institutional Cryosphere Product Development Team to create a variety of fundamental and thematic snow and ice climate data records (FCDR and TCDR).

CIMSS sponsored many national and international visitors during this time (Appendix 5). For example: **Louis Uccellini**, Director NOAA/National Weather Service, **David Turner** NOAA National Severe Storms Laboratory **Yasuhiko Sumida**, Japanese Meteorological Agency (JMA), **Johannes Nielsen** Danish Meteorological Institute, Yufei **Ai** Peking University, **Laura Dobor** Eotvos Lorand University, Department of Meteorology, Hungary, **Jiandong Gong** Deputy Director, China Meteorological Administration (CMA) Numerical Weather Prediction Center (NWPC), **Satya Kalluri** Chief, NOAA/NESDIS/STAR Cooperative Research Program Division, **Burcu Kabatas**, University of Istanbul, **Paul Kucera** National Center for Atmospheric Research (NCAR), Kirsti **Salonen** European Center for Medium-range Weather Forecasting (ECMWF), **Susan Ustin** Director, CSTARS, University of California-Davis, **Aku Riihela** Finnish Meteorological Institute, and Hye-Sil **Kim** Ewha Women's University (Korea).

3. Stimulate the training of scientists and engineers in those disciplines comprising the atmospheric and earth sciences.

CIMSS continues to support NOAA's education and outreach goals. These activities span the landscape of education involving participation in include K-12, undergraduate, graduate and professional training. To improve coordination of these activities CIMSS recently established the

CIMSS Education and Public Outreach Office that reports to the CIMSS Director, allowing the engagement function to be infused throughout the institute.

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. The strong link between education and research at CIMSS provides an excellent path for young scientists entering careers in geophysical fields. Several graduate students are now working for public and private industries to support NOAA activities, and four graduates were recently hired by CIMSS scientists.

We work in collaboration with NOAA and other cooperative institutes in developing training resources for NOAA. The Satellite Hydro-Meteorology (SHyMet) training course was developed and implemented through close collaboration with experts at the CIRA. CIMSS has assisted in the development of the previous five SHyMet courses. Data for case studies/training modules continues to be added to the CIMSS Satellite Blog (http://cimss.ssec.wisc.edu/goes/blog); blog posts include data from MODIS and Suomi NPP VIIRS that can serve as a proxy for GOES-R and JPSS.

A stable AWIPS-II platform at CIMSS allows for manipulation of CIMSS-produced datasets into formats that are compatible with AWIPS-II formats. Thus, the production at CIMSS of products that forecasters wish to see (for example, GOES-R Fog/Low Stratus Products) continues into the AWIPS-II era.

Use of satellite-based weather products in forecasting is enhanced through stationing a CIMSS satellite scientist at the National Weather Service Training (NWS) Center and another at the Aviation Weather Center (AWC) in Kansas City, MO. The CIMSS scientists provide leadership, satellite expertise, and meteorological support for the GOES-R Proving Ground efforts based at the NWS Training Center (NWSTC).

CIMSS Education and Public Outreach (EPO) initiatives prioritize satellite remote sensing awareness and weather and climate literacy while working to ensure that CIMSS research products provide maximum benefits to society. CIMSS EPO is involved in 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. The CIMSS education office created and supports the GOES-R Education Proving Ground (http://cimss.ssec.wisc.edu/education/goesr/) where science teachers presented lesson plans developed to ensure that the education community will be "launch ready" for new satellite imagery and improved products available in the upcoming GOES-R era.

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 new twitter account launched in August 2014 (@UWCIMSS) continues to be of interest to a broad public. The associated twitter account (@CIMSS_Satellite) has over 4,400 followers.. The CIMSS Satellite Blog (http://cimss.ssec.wisc.edu/goes/blog/) has been showcasing examples of meteorological satellite images and products for over 20 years (beginning with the GOES Gallery).

Two web-based projects deserving special mention include an on-line course for undergraduates on Climate and Climate Change (http://c3.ssec.wisc.edu/) and a massive open on-line course (MOOC) on *The Changing Weather and Climate of the Great Lakes Region* (https://www.coursera.org/course/greatlakesclimate). Both of these projects took place in collaboration with the UW–Madison Atmospheric and Oceanic Sciences department (AOS). The undergraduate course was capped at 50 students but the MOOC, with no registration limits, topped 6,500 participants! When CIMSS posted a video from the MOOC on the CIMSS Facebook page on consisting of an interview and tour at the Milwaukee-Sullivan National Weather Service Forecast Office it garnered nearly 10,000 views! An excellent implementation of CIMSS Weather-Ready Nation Ambassador responsibilities with the main interview topics covered were Weather Ready Nation and forecast and warning responsibilities.

Summary

The above are but a few examples of how CIMSS worked with NOAA this year to achieve our mission goals. Details of these and additional projects follow.

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. CIMSS just completed its 5-year review in December 2013. Following a thorough review of the CIMSS, the Review Panel unanimously agreed to a performance rating of Outstanding.

The CIMSS mission includes three goals:

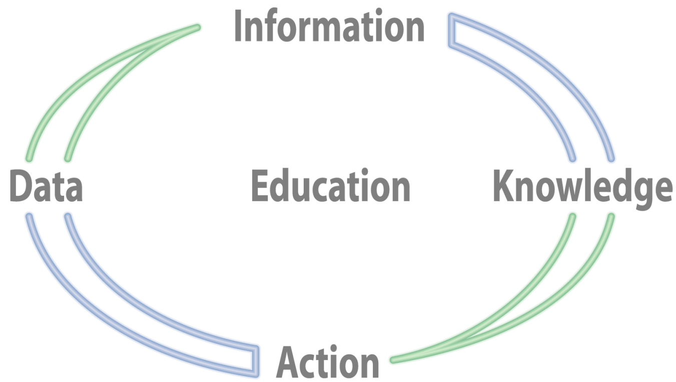
- Foster collaborative research among NOAA, NASA, and the University in those aspects of atmospheric and earth system science that exploit the use of satellite technology;
- Serve as a center at which scientists and engineers working on problems of mutual interest can focus on satellite-related research in atmospheric and earth system science;
- 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 and Applications, to support weather analysis and forecasting through participation in NESDIS product assurance and risk reduction programs and the associated transitioning of research progress into NOAA operations,
2. Satellite Sensors and Techniques, to conduct instrument trade studies and sensor performance analysis supporting NOAA's future satellite needs as well as assisting in the long term calibration and validation of remote sensing data and derived products,
3. Environmental Models and Data Assimilation, to work with the Joint Center for Satellite Data Assimilation (JCSDA) on improving satellite data assimilation techniques in operational weather forecast models, and
4. Outreach and Education, to engage the workforce of the future in understanding and using environmental satellite observations for the benefit of an informed society.

The collaborative relationship between NOAA and the UW–Madison which 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 summarized above and presented in detail in the following sections. Our research process is represented in the figure below. Algorithms are developed and applied to observations (data) to yield information about Earth. We apply this information to gain knowledge about the Earth system, knowledge that can be utilized in decision-making processes. As we rely on this knowledge to take action we demonstrate the need for better observations, and work with our partners, particularly those in SSEC, in designing and testing improved instrumentation. At the center of this research process is education - the training of students, professionals and ourselves.



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 change positions and roles. For example, original CIMSS/SSEC staff associated with GOES VAS (the first geostationary sounding instrument) and GOES-8/12 design, testing, and checkout are now assisting with similar activities in GOES-R. 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. Being collocated in the same building and having similar research interests fosters powerful ties and collaborations. In addition to working with CIMSS scientists, ASPB scientists often mentor graduate students on research projects. These research projects address NOAA needs while helping to satisfy UW–Madison degree requirements. Based on this positive experience, some 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). CIMSS is led by its Director, Dr. Steven Ackerman, who is also a faculty member within the UW–Madison Department of Atmospheric and Oceanic Sciences. Executive Director 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:

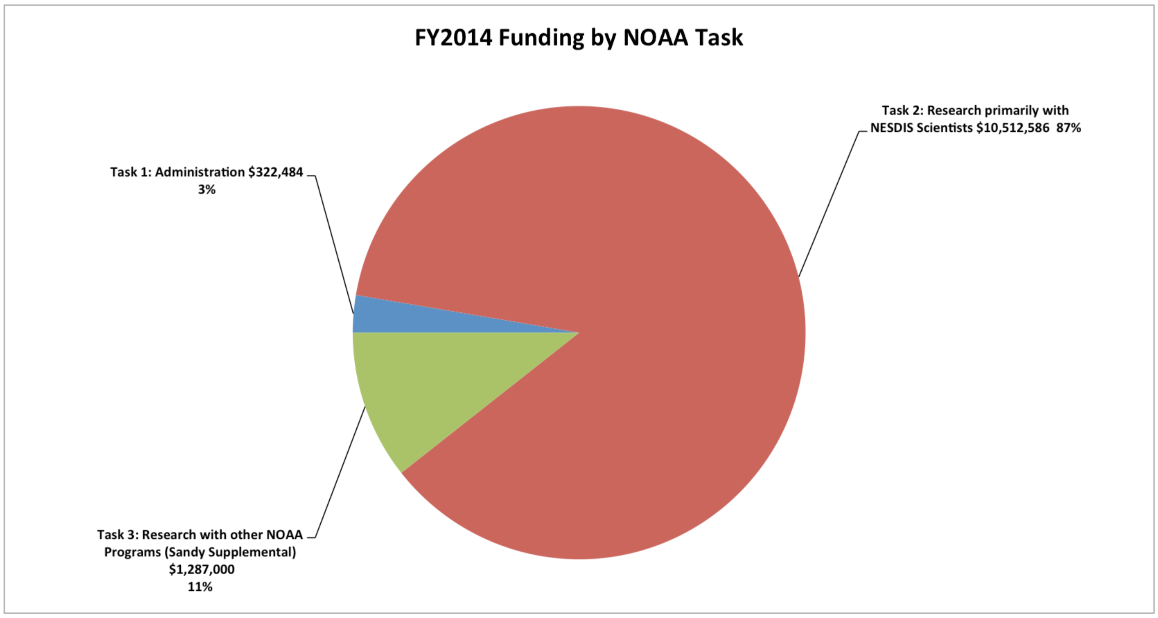
- **Administrative support**
  The administrative support team includes approximately 14 full-time staff and several students providing services that include human relations, proposal processing and publishing, grant and contract management, accounting, financial programming, purchasing and travel.
- **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 FY2014

In FY2014, funding to CIMSS through Cooperative Agreement NA10NES4400013 totaled $10,835,070.FY2015 funding is not sufficiently known at this time to include in this report but will most likely exceed the CIMSS CA FY2014 budget total. 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 FY2014 funds provided to CIMSS under the Cooperative Agreement that began on 1 July 2010 and covers the 12 month period from 1 October 2013 to 30 September 2014.

FY2014 Funding by NOAA Task

CIMSS Task	Funding in dollars	Percentage
Task 1: Administration	$ 322,484	3%
Task 2: Research primarily with NESDIS Scientists	$ 10,512,586	87%
Task 3: Research with other NOAA Programs	$ 1,287,000	11%
	$12,122,070	



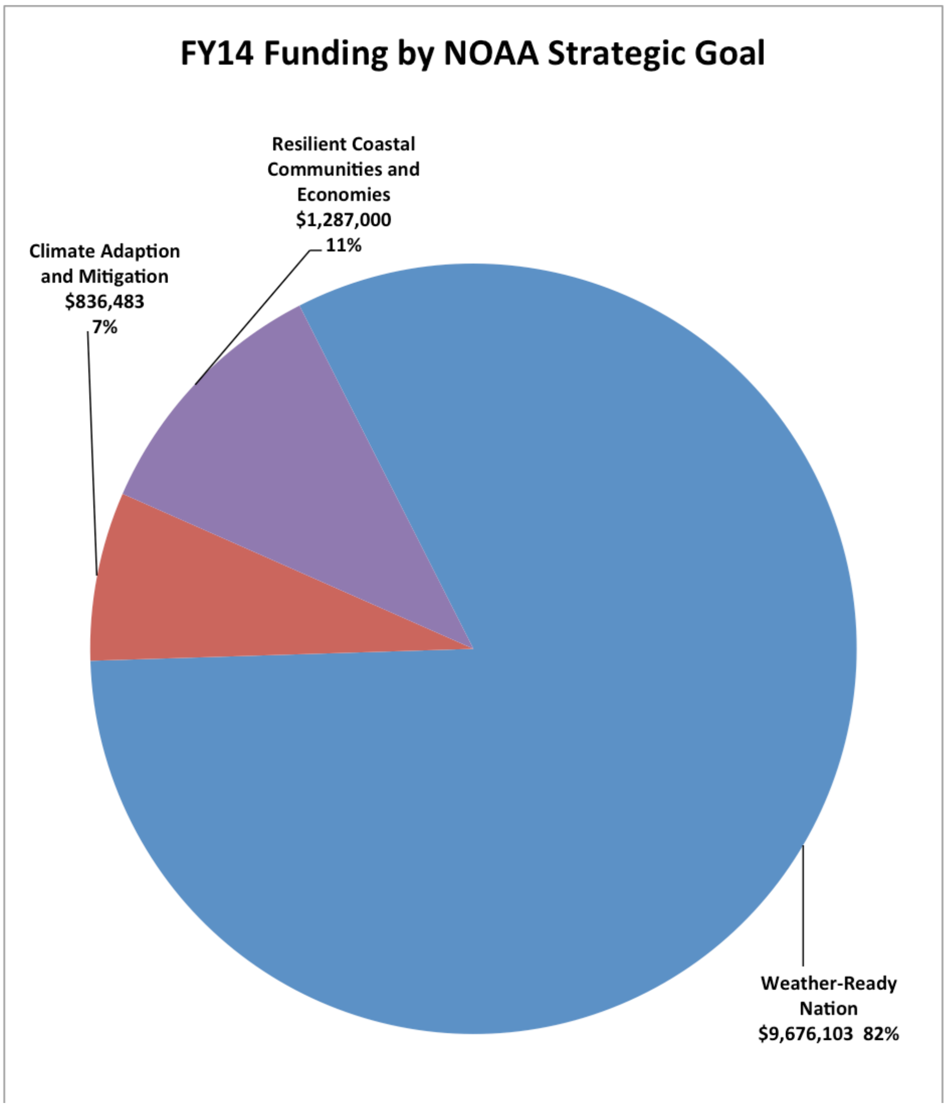
Nearly 90% of CIMSS funding is for Task 2 (69 FTEs) and is research conducted with ASPB scientists.

Funding, not including task 1, is shown below and is an increase of about $1M over last year support. While CIMSS research primarily falls under NOAA's Strategic Goal Weather-Ready Nation, our contributions to the other goals are critical and equally important.

Funding by NOAA Strategic Goal

NOAA Strategic Goal	Funding in dollars	Percentage
Weather-Ready Nation	$9,676,103	82%
Climate Adaption and Mitigation	$836,483	7%
Healthy Oceans	$ 0	0%
Resilient Coastal Communities and Economies	$1,287,000	11%
	$11,799,586*	

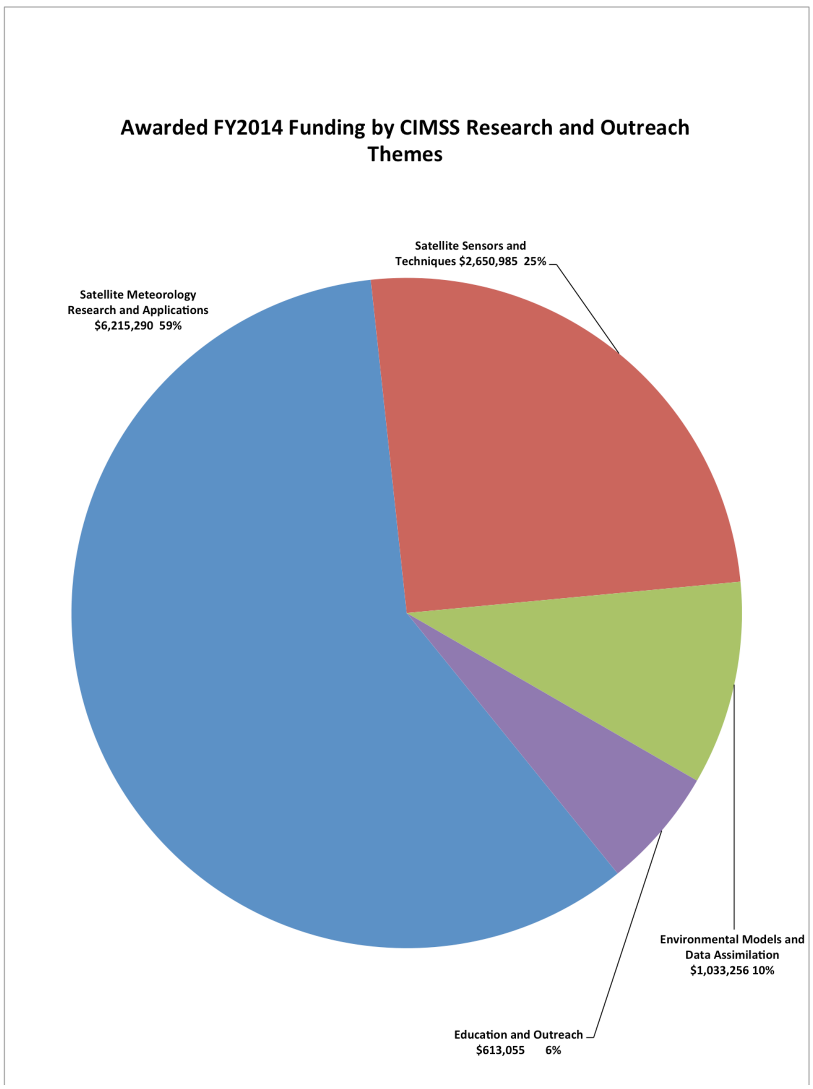
* - does not include the Task 1 funding but include Sandy Supplemental research funding



Task 2 Funding by CIMSS Research and Outreach Themes

CIMSS Theme	Funding in dollars	Percentage
Satellite Meteorology Research and Applications	$6,215,290	59%
Satellite Sensors and Techniques	$2,650,985	25%
Environmental Models and Data Assimilation	$1,033,256	10%
Education and Outreach	$ 613,055	6%
	$10,512,586*	

* - 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 Leaders: Steve Ackerman, Wayne Feltz
CIMSS Support: Maria Vasys, Leanne Avila, Wenhua Wu, 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

Project Overview

The CIMSS Task 1 funding supports activities related to CIMSS-specific administration and non-research programs that are important to the workplace environment of CIMSS. Partial funding support is provided for the CIMSS Director, Executive Director - Science, the Program Assistant, and the CIMSS Webmaster. Task 1 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 1 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-2015-4400013, but which are not tied to a specific project or projects. Task 1 funding includes partial funding/salary support for the CIMSS PI/Director, Steve Ackerman, and other support staff, travel, and visiting researcher support. Also, inclusive of Task 1 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 1 funding supports the development and updates of the CIMSS Web page (see http://cimss.ssec.wisc.edu/). The home page provides an innovative approach to the research pages by allowing users to access CIMSS research projects via three paths: alphabetically, by observing platform and by CIMSS research theme. 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 and Steve Ackerman
CIMSS Support Scientists: Scott Bachmeier and Rick Kohrs
NOAA Collaborators: Tim Schmit, Steve Goodman, Nina Jackson, LuAnn Dahlman

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

Project Overview

CIMSS Education and Public Outreach (EPO) initiatives prioritize satellite remote sensing awareness and weather and climate literacy while working to ensure that CIMSS research products provide maximum benefits to society. CIMSS EPO is involved in 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 two 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, starting with the CIMSS high school student workshop, a STEM camp held each summer since 1991. Following the June 2015 workshop, a local high school student name Grace Przybyl began an after-school internship with SSEC scientist Bob Knutson. Przybyl uses MATLAB software to help categorize AIRS profiles by comparing CAPE values.

Also in June 2015, CIMSS participated and presented in the Boulder Colorado NOAA Climate Stewards meeting. In September, CIMSS presented and participated in the 11th annual Cooperative Research Program (CoRP) Science Symposium in Maryland. Year-round, CIMSS researchers and staff conduct numerous in-person presentations at formal and informal venues.

At the January 2016 annual American Meteorological Society meeting, CIMSS organized a twitter-driven trivia contest (#AmsEd25) in honor of the 25th anniversary of the AMS Symposium on Education consisting of 25 questions and three 1st-place prizes. As always, numerous presentations and posters were presented at multiple AMS symposiums.

As a NOAA Weather-Ready Nation Ambassador™, CIMSS led the 2015 effort for the University of Wisconsin-Madison to become StormReady, a designation that was conferred in September. This achievement followed months of effort and coordination between the UW-Madison and the Milwaukee-Sullivan National Weather Service (NWS) Forecast Office. A plaque was awarded to the UW-Madison Chancellor (and former United States Secretary of Commerce) Rebecca Blank by NWS Director Louis Uccellini in a small ceremony on campus.

Figure 1. Left to Right: Steve Bruske (NWS), Bill Curtis (UW-Madison EM), Tim Halbach (NWS), Louis Uccellini (NWS), UW-Madison Chancellor Rebecca Blank, Steve Ackerman (CIMSS & AOS), Margaret Mooney (CIMSS), Shane Hubbard(CIMSS) *Photo Credit: Bill Bellon (SSEC)*

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 second year, covers broad range of content and has nearly 3000 followers. (up from 772 a year ago) The CIMSS Facebook page (https://www.facebook.com/CIMSS.UW.Madison) has just over 5,200 fans. Two notable posts from 2015 include an interview and tour of the Milwaukee/Sullivan National Weather Service office that received over 10,000 views and a radar animation of Hurricane Winston making landfall on Fiji which reached over 24,000 people.

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) has over 5,600 followers.

The massive open on-line course (MOOC) that CIMSS co-produced with the UW-Madison Atmospheric and Oceanic Sciences Department called *The Changing Weather and Climate of the Great Lakes Region* remained on-line and accessible on Coursera through the end of the calendar year when over 8,000 people had registered and accessed content. Much of the course has since been moved to a permanent CIMSS web page. (http://cimss.ssec.wisc.edu/education/mooc/)

CIMSS has also been producing content for NOAA's Science On a Sphere® (SOS) and in 2015 published 12 monthly climate digests and a feature story entitled "The State of our Lakes". (http://sphere.ssec.wisc.edu/)

Finally, the **GOES-R Education Proving Ground** (http://cimss.ssec.wisc.edu/education/goesr/) led by CIMSS, expanded in 2015 from six educators from 3 states to 30 teachers from 13 states and Puerto Rico in advance of the October 2016 launch. These teachers are attending webinars, implementing new activities and lessons plans, and developing plans to promote the GOES-R launch in their schools and school districts.

Figure 2. GOES-R Educators.

Ensuring that the education community is *launch-ready* for new satellite imagery and improved products in the GOES-R era will be a high priority for CIMSS in 2016 and beyond.

Publications and Conference Reports

Handlos, Zachary; Mooney, M.; Ackerman, S. and Brossard, D. Assessment of climate literacy within a Massive Open Online Course based on information disseminated by mass media. Symposium on Societal Applications, 11th, Policy, Research and Practice, New Orleans, LA, 10-14 January 2016.

Ackerman, Steve; Mooney, M.; Morrill, J.; Handlos, Z. and Morrill, S. Climate literacy through a partnership with public libraries. Symposium on Education, 25th, New Orleans, LA, 10-14 January 2016.

Mooney, Margaret; Schmit, T. J.; Whittaker, T. M. and Ackerman, S. GOES-R education proving ground. Annual Symposium on New Generation Operational Environmental Satellite Systems, 12th, New Orleans, LA, 10-14 January 2016.

Gunshor, Mathew M.; Schmit, T. J.; Schmidt, C. C.; Lindstrom, S. S.; Gerth, J. J.; Mooney, M.; Whittaker, T. M.; Goodman, S. J. and Gurka, J. J. Employing short courses to prepare for the GOES-R satellite series. Annual Symposium on New Generation Operational Environmental Satellite Systems, 12th, New Orleans, LA, 10-14 January 2016.

Mooney, Margaret; Dahlman, L.; Lewis, P. M. and Robinson, E. ESIP education workshops. Symposium on Education, 25th, New Orleans, LA, 10-14 January 2016.

3. CIMSS Participation in the Product Systems Development and Implementation for 2015

3.1 JPSS PSDI: VIIRS Polar Winds

CIMSS Task Leaders: David Santek, Steve Wanzong
NOAA Collaborators: Jeff Key, Jaime Daniels

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

Project Overview

Satellite-derived wind fields are most valuable for the oceanic regions where few observations exist and numerical weather prediction model forecasts are less accurate as a result. Like the oceans at lower latitudes, the polar regions also suffer from a lack of observational data. Since 2001 we have generated wind vectors in the polar regions using the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra and Aqua satellites. Those products are operational. Several years later, we adapted the algorithm to generate winds from the Advanced Very High Resolution Radiometer (AVHRR) on NOAA-15, -16, -18, -19, Metop-A, and Metop-B. The AVHRR winds are also operational. At this time, thirteen numerical weather prediction centers in nine countries use the MODIS and/or AVHRR winds in their operational systems.

The goal of this project is to transition to NESDIS operations the VIIRS polar wind processing system, which was developed in collaboration with colleagues in STAR. As with MODIS and AVHRR winds, the Level 1 sensor data (in this case, VIIRS Sensor Data Record (SDR)) and NCEP Global Forecast System (GFS) products are input and the winds algorithm is applied to the 11 µm channel. However, the VIIRS winds system employs the new code base that was developed for the GOES-R Advanced Baseline Imager (ABI). The primary differences between new algorithm and the heritage ("windco") code are that (1) the new retrieval software uses an advanced tracking algorithm and (2) an externally generated cloud height product is used to assign heights to the cloud-track winds.

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.

As time permits, we have been investigating the use of additional spectral channels for tracking cloud features, specifically in the shortwave infrared band. Initial results from the MODIS 2.1 µm channel are encouraging and we will continue to monitor that effort.

Also, discussions are ongoing with Australia to generate the VIIRS polar winds at their Direct Broadcast (DB) sites in Antarctica: Casey and Davis. This will be modeled after similar systems in the Arctic region at Fairbanks, Alaska and Sodankyä, Finland. 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 operational code at a later time, as part of an update to the codebase for the MODIS and AVHRR polar winds products.

3.2 Polar PSDI: Transition of MODIS and AVHRR Winds to GOES R/VIIRS Algorithm

CIMSS Task Leaders: David Santek, Steve Wanzong
NOAA Collaborators: Jeff Key, Jaime Daniels

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

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.

As part of the transition evaluation, we are formulating a plan to develop validation tools to compare the polar winds product between the two algorithms. This includes the ability to easily reprocess case studies and automated techniques for statistical comparison and validation with independent observations, e.g. radiosondes.

The remaining milestone on this project is to install the nested tracking algorithm at CIMSS, to be complete by June 2016. A follow on PSDI project will:

- Complete the transition to use the nested tracking algorithm for MODIS and AVHRR at CIMSS and Direct Broadcast locations, and
- Develop a case study infrastructure and statistical validation tools.

3.3 An Enterprise Processing System for Polar (CLAVR-x) Products
CIMSS Task Leader: William Straka III
CIMSS Support Scientist: Steve Wanzong
NOAA Collaborator: Andrew Heidinger

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

Project Overview

The Clouds from AVHRR Extended (CLAVR-x) has been the operational NESDIS cloud processing system for the Advanced Very High Resolution Radiometer for over 10 years. With the advent of the NESDIS Framework, NESDIS desires that all operational processing occur with the STAR Algorithm Processing Framework (referred to SAPF in this proposal).

Milestones with Summary of Accomplishments and Findings

The updated GOES-R cloud algorithms which run on AVHRR have been successfully integrated into the SAPF. Code detailing the ingest of AVHRR data has been provided to NESDIS to be integrated into the SAPF.

Milestone: We are currently working on validating the output of the L1b data from the SAPF. In addition, the enterprise algorithms, which are used in CLAVR-x, have been integrated into the SAPF and are awaiting for the L1b to be validated before testing.

3.4 Polar PSDI: Enterprise Processing Ground System – Volcanic Ash Products
CIMSS Task Leader: Justin Sieglaff
NOAA Collaborator: Mike Pavolonis

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

Project Overview

The goal of this project is to address SPSRB user request 0507-05 submitted by the Washington Volcanic Ash Advisory Center (VAAC). The request is to complete the transition of the AVHRR derived volcanic ash products to NESDIS operations within the AIT Framework. We therefore propose to work with the STAR AIT to transition these products into NESDIS operations. The inclusion of this component into the Enterprise Processing Ground System project will address long-standing hardware architecture issues that prevented AVHRR volcanic ash products from being generated operationally within in NESDIS.

Milestones with Summary of Accomplishments and Findings
- Preliminary evaluation of volcanic ash product interface
  We have worked with STAR AIT on best practices toward integrating Enterprise volcanic ash algorithms to operate with AVHRR inputs. Specific plans discussed included methodology for building Fortran code interfaces and determine delivery schedule.
- Identify ancillary data input for volcanic ash algorithm
  The planning with STAR AIT has allowed us to determine which ancillary data will be needed for the Enterprise volcanic ash algorithm. Additionally test cases have been identified for validating STAR AIT algorithm implementation.

References

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.

3.5 GEO PSDI: An Enterprise Processing System for Geostationary (GSIP)
CIMSS Task Leader: William Straka III
CIMSS Support Scientist: Steve Wanzong
NOAA Collaborator: Andrew Heidinger

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

Project Overview
The GOES Surface and Insolation Project (GSIP) has been the operational NESDIS cloud processing system for the GOES Imagers. 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 3 shows the results of the latest cloud algorithms integrated into GSIP. Validation of the algorithms was performed as part of the Algorithm Readiness Review, which is to be 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

Milestones:
- Update GSIP with enterprise cloud algorithms.
- Conduct ARR for GSIP updates.
- Deliver Enterprise cloud algorithms to SAPF to run on current GOES.

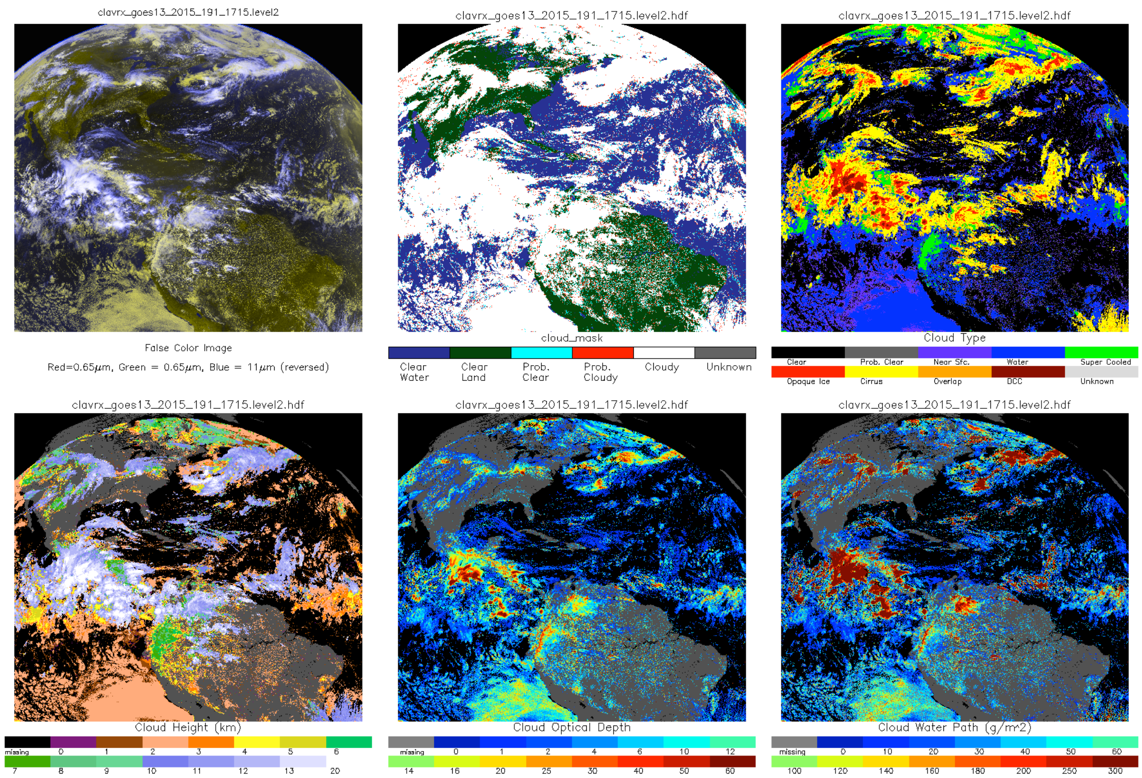


Figure 3. Example GSIP product output.

3.6 GEO PSDI: Enterprise Processing Ground System – Fog and Low Cloud Products
CIMSS Task Leader: Corey Calvert
CIMSS Support Scientist: William Straka
NOAA Collaborator: Michael Pavolonis

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

Project Overview
The goal of this project is to address SPSRB user request 1305-004, submitted by the NWS, to transition the GOES-R Fog/Low stratus (FLS) products to NESDIS operations within the AIT framework. 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 AIT framework. Once the

interface is completed we will continue working with the AIT to evaluate and validate the FLS products in the AIT framework to ensure the quality of the products until the transition is complete.

Milestones with Summary of Accomplishments and Findings

- *Preliminary evaluation of FLS product interface (June, 2015)*
  We developed and implemented the interface to allow the GOES-R FLS algorithm to run in the AIT framework.
- *Identify static ancillary data input for FLS algorithm (June, 2015)*
  All static ancillary data files (e.g., land mask, digital elevation map, SST, surface emissivity data, etc.) were identified and transferred to the AIT.
- *Critical Design Review for FLS products (August, 2015)*
  We successfully completed the CDR for the FLS products. One highlight of the CDR was that the accuracies of the FLS products (validated using surface observations) were all found to easily meet algorithm specifications.
- *Identify dynamic ancillary data input for FLS algorithm (October, 2015)*
  The quality of the GOES-R FLS products is critically dependent on high spatial resolution numerical weather prediction model information from the Rapid Refresh (RAP), and Global Forecast System (GFS) where the RAP is not available. We successfully implemented the ability to utilize these model datasets into the AIT framework.
- *Implementation of FLS algorithm in AIT Framework (December, 2015)*
  The GOES-R FLS algorithm was successfully implemented into the AIT framework, however, additional work to allow temporal data access in the AIT framework is needed to run the FLS algorithm to its full extent. Additional evaluation is underway to ensure the product quality meets our expectations and, if it doesn't, to resolve any issues.

4. CIMSS Participation in the GOES-R Algorithm Working Group (AWG) for 2015

4.1 Proxy Data Support

CIMSS Task Leaders: Tom Greenwald and Allen Huang
CIMSS Support Scientists: Jason Otkin, Todd Schaack, Allen Lenzen, Kaba Bah, Marek Rogal
NOAA Collaborators: Brad Pierce

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

Project Overview

This task supports GOES-R AWG 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 $1^o x 1^o$ 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).

This project works in close collaboration with the GOES-R Data Operations Support Team (DOST), the AWG Algorithm Integration Team (AIT), and the NWS to provide real-time simulated ABI data in GOES-R ReBroadcast (GRB) form for ground system testing, algorithm testing within the AIT Framework through comparison with products produced at CIMSS using GEOCAT (e.g., cloud properties, legacy sounding retrievals, aerosol properties, total column ozone, and fire detection), and for display within AWIPS II for testing and user preparedness. In addition, ABI GRB files are run in near-real-time as needed to support Proving Ground activities through generation of RGB imagery and GEOCAT Baseline products.

Milestones with Summary of Accomplishments and Findings

- Provided real-time Full-Disk (East, West, and 140E) and CONUS (East and West) 16-band proxy imagery for GOES-R ground system testing and validation activities during the FY15 GOES-R Data Operations Support Team (DOST) Data Operations Exercises (DOE0-DOE5).
- Real-time synthetic ABI imagery is being supplied to the AWIPS routinely over the NOAAPORT Satellite Broadcast Network (SBN) on the new GOES-R East feed as part of the end-to-end testing for GOES-R ABI data delivery.
- We worked with Joe Zajic (NOAA/NESDIS) to supply a real-time synthetic imagery data stream into the ABI L1B Simulator RaFTR (Resample and Format, Timed Release) for NWS AWIPS II Environmental Data EXchange (EDEX) testing to support GOES-R pre-launch development, integration, test, and validation activities (Boukabara et al. 2016). (See Figure 4).
- We developed scripts to generate RGB air mass GRIB2 files from our simulated ABI WRF-Chem files for ingest into standard AWIPS II and to support the National Center's Perspective (NCP) version of AWIPS II. NCP is a customized version of AWIPS II used at the NOAA Center for Weather and Climate Prediction.
- We published an article in the Bulletin of the American Meteorological Society that describes the system we developed to generate real-time proxy ABI data and how these data are used for user preparedness and product evaluation (Greenwald et al. 2016).

Publications and Conference Reports

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.

Boukabara, S. A., Z. Tong, S. Lord, S. Goodman, R. Atlas, B. Pierce, Lidia Cucurull, Milija Zupansky, 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. P.F. Casey, D. Lindsey, L. Grasso, K. Kumar, A. Powell, J. Xu, T. Greenwald, J. Zajic, J. Li, J. Li, B. Li, J. Liu, L. Fang and P. Wang, 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. Bull. Amer. Meteor. Soc., provisionally accepted.

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.

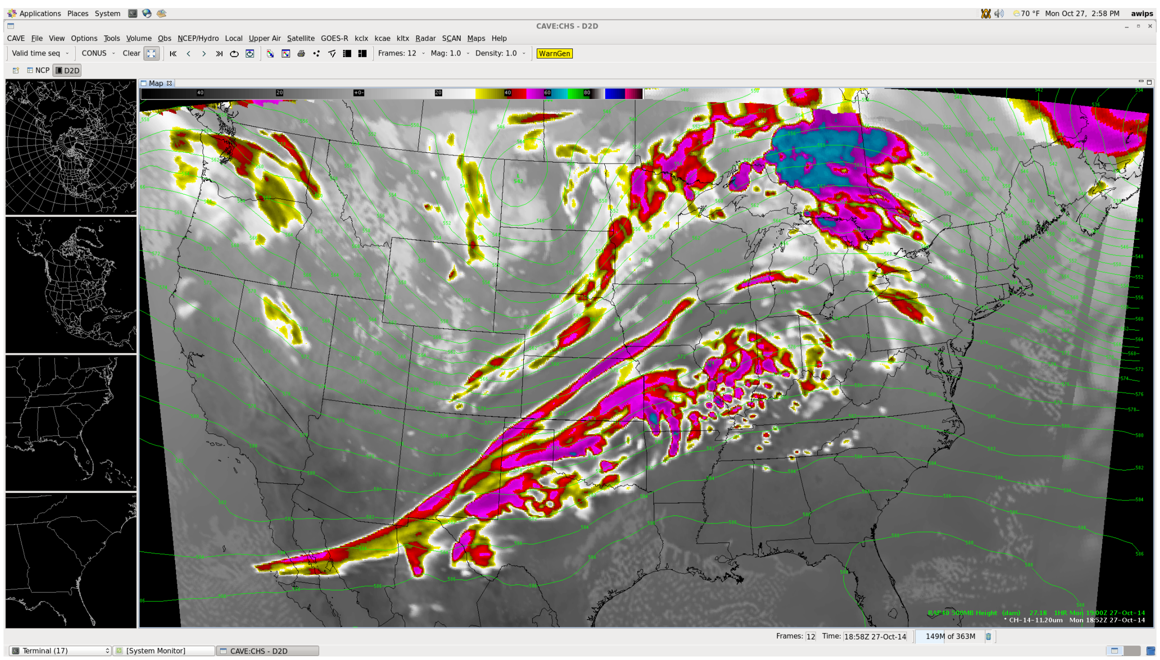


Figure 4. Screen capture during AWIPS II testing on November 7, 2014 which included visualization of synthetic ABI channel 14 (11.2 µm) CMI along with real-time METAR data within AWIPS II Common AWIPS Visualization Environment (CAVE) Display 2-Dimensions (D2D) perspective (Courtesy of Joe Zajic).

4.2 GOES-R Analysis Facility Instrument for Impacts on Requirements (GRAFIIR)
CIMSS Task Leader: Mathew Gunshor
CIMSS Support Scientists: Hong Zhang, Eva Schiffer
NOAA Collaborator: Tim Schmit

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

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.

Milestones with Summary of Accomplishments and Findings

By their nature, waivers are not predictable, which includes the topic of a waiver and the timing. Hence, no milestone dates were chosen for waiver activities. The following were the proposed exercises, or milestones:

- Maintain GRAFIIR datasets and software.
- Respond to AIT requests for support of team product validation activities.
- ABI waiver analysis if necessary: Respond to proposed changes in ABI instrument specifications to assess their potential effects on products, via GOES-R Product Working Group (PWG).
- Update diagnostic tools.

- Updates to Glance will be made available to AWG/AIT.

There were no ABI waivers this reporting period that the GOES-R program requested assistance from the GRAFIIR team to address. Previously the GRAFIIR team has addressed 12 waivers and instrument deviations to date (Figure 5).

Glance updates continued as program needs arose and users requested new capabilities. For example, the arrival of actual data from the Advanced Himawari Imager (AHI), an imager very similar to the GOES-R ABI, prompted a change to Glance in how some plots were generated because the sheer volume of pixels in a 0.5km resolution full disk image taxed the software in ways simulated data previously had not. In June of 2015 Glance was updated to version 0.3.1.8 which included updates to scatter plot behavior and the start of a switch to a new netCDF library, made necessary by updates to netCDF files. In July Glance was updated to version 0.3.1.9, which completed the switch to the new netCDF library. This allows Glance to handle a much wider range of files. Glance also went through compatibility investigations with special file types, such as GOES-R ground system files as well as Himawari files generated from "Himawari Standard Format."

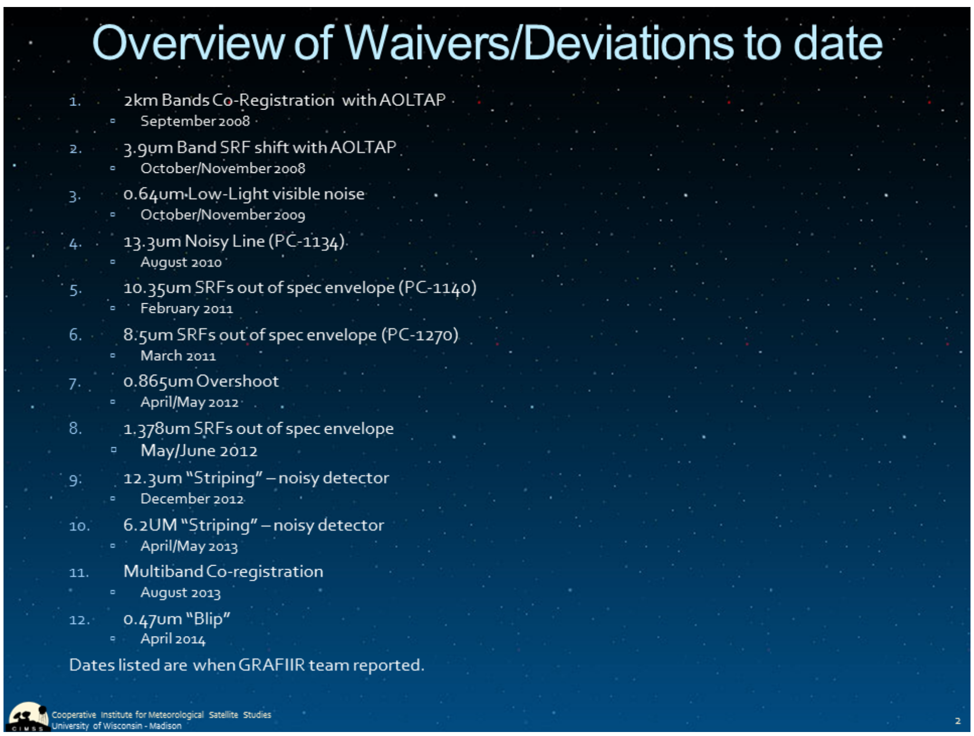


Figure 5. A list of all ABI waivers addressed by the GRAFIIR program to date.

4.3 Algorithm Integration Team Technical Support

CIMSS Task Leader: R. Garcia
CIMSS Support Scientists: G. Martin, E. Schiffer, W. Straka
NOAA Collaborators: M. Pavolonis, W. Wolf

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

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.
- Maintained expanded, and deployed verification and automation test tools in coordination with GRAFIIR and AIT-East.
- 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.
- Added Himawari-8 (AHI) processing capability to algorithm development environment software (Geocat, CLAVR-X) as a proxy for ABI.
- Work with proxy team to integrate additional proxy input into reference/test science software.
- Continued 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 work and Cal/Val.
- 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 integration and 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.
- 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 preliminary assessment of Harris/AER operational code algorithm samples.
- NOFS workflow improvements to improve speed of algorithm integration and testing work.

- Continued work on extracting sharable functionality in Geocat to external libraries usable by SAPF, CLAVR-X et al including ingest, calibration, navigation and numerical utilities.
- Authored C/Fortran/Python callable toolbox used for algorithm development systems to access Himawari Standard Data format, permitting imagery and Level 2 algorithms to be tested shortly after the availability of AHI near-real-time data.
- Integration of libHimawari into GEOCAT, and rapid NetCDF transcoding capability provided for imagery and CLAVR-X rapid validation using AHI data.
- Technical and product feedback for AHI provided to JMA through NOAA channels.
- Retained and distributed test and ancillary datasets in support of AWG deliverables
- Provide guidance and assistance to science staff as needed to improve computer science aspects of algorithm reference software. This included CIMSS/SSEC infrastructure maintenance in support of AWG algorithm work and Cal/Val.
- 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.
    - Preliminary integration activities for CIMSS algorithm updates for delivery to AIT-East also to be included.
- 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.

4.4 GOES-R Collocation

CIMSS Task Leader: Robert Holz
CIMSS Support Scientists: Greg Quinn, Ralph Kuehn, Fred Nagle, and Alexa Ross
NOAA Collaborators: Walter Wolf and Jaime Daniels

NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation
- Healthy Oceans
- Resilient Coastal Communities and Economies

NOAA Strategic Goals:

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

CIMSS Research Themes:

- Satellite Sensors and Techniques

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 1970's as part of the NOAA satellite group lead by Bill Smith Sr. and Fred Nagle to help support the early NOAA polar and geostationary 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

This is the fourth year of funding under the GOES-R program. Accomplishments to date include:

- Porting the AIRS/MODIS collocation software to C++
- Developing a test system to validate the new C++ library
- Inter-comparing the UW-Madison and NOAA versions of the AIRS/MODIS spatial weights
- Testing the new collocation software by inter-calibrating AIRS and MODIS (both TERRA and AQUA)
- Developed GEO-LEO collocations including JPSS CrIS and VIIRS observations
- Validation web interface and products for the GOES-R program. We have successfully implemented into the GOES-R validation system:
  - Cloud Property (SEVIRI GOES-R products)
  - Wind heights (SEVIRI GOES-R products)
  - Aerosol (using SEVIRI operation product as test data)
  - CALIPSO and MODIS validation products for clouds, winds, and aerosols.

Publications and Conference Reports

AMS Meeting 2016: An Integrated Geo-Stationary Validation System for GOES-R

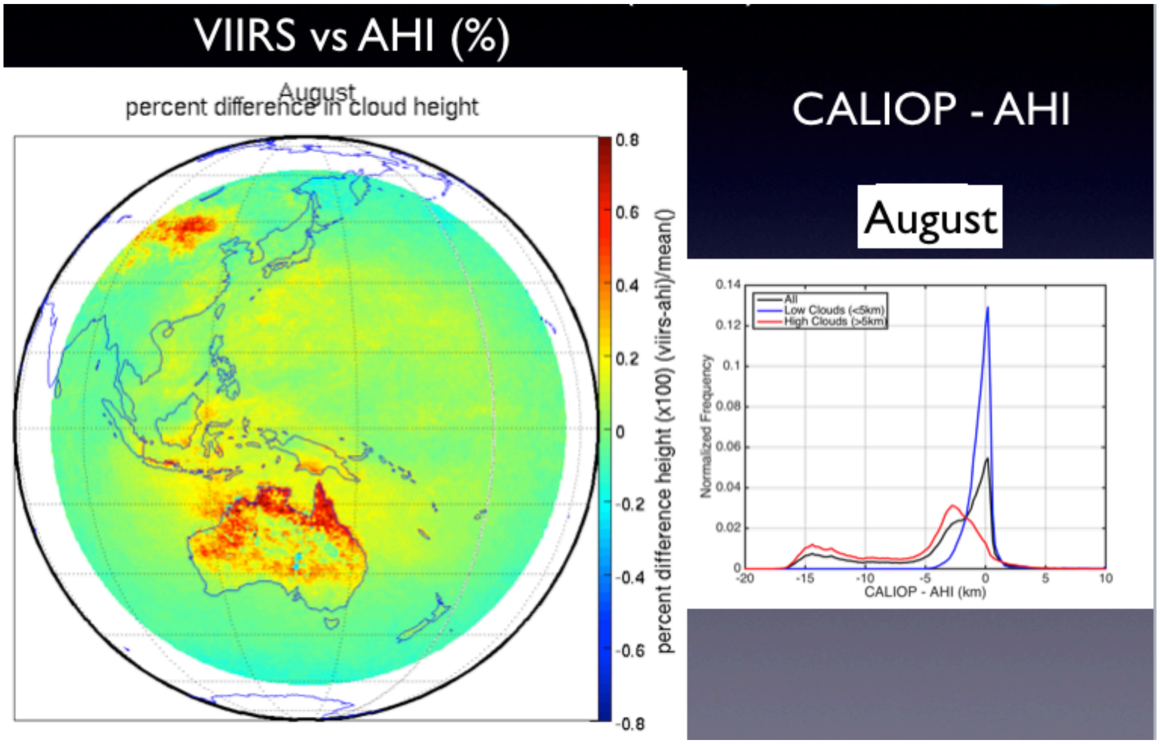


Figure 6. The Inter-comparison of one month of AHI and VIIRS cloud top height retrievals presented as % differences. The GOES-R cloud top height algorithms was applied to both the VIIRS and AHI observations.

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

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

Project Overview

National Environmental Satellite, Data, and Information Service, Center for Applications and Research (NESDIS/STAR) and the Cooperative Institute for Meteorological Studies (CIMSS) have been developing a suite of products that will offer advanced cloud detection and retrievals of cloud properties utilizing the GOES-R ABI instrument. The Cloud 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 sensors, COMS, Himawari-8 (ABI like imager), MTSAT, MODIS, VIIRS as well as making sure that the baseline algorithms work on the simulated ABI datasets. This will ensure that the algorithms will be fully tested and validated prior to the launch of GOES-R and the ABI instrument.

Validation of the current and updated algorithms is important to ensure the algorithms perform as expected once GOES-R launches. 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 EUMETSAT Cloud Retrieval Evaluation Workshop (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, was used during the Hurricane and Severe Storm Sentinel (HS3) campaign to aid in flight path decisions for the Global Hawk Unmanned Aerial Vehicle (UAV) over and around Atlantic tropical cyclones. Figure 7 shows how post processing comparisons between cloud height and CALIPSO allow the HS3 team confidence in the product. In addition, the cloud algorithms are also being used as part of the University of Alabama, Huntsville Convective Initiation algorithm, in near-realtime, which is discussed in section 5.9 of this report.

As mentioned, the Cloud AWG continues to support the GOES-R Ground Segment (GS) System Prime, Harris Corporation, in their implementation of the cloud algorithms. The GS released their first output of the cloud algorithms in November 2013, where several issues were noticed. Along with the Algorithm Integration Team, Midwest (AIT-MW) at CIMSS, the Cloud AWG passed along comments and analysis to help improve the GS.

In 2015, the Cloud AWG continued to improve the various cloud algorithms, support the GS in their effort as they produce output from the baseline cloud algorithms, 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. In addition, 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. This will prepare the team for the launch of GOES-R in 2016. In addition, this will provide information on possible post-launch improvements for each algorithm.

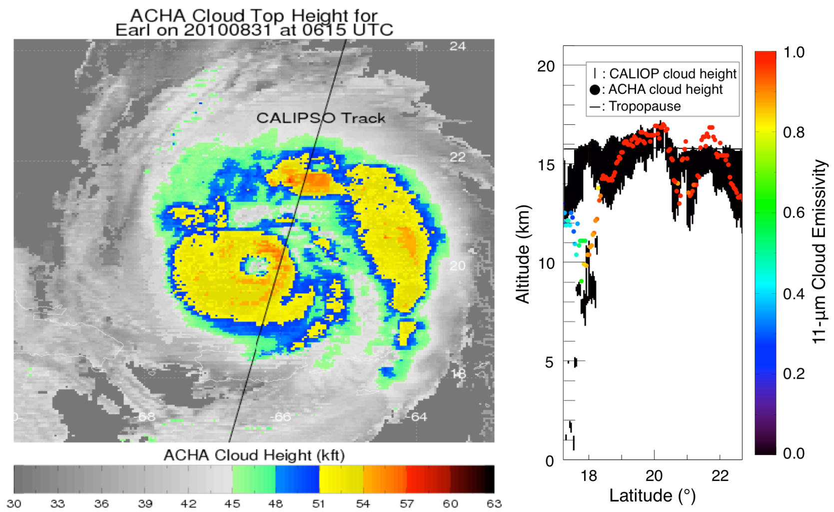


Figure 7. Post hurricane analysis of category 4 Hurricane Earl comparing ACHA cloud heights with CALIPSO. ACHA cloud heights match CALIPSO well in the convective eyewall and outer band.

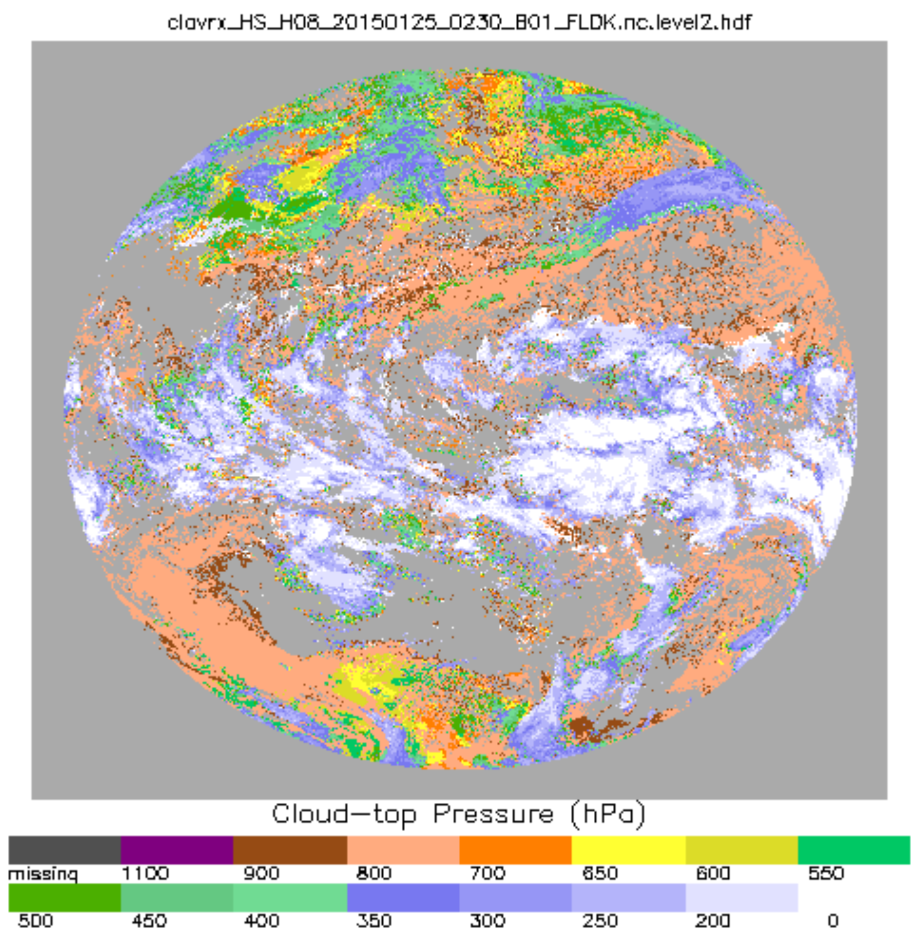


Figure 8. Example ACHA cloud top pressure product derived from Himawari 8 AHI observations.

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4.6 Active Fire/Hot Spot Characterization
CIMSS Task Leader: Chris Schmidt
NOAA Collaborators: Yunyue Yu (NOAA/NESDIS/STAR), Ivan Csiszar (NOAA/NESDIS/STAR)

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

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

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

Project Overview
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. This effort includes collaboration with MODIS and NPOESS VIIRS fire product development experts to maximize future use of multiple data sources (geo and leo) that take advantage of the strengths of each system to create improved fused fire products. The collaboration also has led to the development of innovative "deep-dive" validation tools. This activity will ensure enhanced future geostationary fire detection, diurnal monitoring, and characterization in the GOES-R era. The validation component of this work is performed in conjunction with Dr Wilfrid Schroeder from CICS.

Milestones with Summary of Accomplishments and Findings
The FY15 milestones for CIMSS were
- Maintenance update(s) to fire algorithm using pre-launch test samples based on AHI input data
- Perform pre-launch routine validation tests using AHI input data
- Draft paper on ABI fire algorithm and proxy data
- Support AIT and/or ground system contractor with Level 2 fire product verification; exercise/demonstrate the corresponding fire validation tools

The expenditure period for this project encompassed April through July of 2015. Work primarily consisted of development of validation software, support for AIT and the ground system contractor with respect to algorithm implementation, and outreach to the Broadcast community.

The validation software for the FDCA is composed of two components, routine and deep-dive validation. The deep-dive validation software is being primarily developed by Dr Wilfrid Schroeder at CICS, with participation from CIMSS, and utilizes high resolution (Landsat class) data to validate fire detections by lower resolution satellites, such as current GOES, MODIS, and VIIRS. Ground truth validation of a fire algorithm is difficult, various fire databases exist for federal, state, Native American, and private lands, but at best they provide locations. This deep-dive tool can provide precise location and size information, though not temperature or fire radiative power. It allows some assessment of omission and commission errors on the part of the FDCA. CIMSS has been working the Dr Schroeder on developing the tool and providing reference data for testing. Deep-dive validation is a manual process as the high resolution data matchups is relatively infrequent.

The routine validation process consists of visual comparison between various satellite sources of fire data for what amounts to a sanity check of the FDCA data. The performance of the FDCA will be assessed by comparing the fire location data to other available sources, such as polar orbiting platforms using visualization software (IDL, Google Earth, McIDAS-V, etc) that can display multiple datasets simultaneously; web-based mapping tools like SSEC's RealEarth will be the primary tools as they can function through a web browser. This tool won't assess performance for false alarms, missed detections, and fire characteristics as the deep-dive tool does.

Outreach for the FDCA (and WFABBA) was once again extended to the broadcast meteorology community in 2015. CIMSS presented the science behind the algorithm and sample outputs, including 1-minute GOES-14 data, at the 43rd Conference on Broadcast Meteorology in Raleigh, NC in June. As with the year before, the team received feedback on how to best present satellite fire data to garner the interest of the broadcast community, specifically timely data and animations accompanied by localized information about the fire complex and its impact (such as comparing extent to local references) was strongly encouraged.

L2 data with fires output did not become available during the project period.

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, Jordan Gerth, Jim Nelson and Bill Bellon

NOAA Collaborator: Tim Schmit

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

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) Advanced Baseline Imager (ABI) (Schmit et al. 2005) 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 LAP algorithm to be able to process high temporal and spatial resolution ABI data efficiently. This project provides science codes to the GOES-R algorithm integration team (AIT) for algorithm integration and helps the system provider to implement the algorithm and prototype codes into the GOES-R ground system. CIMSS scientists will also evaluate and validate the GOES-R LAP algorithm to assure that the GOES-R legacy atmospheric temperature and moisture profiles, TPW, LI, CAPE, TT, SI and KI products meet the science requirements and operational applications.

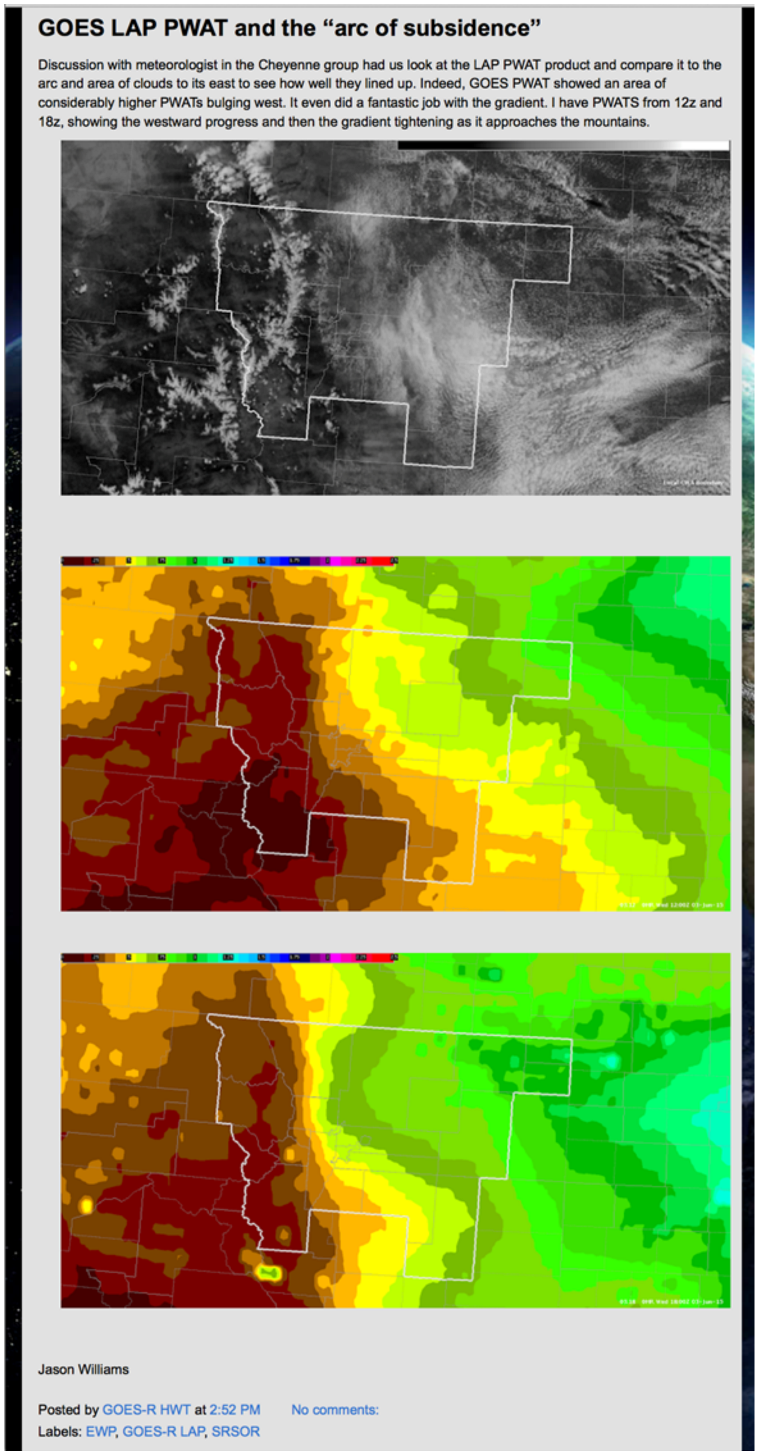
Milestones with Summary of Accomplishments and Findings

Participated 2015 HWT spring experiment (March – June 2015)

The GOES Sounder LAP products were accessed for 2015 HWT experiments and forecast applications since May 2015. The satellite Proving Ground (PG) at the Hazardous Weather Testbed (HWT) took place from 04 May to 12 June 2015. HWT has accessed the GOES-13/-15 Sounder LAP products for PG applications since early May 2015. There were two times when the GEOCAT stopped sending data and this issue was quickly resolved. Overall good demonstration and useful products, but GOES Sounder as proxy has certain limitation (too noisy for GOES-13 Sounder).

A lot of feedback obtained from forecasters during HWT PG demonstration, some of them are listed here: (a) Allow direct comparisons between LAP products and other fields (from RAOB, NWP, etc). The gradients and trends in the fields very useful; (b) Helpful for environmental analysis, where convective activity was most likely to occur; (c) The discontinuities negative for the forecasters (resolved for GOES-13 Sounder later); and (d) Training material could have more useful examples.

More comments/feedback on all-weather LAP product applications can be viewed from the following link: http://goesrhwt.blogspot.com/search/label/GOES-R%20LAP



GOES LAP PWAT and the "arc of subsidence"

Discussion with meteorologist in the Cheyenne group had us look at the LAP PWAT product and compare it to the arc and area of clouds to its east to see how well they lined up. Indeed, GOES PWAT showed an area of considerably higher PWATs bulging west. It even did a fantastic job with the gradient. I have PWATS from 12z and 18z, showing the westward progress and then the gradient tightening as it approaches the mountains.

Jason Williams

Posted by GOES-R HWT at 2:52 PM No comments:

Labels: EWP, GOES-R LAP, SRSOR

Figure 9. Comments from Jason Williams during HWT PG.
One example of feedback from HWT on 03 June 2015 is listed below.

One example of comment during HWT: GOES LAP PWAT and the "arc of subsidence". "Discussion with meteorologist in the Cheyenne group had us look at the LAP PWAT product and compare it to the arc and area of clouds to its east to see how well they lined up. Indeed, GOES PWAT showed an area of considerably higher PWAT bulging west. It even did a fantastic job with the gradient. I have PWATS from 12z and 18z, showing the westward progress and then the gradient tightening as it approaches the mountains. " (see Figure 9)

The complete report on HWT applications of GOES Sounder LAP products with GOES-R algorithm is also provided by William Line.

GOES-R LAP algorithms have been successfully applied to INSAT-3D for demonstration (June 2015 – September 2015)

INSAT-3D sounder has the similar characteristics and instrument specification as U.S. GOES Sounder. CIMSS sounding team have applied the GOES-R LAP algorithm to INSAT-3D. The algorithm includes: the INSAT-3D PFAAST type radiative transfer model developed at CIMSS in clear skies. The inputs include INSAT-3D IR counts (converted to brightness temperatures), and GFS forecasts (could be other NWP model forecasts), while the outputs include the atmospheric temperature and moisture profiles, TPW and 3 LPW, atmospheric instability indices, cloud-top pressure, optical thickness, and retrieval quality flags. Animation and more examples can be seen from the following PPT:
ftp://ftp.ssec.wisc.edu/ABS/AWG/insat_3d_RTVL_example.pptx

Publications and Conference Reports

Lee, Y.-K., Z. Li, E. Borbas, J. Li, and T. J. Schmit, 2015: Validation of GOES-R LAP algorithm with MODIS measurements, AMS Annual Meeting, 04 – 08 January 2015, Phoenix, ZA

4.8 ABI Derived Motion Winds

CIMSS Task Leaders: Chris Velden and Steve Wanzong
CIMSS Support Scientist: David Stettner
NOAA Collaborator: Jaime Daniels (STAR)

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

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

Milestone 1. Keeping the AWG cloud team software in sync with the AWG DMV team software. The software is developed in a different framework (CLAVRx) than the DMV software

(GEOCAT), so it is necessary to modify bridge and services software to correctly access the cloud products in the DMV code. Testing and modifications to the DMV processing code, along with all validation activities, were dependent on this interaction.

Milestone 2. The DMV reprocessing effort using the GOES-R algorithms. 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. In addition, software was needed for several unit conversions and missing variables (eg: finding tropopause temperature and pressure).

Milestone 3. The DOE version 1&2 L2 validation exercise was completed. Although the DMV data from Harris was problematic, we were still able to run some validation tools on the data.

Publications and Conference Reports

Foster, M., A. Heidinger, M. Hiley, S. Wanzong, A. Walther, and D. Botambekov, 2016: PATMOS-X Cloud Climate Record Trend Sensitivity to Reanalysis Products. JRS, in review.

4.9 Hurricane Intensity Estimation (HIE) Algorithm

CIMSS Task Leaders: Chris Velden and Tim Olander
NOAA Collaborator: Jaime Daniels (STAR)

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

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 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 the launch of the GOES-R satellite:

Milestone 1. Preparation and testing of the HIE validation software package to be utilized within the GOES-R AWG framework. The software package has been tested globally in real-time at CIMSS during the previous 2015 and current 2016 TC seasons. All validation results are presented via the CIMSS ADT webpage. In addition, the GOES-R HIE Validation Readiness, Implementation, and Management Plan (RIMP) document has been updated to include all latest modifications to the AWG validation software package.

Milestone 2. 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. To assess the impact of the higher spatial-resolution data on the ADT, parallel intensity analyses were derived in real-time utilizing MTSAT imagery and the higher spatial-resolution Himawari-8 imagery during the period when both data sets were available. In addition, a second study was performed to investigate the use of higher-temporal resolution data on the ADT algorithm. Intensity analyses using 10-minute and 30-minute imagery were compared. Examples are provided in Figure 10. Real-time comparisons are presented via the CIMSS GOES-R Proving Ground HIE webpage.

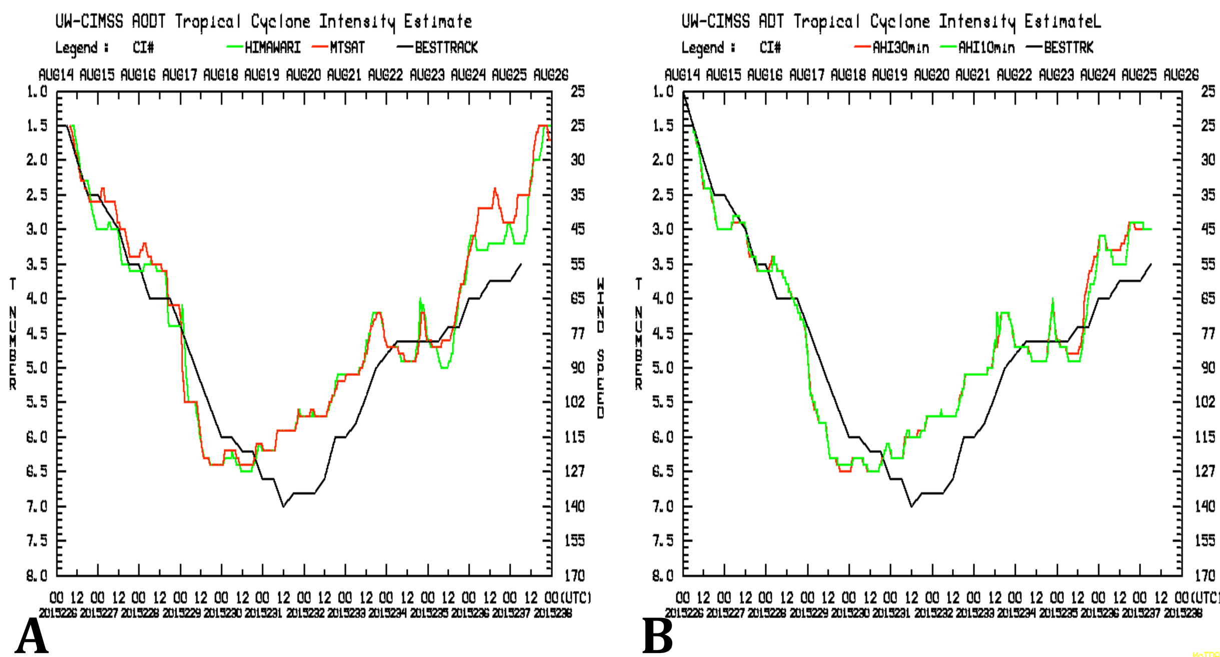


Figure 10. Comparisons between ADT intensity analyses using A) MTSAT (red line) and Himawari-8 (green line) imagery and B) Himawari-8 30-minute (red line) and 10-minute (green line) imagery for Tropical Cyclone 17W. The JTWC best track intensity is provided for comparison (black line).

Publications and Conference Reports

Olander, T. and C. Velden, 2016: The current status of the Advanced Dvorak Technique (ADT). 32nd AMS Hurricanes and Tropical Meteorology Conference, San Juan, PR, April 17-22.

Velden, C. and T. Olander, 2016: Reprocessing the "Top Ten" most intense tropical cyclones in the satellite era using the Advanced Dvorak Technique. 32nd AMS Hurricanes and Tropical Meteorology Conference, San Juan, PR, April 17-22.

Olander, T. and C. Velden, 2016: The Advanced Dvorak Technique. 2nd International Workshop on Satellite Analysis of Tropical Cyclones (IWSAT-II), Honolulu, HI, February 17-19.

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
CIMSS Support Scientist: John Cintineo
NOAA Collaborator: Mike Pavolonis

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

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. We propose to continue 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 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 GS TIM's as needed and respond to Harris-AER questions
  We evaluated the level 2 file contents of the GOES-R DOE 1&2 delivery for the volcanic ash algorithms. This evaluation revealed the file attributes and variables were as expected; however no ash pixels were detected and it was necessary for the ground system implementation of the ash detection algorithm be analyzed and any errors corrected.
- Complete development of validation code for volcanic ash product
  The volcanic ash product validation code has continued to be developed.
- Update GEOCAT processing software to ingest AHI proxy data
  GEOCAT updates were made for ingest of AHI proxy data, which enables processing volcanic ash products using AHI data.
- Participate in international volcanic ash product inter-comparison workshop
  We delivered GOES-R volcanic ash products to the WMO volcanic ash product inter-comparison workshop and an example of the inter-comparison activities are shown in

Figure 11. The inter-comparison found "NOAA scheme has good level of consistency….also tendency to correlate with other schemes".

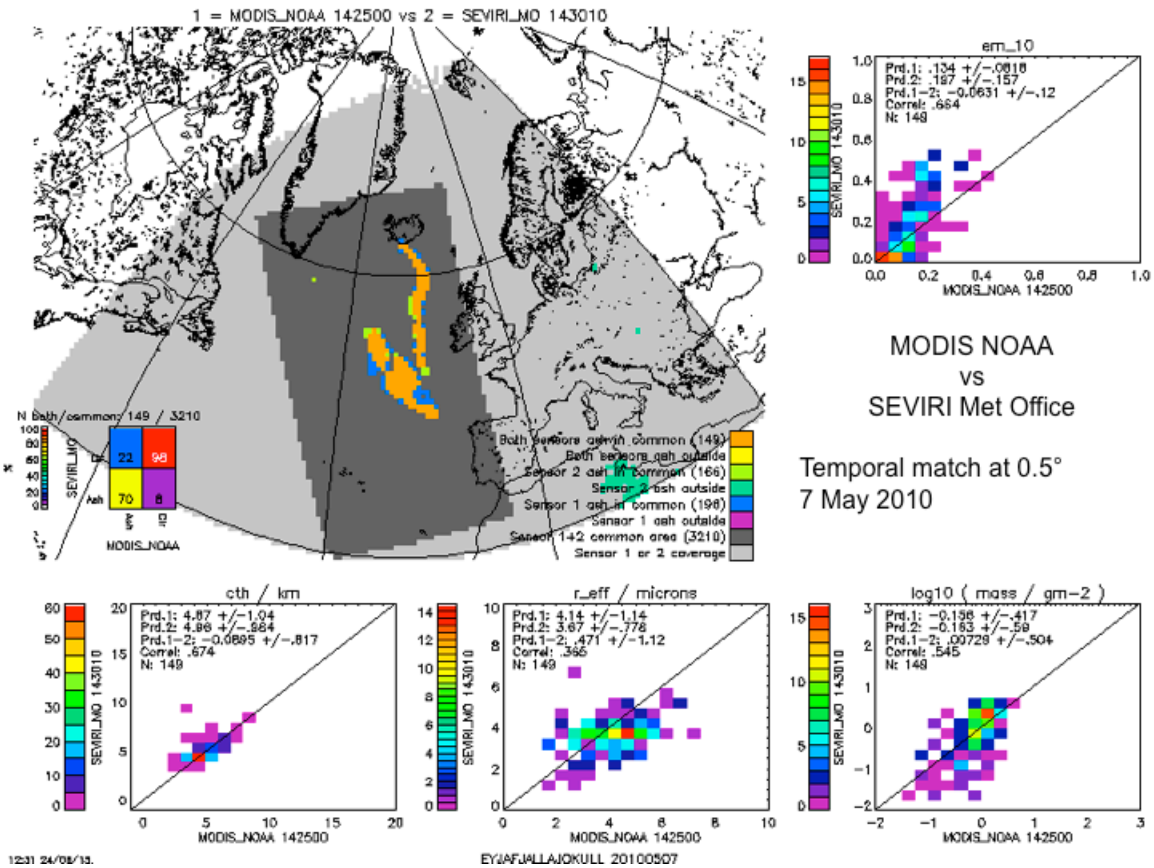


Figure 11. Example of the WMO volcanic ash inter-comparison workshop—comparing NOAA results vs UK Met Office results for 7 May 2010 of the Eyjafjallajokull volcanic eruption. Source: WMO Volcanic Ash Inter-Comparison Workshop, 2015.

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, Jim Nelson
NOAA Collaborator: Tim Schmit

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

Project Overview

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

For visualization, McIDAS-V is CF-netCDF ready, meaning it understands the structure and semantics of CF conventions so the official product files of the GOES-R ABI can be immediately imported into the system without any additional programming. While an excellent interactive visualization tool, it remains relatively under-utilized as a scripting tool for more automated, or repeatable, validation applications. The Imagery Team is exploring McIDAS-V scripting capabilities and working with the McIDAS programming team to more fully develop them.

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 develop ADDE servers for visualization and generation of McIDAS AREA files, both AHI and ABI; support study of alternative scan mode scenarios; and continue algorithm and ATBD maintenance as needed.

Milestones with Summary of Accomplishments and Findings

The milestones proposed this year were as follows:

- Apr 2015: Test AHI McIDAS-X/V ADDE server; validation activity for ABI
- May 2015: Test ABI McIDAS-X/V ADDE server, serving DOE generated output.
- Jun 2015: Reports on PUG, DOE, and DOST validation activities.
  - Jun 2015: DOE-1
  - Jul 2015: DOE-2
  - Aug 2015: DOE-3
  - Nov 2015: DOE-4
- Dec 2015: McIDAS-V scripts to display Level 2B Imagery
- Jan 2016: McIDAS-V scripts to display difference images, with statistics.
- Feb 2016: GOES-R Imagery website prototype; imagery from scripts.
- March 2016: Validation plan documentation (updates as required).
- March 2016: Updated versions of McIDAS-V complete with documentation, if applicable.

Some of the calendar year 2016 milestones will be addressed in a future report. The ABI and AHI ADDE servers have been released and tested. Testing is ongoing with other McIDAS functions related to ABI data as well. The DOE-1 and DOE-2 tests were combined by the Program into one test. Since the GOES-R launch date was pushed back to October 2016, the date of DOE-4 has been pushed back into 2016 as well. In addition to these DOE tests, the GOES-R program has added GRE (Ground Readiness Exercises) and prior to that were asked to analyze the "Final Product Set" FPS data set CMIP files. The Imagery Team has developed, and continues to improve, a McIDAS-V script to display imagery.

There were several datasets that were provided for testing the Imagery validation tools. The first was the Final Product Set (FPS) data that the team analyzed. Starting with Level1b radiance data, CMIP files were generated and compared to the FPS CMIP file output. File contents were compared to expectations based on Product User Guide (PUG) documentation. Discrepancies between the file sets were noted and reported to the GOES-R Program. File comparisons were done in Glance, a tool developed by the GOES-R AWG program at CIMSS by the GRAFIIR and AIT teams. The same tests were performed later on DOE-1/2 imagery outputs as well. In addition to this, contents of the PUG volume covering Imagery were reviewed and errors were reported to the Program.

The Imagery Team has opted to make use of the SSEC RealEarth web mapping service project as a website to display imagery. AHI, including true color composite imagery, is being displayed on RealEarth as a preparatory exercise for GOES-R. The team also makes use of other display tools such as AWIPS-II and demonstrated the ability to visualize proxy data flowing through NOAAPORT to our AWIPS-II station (Figure 12). The team also worked with National Weather Service personnel to improve AWIPS-II satellite data enhancements.

Multiple McIDAS-V and McIDAS-X programming and scripting improvements were made during this time. For McIDAS-V this included layer rendering improvements to alleviate visual artifacts on overlapping satellite images, crontab scripts to automate region selection to produce AHI RGB kmz files for RealEarth (converted from kmz to geoTiff), scripting tools were updated to better handle DOE-1/2 datasets, , making use of Virtual network Computing (VNC) to remotely run McIDAS-V scripts on a server, newly developed functions for reading and processing gridded data such as netCDF, and updating McIDAS-V scripting capabilities to be able to convert GOES-R epoch times to a human-readable format. For McIDAS-X the primary focus was on unix shell scripts to generate animations from McIDAS-X images which could be posted to YouTube or on the CIMSS Satellite Blog, especially making use of the GOES-14 SRSOR data.

In addition to these activities, the Imagery Team contributes to the ABI Band Fact Sheets that are published on the GOES-R website. The team provides multiple types of images and figures for these types of education and outreach activities, including images that show approximate pixel area maps, the size of CONUS scans for GOES-East and GOES-West locations, and the size/shape of mesoscale scans which can vary greatly depending on location. Additionally weighting function plots from forward model calculations and spectral response functions figures have been provided for training and use in the Fact Sheets.

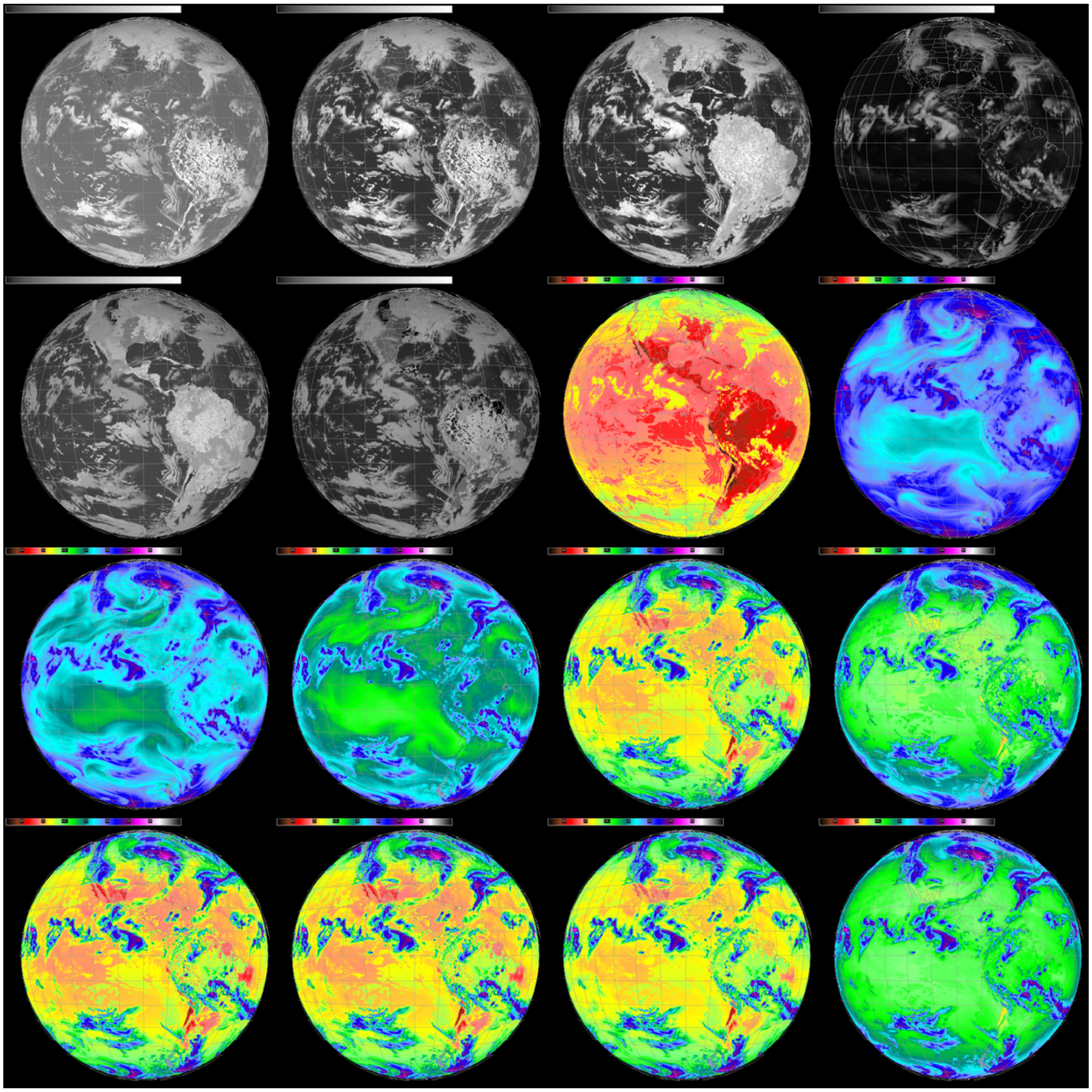


Figure 12. GOES-R ABI simulated data at the post-launch "central" location generated from forecast model, remapped to teh ABI fixed-grid, ingested through NOAAPORT, and displayed on an AWIPS-II workstation at CIMSS. All bands are shown here with the "square-root enhancement" on the visible and near-IR bands (1-6) and an 11-bit color enhancement on the IR bands.

Publications and Conference Reports

"Preparing for imagery from the next generation of geostationary imagers," a poster by Mathew Gunshor, Tim Schmit, Kaba Bah, Joleen Feltz, and Tom Rink was presented at the 2015 NOAA Satellite Conference in Greenbelt, MD (Apr 27-May 1, 2015).

There were two presentations: "Using McIDAS to Prepare Users for the ABI" by Mat Gunshor and "Using the McIDAS-V Scripting API for Daily Research Tasks" by Joleen Feltz at the McIDAS Users Group (MUG) Meeting 8-11 June 2015. Joleen Feltz also led the McIDAS Advisory Committee (MAC) breakout and provided an Update to the MUG and led a group discusson.

4.12 Estimation of Fractional Snow Cover with ABI
CIMSS Task Leaders: Yinghui Liu, Xuanji Wang
NOAA Collaborator: Jeffrey Key

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

Project Overview
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). 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.

Milestones with 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. Case studies of GOES-R ABI fractional snow product have been carried out to evaluate and improve the current level 2 products. Figure 13 shows a comparison of GOES-R ABI Level 2 snow cover on June 19, 2015 using proxy data during the data operations exercise 1 and 2, and snow cover from the National Ice Center's Interactive Multisensor Snow and Ice Mapping System on June 19, 2015. Near real time product is being developed using MODIS data as proxy here in CIMSS. A website will be created to present the results. Future work includes routine runs on more test data on MODIS, SEVERI, and possibly AVHRR and JMA's H-8/AHI data when available. New validation studies that extend previous activities, both spatially and with other comparison datasets (e.g., IMS, passive microwave products, and Landsat) will be carried out.

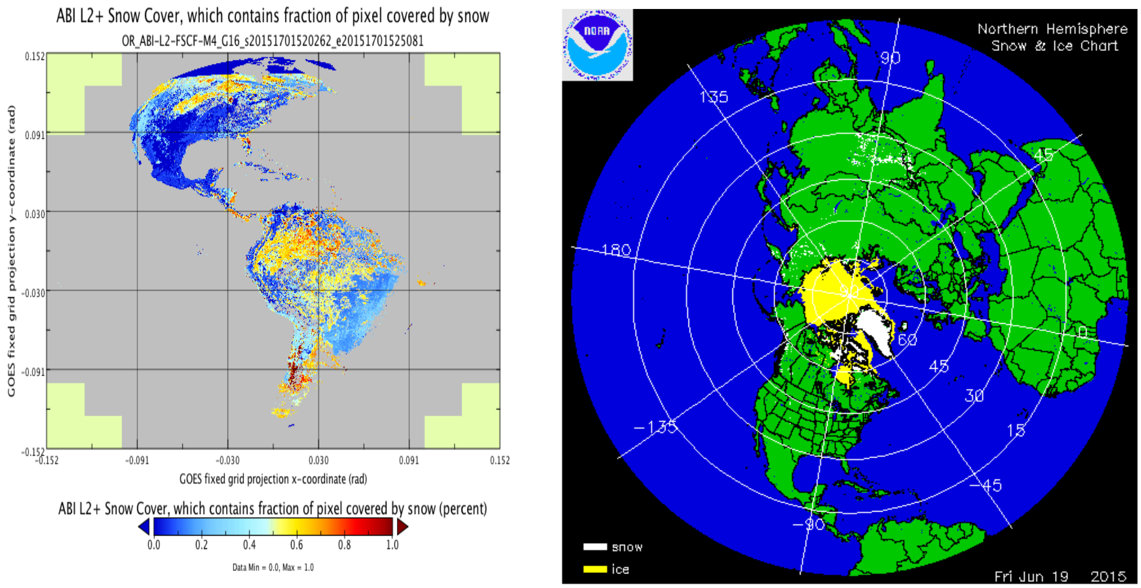


Figure 13. GOES-R ABI Level 2 snow cover on June 19, 2015 using proxy data during the data operations exercise 1 and 2 (left), and snow cover from the National Ice Center's Interactive Multisensor Snow and Ice Mapping System on June 19, 2015.

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 Continuation, Future Capabilities, and Visiting Scientist for GOES-R Risk Reduction Program for 2015

5.1 Development of a GOES-R Automated Volcanic Cloud Alert System
CIMSS Task Leader: Justin Sieglaff
CIMSS Support Scientist: John Cintineo
NOAA Collaborator: Mike Pavolonis

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

Project Overview

The GOES-R volcanic ash and SO_2 products developed by the Algorithm Working Group (AWG) provide valuable information on volcanic ash cloud height and mass loading, as well as information on the presence of SO_2 clouds. The products, however, are not designed (or required) to issue text alerts to forecasters when a volcanic cloud (ash and/or SO_2) is identified. Text alerts are critical for ensuring that the GOES-R capabilities are fully utilized in the effort to address the 5-minute volcanic cloud warning criteria established by the international aviation community, as forecasters cannot constantly manually analyze GOES-R imagery and products in real-time. As such, we proposed to develop an automated volcanic cloud alert system for GOES-R. More specifically, we proposed to utilize the output of the official GOES-R volcanic ash, SO_2, and lightning detection algorithms in combination with a sophisticated, but computationally efficient, scheme to identify volcanic clouds with skill comparable to that of a human analyst. When a volcanic cloud is identified, a text alert with quantitative information on the physical properties of the cloud, along with a quicklook product image, will be issued. The proposed alert system will build upon the automated ash cloud alert system developed by NOAA/NESDIS/STAR for the Advanced Very High Resolution Radiometer (AVHRR). Unlike the AVHRR system, the GOES-R system will be capable of identifying SO_2 clouds and identifying volcanic ash clouds with greater accuracy. The GOES-R system will also be able to take advantage of temporal information. The Spinning Enhanced Visible/Infrared Imager (SEVIRI) and the Moderate Resolution Imaging Spectroradiometer (MODIS) will be used as proxy for GOES-R Advanced Baseline Imager (ABI) data, and a ground-based lightning detection network will be used as a proxy for the GOES-R Lightning Mapper (GLM). M. Pavolonis (NOAA/NESDIS/STAR) led the development of the official GOES-R volcanic ash and SO_2 products, and will lead the development of the proposed automated alert system at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) with Co-I J. Sieglaff. Co-I Ronald Thomas (New Mexico Tech) will provide the proxy GLM data and lightning network expertise. Co-I Nathan Eckstein (SOO, Alaska Aviation Weather Unit) will coordinate the user feedback component of the development process. The Anchorage and Washington Volcanic Ash Advisory Centers support the proposed activities, which are well aligned with the goals of the NOAA Volcanic Ash Working Group (VAWG) (M. Pavolonis is a member of the VAWG).

Milestones with Summary of Accomplishments and Findings

1. *Provide third version of cloud object filtered (within alert system) GOES-R AWG volcanic ash products to modeling groups for use in model validation and data assimilation studies.*
   We have provided quality controlled, filtered volcanic ash cloud object output to Co-Is within the HYSPLIT group for incorporating results into an automated HYSPLIT model initialization.
2. *Provide near-realtime alerts to the Anchorage and Washington Volcanic Ash Advisory Centers (VAACs) and collect their feedback on alert performance, format, and content.*

The Washington and Anchorage VAACs have been given full access to automated volcanic cloud alerting system, including user customizable subscription options (e.g., users can select which alerts they receive based on alert type, geography, satellite, region of responsibility, etc.). Additionally M. Pavolonis and J. Sieglaff met with representatives from the Washington and Anchorage VAACs during June 2015 at the WMO Volcanic Ash Intercomparison Meeting to discuss additional improvements to the alerting system. Figure 14 shows an example of a real-time alert used by the Anchorage VAAC for an ash resuspension event during August 2015 (ash was resuspended off the ground by high winds coincident with the annual minima of snow cover).

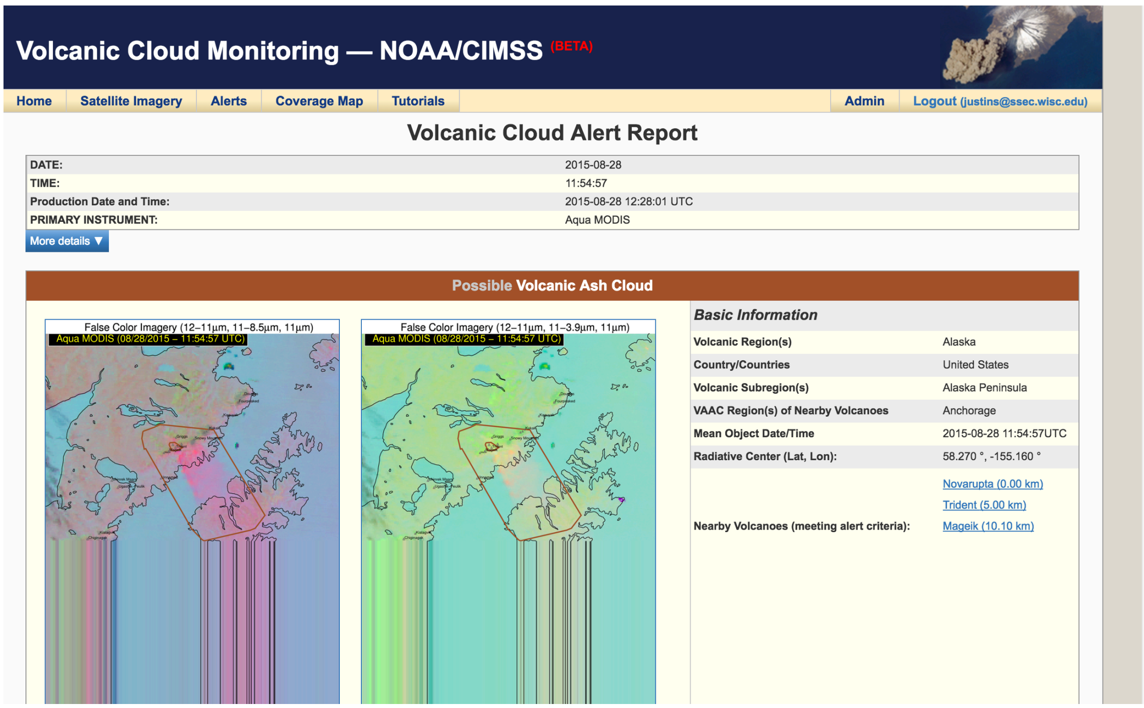


Figure 14. Screen shot of NOAA/CIMSS volcanic ash cloud alert for a Katmai ash resuspension event in Alaska during August 2015. The automated email alert and associated information on the website was used by the Anchorage VAAC in issuing volcanic ash advisories and SIGMETS for this event.

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.

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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.

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

CIMSS Task Leader: James Jung
CIMSS Support Scientists: Sharon Nebuda, Dave Santek
NOAA Collaborators: Jaime Daniels, John Derber

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

Project Overview

An improved Atmospheric Motion Vector (AMV) product was developed for the Geostationary Operational Environmental Satellite (GOES-R) Advanced Baseline Imager (ABI) using a new tracking algorithm developed by Bresky et al, (2012). This new tracking algorithm has been demonstrated to significantly improve the slow speed bias inherent in the AMVs derived from previous algorithms. This significant reduction in the speed bias of the AMVs could benefit Numerical Weather Prediction (NWP) by improving the analyses and the accuracy of NWP forecasts.

Hourly proxy data sets were created by applying this new GOES-R AMV nested tracking algorithm to imagery from the Meteosat Spinning Enhanced Visible InfraRed Imager (SEVIRI). The data set includes four AMV types from channels 2 (visible), 7 (near infrared), 8 (cloud top water vapor), and 14 (infrared). This hourly proxy data provided the opportunity to improve the AMV algorithm and determine software changes needed for the National Center for Environmental Prediction (NCEP) Global Data Assimilation System / Global Forecast System (GDAS/GFS) using the Gridpoint Statistical Interpolation (GSI) to successfully assimilate these data. The GDAS/GFS analyses during two different seasons were used to collect data assimilation statistics for evaluation. Quality control procedures were reviewed by examining existing quality control parameters as well as considering new parameters related to the new GOES-R AMV algorithm. Estimating the appropriate observation error for this AMV product was also required. The new assimilation techniques were determined, reviewed and incorporated into the GSI by the NCEP Environmental Modeling Center (EMC).

Milestones with Summary of Accomplishments and Findings

In April 2015, Dr. Kirsti Salonen from the European Center for Medium Range Weather Forecasting (ECMWF) traveled to meet with Sharon Nebuda at CIMSS to discuss strategies for the successful assimilation of the future GOES-R AMV. Concurrent with Kirsti's visit, Xiujuan Su and Iliana Genkova from NOAA National Centers for Environmental Prediction (NCEP) were able to travel to CIMSS to participate in the AMV discussions. The issues discussed included GOES-R AMV quality control and observation error, data thinning, blacklisting, observation operator (point versus layer), and the situational dependent observation error approach used at ECMWF.

To prepare for the use of GOES-R AMVs by operational data assimilation centers, a proxy dataset has been provided by NOAA NESDIS using imagery from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) onboard Meteosat-10. Conclusions from testing the proxy GOES-R AMV data with the Global Forecast System (GFS) Data Assimilation System was presented during the visit (Nebuda et al, 2012 & 2014). The new algorithm provides a set of parameters related to the tracking and height assignment which were examined for use in quality control. Using the GFS background winds, statistics of AMV wind departure were compiled and the dependence of the departure on the various parameters was examined to determine if the parameter had any skill predicting departure bias or wind vector difference root mean square error. A description of the algorithm parameters, their characteristics, and the selection of the quality control procedures were presented. The mean speed bias for the observation AMVs minus the GFS first guess as well as the vector difference RMS for the hourly proxy GOES-R AMVs for November 2013 (Figure 15) demonstrates the impact of the selected quality control procedures on the departure statistics. Counts for the 4 types of AMV are presented for reference (Figure 16). Gridpoint Statistical Interpolation (GSI) tuning tests which indicate a preference to using a smaller observation error than the current GOES AMVs were discussed as well. Results from the GFS testing was provided for reference to ECMWF to facilitate comparison between the two centers. Testing at NOAA NCEP is also underway using AMVs created from the current GOES imagery using the nested tracking algorithm; preliminary results were presented from this effort. Continued collaboration is planned to support both ECMWF and NOAA NCEP efforts to minimize the time between GOES-R AMV availability and operational use.

The recommended quality control and departure check procedures were accepted by NCEP EMC and software modifications have been provided for incorporation into the next GSI implementation release. NCEP has begun testing the modified software necessary to read the future satellite wind BUFR table sequence soon to be released by the World Meteorology Organization. Incorporating both the reading sequences and GSI procedures are on schedule to assure timely use of the operational GOES-R AMVs.

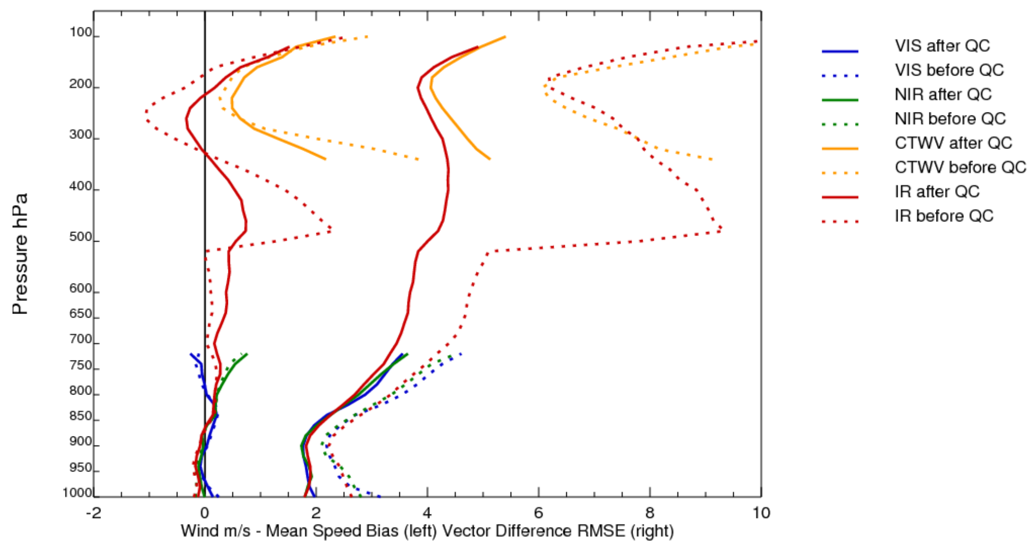

Figure 15. Nov 2013 Mean speed departure as a function of pressure for Observation minus GFS first guess (left) and vector difference RMS (right) for the proxy GOES-R AMVs before and after quality control procedures are applied. The 4 types of AMVs are visible (VIS), Near infrared (NIR), Cloud Top Water Vapor (CTWV), and Infrared (IR).

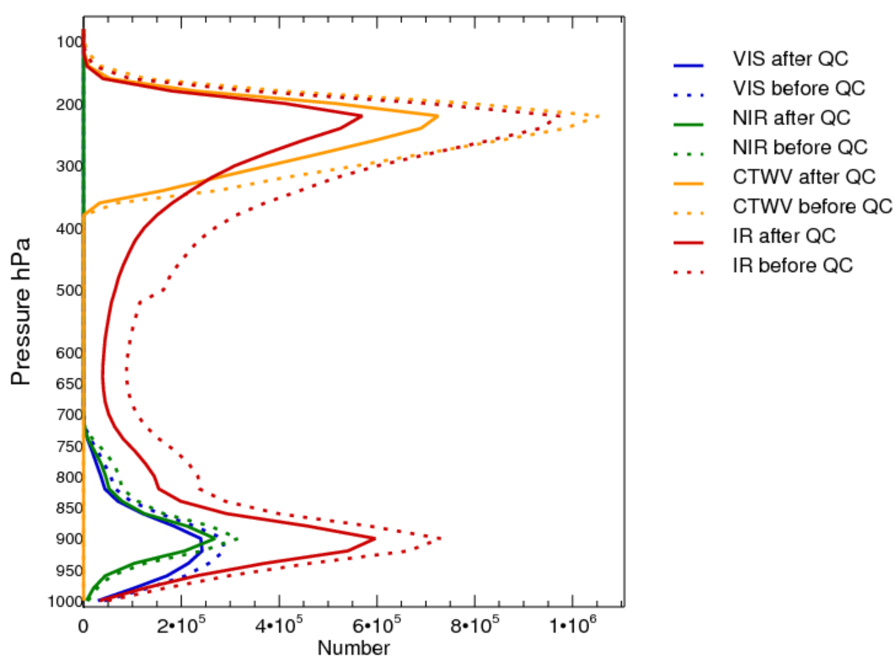

Figure 16. Nov 2013 Data counts for the 4 types of proxy GOES-R AMVs before and after quality control procedures are applied.

References

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

Nebuda, S., J. Jung, D. Santek, J. Daniels, and W. Bresky, 2012: Evaluation and Quality Control of Nested Tracking Approach for Atmospheric Motion Vectors (AMVs). *Proc. 11th Intl. Winds Workshop*, Auckland, New Zealand.

Nebuda, S., J. Jung, D. Santek, J. Daniels, and W. Bresky 2014: Assimilation of GOES-R Atmospheric Motion Vectors (AMVS) in the NCEP Global Forecast System. *Proc. 12th Intl. Winds Workshop,* Copenhagen, Denmark

5.3 Ensemble Simulation of GOES-R Proxy Radiance Data from CONUS Storm-Scale Ensemble Forecasts, Product Demonstration and Assessment at the Hazardous Weather Testbed GOES-R Proving Ground
CIMSS Task Leader: Jason Otkin
NOAA Collaborators: Steve Weiss, Fuzhong Weng, Jack Kain, and Dave Turner

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

Project Overview

As part of the NOAA Hazardous Weather Testbed (HWT) Spring Experiment (Clark et al. 2012), the Center for the Analysis and Prediction of Storms (CAPS) has produced high-resolution ensemble model forecasts in real-time over the contiguous U.S. since 2007. By utilizing national supercomputing resources, sophisticated forward radiative transfer models will be used to generate synthetic infrared brightness temperatures at hourly intervals for several CAPS ensemble members during the HWT Spring Experiments. Because the ensemble members employ different cloud microphysical and planetary boundary layer parameterization schemes, an evaluation of the radiative transfer models, parameterization schemes, and forecast model performance will be possible at a convection-allowing resolution. The synthetic GOES satellite imagery will be made available in near realtime to the HWT as part of the GOES-R Proving Ground. The project will help familiarize operational forecasters, numerical modelers and physical scientists with the capabilities of the GOES-R Advanced Baseline Imager (ABI) sensor.

Milestones with Summary of Accomplishments and Findings

During the past year, we continued to support GOES-R Proving Ground activities by generating synthetic GOES and GOES-R ABI infrared brightness temperatures for several members of the CAPS ensemble during the 2015 NOAA HWT Spring Experiment. The accuracy of the simulated brightness temperature datasets was evaluated through comparison with real GOES observations. In addition, collaborative efforts were initiated with scientists at the German Deutscher

Wetterdienst and the University of Oklahoma to explore the impact of assimilating clear and cloudy sky infrared brightness temperatures at convection-resolving resolutions using an ensemble Kalman filter (EnKF) data assimilation system.

References

Clark, A., and Coauthors, 2012: An overview of the 2010 Hazardous Weather Testbed Experimental Forecast Program Spring Experiment. *Bull. Am. Meteorol. Soc.,* **93**, 55-74.

5.4 Infrastructure – RGB Products in AWIPS II

CIMSS Task Leader: Mathew Gunshor
CIMSS Support Scientist: Kaba Bah
NOAA Collaborator: Tim Schmit

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

Project Overview

This project builds on previous work done at CIMSS, CIRA, and SPoRT. Feedback from operational forecasters highlights the usefulness of RGB satellite imagery which helps to discriminate specific features of interest that are present in a complex scene. The three institutes in the past have developed and focused on their own RGB products and this year were coordinating more to better serve National Weather Service (NWS) forecast office eventual needs in the GOES-R era in terms of how products are delivered to the operational environment. The CIMSS team was focusing on the CIMSS RGB Air Mass product. The real-time ABI forecast imagery generated using WRF-CHEM and the CRTM (funded by GOES-R AWG) were used to generate the RGB imagery.

RGB imagery, along with more quantitative products, may provide the most information by exploiting the best of both attributes. The RGB allows a quick look, while the derived product, such as ozone, total precipitable water, etc. can provide for a better understanding of the current state. Simulated forecast imagery of the ABI spectral bands allow for preparation for the RGB combinations possible with the GOES-R ABI and provide a means of forecasting RGB imagery.

Results from this Infrastructure RGB Project will eventually be integrated into operations at WFOs and National Centers. The volume of data coming down from GOES-R is substantial and finding innovative ways to visualize the data to aid forecasters and others in operational arenas will help ensure the future success of GOES-R.

Milestones with Summary of Accomplishments and Findings

The proposed milestones were as follows.

- Utilize the GRIB2 output from the NCEP Unified Post Processor (UPP) as a template to generate simulated ABI GRIB2 files.
- Use the newly defined synthetic GOES-R ABI bands in the NCEP GRIB2 tables to output CIMSS simulated ABI reflectance and brightness temperatures into GRIB2 files for visualization of air mass RGB images within the D2D and the National Centers Perspective (NCP).
- Work with NCEP to test and properly display these newly developed GRIB2 files from our simulated ABI reflectance and brightness temperatures in the NCP.

Testing Sample GRIB2 Files at NCEP in the NCP Perspective

We have successfully worked with Stephen Gilbert at NCEP to test sample GRIB2 simulated ABI airmass RGB images for proper display locally at NCEP. These sample files were generated by using CIMSS in house developed IDL and Fortran code that leverages current GOES GRIB2 tables and definitions and associated parameters. In addition, we have also worked with the NCEP Central operations (NCO) representative Jeff Ator to test the newly defined synthetic GOES-R GRIB2 Discipline 3 (SPACE products) category 192 (forecast satellite imagery category) for the purpose of generating simulated ABI GRIB2 files for visualization of airmass RGB images at NCEP. Sample feedback image provided by Stephen Gilbert at NCEP is shown below in Figure 17.

Code Development for Routine Airmass RGB GRIB2 Files

The Fortran code used in our first testing for sample GRIB2 files was relatively old and not ideal for generating GRIB2 files for future satellites such GOES-R, partly due to hard coded fields and parameters for current GOES. As a result we decided to adopt the more general and heavily used GRIB files generation package within the community called Unified Post Processor (UPP V2.2). This turned out to be a dead end because the GRIB2 file generation subroutines in UPP were not fully functional within the package at the time. After further investigation, we determined that the best path forward is to develop a python based package that leverages WGRIB2, pyresample and pyproj to accomplish this goal. We are currently in an advanced stage of this code development and are planning to deliver our first set of sample files to NCEP for testing in early May. This new package will also be portable to NCEP so that post GOES-R launch, instead of transferring files via the LDM to NCEP, we can hand over code for local generation of derived GOER-S ABI airmass RGB images on the fly.

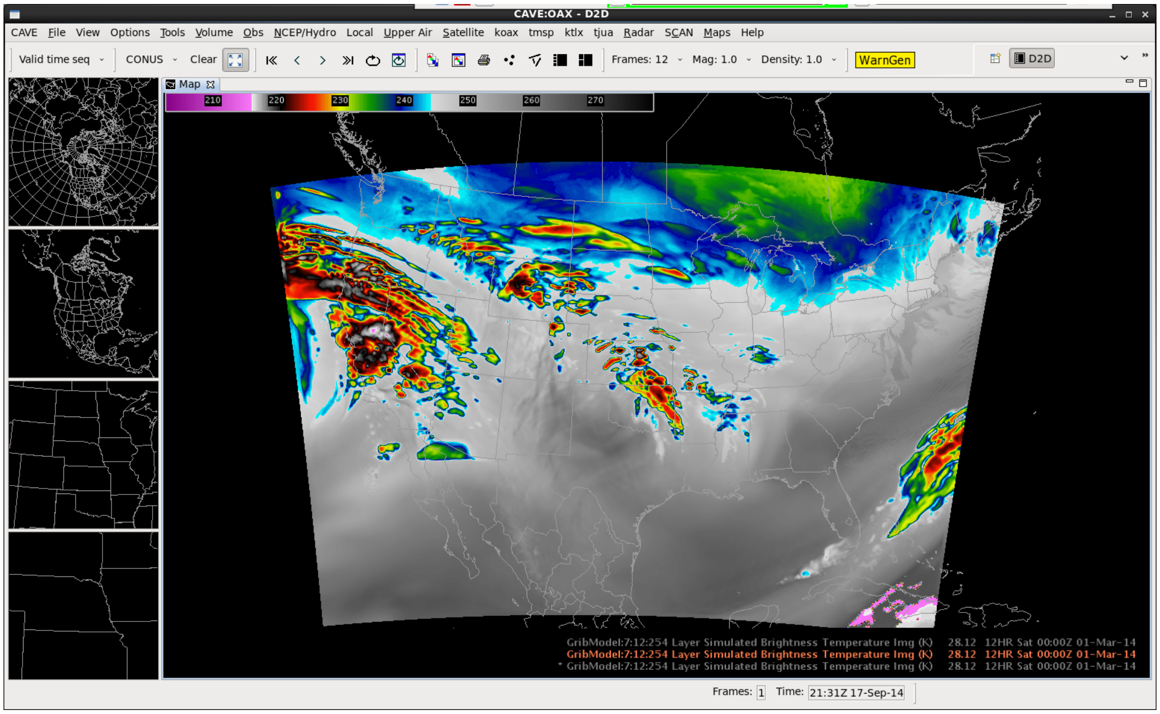

Figure 17. Sample simulated GOES-R ABI brightness temperatures needed to generate AIRMASS RGB images on the file packaged in GRIB2 and display at NCEP. (Stephen Gilbert at NCEP proved this image and Kaba Bah at CIMSS generated the sample GRIB2 files for testing).

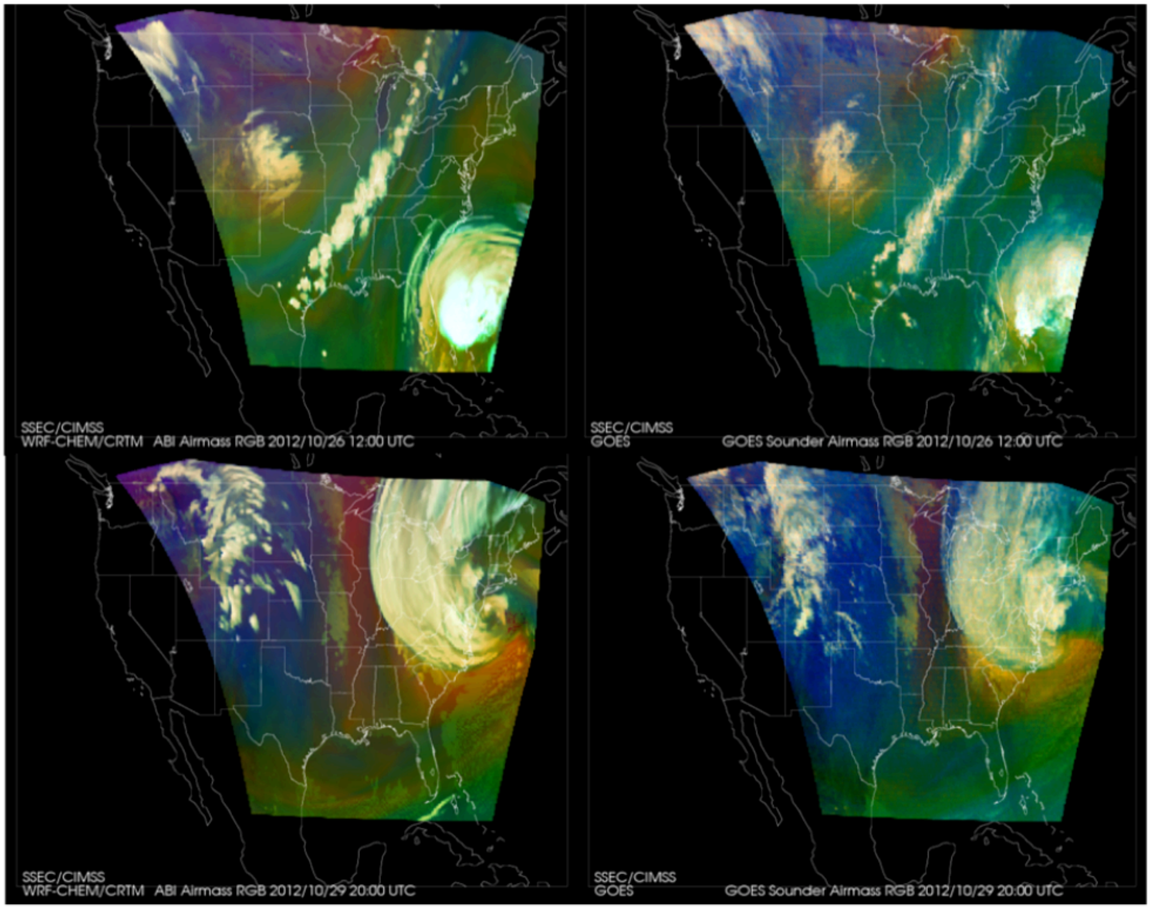

Figure 18. Simulated (a) ABI- and (b) GOES-13-observed RGB airmass imagery for hurricane Sandy at 1200 UTC 26th Oct-2012. (c),(d), but for 2000 UTC 29th 0ct-2012.

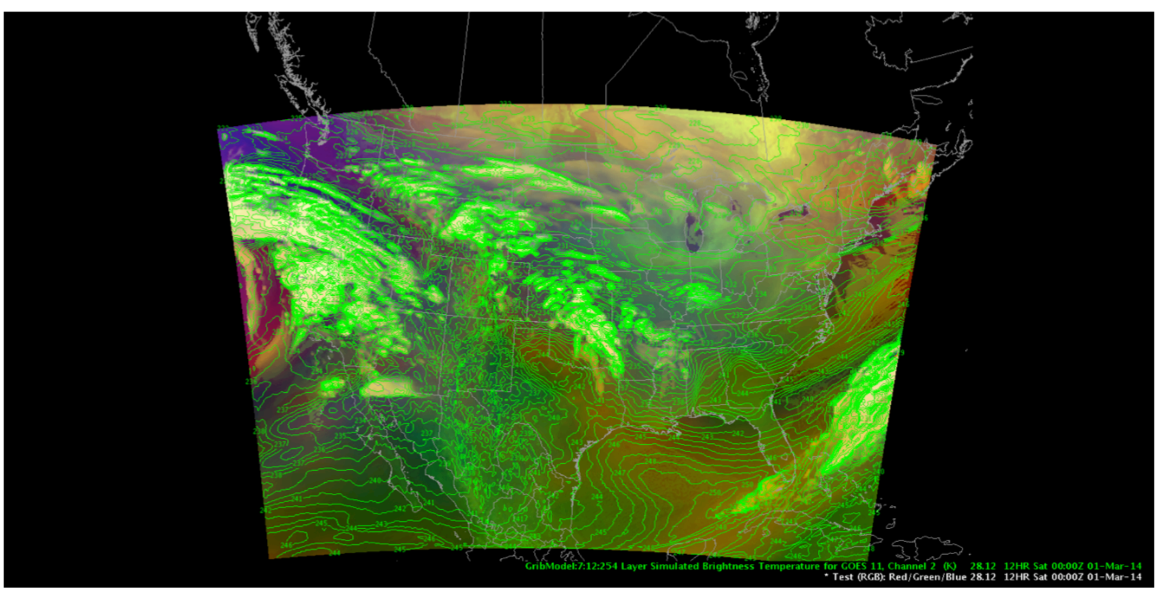

Figure 19. Simulated ABI airmass RGB images displayed in AWIPSII FOR 00:00utc 01ST March 2014, overlaid with simulated ABI channel 11(8,5um). The input file format is GRIB2 and these files were locally generated at CIMSS.

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

CIMSS Task Leader: Corey Calvert
CIMSS Support Scientists: Chad Gravelle and Scott Lindstrom
NOAA Collaborator: Michael Pavolonis

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

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 and SEVIRI) and future operational sensors (ABI and VIIRS) and NWP data from a variety of models (GFS, RUC and RAP). In addition to the probability-based products, the GOES-R FLS algorithm also produces an estimation of the fog/low stratus thickness (cloud top height minus cloud base height).

For the most part, the main products mentioned above have already been developed. However, only a few people outside of the algorithm developers have been trained to properly use and understand the products. For this reason, along with further algorithm development, we proposed to create and maintain a comprehensive training module that can be used to remotely train forecasters and other users on how to correctly interpret the GOES-R FLS products. Using this training module we want to continue introducing the GOES-R FLS products to more NWS WFO's and other potential users so they can start working with them, evaluate them, provide feedback and eventually replace the traditionally-used 3.9-11 μm BTD as they become more comfortable using them. This project will ensure the readiness of the fog/low cloud algorithm for operational implementation upon the deployment of GOES-R.

Milestones with Summary of Accomplishments and Findings

- *Refine approach used to incorporate morphometric characterization of landforms into IFR probability algorithm.*
  Initial progress on using morphometric landform classifiers, such as "valleyness," and LEO data to downscale the GOES-R FLS products to the resolution of the Digital Elevation Model (DEM) has been made. The goal of this research is to improve the ability of the GOES-R FLS products to resolve small-scale valley fog events. An example result from the downscaling procedure is shown in Figure 20.
- *Continue development of fog formation alerting capability.*
  We are continuing to evaluate and improve the downscaled FLS probabilities and are still working on determining the best way to use them to develop a valley fog formation alerting capability.
- *Utilize high spatial resolution visible data on GOES/GOES-R satellites to improve the detection and characterization of fog/low cloud during the day.*
  The GOES-R FLS products were produced using the 1km visible band from GOES-13 for support on field campaigns conducted by Environment Canada over Newfoundland and Toronto. Further evaluation is needed to determine if any fine-tuning is needed to improve the overall product quality, but the higher resolution data was warmly received.
- *Validate GOES-R fog/low cloud products using standard surface observations as well as detailed cloud property measurements from field campaigns conducted by Environment Canada.*
  Validation was performed using standard surface observations of surface visibility and cloud ceiling. These results will be presented in a publication to be submitted soon. Additional validation analyses were conducted using high latitude (cold climate) field campaign measurements provided by Environment Canada.
- *Continue Satellite PG demonstration at Alaska Aviation Weather Unit, AWC and Alaska, East, Central, and Western Region WFO's.*
  The AWC, AAWU, and, more than 30 NWS WFO's are utilizing the GOES-R FLS products in operations
- *Maintain training module.*
  The GOES-R FLS training module has been kept up-to-date with region specific training material so that forecasters are trained using examples from geographic locations they are familiar with. Many new examples have also been added to the GOES-R FLS Blog ("the fog blog" - http://fusedfog.ssec.wisc.edu) for user training purposes.

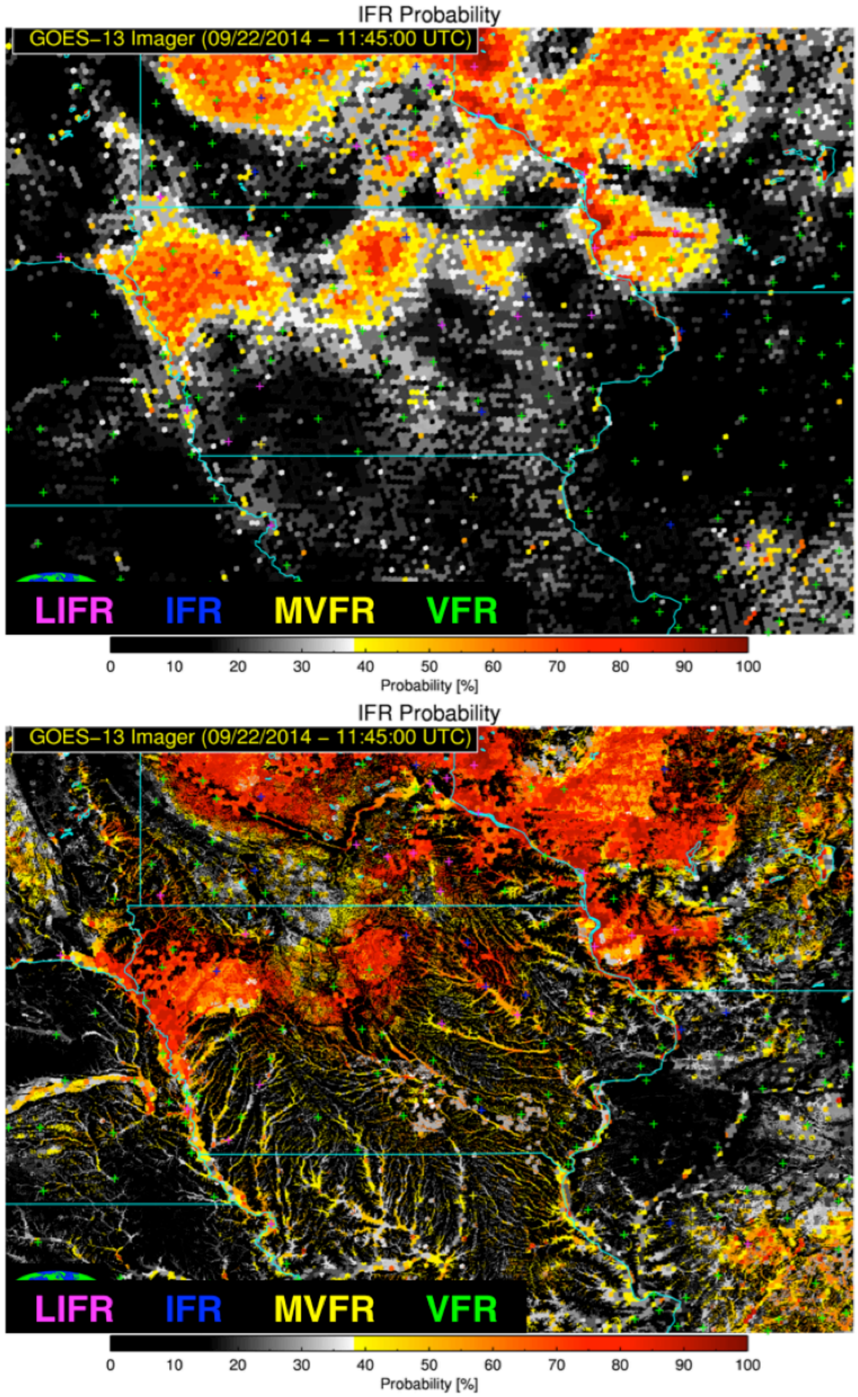

Figure 20. The results of the GOES-R FLS downscaling procedure are demonstrated using GOES-13 data over the Midwest U.S. from September 22, 2014 at 11:45 UTC. The top panel shows the IFR probability derived from native resolution GOES data. The IFR probabilities derived using GOES-13 data and the downscaling procedure is shown in the bottom panel. The downscaled results (500 m resolution) were derived using a 500 m Digital Elevation Model (DEM) and an earlier S-NPP VIIRS overpass. On this day, surface observations (overlaid on each figure) and web cameras indicated that radiation fog formed in many of the river valleys. The fog was generally confined to the river valleys. The downscaling procedure is able to capture the true spatial extent of the fog much better than the results derived from the native resolution GOES-13 data.

Publications and Conference Reports

Conference Presentations:

- Gave a presentation entitled: "Improved FLS Detection Using Multiple Satellite Sensors, NWP Models, and a DEM" at the 2015 OCONUS Technical Interchange Meeting.
- Gave a presentation entitled: "Data Fusion for Fog and Low Stratus Applications" at the 2015 NOAA Satellite Proving Ground/User Readiness Meeting.
- Gave a presentation entitles: "The GOES-R/JPSS Approach for Identifying Hazardous Low Clouds: Overview and Operational Impacts" at the 2016 AMS Annual Meeting.

Gultepe, I., R. Rabin, R. Ware, and M.J. Pavolonis, 2015: Arctic light snow observations: Emphasis on "missing" precipitation., Submitted to *J. Hydrometeorology*.

Calvert, C.G. and M. Pavolonis, 2016: A fused probabilistic approach for detecting fog and low stratus clouds. *To be submitted to Weather and Forecasting*.

5.6 GOES-R Future Capability: Development of the GOES-R Tropical Overshooting Top (TOT) Product

CIMSS Task Leaders: Chris Velden and Sarah Griffin
NOAA Collaborator: Mark DeMaria (NHC)

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

Project Overview

The GOES-R Tropical Overshooting Top (TOT, Monette et al. 2012) product is an algorithm designed to identify convective updrafts and overshooting tops in tropical environments, specifically tropical cyclones (TCs). 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 pixels that are significantly colder than their surroundings (convective overshoots). Trends in TOTs have some correlation with TC genesis and rapid intensification, and have been a part of the National Hurricane Center (NHC) Proving Ground product list since 2011. Feedback from the Proving Ground has facilitated multiple updates to the TOT product.

The TOT product has also been used as a real-time hazard avoidance tool for the Global Hawk pilotless aircraft flown during NASA's Hurricane and Severe Storm Sentinel (HS3) and NOAA's SHOUT field experiments for the past 3 Atlantic hurricane seasons. Feedback from these field programs was positive, with a request that the TOT heights (rather than temperatures) be estimated for better use with aircraft altitude data.

Milestones with Summary of Accomplishments and Findings

Milestone 1: Based on feedback from HS3 and PGs, a method was developed to calculate the height of an overshooting top (OT) using the OT brightness temperature (BT) and numerical weather prediction (NWP) model output. The height of an overshoot can be calculated using the equation:

Overshoot Height (m) = Overshoot Anvil Height + (Overshoot BT – Mean Anvil BT) / lapse rate

where the overshoot anvil height can be estimated by comparing the mean anvil BT to a collocated NWP model profile of temperature and height. The value of the lapse rate is estimated empirically from a dataset of 108 MODIS-detected overshoots that are also observed by the CloudSat Cloud Profiling Radar (CPR). A paper describing this method has been published (Griffin et al. JAMC, 2016).

Milestone 2. The Topical Overshooting Top (TOT) algorithm was updated in 2015 to increase detection in the inner core of tropical cyclones (TC) and reduce false alarms. After the update, TOTs were again tested for skill at predicting tropical cyclone (TC) rapid intensification (RI). TOTs are found to be skillful at predicting RI, as indicated by the positive Peirce Skill Score (PSS) in Figure 21.. The PSS is defined as the probability of detection (POD) minus the probability of false detection (POD). However, the TOT RI Index is less skillful at predicting RI compared to the multi-predictor Rapid Intensification Index (RII). The RII (red bars) has a greater POD and lower false alarm rate (FAR) than the TOT RI Index (blue bars). Adding TOTs to the RII (black bars) increases the skill of yes-no RI forecast, based on the PSS, by increasing the POD while only slightly increasing the FAR compared to the RII. Given the positive results for TOTs predicting TC RI as a single predictor, TOTs were added to an experimental operational probabilistic RI forecast scheme with multiple predictors. Overall, the TOTs had negligible impact on the Brier Skill Score, therefore TOTs are currently not considered for inclusion in a multi-predictor RI scheme which already has other satellite-derived and lightning predictors.

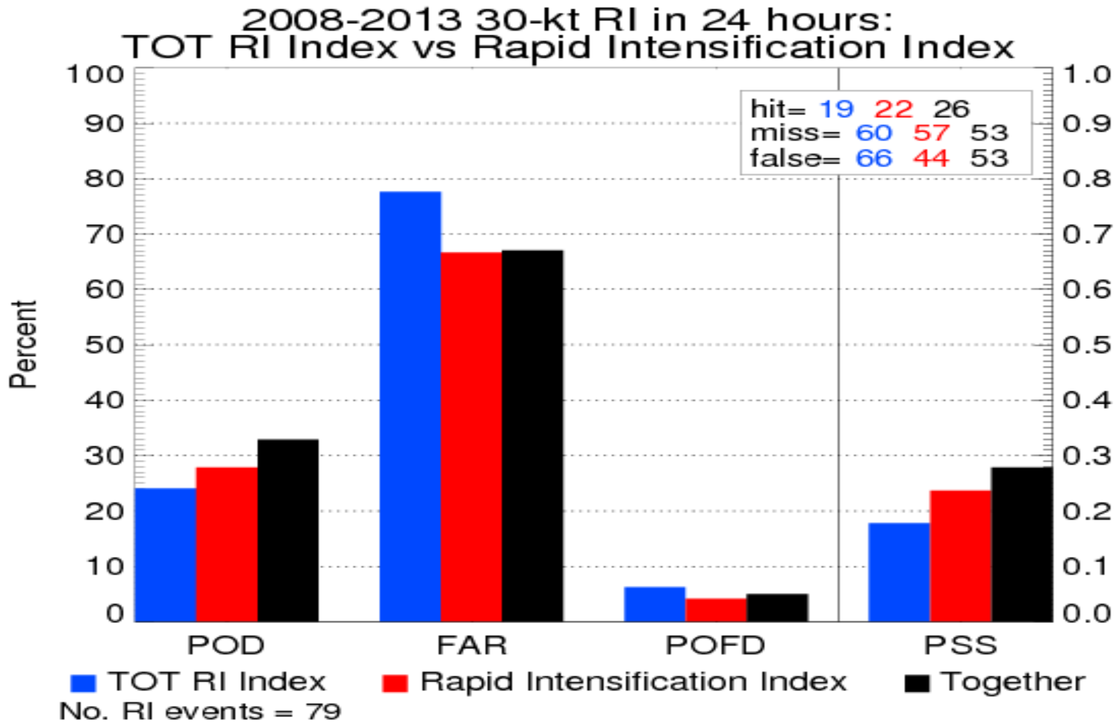

Figure 21. Results of a yes-no forecast for tropical cyclone (TC) rapid intensification (RI) for the single-predictor TOT RI Index (blue), multi-predictor Rapid Intensification Index (RII; red) and combined (black). Overall, all methods are skilful at predicting TC RI, as indicated by the positive Peirce Skill Score (PSS). The multi-predictor RII is more skilful than the TOT RI Index, but adding the TOTs to the RII increases the RII skill.

<u>Milestone 3</u>. TOTs can also serve as a proxy for measuring the amount of active convection associated with a potential developing TC. As increased convection is associated with TC genesis, TOTs could potentially predict if TC genesis will occur or not. TOTs are tested as a stand-alone predictor of TC genesis using tracks of 324 National Hurricane Center (NHC) "Invests" from 2005-2013. TOTs are averaged within selected radii/annuli and over different time frames to find the optimal combination for predicting genesis. To simulate the skill at forecasting TC genesis, a leave-one-year-out cross validation approach is utilized: An optimal combination of radius/annulus and time frame for TOT averages is found using all but one year of Invests. Then, this combination is used to predict genesis for the one year of Invests left out. This process is repeated 9 times, until each year is left out. The results are shown in Figure 22. Overall, the TOTs are skillful at predicting if an Invest will develop in the next 12, 24, 48, and 120 hours based the positive Heidke Skill Score (HSS).

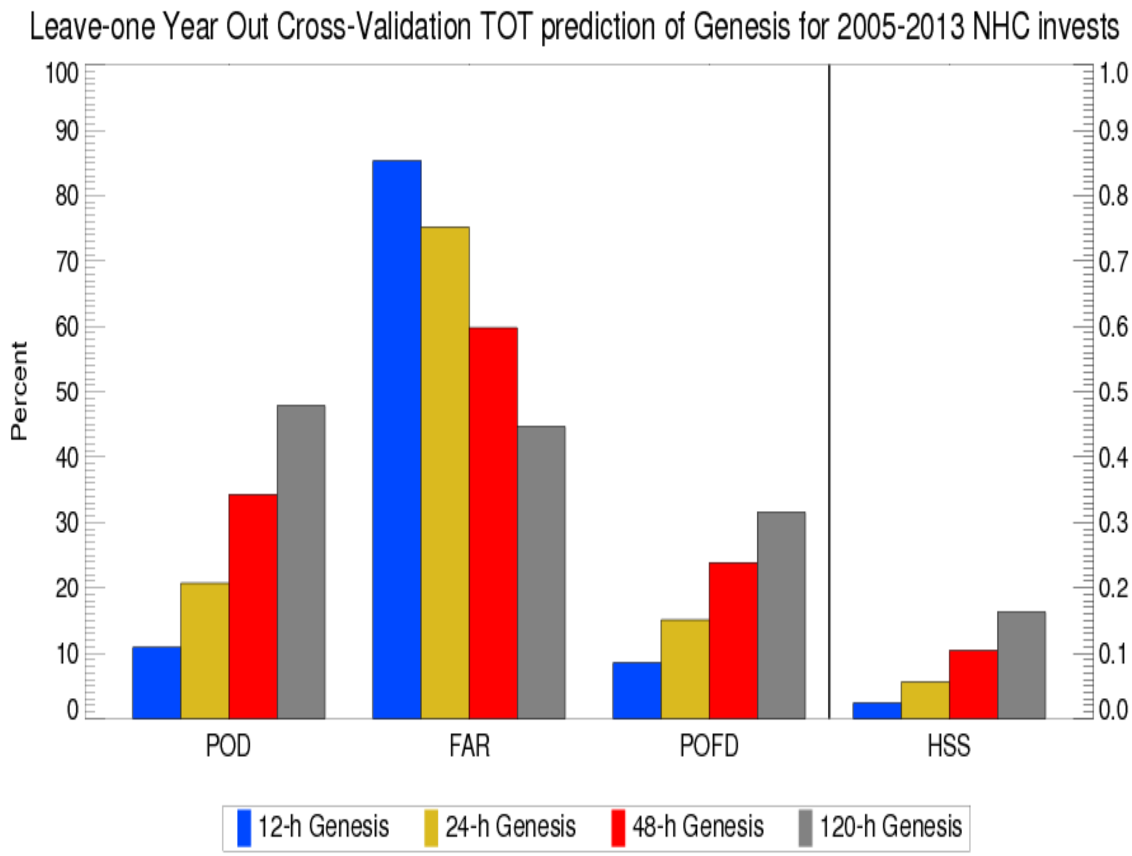

Figure 22. Probability of detection (POD), false alarm ratio (FAR), probability of false detection (POFD), and Heidke Skill Score (HSS) for TOT prediction of TC genesis. Positive HSS indicates the forecast for each timeframe is skillful.

Publications and Conference Reports

Griffin, S. M., K. M. Bedka, and C. S. Velden, 2016: A Method for Calculating the Height of Overshooting Convective Cloud Tops Using Satellite-Based IR Imager and *CloudSat* Cloud Profiling Radar Observations. *J. Appl. Meteor. and Climatol.*, **55**, 479-491.

5.7 Enhancing Future GOES-R Assimilation Capabilities by Exploring the Impact of SEVIRI Infrared Brightness Temperatures in an Operational Ensemble Data Assimilation System

CIMSS Task Leader: Jason Otkin

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

Project Overview

Clouds and atmospheric water vapor (WV) influence sensible weather conditions through their combined effect on surface temperatures and precipitation. Small changes in the WV and cloud distributions can have a large impact on the evolution of high impact weather events, such as severe thunderstorms, heavy rainfall, and tropical cyclones. Thus, an accurate and spatially representative specification of clouds and WV in datasets used to initialize high-resolution numerical weather prediction models is essential to produce accurate forecasts of cloud cover, precipitation, and storm evolution. Because WV and clouds are highly variable in space and time and are poorly sampled by conventional in situ observations, it is important that more attention be directed toward maximizing the use of cloud and WV sensitive infrared brightness temperatures from geosynchronous satellite sensors in data assimilation systems. The primary goal of this project was to use expertise gained during prior Observing System Simulation Experiments (OSSE) to conduct data assimilation studies using real SEVIRI infrared brightness temperatures and the future operational ensemble data assimilation system being developed at the German Deutscher Wetterdienst (DWD).

Milestones with Summary of Accomplishments and Findings

Extensive assimilation experiments were performed using the Kilometer-scale Ensemble-based Data Assimilation (KENDA) system coupled to the COSMO limited area model. Initial system development focused on evaluating the satellite data assimilation capabilities in KENDA and the interface between COSMO and the RTTOV radiative transfer model used to generate simulated brightness temperatures. Several bugs were identified and removed. Once these tests were completed, a cloud-dependent bias correction scheme was implemented that applies different bias corrections for clear grid points and for cloudy grid points with cloud top heights in the lower (surface to 2 km AGL), middle (2 to 6 km AGL), and upper troposphere (6 to 14 km AGL), respectively. These cloud top heights were chosen to account for potentially different biases in liquid, mixed-phase, and glaciated clouds. The bias correction terms were set to constant values computed using bias statistics from a 3-day period preceding the start of the assimilation experiments. The bias correction approach that we used applies bias corrections to the model equivalent brightness temperatures rather than to the real observation. With this approach, the model-simulated cloud field from a given ensemble member is used to determine the cloud top height, with the appropriate bias correction value then applied to the simulated observation. This means that for a given SEVIRI observation that different bias correction values may potentially be used for each ensemble member. This was deemed to be a reasonable approach since the model-simulated clouds may have different biases depending on the cloud top height, thus, it may be better to apply different bias correction values to each ensemble member rather than only applying the bias correction to the real observation.

After implementing the cloud-dependent bias correction scheme, several assimilation experiments were performed to assess the impact of the infrared observations and bias correction scheme on the analysis accuracy and the sensitivity of the results to the observation error and horizontal and vertical covariance localization radii. The assimilation experiments were initiated at 00 UTC on 05 June 2011 and run for 12 hours with observations assimilated at hourly intervals. This was a very challenging time period to simulate with a wide range of cloud types, including scattered areas of deep convection by the end of the assimilation period. A Control experiment was performed in which only conventional observations were assimilated. Conventional observations along with clear and cloudy sky infrared brightness temperatures from the SEVIRI 7.3 μm band were assimilated during the sensitivity tests. After evaluating the bias statistics accumulated during the passive monitoring period, the bias correction values were set to -2.9 K, -2.9 K, -3.1 K, and -4.4 K, respectively, for the clear sky, low-level clouds, mid-level clouds, and high clouds, respectively. The negative biases indicate that the COSMO model has a dry moisture bias or contains too few clouds. The clear sky and low-level cloud bias corrections are set to the same value because the 7.3 μm observations will be unable to distinguish between these cloud types. The biases are likely larger for the upper level clouds due to greater uncertainty in parameterizing ice cloud processes in the COSMO and RTTOV models. This shows one of the benefits of using a cloud-height dependent bias correction scheme when assimilating infrared observations.

In general, the results show that there is some sensitivity to the assimilation parameters, with the best results obtained when the observation error was set to 3.5 K, and the horizontal and vertical covariance localization radii were set to 35 km and 0.7 log pressure units, respectively. The observation-background brightness temperature bias was lower during most of the assimilation period when the SEVIRI observations were assimilated. By the end of the assimilation period, large improvements were also evident in the relative humidity field throughout most of the troposphere as indicated by the smaller ensemble spread and RMSE, with smaller improvements evident in the wind field with neutral impact on temperature (Figure 23). These results show that the assimilation of WV and cloud sensitive SEVIRI infrared brightness temperatures and the use of a cloud-dependent bias correction scheme have a positive impact on the model accuracy.

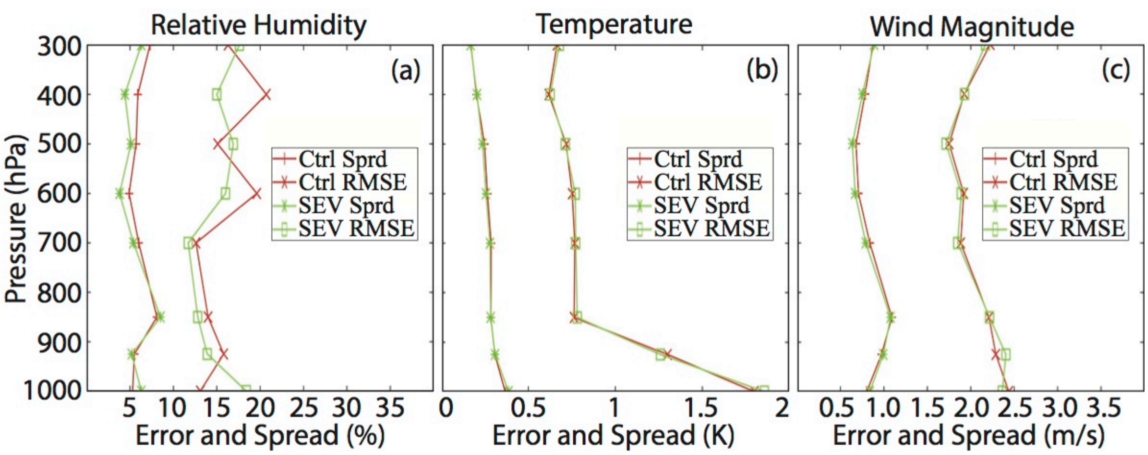

Figure 23. Vertical profiles of root mean square error and ensemble spread for (a) relative humidity (%), (b) temperature (K), and (c) wind magnitude (m s-1). The profiles were computed using data from the posterior ensemble mean at 00 UTC on 05 June 2011. Results are shown for the Control (red) and SEVIRI (green) assimilation experiments.

Publications and Conference Reports

Perianez, A., J. A. Otkin, A. Schomburg, R. Faulwetter, H. Reich, C. Schraff, and R. Potthast, 2015: Infrared brightness temperature assimilation in an ensemble Kalman filter with a cloud-dependent bias correction scheme. In preparation for submission to *Mon. Wea. Rev.*

Perianez, A., J. A. Otkin, A. Schomburg, R. Faulwetter, H. Reich, C. Schraff, and R. Potthast, 2015: Infrared brightness temperature assimilation using an LETKF at convection-resolving resolutions. *Eugenia Kalnay Symposium*, Phoenix, AZ.

Otkin, J. A., 2015: Ensemble data assimilation and model validation studies using cloud and water vapor sensitive infrared brightness temperatures. *NOAA Science Seminar Series*, College Park, MD.

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

CIMSS Task Leader: Christopher M. Rozoff
NOAA Collaborator: James P. Kossin (NOAA/NCEI/CWC)

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

Project Overview

Improved tropical cyclone (TC) intensity prediction has been a primary goal of TC research over the last two decades. However, TC structure change is another challenging aspect of TC prediction deserving further examination since TC structure relates directly to the area of damaging winds and the magnitude of a TC's storm surge at landfall.

To contribute toward GOES-R TC structure, algorithms, we have conducted a multi-institutional project consisting of NOAA Cooperative Institute for Research in the Atmosphere (CIRA) and UW-Madison/CIMSS collaborators to develop a variety of GOES-R related tools for the diagnosis and forecasting of TC structure change. The CIRA Project Lead, Dr. John Knaff (NOAA), and NOAA collaborators have led tasks incorporating GOES-R advanced baseline imagery (ABI) and GOES lightning mapper (GLM) proxy datasets, including the development of algorithms that improve the estimates of TC location, TC size, and the radius of maximum winds, and the relationships between total precipitable water and TC size. CIMSS has contributed to TC structure algorithms by developing an objective technique to estimate a TC's wind field from passive microwave imagery.

Milestones with Summary of Accomplishments and Findings

1. This project contributed to an observational paper on the thermodynamic changes associated with hurricane eyewall replacement cycles by analyzing flight-level data from numerous Atlantic Ocean basin TCs (Sitkowski et al. 2012).

2. An idealized high-resolution hurricane simulation was diagnosed to gain physical insight into processes driving secondary eyewall formation in TCs (Rozoff et al. 2012).

3. Using a developmental dataset consisting of passive microwave imagery, flight-level wind data from aircraft reconnaissance into Atlantic TCs (Knaff et al. 2015), and data from the North Atlantic Hurricane Database (HURDAT; Jarvinen et al. 1984), a multiple linear regression model was designed to estimate two-dimensional wind fields from passive microwave imagery (Rozoff and Knaff 2016) (e.g., Figure 24 below).

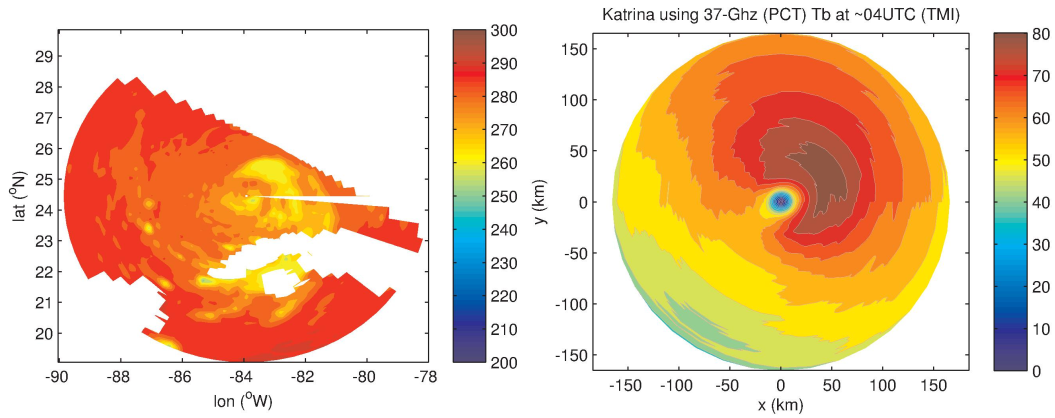

Figure 24. (left) TMI polarization corrected temperatures (K) (37-GHz) of Hurricane Katrina (2005) at 0400 UTC 27 August. Missing data are seen in this image where there is land and in the northeast due to the region falling outside of the satellite overpass. (right) Model diagnosed flight-level tangential wind (kt) diagnosed from the 37-GHz microwave imagery at left.

Publications and Conference Reports

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

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

Rozoff C. M., and J. A Knaff, 2016: Objective estimation of a tropical cyclone's wind field from passive microwave imagery. *J. Appl. Meteorol. Climatol.*, to be submitted.

References

Jarvinen, B. R., C. J. Newmann, and M. A. S. Davis, 1984: A tropical cyclone data tape for the North Atlantic basin, 1886-1983: Contents, limitations, and uses. NOAA Tech Memo. NWS NHC 22, 21 pp.

Knaff, J. A., S. P. Longmore, R. T. DeMaria, and D. A. Molenar, 2015: Improved tropical-cyclone flight-level wind estimates using routine infrared satellite reconnaissance. *J. Appl. Meteor. Climatol.*, **54**, 463-478.

5.9 Convective Cloud Collaboration with UAH
CIMSS Task Leader: William Straka III
CIMSS Support Scientist: Steve Wanzong
NOAA Collaborator: Andrew Heidinger

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

Project Overview

The University of Alabama at Huntsville (UAH) is transitioning their current proxy Convective Initiation (CI) algorithm towards the GOES-R data stream. This transition involves incorporating the Cloud Type and Cloud Optical properties from the GOES-R algorithms into their processing system. Cloud properties such as visible optical depth, emittance, liquid water path, and effective particle radius can be used to quantify cumulus cloud growth in advance of CI. CIMSS has been tasked to process the cloud algorithms from the current GOES (East and West) and provide the optical properties in a timely manner. Funding was provided by UAH for a new computer to perform the necessary processing.

Milestones with Summary of Accomplishments and Findings

In order to accomplish the task set by UAH, CIMSS has set up a new computer to process current GOES (East and West) over the region needed by UAH. This was accomplished and the GOES data is flowing to UAH within the latency required by the UAH CI algorithm. The current production system supplies a Level2 hdf file at 4 km resolution. An example output of the optical depth is shown in Figure 25.

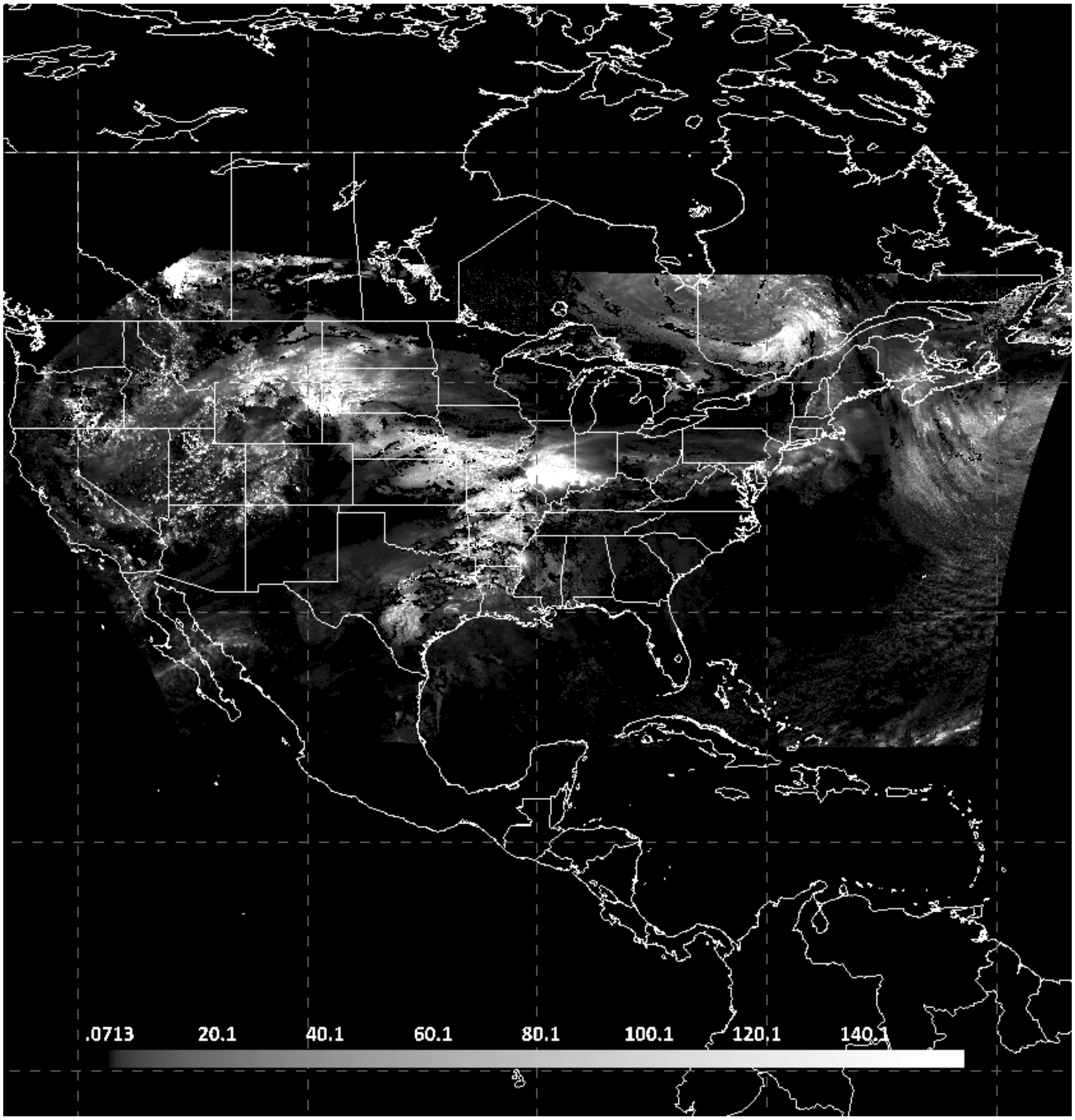

Figure 25. Example cloud optical depth calculation at the nominal wavelength of 0.65 µm.

References

Mecikalski, John R.; Jewett, C. P.; Weygandt, S.; Smith, T. L.; Heidinger, A. K.; Straka, W. and Benjamin, S.. Convective initiation of 0-6 hr storm nowcasting for GOES-R. Boston, MA, American Meteorological Society, 2014, abstract only.

6. CIMSS GOES-R Risk Reduction Program New Starts 2015

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

CIMSS Task Leader: Bryan Baum
CIMSS Support Scientist: Scott Bachmeier
NOAA Collaborators: Andrew Heidinger (NOAA/NESDIS/STAR), Dan Lindsey

(NOAA/NESDIS/STAR), Roland Draxler (NOAA Air Resources Laboratory), Timothy Lang (NASA Marshall Space Flight Center), Mark Ruminski (Satellite Analysis Branch, NOAA/NESDIS/SPSD), Gregory Gallina (Satellite Analysis Branch, NOAA/NESDIS/SPSD)

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

Project Overview

The primary goal of this proposal is to use geostationary satellite data to investigate the impact of wildfire events that become pyroconvective (producing convective cloud plumes which quickly grow to incredible heights, often punching briefly through the tropopause) over the course of several hours and become pyroCumulonimbus, or pyroCb (Fromm et al. 2010). The pyroCb events inject huge amounts of burning emissions into the upper troposphere and even into the lower stratosphere. The emissions contain soot, mineral dust, and "brown carbon" (or BC; complex light absorbing organic material). The PyroCb blog hosted at CIMSS/SSEC serves as (1) a training resource for undergraduate students to discuss a severe pyroCb event as it unfolds, (2) provides information to NWS forecast offices as well as the general public, and (3) supports scientific research that will eventually makes its way into the peer-review literature. A number of PyroCb events were documented during 2015, over 60 in fact, and one undergraduate student in particular (Anna Sienko) was instrumental in keeping up with the unprecedented activity. A number of our blog posts were mentioned on other blogs, which brought an increased level of attention to some of the more severe and noteworthy events. In addition to the blog, a Twitter account @PyroCb_CIMSS was initiated as another social media tool that can be used to increase the speed that we disseminate pyroCb information to forecasters as well as anyone else with an interest in these events.

Milestones with Summary of Accomplishments and Findings
- Documented over 60 extreme pyroconvection events in 2015; collected pertinent data necessary for detailed case studies and post results on PyroCb blog (http://pyrocb.ssec.wisc.edu).
- Continued to improve VISITview module for training purposes.
- Worked with Andrew Heidinger to collect/analyze cloud/aerosol products from geostationary data using the GOES-AWG software.
- Integrated HYSPLIT trajectory software into geostationary satellite image analysis.
- Ease transition from GOES-13/15 (and potentially GOES-14) to GOES-R ABI/GLM sensors by working with Himawari-8 data, as we did in 2015 for a number of events.

- Anna Sienko (currently a senior) at UW-Madison built a database of over 120 PyroCb events from 2013-present. She is learning how to analyze these 120 events as part of her senior thesis.
- In preparation for the upcoming 2016 fire season, Anna Sienko is now using GEMPAK to calculate/investigate some additional atmospheric state parameters such as CAPE, the Haines index, and the mid-tropospheric water vapor.

Our blog continues to track the occurrence of new events: http://pyrocb.ssec.wisc.edu. The original intent of the blog was to keep track of pyroCb events beginning with the 2013 fire season so that we have a record of the events for future detailed study. The pyroCb blog continues to evolve as we learn how to integrate other data products with more efficiency and expertise. For quickly-evolving events, information is routinely posted to a Twitter account: @PyroCb_CIMSS.

A VISITview® training module titled "Satellite Identification and Tracking of Pyrocumulonimbus (PyroCb) Clouds" was developed to assist end-users (for example, National Weather Service forecasters and incident meteorologists or IMETS, US Forest Service wildfire management teams, etc.) in the interpretation of satellite images/products and other tools needed for (1) pyroCb detection, and (2) monitoring long-range transport of the high-altitude smoke aerosols. This module continues to evolve as new information is acquired.

Indications from Lang et al. (2014) are that severe pyro-convection is associated with lightning activity, particularly in the upper part of the cloud. This may be due to the rapid formation and growth of ice particles as the plume reaches the upper troposphere. This convection was associated with rapid wildfire growth, as indicated by incident reports and the presence of shortwave-IR hot spots. For example, electrified pyro-convection was associated with the explosive growth of the Waldo Canyon fire (23 June 2012) that led to the burning of the Mountain Shadows subdivision. Follow-on analysis also established that lightning occurred during the explosive growth at Yarnell Hill in Arizona on 30 June 2013 that led to the deaths of 19 firefighters. This aspect will make progress once the GLM is operational.

Since the beginning of this project in 2013, we have trained a number of undergraduate students in the Atmospheric and Oceanic Science Department in the preparation of geostationary satellite image animations, organization of ancillary data (such as CALIPSO lidar tracks and OMPS aerosol index maps), and participate in preparing blogs describing specific events. Previously, the students were not being asked to perform more complex tasks such as actually working with the cloud products or looking into the scientific questions that come into play for each event. In 2015, one of the students, Anna Sienko, showed exceptional initiative with this effort. She basically did most of the blogging over the 2015 northern hemisphere fire season. In the previous two years (2013-2014), the blog recorded about two dozen events per year. In 2015, we recorded over 60 events. We ascribe no particular reason for this increase, although a small part of it is that the temporal resolution of Himawari-8 permits us to capture PyroCb events that we could not discern previously. Anna Sienko decided to learn more about the science by making this work part of her senior thesis at UW-Madison, beginning in September 2015, and has organized over 100 PyroCb events based on what has been recorded in the blog. She has recently been admitted to graduate school in AOS and will pursue a M.S. on this PyroCb work.

Now that Himawari-8 is operational, we began to incorporate the imagery into the pyroCb blog. An example is provided in Figure 26 for a severe fire near Perth, Australia on 6 January, 2016. This was a particularly devastating fire that burned down most of a small town near Perth, including a favorite pub of one of our CIMSS colleagues, Jim Davies (who’s from that region).

We actually had a number of PyroCb events in 2015 for which this new imager was instrumental in being able to capture. The temporal resolution of the previous imager was generally insufficient to capture the actual PyroCb growth.

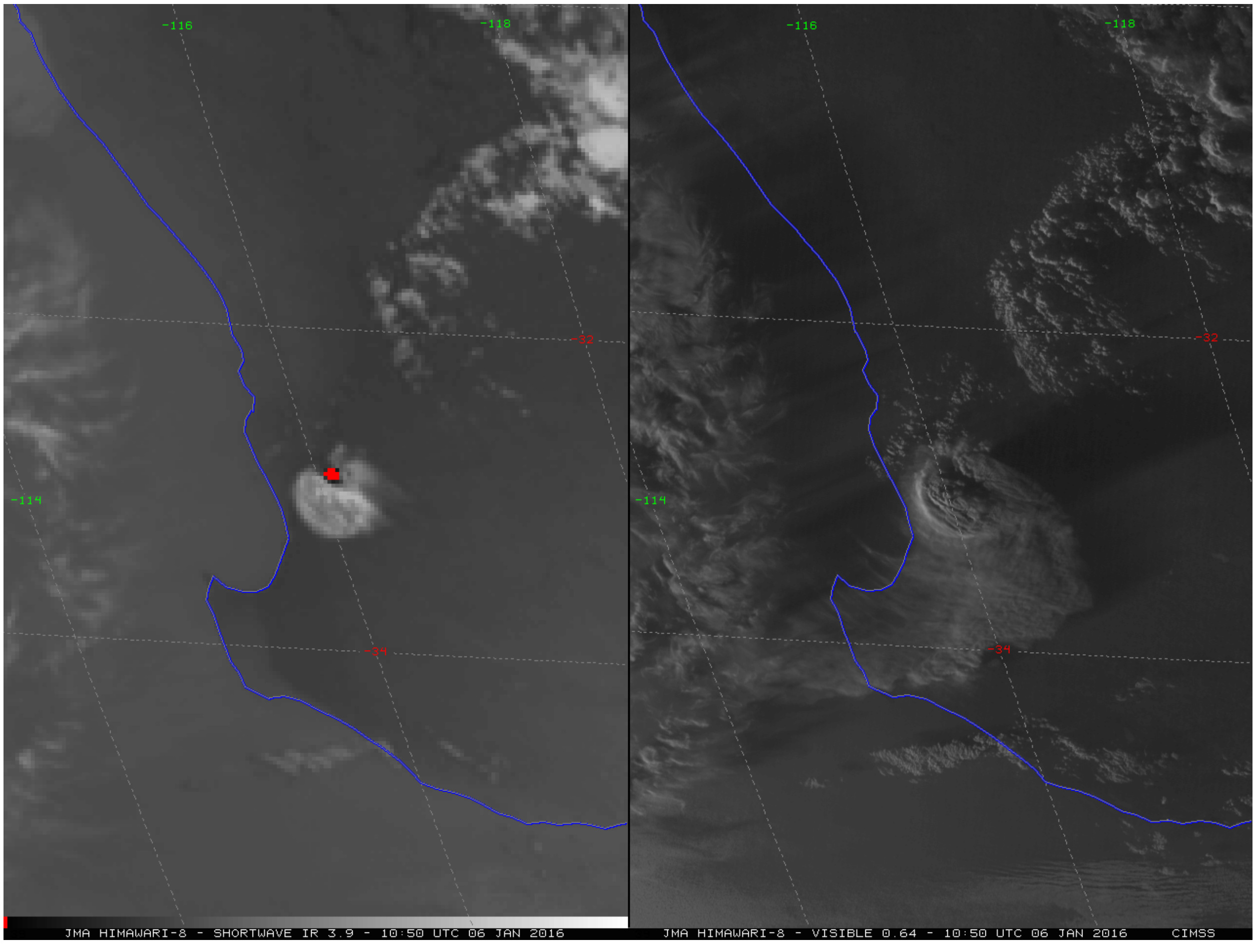

Figure 26. The left panel shows the large fire hot spot along with smoke from the fire. The right panel shows the growing pyroCb tower in the visible reflectance image.

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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.

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: Tim Schmit, Bob Rabin

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

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, and 2015 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.
We proposed to demonstrate a prototype "combined" analysis system using data from the GOES-14, MPAR and/or TDWR Doppler radar, and LMA and Earth Networks flash rate data at 1-minute intervals. From the available data, we planned to explore the importance of 1-minute continuity in the identification and tracking of boundaries from radar and visible satellite imagery and their possible influence on convective initiation and interaction with existing convection. The time continuity of overshooting tops, lightning height and frequency, precipitation intensity, and significant weather events (radar detected mesocyclones, hail signature, etc.) also will be investigated. One emphasis will be to quantify the improvements in determining the maxima/minima and temporal trends of overshooting tops that will be provided by the 1-min frequency of satellite imagery from GOES-R.

This project was 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 involved visualization of multiple data sets combined in McIDAS-V.

Milestones with Summary of Accomplishments and Findings

The proposed milestones for CIMSS were as follows.
- Combined analysis of 1-minute GOES-14, radar (NSSL MPAR and/or TDWR) and lightning (LMA) for May 20-21, 2014 case over Colorado.
- Transfer of 2015 GOES-14 SRSOR data from SSEC to CLASS, as needed.

Combined analyses of 1-minute GOES-14, radar (NSSL MPAR and/or TDWR)and lightning (LMA) were assembled for a study of severe thunderstorms in Colorado on 20-21 May 2014. Animations were developed showcasing the parallax corrected SRSOR GOES imagery with overlays of LMA frequency, overshooting top location and temperature, radar reflectivity and radial velocity. NSSL scientists put these data into an interactive web-based tool.

- FAA Terminal Dopper Radar (TDWR): low elevation scan reflectivity, radial velocity, spectrum width were processed at 1-minute intervals for the 20-12 May 2014 study. These data were made available courtesy of the FAA, and were acquired with the help of Aaron Tuttle (FAA/Program Support Facility). They were converted from an internal FAA format to Level-III structured files by Scott Ganson (NOAA/NEXRAD/OSF). Level-III format data archived at the NCDC were only available at 5-minute intervals for the dates of interest.
- Vertically integrated lightning source density during 1-minute intervals detected from the Colorado LMA system (Total LTG) have been processed. These data were provided courtesy of New Mexico Tech University.
- Overshooting top (OT) locations and temperature differential from background anvil were obtained from Kris Bedka (NASA Langley Research Center). These are based on the GOES-R OT algorithm developed by Kris and others at UW-Madison CIMSS. This version of the algorithm uses GOES channel 4 brightness temperatures only for the detection of overshooting tops.
- The multi-sensor wind analysis system (3DVAR) developed at the NOAA National Severe Storms Lab (NSSL) was used to combine radial velocity wind observations from WSR-88D and TDWR Doppler radars and GOES AMVs.
- Multi-sensor displays of the data and the generation of MPEG-4 format movies using McIDAS-V have been explored and developed at University of Wisconsin-CIMSS.

The McIDAS-V visualization tool has many strengths, one being the ease in which multiple datasets can be viewed interactively and simultaneously. That is demonstrated in Figure 27 where the total lightning counts and TDWR radar data from Denver are overlain on a GOES-14 visible image. Animations of this case demonstrate the potential power of visualizing multiple datasets such as these together. As we make technological advances in observational capabilities, human observers are still limited in what they can visualize in a given amount of time. A forecaster with limited time cannot always take the time to visualize all of the available sources of data individually.

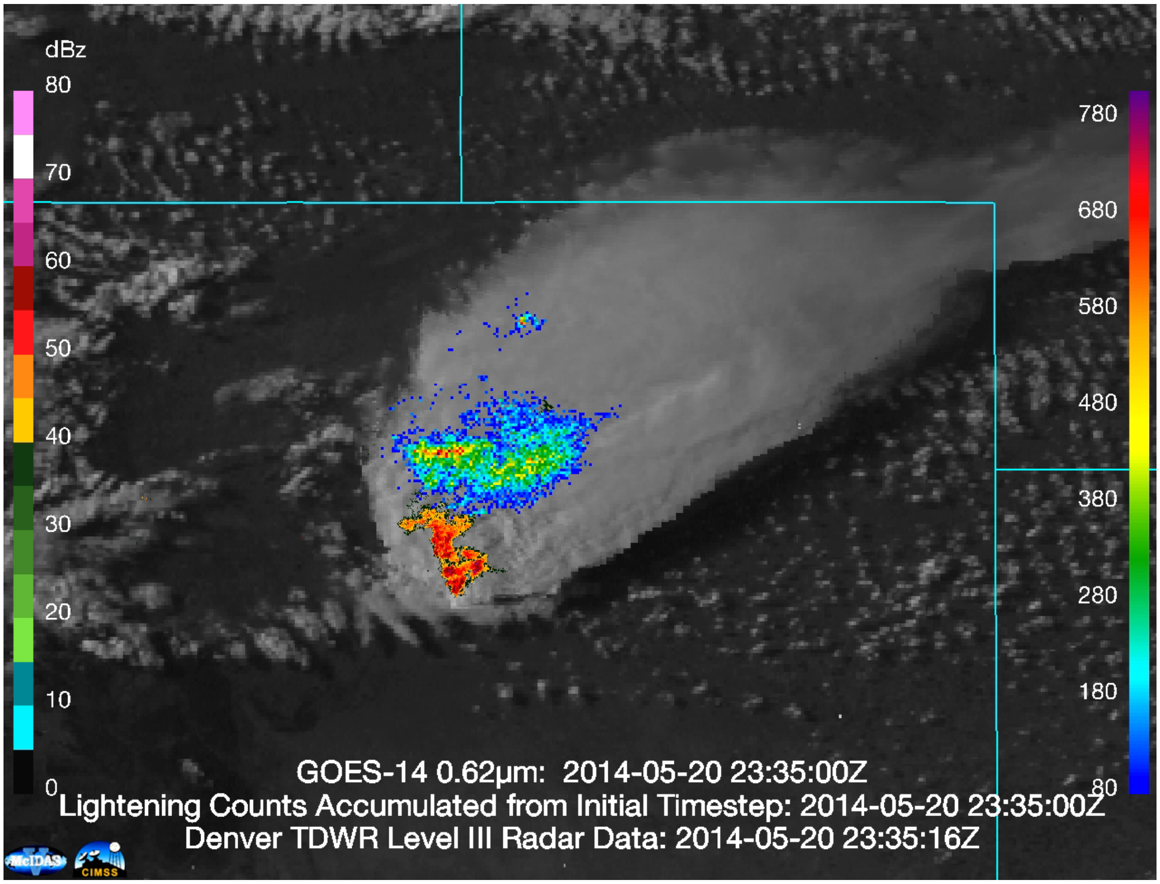

Figure 27. GOES-14 visible image from May 20, 2014 with both accumulated lightning counts and TDWR radar from Denver overlaid in a McIDAS-V display.

6.3 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, Vijay Tallapragada

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

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

Milestone 1. Results of HWRF model hurricane forecast impact experiments based on assimilation of the two sets of AMVs (shown in our last report) are now being synthesized and written up for publication in a peer-reviewed journal.

Milestone 2. 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) are now being 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 are shown in the figures below. From a quick, preliminary examination, the Benchmark AMVs generally show minor initial analysis impacts. The next step will be to run the HRRR model forecast experiments using the RAP with AMV assimilation to provide initial and boundary conditions, to see if the forecasts result in better convective evolution.

Milestone 3. The GOES-R AMV algorithm settings, tuning, and QC procedures for mesoscale processing are being optimized to increase the data density and improve the ultimate quality. This process involves empirical testing and statistical validation of the AMVs, as well as additional model forecast impact experiments in Year 3 of this project.

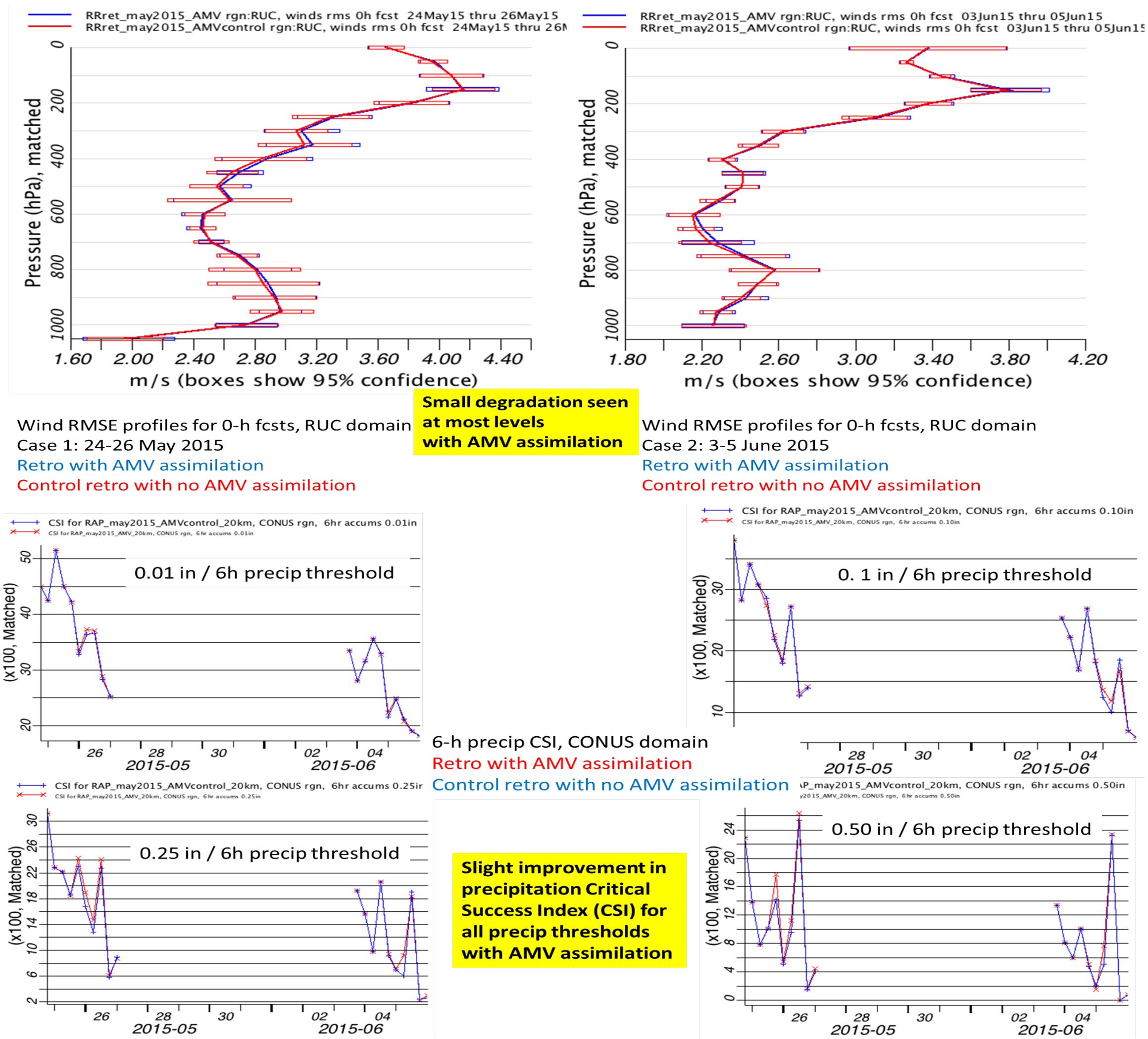

Figure 28. Forecast impact experiments with the RAP model for two selected severe weather cases (flooding event in Texas, and EF-3 tornado event in Colorado, both in May-June 2015) were conducted with assimilation of the heritage mesoscale AMVs (Benchmark dataset) and compared with a control run (without assimilation). Selected results from RAP analyses are shown above.

Publications and Conference Reports

Velden, C., J. Daniels, W. Bresky, S. Wanzong, 2015: High-resolution AMVs for applications in high-impact weather events in the GOES-R era. *2015 NOAA Satellite Science Week.*

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 and Lee Cronce
NOAA Collaborators: Steve Weiss, Steve Weygandt, David Bright, and Bruce Entwistle

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

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 2015 Aviation Weather Testbed (AWT) Summer Experiment in Kansas City, MO. Feedback from participants, including several operational aviation weather forecasters from both the public and private sector, was generally positive. Forecasters found the side-by-side animations of the observed and simulated GOES satellite imagery shown on the webpage for each forecast cycle to be very valuable as a forecasting aid and because they allow them to circumvent the single-panel restriction of N-AWIPS that prevents them from easily comparing simulated and observed satellite imagery.
- *Modify the webpage display and statistical metrics based on participant feedback.*
  Based on feedback from the 2015 AWT participants and the HRRR model developers, the real-time model verification webpage was updated to include error matrix graphics (see Figure 29 for an example) showing how the model forecast errors have been changing with time during the past 12 forecast cycles. These images have proven very useful because they allow users to quickly identify trends in the forecast errors and to determine if a particular forecast cycle is performing particularly well or poor at the current time. Each error matrix graphic is organized so that the most recent forecast cycle is shown at the top. The observation time is shown along the x-axis, with the most recent time on the left. Figure 29 shows a representative example of the bias and root mean square error (RMSE) matrix graphic for the Midwest sector on 19 November 2015 for the 10.7 μm band. The bias is shown in color with the RMSE value overlaid on top. Because clear skies were present across most of the region during this time period, the 10.7 μm brightness temperatures were primarily sensitive to surface temperature. The pattern of positive biases during the night (right side of image) and negative biases during the

morning (left side) shows that the diurnal cycle of surface temperatures was too weak in the HRRR model forecast.

- *Incorporate additional statistical metrics into the evaluation process.*
  We developed the capability to compute the Fractions Skill Score (FSS) using the observed and simulated GOES brightness temperatures for each observation and forecast time. The FSS is a neighborhood-based verification method that can be used to determine the spatial length scales for which a model has forecast skill, and is less sensitive to spatial location errors that can make it difficult to use traditional grid point statistics (e.g. RMSE) with high-resolution models. Figure 30 shows a box plot diagram depicting the range of FSS values from all forecast cycles and lead times on 23 July 2015 for three regions that contained different modes of convection (top panel). The FSS was computed using a brightness temperature threshold equal to the 10th percentile of the observed brightness temperature distribution from the previous 10-day period. This means that we are focused on the coldest cloud tops most indicative of deep convection. Overall, the results show that the forecast skill increases with larger spatial scales as you move toward the right side of the image, with the highest skill associated with an area of widespread and strongly forced convection across the north-central U.S., with the lowest skill found in the central U.S. where the thunderstorms were isolated and weakly forced. This analysis tool has proven very useful for better understanding the skill of the HRRR model in different weather situations.
- *Prepare peer-reviewed article describing project results.*
  We are writing a journal article describing results from our model validation efforts using the FSS, traditional grid point statistics, and object-based verification methods. This paper will focus on a case study from 23 July 2015 that contained different modes of convection across different parts of the U.S. and will be used to evaluate the merits of each verification method.

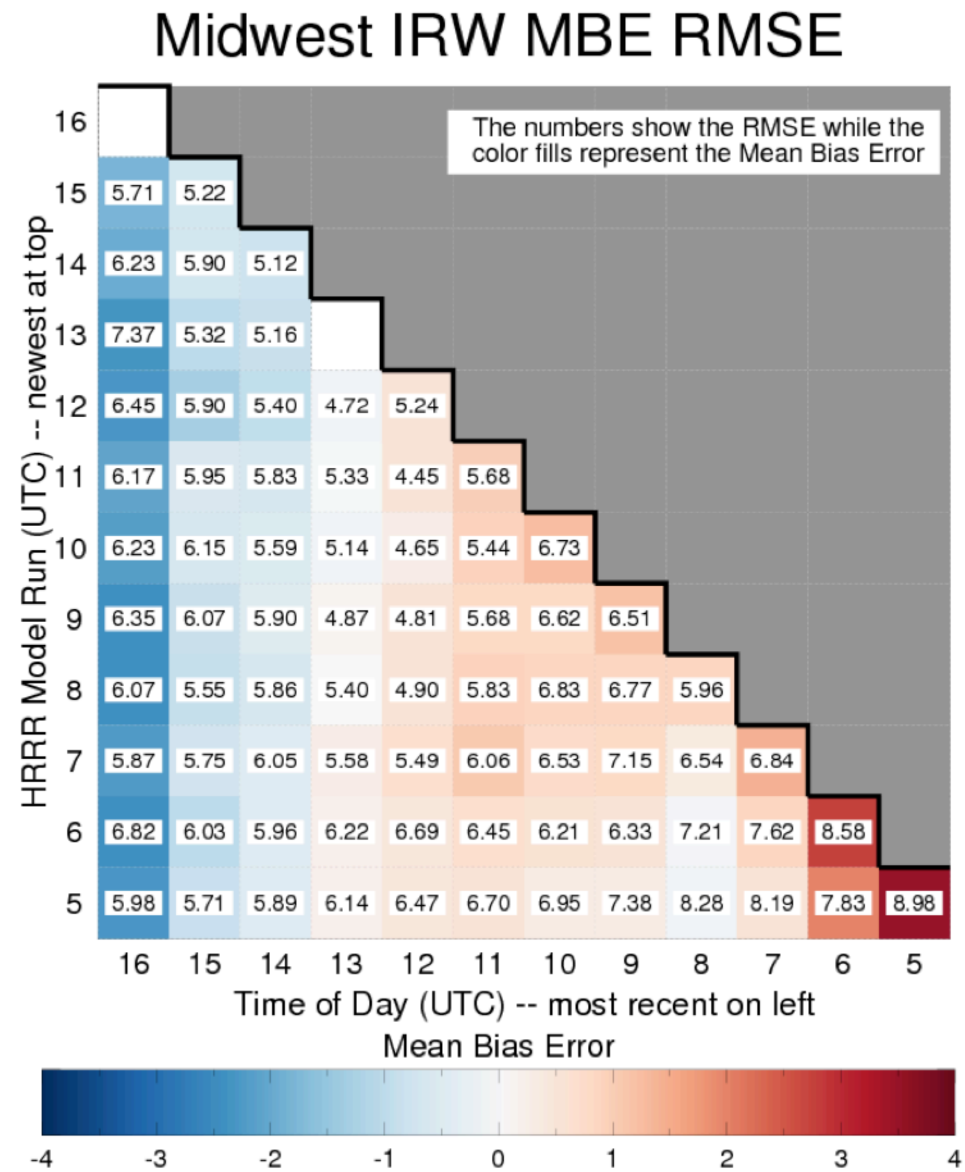

Figure 29. A representative example of a bias and root mean square error (RMSE) matrix graphic showing how the forecast errors have been changing with time during the previous twelve HRRR model forecast cycles. The bias is shown in color with the RMSE value overlaid. The most recent HRRR forecast cycle is shown in the top row, with progressively older forecast cycles toward the bottom. The observation time is shown along the x-axis from the most recent time on the left side to the oldest time on the right. This image shows the errors for the GOES 10.7 µm band for the Midwest U.S. sector on 19 November 2015. These error matrix graphics are computed for each region across the U.S. for each forecast cycle.

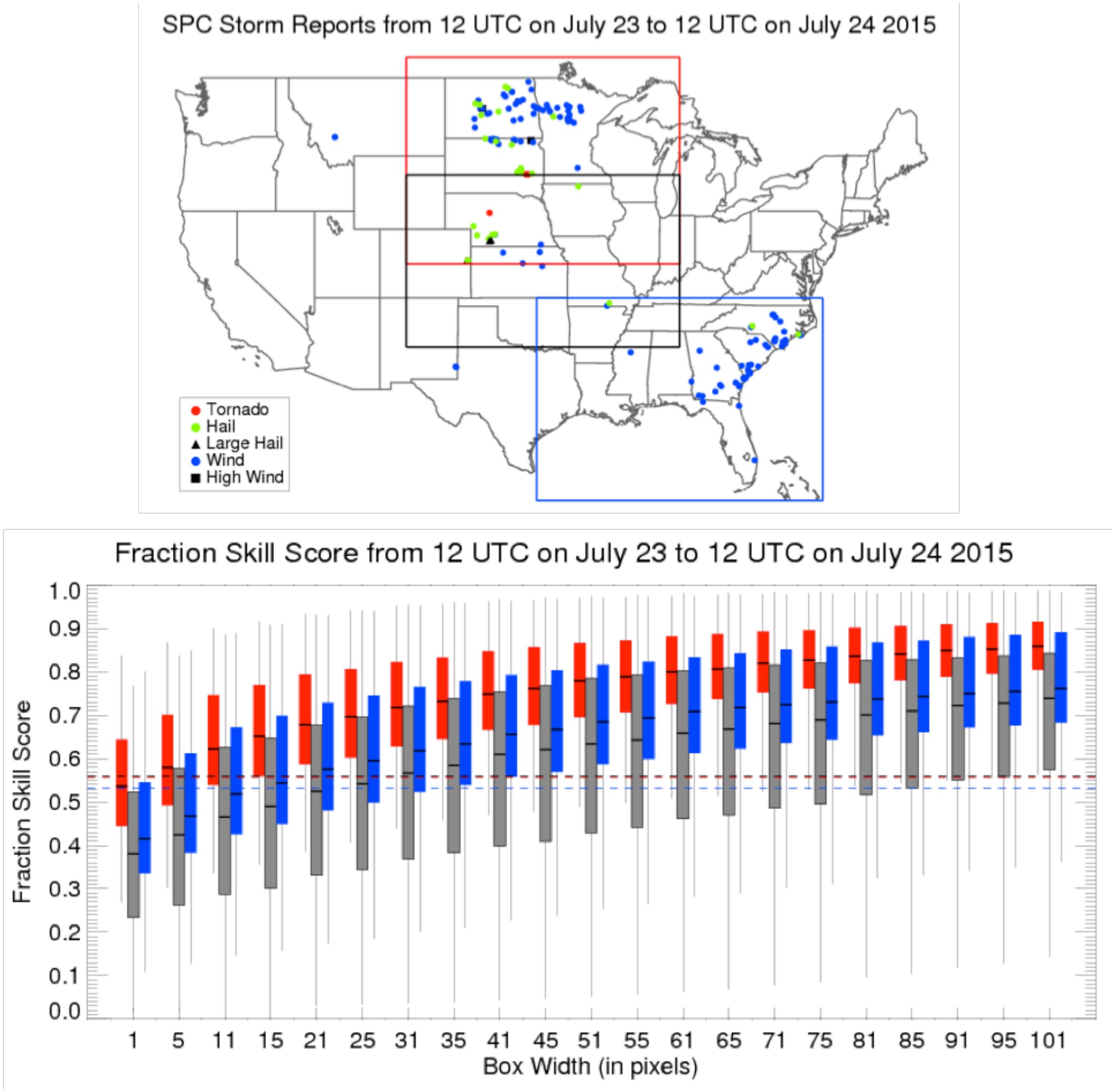

Figure 30. (top panel) Storm reports from the Storm Prediction Center (SPC) from 12 UTC on 23 July to 12 UTC on 24 July 2015. The colored boxes show the three regions for which the Fractions Skill Score (FSS) was computed using the observed and simulated GOES 10.7 mm brightness temperatures. (bottom panel) Box plot diagram showing the range of FSS values for each region computed using all forecast cycles and lead times during the 1-day period. The box width used to compute the FSS is shown along the x-axis, and increases from 1 grid point on the left to 101 grid points (303 km) on the right. FSS values above the horizontal dashed lines indicate a skilful forecast. The horizontal line within each box shows the median FSS value with the box ends indicating the 25th and 75th percentiles, respectively.

Publications and Conference Reports

Griffin, S. M., J. A. Otkin, C. M. Rozoff, J. M. Sieglaff, L. M. Cronce, and C. Alexander, 2016: Methods for comparing simulated and observed satellite infrared brightness temperatures and what do they tell us? In preparation for submission to *Mon. Wea. Rev.*

Otkin, J. A., J. Sieglaff, S. Griffin, L. M. Cronce, and C. R. Alexander, 2016: Development of a GOES-based verification and forecaster guidance system for the High-Resolution Rapid Refresh model. 12th Annual Symposium on New Generation Operational Environmental Satellite Systems. New Orleans, LA.

Otkin, J. A., J. Sieglaff, S. Griffin, L. Cronce, and C. Alexander, 2015: Development of a GOES-based verification and forecaster guidance system for the High-Resolution Rapid Refresh model. *2015 EUMETSAT Meteorological Satellite Conference*, Toulouse, France.

6.5 Development of Realtime 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, NWS Forecast Office, Milwaukee/Sullivan, WI; Tim Schmit, NOAA/NESDIS/STAR

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

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.

Milestones with Summary of Accomplishments and Findings

Algorithm improved on all-weather LAP product for GOES-13 Sounder to mitigate the product discontinuity between clear and cloudy skies (April 2015 – June 2015)

CIMSS sounding team have developed the GOES-R legacy atmospheric profile (LAP) algorithm in clear skies under algorithm working group (AWG) support and in cloudy skies under this GOES-R Risk Reduction (GOES-R3) support. In the cloudy skies, the LAP products are produced by combining infrared (IR) cloudy radiances and NWP forecasts. The all-weather algorithm works quite reliable for GOES-15 Sounder but since GOES-13 Sounder has a few channels that have large noise, the all-weather LAP products produced from GOES-13 Sounder show discontinuity between clear and cloudy skies. In order to mitigate this discontinuity, algorithm has been adjusted for GOES-13 Sounder, the refinement has been made by removing extremely noisy channels and putting less weighting for remaining GOES-13 Sounder cloudy radiances, which means in cloudy region the LAP products from GOES-13 Sounder are more closer to the background (GFS forecasts). GOES-15 Sounder all-weather LAP products are fine since the channels have much less noise than GOES-13 Sounder.

The adjusted algorithm has been used for GOES-13/-15 Sounder LAP product generation in NRT in GEOCAT since 19 UTC on 25 May 2015. After algorithm adjustment, the LAP products have smooth transition between clear and cloudy skies. Figure 31 shows the improvement of TPW field from combined GOES-13 Sounder and GOES-15 Sounder after the algorithm adjustment. The upper panel shows the TPW from 18 UTC on 25 May 2015 before the algorithm adjustment and the lower panel shows the TPW from 19 UTC on 25 May 2015 after the algorithm adjustment. After the algorithm adjustment, the discontinuity between clear and cloudy skies are mitigated.

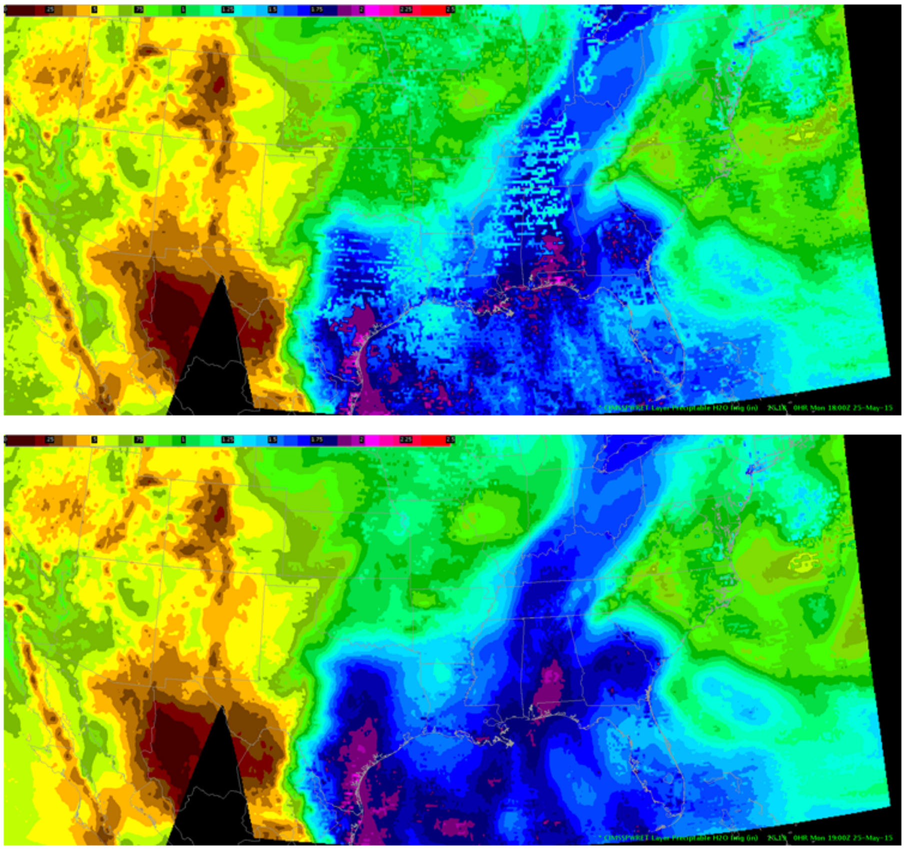

Figure 31. The TPW from combined GOES-13 Sounder and GOES-15 Sounder for two consecutive times, the upper panel shows the TPW from 18 UTC on 25 May 2015 before the algorithm adjustment and the lower panel shows the TPW from 19 UTC on 25 May 2015 after the algorithm adjustment.

All-weather GOES Sounder LAP products generated in NRT at CIMSS GEOCAT frame and are made available via AWIPS-II (May 2015 – June 2015)

The all-weather LAP products have been generated in CIMSS GEOCAT frame work in HDF format, the HDF format is converted to GRIB2 format via LDM on the EXP feed and put into AWIPS II. GOES Sounder LAP products put into AWIPS-II include total precipitable water (TPW), layered precipitable water (LPW) and atmospheric instability indices. The three layers for LPW are:

- 0.3-0.7 (in sigma level)
- 0.7-0.9 (in sigma level)
- 0.9-1.0 (in sigma level)

Many of the fields are accessible from the volume browser and product browser in AWIPS II. The GOES-13/-15 Sounder all-weather LAP products have been available in NRT in AWIPS-II since early May 2015.

Note that GOES-13 Sounder is not available now and GOES-14 Sounder will be used instead during 2016 HWT.

Publications and Conference Reports

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Jin, X., J. Hanesiak, and D. Barber, 2006: Detecting cloud vertical structures from radiosondes and MODIS during CASES field experiment. Atmos. Res., 83, 64–76

Li, J., C.-Y. Liu, P. Zhang, and T. J. Schmit, 2012: Applications of Full Spatial Resolution Space-Based Advanced Infrared Soundings in the Preconvection Environment, Weather and Forecasting, 27, 515 - 524.

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Schmit, T. J., M. M. Gunshor, W. Paul Menzel, J. Gurka, J. Li, and S. Bachmeier, 2005: Introducting the next-generation advanced baseline imager (ABI) on GOES-R. Bull. Amer. Meteorol. Soc., 86, 1079-1096.

Seemann, S., E. Borbas, R. Knuteson, H.-L. Huang, and G. R. Stephenson, and H. – L. Huang (2008), Development of a global infrared land surface emissivity database for application to clear sky sounding retrievals from multispectral satellite radiance measurements, J. Appl. Meteorol., 47, 108 - 123.

Smith, W. L., E. Weisz, S. V. Kireev, D. K. Zhou, Z. Li, E. E. Borbas (2012), Dual-Regression Retrieval Algorithm For Real-time Processing of Satellite Ultraspectral Radiances. J. Appl. Meteorol. Clim., 51, 1455-1476.

6.6 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: Mike Pavolonis

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

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). We propose to build 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. This proposal 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. The proposed research will directly address 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
- *Co-I at USGS will implement current near-real time VOLCAT alerts into USGS VolcView for evaluation.*
  We have worked with Co-Is at the USGS to enable a real-time delivery of all NOAA/CIMSS volcanic cloud alerts to a USGS server. The USGS has enabled the display of the NOAA/CIMSS alerts with the USGS "VolcView" display system with links to the NOAA/CIMSS Volcano website where a user can explore the full alert content (Figure 32).

- *Install the HYSPLIT software on a research server at CIMSS.*
  We have worked with the HYSPLIT group to obtain, compile, and test the latest HYSPLIT code on a server at CIMSS. Using a test case we were able to initialize HYSPLIT with a hypothetical volcanic eruption using heights based on NOAA/CIMSS volcanic alert ash cloud heights. This prototype is scriptable and provides a path to fully automate HYSPLIT runs using NOAA/CIMSS ash cloud heights in the future.

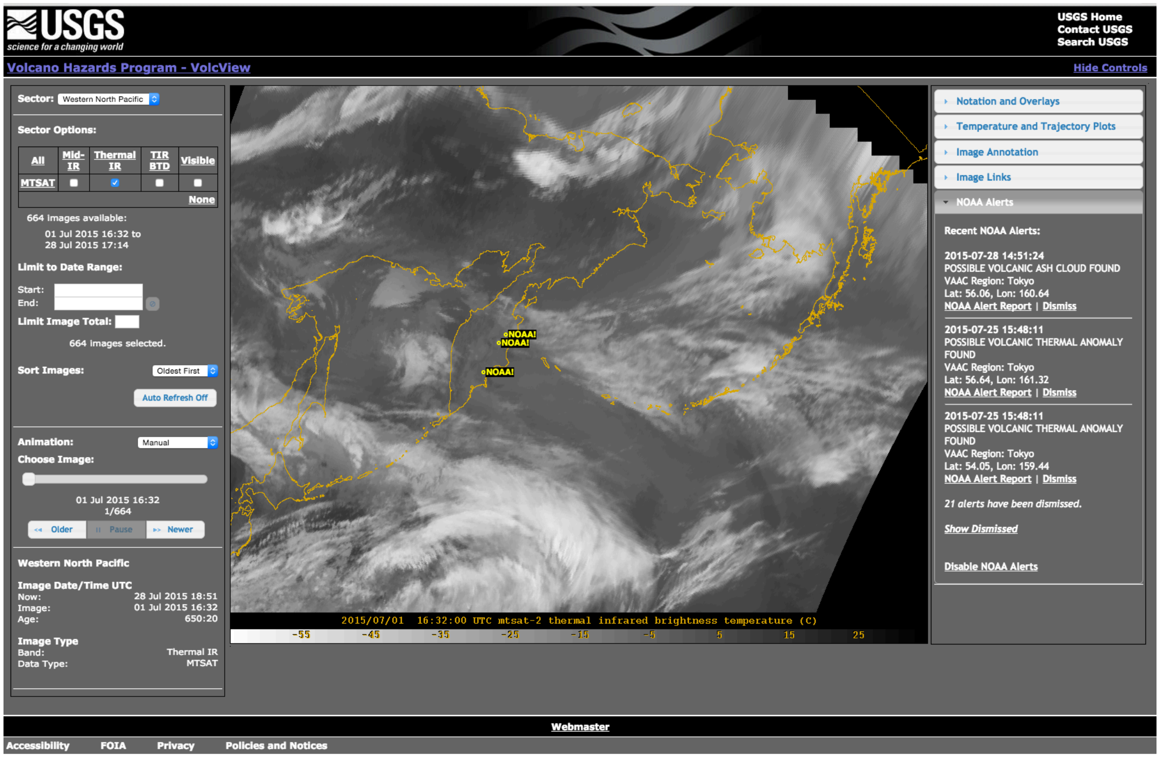

Figure 32. NOAA/CIMSS VOLCAT alerts displayed within the USGS VolcView system on 28 July 2015. The center panel is a satellite image over the western Pacific Ocean. Various VOLCAT alerts can be seen over the Kamchatka Peninsula, Russia. The essential information of the VOLCAT alerts is displayed when an alert is moused over (small yellow "NOAA!" icons). The VOLCAT alert information is also located on the far right panel, where the user can click a link to the full NOAA alert report staged on http://volcano.ssec.wisc.edu/.

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.

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6.7 Assimilation and Forecast Impact of High Temporal Resolution Leo/Geo AMVs in the High-Latitude Data-Gap Corridor

CIMSS Task Leader: Brett Hoover

CIMSS Support Scientists: David Santek, Matthew Lazzara, Jeff Key, Anne Sophie Daloz

NOAA Collaborators: Andrew Collard, Jaime Daniels

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
- Satellite Sensors and Techniques
- Environmental Models and Data Assimilation

Project Overview

The goals of the project are to assimilate atmospheric motion vectors (AMVs) from combined low- Earth-orbiting/geostationary data, referred to as LEO/GEO AMVs, which are generated in the sparsely sampled region between 60-70 degrees latitude in the northern and southern hemispheres. Our interests are: (1) Providing a comprehensive analysis of how to reconcile quality control between AMVs from low-Earth-orbiting (polar) satellites and from geostationary satellites, which have been treated differently for some time. Where these data are blended in the data-gap corridor, a reconciliation of quality control techniques is warranted. (2) Determine the analysis and forecast impact of assimilating LEO/GEO AMVs in the GDAS/GFS. Since the data-gap corridor is a region that is sparsely sampled, the analysis has historically relied heavily on the model background; introducing LEO/GEO AMVs may require some careful considerations for quality control to account for this. We wish to investigate the analysis-impact on radiosonde and non-radiosonde analysis periods separately to see if there is any significant difference in assimilation, as well as examine model forecast bust events, which previous research has shown to be where LEO/GEO AMVs can provide the most impact.

Milestones with Summary of Accomplishments and Findings

Milestones for this period include:

- Complete development of initial data assimilation quality control procedures for LEO/GEO AMVs
- Begin a 2-season experiment
- Develop presentation/report for JCSDA Workshop

A cycled control and experiment have been completed for the period 01 April – 31 May 2014, with simple quality control of LEO/GEO AMVs, treating them the same as MODIS IR (polar) AMVs. This experiment has yielded positive results, with statistically significant improvement in

500 hPa height anomaly correlation and wind speed bias (Figure 33); improvements are significant out to day-4 in the northern hemisphere and to day-3 hours in the southern hemisphere. These impacts are very different from impacts derived from an experimental assimilation of LEO/GEO AMVs in the GDAS from 2012, where impacts were larger and more positive in the southern hemisphere than in the northern hemisphere. A significant change to the GDAS that has taken place since the 2012 experiment is the operational hybrid ensemble 3DVAR system; to test the impact of the hybrid system, the experiment was repeated with a cycled experiment and control using the non-hybrid 3DVAR system, but otherwise keeping the system identical. Impacts were larger and more positive in the southern hemisphere in the non-hybrid experiment (not shown). The difference may stem from two possible sources: (1) the hybrid system produces a more accurate southern hemispheric forecast than the non-hybrid system, and there are far fewer forecast dropouts, which is where the majority of positive impact was found in the 2012 experiment, and (2) the analysis variance of the zonal and meridional wind in the data-gap corridor is larger in the northern hemisphere than in the southern hemisphere (Figure 34), probably owing to the presence of continental land features in the northern hemisphere. The flow-dependent background error covariance produced in the hybrid system are capable of taking this into account, and possibly weighting the LEO/GEO AMVs more heavily in the northern hemisphere, all else being equal.

A second seasonal experiment is currently underway for 01 December 2014 – 31 January 2015, using the same methodology as the first seasonal experiment.

The LEO/GEO AMVs have different characteristics ob-to-ob, based on how they were derived from the combined satellite imagery; this could potentially have an impact on their quality. To investigate this, statistics were collected from the first seasonal experiment on ob-minus-background (OMB) for assimilated LEO/GEO AMVs, and the statistics were grouped by two LEO/GEO characteristics. Observations were collected into groups based on whether they were composed from one or two satellites (single-satellite LEO/GEO AMVs were excluded for this test); the purpose is to determine if there is an impact on AMV quality due to the extra parallax error that can be introduced by using three satellites, versus only two satellites. Observations were also collected into groups based on whether the middle-image used to derive the AMV came from a LEO or a GEO satellite; the purpose of this test is to determine if there is an impact on AMV quality due to height assignment of the AMV (which is based on the middle-image) being derived from low-spatial-resolution GEO imagery or high-spatial-resolution LEO imagery.

Based on these statistics, it was found that LEO/GEO AMVs that use fewer than three satellites and a LEO middle-image have lower OMB for wind speed, direction, and log-normal vector departure (the criteria used in MODIS IR polar AMV quality control) than other LEO/GEO AMVs (Figure 35). Based on these findings, another first-season experiment has begun with modified quality control. In this experiment, LEO/GEO AMVs that use fewer than three satellites and a LEO middle-image are given a reduction in observation error of 50%, subject to a prescribed minimum observation-error.

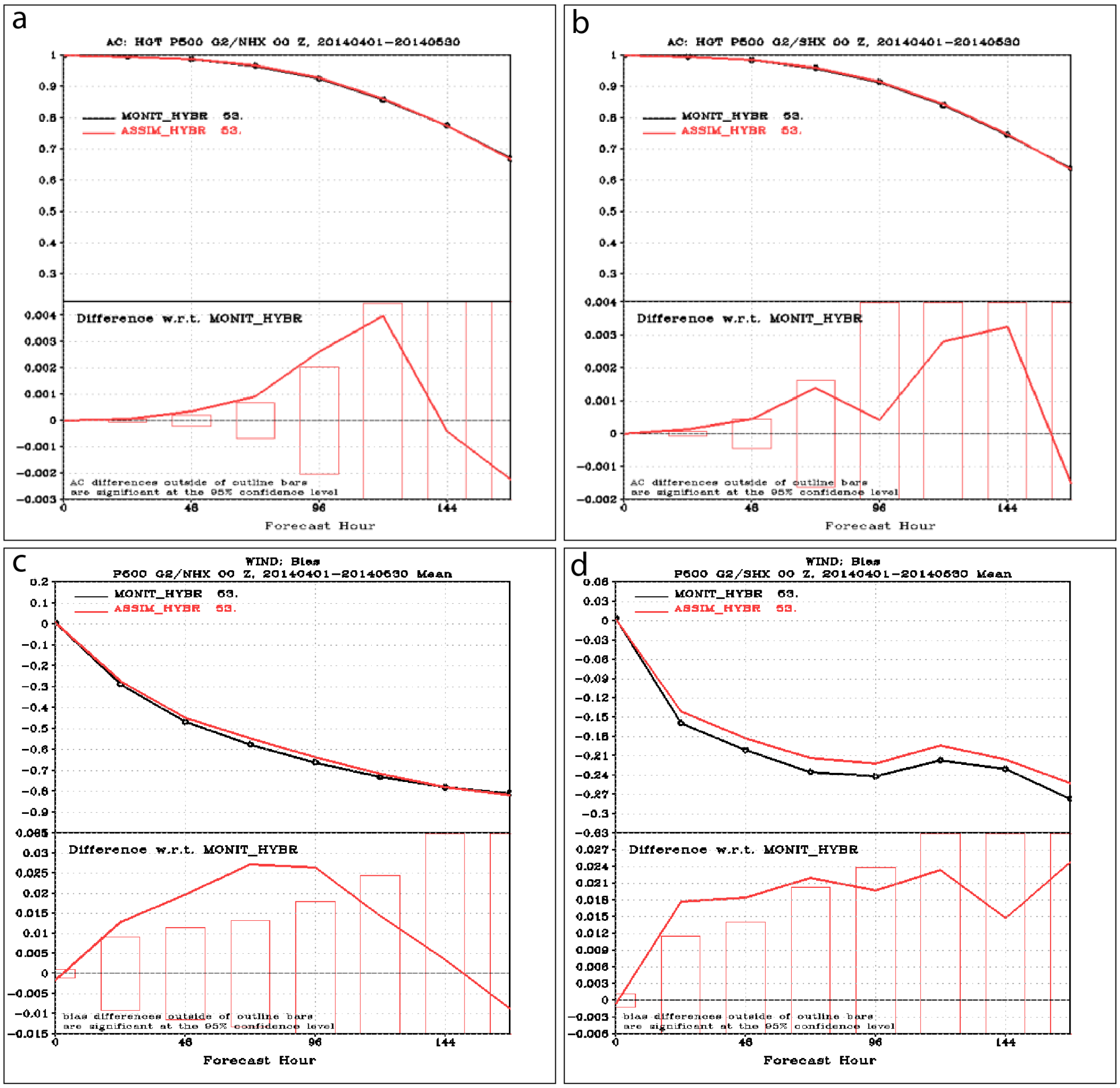

Figure 33. Impact scores of LEO/GEO AMV assimilation for (left) northern hemisphere and (right) southern hemisphere. (Top) Mean 500 hPa geopotential height anomaly correlation from day-0 to day-7. (Bottom) Mean 500 hPa wind speed bias from day-0 to day-7. Black contours represent the control, and red contours represent the experiment. Below each mean plot is a plot of the difference (exp – ctl), with bars representing the necessary difference for 95% statistical significance.

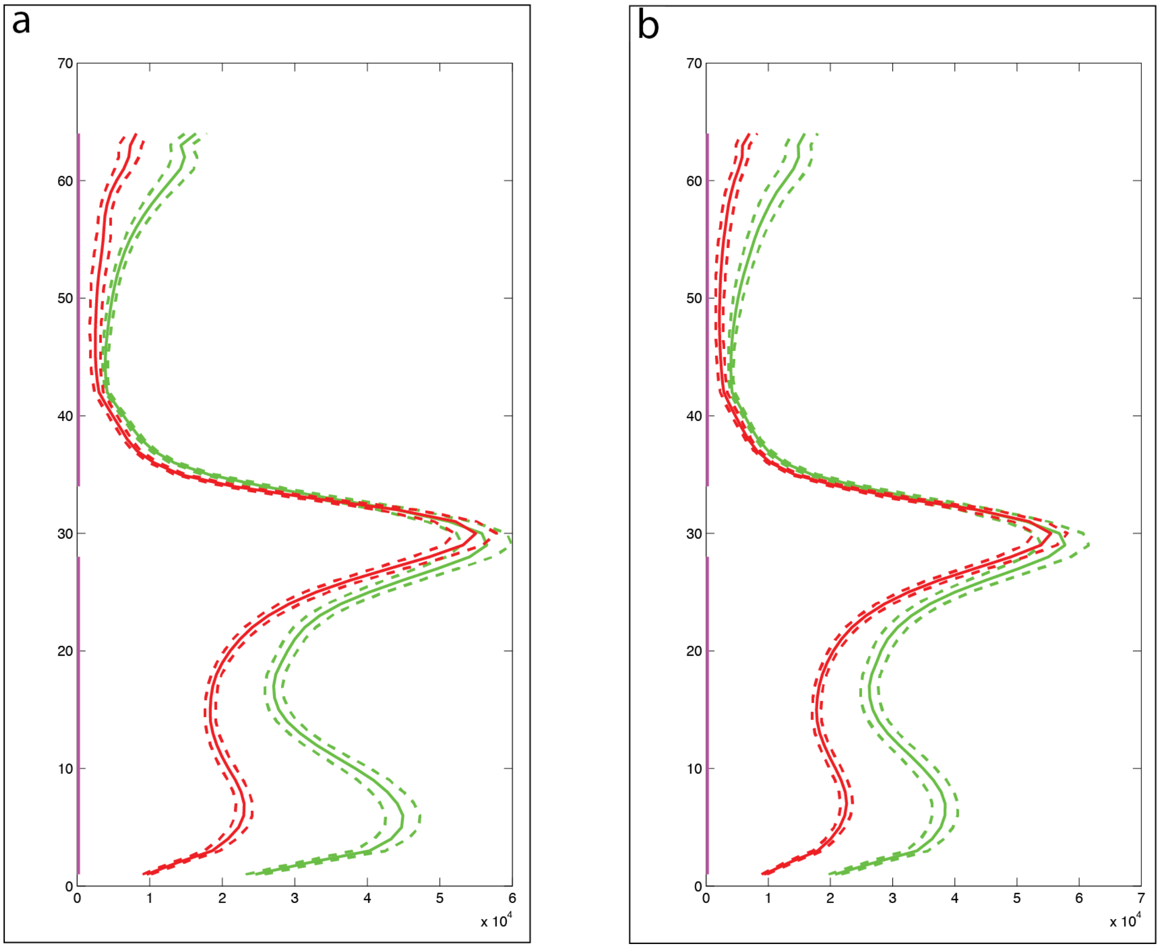

Figure 34. Vertical profile of summed variance in (a) zonal flow, and (b) meridional flow, within the 50-80 degree latitude bands representing the 'gap-corridor' in each hemisphere. The northern hemisphere is represented by the green contours and the southern hemisphere is represented by the red contours. Solid contours represent the mean variance computed from all 80 ensemble members of the GDAS, averaged across all 0000 UTC analyses from April 01 2014 – 30 May 2014, and the dashed contours represent the 95% confidence limits around the mean. Magenta lines along the ordinate show which (sigma-) levels have a 95% statistically significant difference in mean values based on a student's t-test.

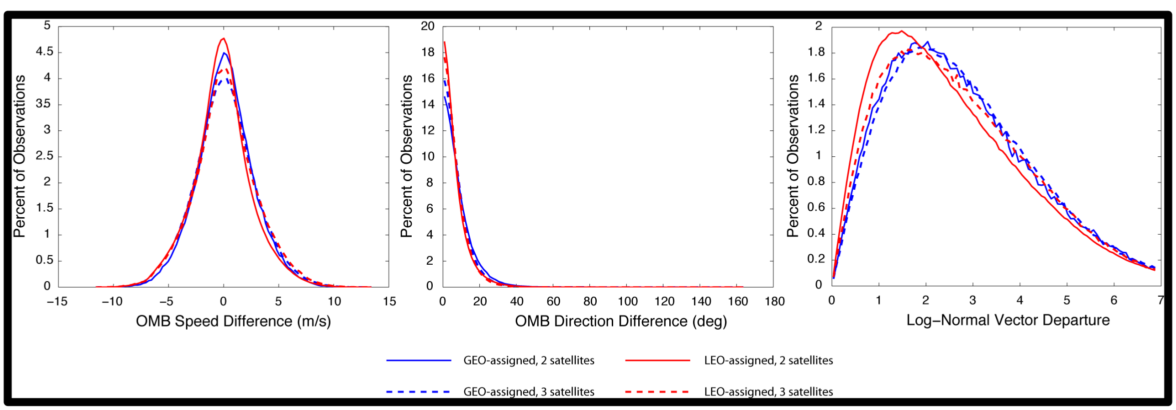

Figure 35. Ob-minus-background statistics for assimilated LEO/GEO AMVs in the first seasonal experiment. (a) OMB of wind speed. (b) OMB of wind direction. (c) OMB of log-normal vector departure. The red curves represent 2-satellite AMVs and the blue curves represent 3-satellite AMVs. The solid curves represent AMVs that use a LEO middle-image and the dashed curves represent AMVs that use a GEO middle-image.

Publications and Conference Reports

These findings were presented at the 13th JCSDA Technical Review and Science Workshop on Data Assimilation, NCWCP, College Park, MD (May 13-15, 2015).

6.8 SPoRT/CIRA/CIMSS Joint Collaboration on Testing Platform-specific Satellite Data Visualization Plugins at NCWCP

CIMSS Task Leader: Kaba Bah

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**

Project Overview

Feedback from operational forecasters highlights the usefulness of RGB satellite imagery, which helps to discriminate specific features of interest that are present in a complex scene. CIRA, SPoRT, and CIMSS have developed several RGB products, building on recipes introduced by EUMETSAT. Most RGB products are currently produced outside of the AWIPS environments and sent to various NWS locations for evaluation. This visiting scientist proposal was a joint SPoRT/CIRA/CIMSS effort to support testing these alternative approaches within AWIPS II and N-AWIPS at NCWCP in preparation for the GOES-R Advance Baseline Imager. SPoRT and CIRA are developing methods to produce RGB products directly within the AWIPS II environment, while SPoRT and CIMSS have focused on developing AWIPS II plug-ins. SPoRT has been instrumental in integrating these products into N-AWIPS and AWIPS. CIRA/ RAMMB staff have investigated existing image overlay capabilities using the AWIPS II National Centers Perspective (NCP) satellite display and found that these need to be enhanced before NCP can be utilized to produce actual RGB displays. In addition, CIRA/RAMMB has also worked with the GOES-R AWIPS II Experimental Products Development Team (EPDT) to investigate the RGB image display framework available in the AWIPS II D2D perspective.

Milestones with Summary of Accomplishments and Findings

CIMSS/STAR/ASPB successfully tested the CIMSS RGB Air Mass product within AWIPS II and at NCWCP based on real-time ABI forecast imagery generated using WRF-CHEM and the CRTM. We worked with the NCWCP POCs on incorporation of ABI brightness temperatures and NWS model gridded data products as overlay to the ABI RGB Air Mass to provide more quantitative information to AWIPS II and N-AWIPS users. CIMSS utilized the already developed Grib2 AWIPSII baseline plugin approach to display our gridded products within AWIPS II via conversation to grib2 using the unified grid de-coder. To accomplish this goal, we first had to develop IDL routines that extracts binary synthetic brightness temperatures from achieved netCDF CRTM output files, utilized Fortran routines to convert binary synthetic brightness temperatures to grib2 using standard grib2 libraries and leverage AWIPS-II XML scripts to unscale and rescale grib2 synthetic brightness temperatures for RGB guns in AWIPSII. Figure 36, shows sample grib2 simulated brightness temperatures for GOES 11 bands as test placeholders for the ABI bands needed to generate an AIRMASS RGB image (band 08, band 10, band 12, band 14).

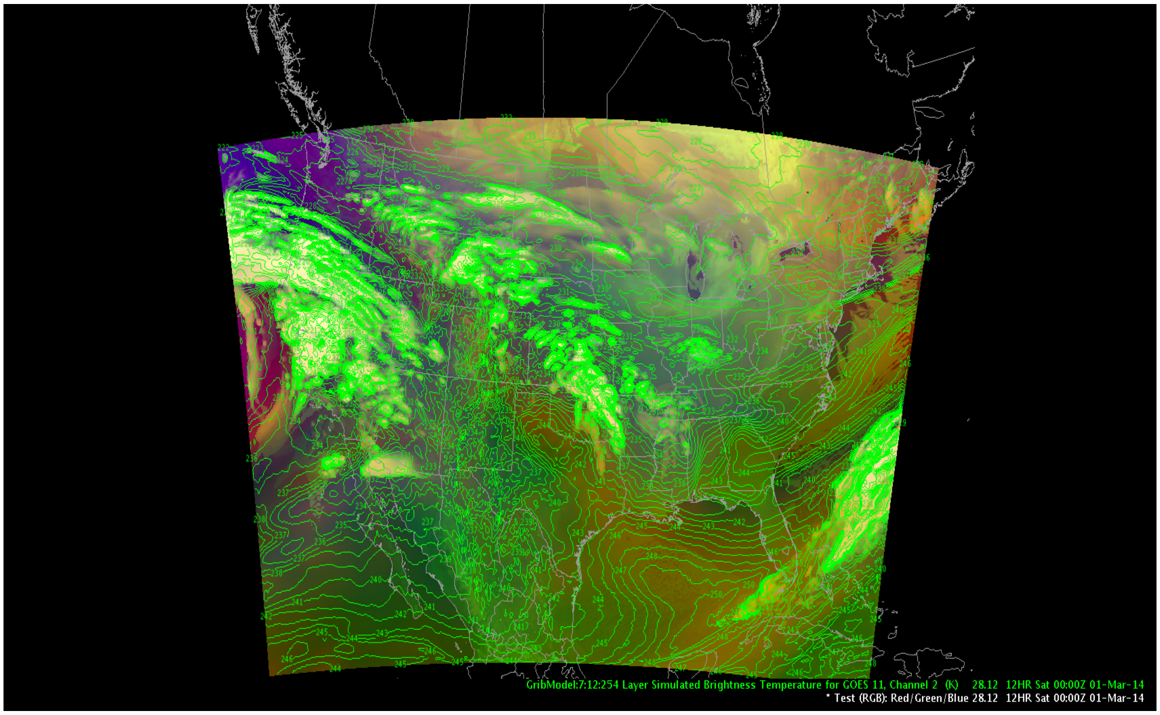

Figure 36. March 01, 2014 00z WRF-CHEM simulated ABI airmass RGB overlay with simulated ABI band 08 high density contours showing brightness temperatures greater than 240k (driest air) in AWIPS-II. This image was made by leveraging predefinted AWIPS-II GOES-11 grib2 placeholders for ABI bands. This approach required scaling the date when generating the grib2 files and unscaling at the display end.

After successfully displaying these images, we found that there is a need to develop capabilities to better control contour levels within AWIPS-II. The current options only offers low-density contours (which shows very few contours) or high-density contours (which over populates the images and makes it look much busier than necessary). In addition, we also learned that new GOES-R ABI grib2 parameters for Discipline 3 (Space Products) category 192 (forecast satellite imagery category) needed to be developed through NCEP to avoid using GOES11 grib2 place holders for ABI bands.

As a result of the above mentioned needs, the CIMSS RGB team worked with the NCEP grib2 team to help define new GOES-R parameters for discipline 3, category 192 for the ABI. These are now available to the public through NCEP and can be used when generating AWIPSII and N-AWIPS grib2 files without the need to scale and unscale data in the GOES-11 grib2 placeholders. Figure 37 shows the newly defined NCEP GOES-R ABI parameters for Discipline 3. With these defined parameters, there is no need to scale ABI bands prior to putting them into grib2 and the AWIPS-II XML scripts do not have to un-scale ABI bands prior to generation of RGB guns.

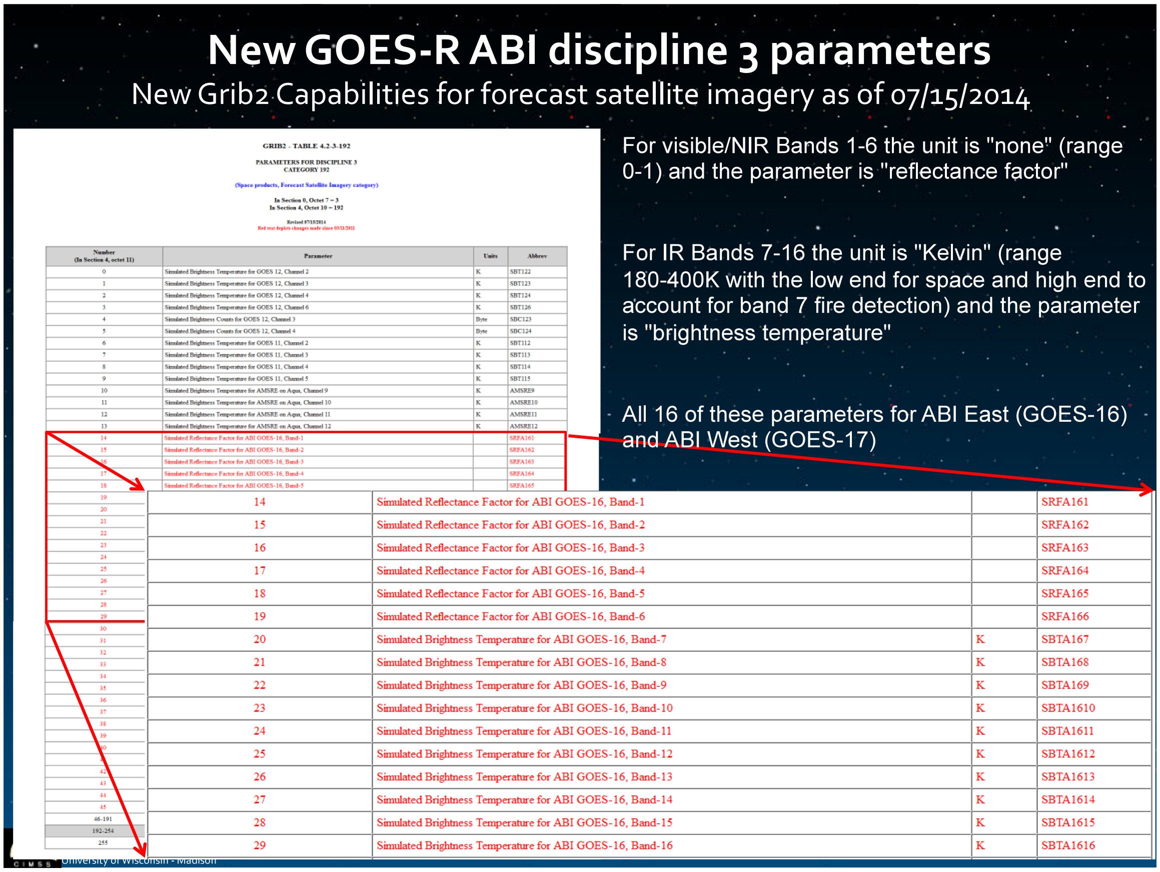

Figure 37. The newly NCEP defined GOES-R ABI discipline 3 parameters forecast satellite imagery as of 07/15/2014. Showing the grib2 parameter name, abbreviations, and units.

All 16 of these grib2 parameters for ABI East (GOES-16) and ABI west (GOES-17) have now been defined and can be used for testing. For the visible/NIR bands 1-6 the units is "none" (range 0-1) and the parameter is "reflectance factor". For the IR Bands 7-16 the unit is "Kelvin" (range 180-240k with the low end for space and high end to account for band 07 fire detection) and the parameter is "brightness temperature".

Publications and Conference Report

Greenwald, Tom.; Pierce, R. B.; Schaack, T. ; Otkin, J. A.; Rogal, M. ; Bah, K. ; and Huang, H. L. 2015: Real-Time Simulation of the GOES-R ABI for User Readiness and Product Evaluation. Submitted and approved for BAMS publication.

Pierce, Bradley,; Bah, K. 2014: CIMSS/ASPB Metrics: Real-time ingest of CIMSS proxy RGB Air Mass product with quantitative overlay within NCWCP AWIPS environment and forecaster training sessions. AWIPSII VSP Meeting, College park, MD. Sept-15th-18th, 2014.

Schmit, Timothy J.; Gunshor, M.; Bah, K.; Gerth, J.; Pierce, B. and Goodman, S. J. Preparing users for the Advanced Baseline Imager (ABI) on GOES-R. Boston, MA, American Meteorological Society, 2015.

7. CIMSS Participation in the Development of GOES-R Proving Ground

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)

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

Project Overview
This proposal is for continued support to the NOAA GOES-R Proving Ground that will test and validate satellite-based algorithms and products before they are integrated into operational use. The Proving Ground mission is designed to ensure User Readiness on Day 1 for GOES-R. To this end, we are seeking assistance via the GOES-R Proving Ground in evaluating the GOES-R Algorithm Working Group demonstration algorithms and baseline/future satellite capability decision support products, testing enhancements and advanced products (Risk Reduction), and providing user assessments and feedback to the product developers. 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-R products will be available and useful to forecasters soon after launch.

Milestones with Summary of Accomplishments and Findings
CIMSS supported the GOES-R Proving Ground demonstrations by evaluating the GOES-R 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 2015-2016 to help train additional forecasters in product applications and to evaluate their utility. This work helped to ensure that GOES-R products were available and useful to forecasters soon after launch.

In 2015-2016 research period of performance, the primary focus was to test, apply, and improve select GOES-R satellite baseline, future capability, and risk reduction imagery/products in support of National Centers and local NWS offices. CIMSS researchers and scientists attended the June 2015 Proving Ground and User Readiness Satellite Science week in Kansas City, MO to determine goals/milestones of the GOES-R Risk Reduction and Proving Ground tasks and were present at regular by-monthly GOES-R Proving Ground coordination/reporting teleconferences. GOES-R 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 2014 EUMETSAT Annual conference in Toulouse, France. Internet web site access to GOES-R Proving Ground activities is hosted at: http://cimss.ssec.wisc.edu/goes_r/proving-ground.html.

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

The following Proving Ground activities occurred in 1 April 2015 – 30 March 2016 funding cycle where several GOE-R proxy decision support products developed at CIMSS were demonstrated with operational forecasters to obtain feedback:

1. Hazardous Weather Testbed (HWT) Spring Experiment (4 May – 12 June, 2015). Participants included 4 CIMSS researchers, 25 NWS forecasters, 5 Broadcast Meteorologists and several visiting scientists.
2. National Hurricane Center (NHC) Tropical Cyclone Demonstration (1 August – 30 November 2015) Participants included forecasters from NHC
3. Aviation Weather Center (AWC) Summer Experiment (10 August – 21 August 2015). 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).
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.

CIMSS scientists were engaged with the demonstrations listed above by providing the following GOES-R Baseline, Future Capability, or Risk Reduction decision support proxy data. Product assessment highlights for eight of the UW-CIMSS decision support products are listed below as reported in the GOES-R PG 2015 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-R Proving Ground Significant Outcomes and Product Assessment Highlights:

CIMSS scientists were engaged with the demonstrations listed above by providing the following GOES-R Baseline, Future Capability, or Risk Reduction decision support proxy data. Product assessment highlights for eight of the UW-CIMSS decision support products are listed below as reported in the GOES-R PG 2014 Annual report (to be published) and HWT/AWC/NHC Testbed final evaluation reports located at: http://www.goes-r.gov/users/proving-ground.html

1. UW-CIMSS Decision Support Product GOES-R Proving Ground Significant Outcomes and 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.
2. The NOAA/CIMSS ProbSevere model was evaluated in the HWT for the second 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 (experimental).
4. The GOES-R convective overshooting top product was transitioned into SPC and AWC operations (experimental) in 2014 and the use of the product has continued to gradually increase.
   GOES-R 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 in May and August 2014, 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/srsor2014/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-R Risk Reduction (GOES-R3) algorithm.

NOAA Testbed Specific Feedback

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: While the simulated imagery clearly was shown to be a beneficial forecast tool by a vast majority of the desks at the AWC, it is important to recall that the original purpose of the simulated imagery was to familiarize forecasters with the baseline capabilities of the ABI. For this reason AWC forecasters would like to continue to evaluate the simulated imagery, but shift their focus to further explore the potential capabilities of each new band. For example, exploring the benefit of having three water vapor channels in forecasting for various levels of turbulence. Though this concept was explored to some extent this year, forecasters would like more evaluation done to this end during the next demonstration period.

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: After several hours, the consensus of both AWC and CWSU forecasters was that there really wasn’t a noticeable benefit to having the 1-minute over the 5-minute imagery. By in large, the majority of aviation products are issued on a broad scale, even for the CWSUs. Additionally, with such large areas of responsibility the details of 1-minute imagery are lost in the rapid pace of issuing products. For these reasons, 5-minute imagery would likely suffice.

Perhaps the only part of aviation operations that isn’t always broad scale is in terminal traffic flow. While the NAMs are monitoring all terminals, if there is weather around a specific terminal causing variations in mesoscale flow, they will take a closer look. Changing mesoscale flow patterns can cause a change of operations (i.e. runways) at a terminal and in some cases, compression issues (i.e. stronger winds above with lighter winds below, causing traffic compression on arrival). Though it hasn’t been explored in detail, 1-minute imagery may be useful in these situations. More information and SRSOR can be found at http://cimss.ssec.wisc.edu/goes/srsor2014/GOES-14_SRSOR.html

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-R 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: In general, the FIT has been used a situational awareness tool for the issuance of icing AIRMETS, providing forecasters an at-a-glance overview of cloud layers that may contain moderate or greater icing. However, as the icing intensity is only available during the day, forecasters found little use of the product at night, when only a 'yes/no' mask is available. Furthermore, the current inputs only allow for icing intensity solutions to be available given that there are no higher ice clouds obscuring the lower layers. In the case of larger scale synoptic systems, where large areas of high ice clouds often do exist, the product is also found to be of little use.

During the 2015 evaluation, NASA LaRC added additional inputs to a very similar algorithm, which dramatically increased the solutions in the presence of higher clouds. Additionally, it allowed the estimation of the base and top of the icing layer. AWC forecasters viewed this algorithm and noted that the addition of those inputs to the GOES-R FIT made the product much more useful. They believe that if these inputs could be combined with the GOES-R DCOMP version of the algorithm (perhaps in a collaborative effort between CIMSS and LaRC), it would provide a much more robust and useable version of the FIT.

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.

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. CIMSS participated in multiple GOES-R Proving Ground organizational and testbed/PG demonstration planning telecons. SSEC conducted infrared/microwave/lightning remote sensing "bootcamp" in July 2013 for GOES-R satellite liaison team which was one-week immersion training.

Publications

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8. CIMSS High Impact Weather Studies with GOES-R and Advanced IR Sounder Measurements

CIMSS Task Leader: Jun Li

NOAA Collaborators: Timothy J. Schmit (STAR/NESDIS), John L. (Jack) Beven (NHC/NWS), Vijay Tallapragada, (EMC/NWS), Mark DeMaria (NHC/NWS), and Andrew Collard (EMC/NWS)

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

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 ABI (Advanced Baseline Imager), GOES Sounder, SEVIRI (Spinning Enhanced Visible and Infrared Imager), 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 ABI and NPP/JPSS sounder measurements in HIW nowcasting and short-range forecasting. AIRS, IASI, CrIS from POES and ABI, GOES Sounder, SEVIRI, AHI from GEO will be used altogether 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).

CIMSS HIW project is highly related to reliable and stable forecasts on super storm such as hurricane Sandy (2012) landed on CONUS. Continuous observations of atmospheric moisture information in environment are very important to the prediction of the genesis, intensification, motion, rainfall potential, and landing impacts of storms through NWP models. ABI on GOES-R series will provide water vapor information with much better coverage and higher temporal/spatial resolution than the current GOES. A dedicated research towards operational application of GOES-R water vapor measurements for HIW events is needed to optimize the information extraction, data assimilation and utilizations within a higher resolution regional NWP framework. The advantages of GOES-R data for regional NWP are that (a) the data have good temporal coverage to assure the data availability within each assimilation time window; (b) the assimilation window can be narrowed (i.e., ±0.5 hour) in order to keep consistency between model's atmospheric states and the observations in a rapid changing weather situation; and (c) more frequent assimilation of data (i.e., hourly assimilation instead of 6-hourly assimilation) is possible.

Milestones with Summary of Accomplishments and Findings

4DVAR versus GSI-3DVAR for high temporal resolution moisture assimilation (Mar 2015 – June 2015)

In order to address the question on how to better assimilate the very high temporal resolution of GOES/GOES-R moisture information, the following two approaches are included in the experiments:

- 4DVAR assimilation and its comparison with 3DVAR for GOES Sounder TPW, and
- Cycling assimilation of GOES sounding information.

Figure 38 shows the 6-hour cumulative precipitation from forecasts with GSI-3DVAR assimilation (upper right) and 4DVAR assimilation (lower left), along with observations (lower right). The data assimilated include conventional data from GTS and the GOES Sounder TPW. In 3DVAR, the GOES Sounder TPW at only 18 UTC on 20 May 2013 was assimilated, while in 4DVAR, the GOES Sounder TPW at 7 times within plus/minus 3 hours from 18 UTC are assimilated (see the upper left).

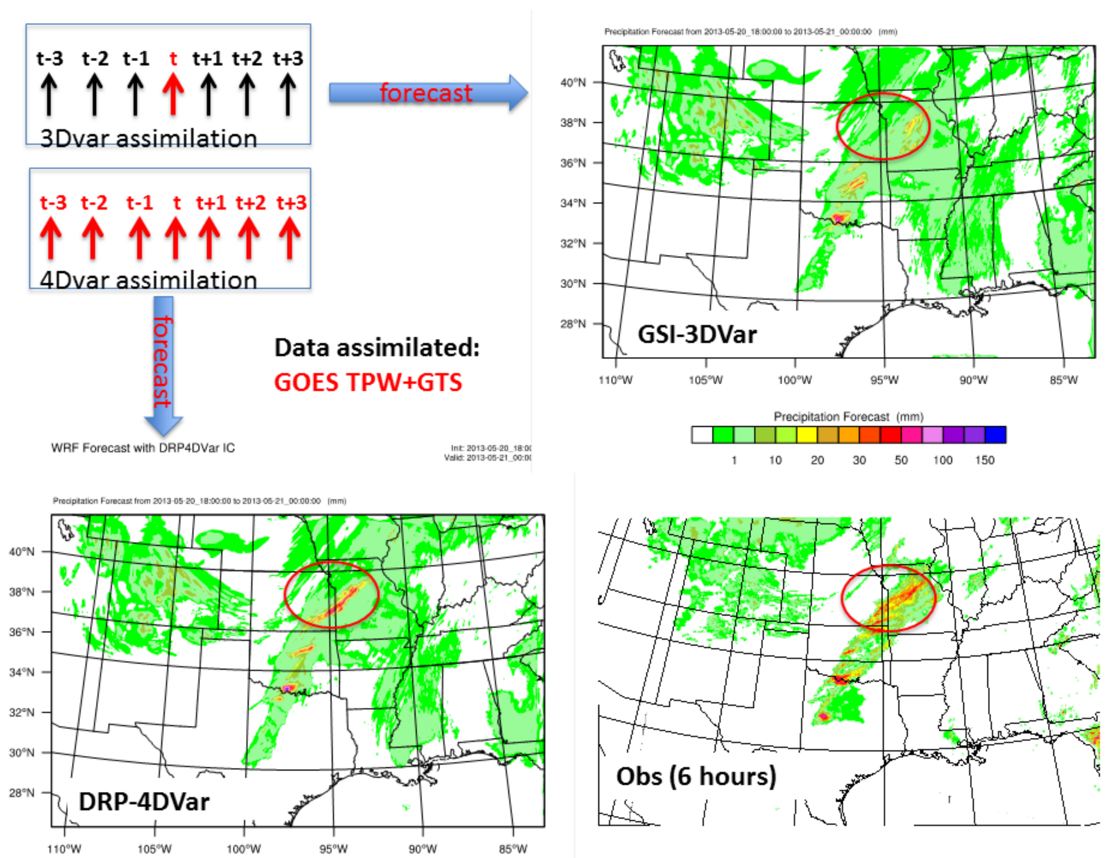

Figure 38. The 6-hour cumulative precipitation from GSI-3DVAR (upper right), 4DVAR (lower left), along with the observations (lower right). The data assimilated include the conventional data from GTS and the GOES Sounder TPW. In 3DVAR, the GOES Sounder at only 18 UTC on 20 May 2013 was assimilated, while in 4DVAR, the GOES Sounder TPW at 7 times are assimilated (see the upper left panel). It shows the advantage of 4DVAR in assimilating frequently observed GOES Sounder moisture information.

Other experiments in OSSE also show hourly cycling assimilation with 3DVAR is better than 3-hour cycling and 6-hour cycling, indicating more frequent assimilation for GEO moisture information provides improved forecasts. This cycling assimilation work is still ongoing.

Therefore, either 4DVAR or high frequently cycling assimilation should improve the utilization of high temporal GOES/GOES-R moisture information in HIW applications

Real time GOES Sounder clear sky TPW data (with GOES-R algorithm) have been assimilated in CIMSS SDAT for applications, and also have been provided to ESRL for LAPS assimilation (July 2015 – Oct 2015)

Real time TPW product from GOES Sounder have been developed at CIMSS with GOES-R LAP algorithm, it has been assimilated into CIMSS SDAT (Satellite Data Assimilation for Tropical Storm forecasts) for applications, and provided in NRT to ESRL since October 2015 for LAPS applications.

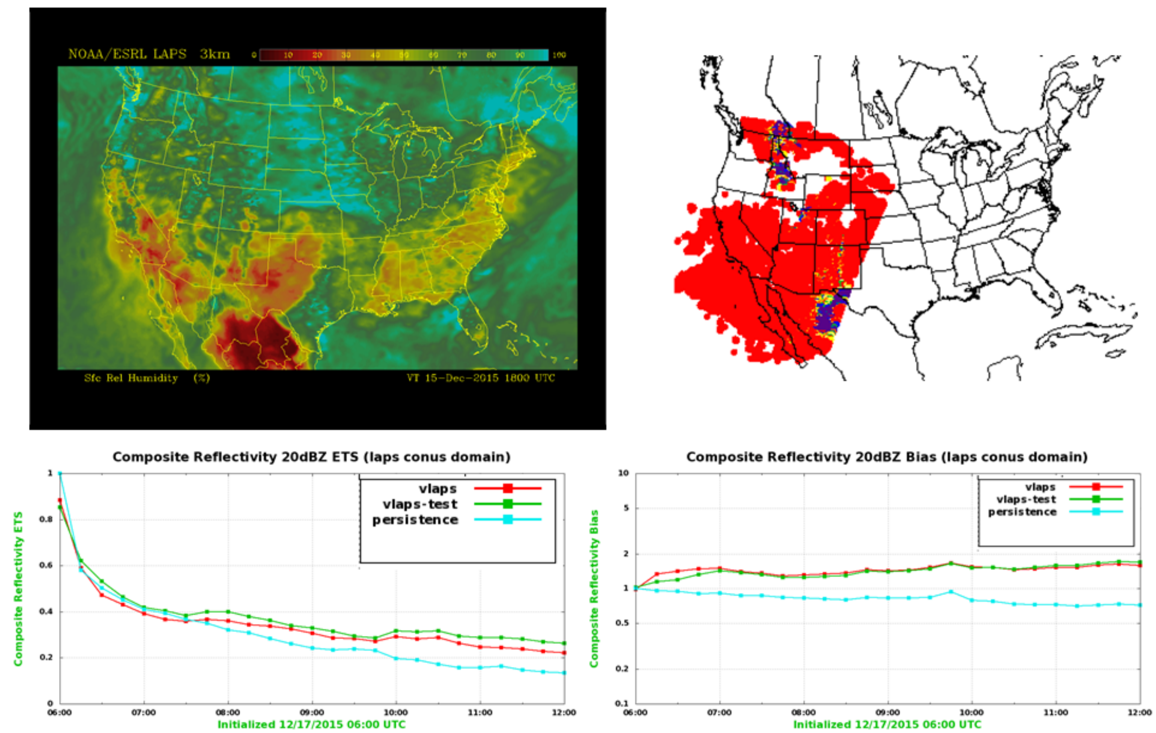

Figure 39. US CONUS domain (upper left), LPW data coverage (upper right), ETS scores from real time LAPS (red) and LAPS test with GOES Sounder LPW assimilated (green) (lower left), bias from the two tests (lower right).

Over the CONUS, the 3-km resolution domain (see upper two panels in Figure 39 for US CONUS domain and LPW data coverage) are localized for vLAPS (real time LAPS version) analysis which assimilates all in-situ, radar and satellite visible and 11 µm dataset. The system has been running with two identical sets of namelists and parameters to initialize two WRF-ARW forecasts for months in real time. After checking that these two WRF runs produced identical analysis and forecasts, then one WRF run is ingesting the GOES Sounder real time LPW (300 – 700 hPa) data from CIMSS and another WRF run is not. The experiments have been running for months in real time for comparisons.

Since recently GOES-east data is not available, GOES-west data is tested in the experiments. For this given time, the GOES-west LPW data coverage is seen in the upper right panel of Figure 39, about a quarter of the analysis domain. For the two assimilation tests, we turned on LPW data on one of the test, called vLAPS_test. Running the analysis and then initializing WRF for 6 hour forecast. For this given time, we compared the two forecasts from 0 – 6 h and calculated their bias and ETS (see the lower two panels in Figure 39). The GOES Sounder LPW data clearly show positive impact from 0 to 6 hour WRF forecasts, with better ETS scores and smaller bias.

Publications and Conference Reports

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9. Investigations in Support of the GOES-R Program

9.1 Ongoing Support
CIMSS Task Leader: W. Paul Menzel
NOAA Collaborators: Tim Schmit, Steve Goodman

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

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- Satellite Sensors and Techniques
- Education and Outreach

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 the GOES-R Technical Advisory Committee, JPSS Reviews, and other evaluation boards, (4) presenting program plans and research results at appropriate venues, and (5) collaborating with international partners pursuing the same goals.

Milestones with Summary of Accomplishments and Findings

Participation in the Independent Advisory Committee
From 23 to 27 February 2015, at the NOAA Science Week in Boulder, CO, WPM participated in the Independent Advisory Committee discussions and helped to draft the final recommendations to the JPSS and GOES-R programs.

Collaborations with EUMETSAT

WPM co-authored with Dr Johannes Schmetz "A Look at the Evolution of Meteorological Satellites - Advancing Capabilities and Meeting User Requirements," (Schmetz, J. and W. P Menzel, 2015: Weather, Climate, and Society. http://dx.doi.org/10.1175/WCAS-D-15-0017.1. Copies are available upon request.

Coordinating with Indian Scientists on INSAT-3D Utilization

SSEC has processed several days of INSAT 3D sounding data. A 24 hour loop of TPW, LI, and CAPE generated from clear and cloudy soundings data as well as GFS soundings (when profile retrieval from INSAT 3D is not achieved for a given field of view) has been shared with ISRO SAC colleagues. Comparison of soundings and utilization will start in early 2016.

Assisting the AMS History Committee

WPM is assisting the AMS history committee chairman Dr Tom Vonderhaar in the organization of an agenda for the History session at AMS 2017. WPM has suggested a theme of "Realizing FGGE - Looking Back after almost 4 Decades" with talks on:

- International cooperation to accomplish global coverage,
- Moving GEOs to fill gaps,
- GMS joins the field,
- EUMETSAT contributes Meteosat with WV channel,
- NOAA LEOs complement GEOs (soundings and AMV heights),
- NASA and NOAA coordinate US satellite processing,
- Global models get reference data sets, and
- Lasting impacts.

Some of the presentations would be by invitation (to Europe, Japan, Russia, NASA, NOAA, ...).

9.2 McIDAS-V Support for GOES-R Development
CIMSS Task Leader: Tom Rink
CIMSS Support Scientist: Joleen Feltz
NOAA Collaborators: Tim Schmit, Ralph Petersen

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

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

Developed necessary software infrastructure incrementally: 2D domains with no time interpolation of (u,v) components first, then implemented an extendable spatial-temporal interpolation algorithm for parcel displacement, followed by full support for 3D+Time trajectory computation and visualization. Developed multiple trajectory visual depiction types including basic line, kinematic derived deformable ribbons, and shaded, fixed width cylinders. Implemented interactive control including adjustable time visibility window, trajectory density, and support for arbitrary starting locations. Trajectory depictions can be colored by an initial scalar field, e.g. a conservative parameter such as Potential Temperature, or non-conservative such as smoke density, or according to a time varying parameter like speed. High spatial and temporal resolution can be computationally challenging, particularly with 3D domains, so interpolation and parcel displacement are performed “lazily”, i.e. only on grid cells containing a trajectory path. Figure 40 shows only a single time of an animation sequence for hurricane Sandy computed from the Non-Hydrostatic Mesoscale Model (NMN) at 8km resolution at 10min model intervals. Figure 41 shows volumetric computed trajectories on a subset of the RAPS domain between 200 and 1000 mb, depicted as fixed width cylinders which can be shaded for enhanced depth perception along with a perspective display projection. Again, only a single time step of the time sequence is shown.

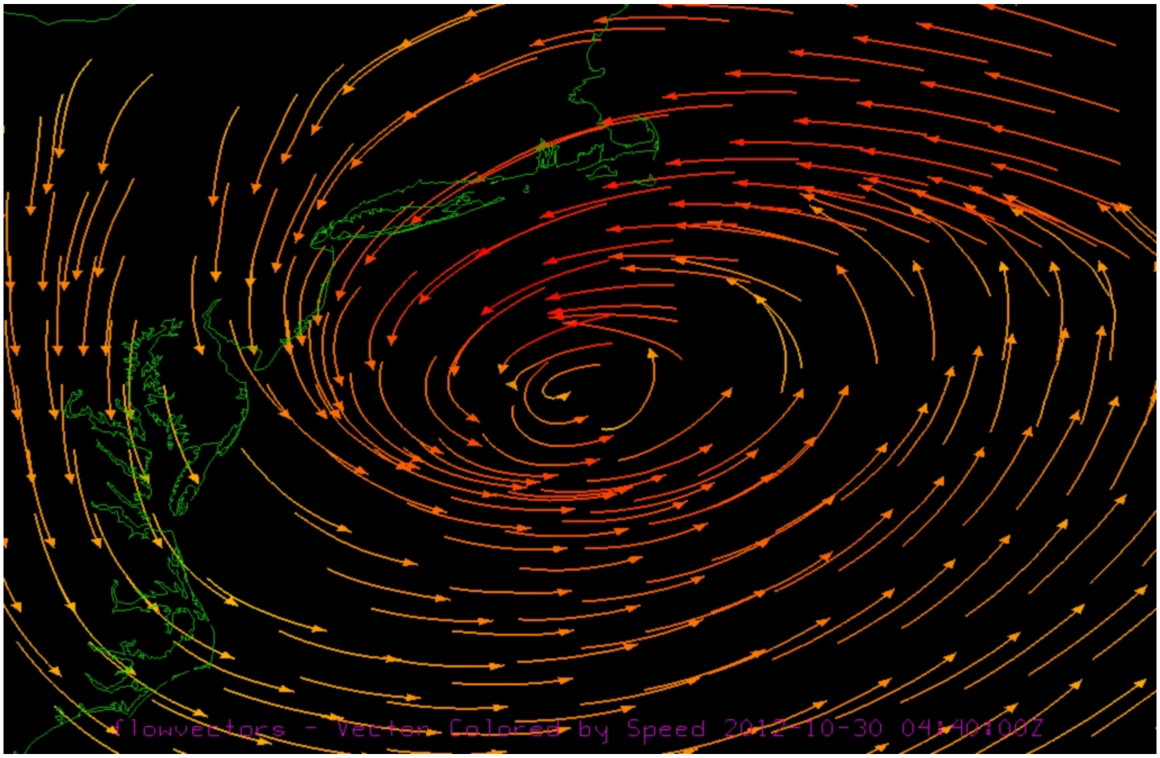

Figure 40. Wind parcel trajectories on 850mb during hurricane Sandy and colored by speed.

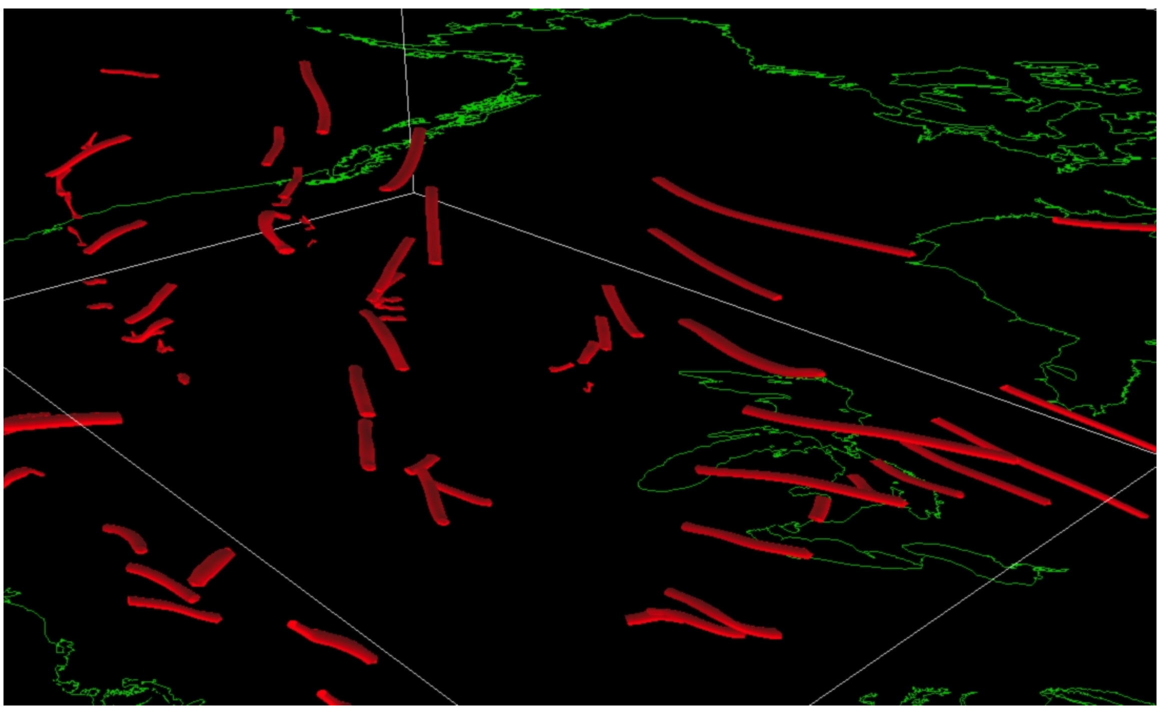

Figure 41. Wind parcel trajectories depicted as shaded cylinders (for better depth perception) computed in a RAPS 3D domain.

Publications and Conference Reports

AMS Annual Meeting (IIPS): 2005-2015
AMS Satellite Meteorology Conference: 2007, 2009, 2010, 2012, 2015

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), 2009-2013
International TOVS Working Group Meeting: 2007, 2008, 2010 (workshop), 2012, 2013
McIDAS Users Group: 2006-2015 (workshops 2008-2015)

10. Cryosphere Products from Himawari-8 for the High-Latitude Proving Ground

CIMSS Task Leader: Yinghui Liu
CIMSS Support Scientist: Xuanji Wang
NOAA Collaborator: Jeffrey Key

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

Project Overview

The goal of this project is adapt snow and ice algorithms that were developed for the GOES-R Advanced Baseline Imager (ABI) to run on Himawari-8 Advanced Himawari Imager (AHI) data over the Alaska region. This activity will ensure enhanced future geostationary cryosphere applications in the GOES-R era. The project is being undertaken by request of the Alaska Region National Weather Service (NWS) in support of their High-Latitude/Arctic Testbed activity.

As a follow-on to the MTSAT series, the Japan Meteorological Agency is operating/will operate its next-generation satellites, called Himawari-8 and Himawari-9 (himawari means "sunflower" in Japanese). JMA launched Himawari-8 in 2014 and began its operation in 2015. The launch of Himawari-9 is scheduled for 2016. JMA will continue to operate Himawari-8 and -9 near 140 degrees east longitude covering the East Asia and Western Pacific regions, as with the GMS and MTSAT series. Both satellites will have the AHI, which is essentially an ABI without the shortwave cirrus band (~1.3 microns). Therefore, the conversion of ABI snow and ice algorithms for use with AHI should be relatively straightforward.

The products of interest are:

- Fractional snow cover,
- Sea ice thickness,
- Sea ice concentration,
- Sea ice surface temperature, and
- Sea ice motion.

Only fractional snow cover is a GOES-R ABI baseline product. The ice products are "future capability." CIMSS and the NOAA personnel developed the ABI ice products. The snow cover algorithm was developed by members of the Algorithm Working Group (AWG) Cryosphere Team at the NWS National Operational Hydrologic Remote Sensing Center (NOHRSC) and the University of Utah (Tom Painter, now at UCLA/JPL). The snow cover algorithm is currently being transitioned from NOHRSC to CIMSS. Therefore, CIMSS is in an ideal position to undertake the application of the snow and ice algorithms to Himawari.

Milestones with Summary of Accomplishments and Findings

Alaska is in the extreme northeast portion of AHI full-disk coverage, so AHI is not the optimal sensor for Alaska. It is important, however, in that allows us to test algorithms on real ABI-like data, reducing the risk for GOES-R products and services. The main area of interest for the Himawari application is the northwest Bering Sea in the vicinity of the Kamchatka Peninsula and possibly the Gulf of Anadyr and St Lawrence Island.

A number of Himawari-8 AHI images that are suitable for high-latitude work have been acquired. Cases are from February and March 2015. The algorithms listed above have been modified for use on the AHI data. Ice surface temperature and concentration using ice algorithm developed for GOES-R ABI with Himawari-8 AHI data as input show reasonable retrieval values and spatial distribution as shown in Figure 42.

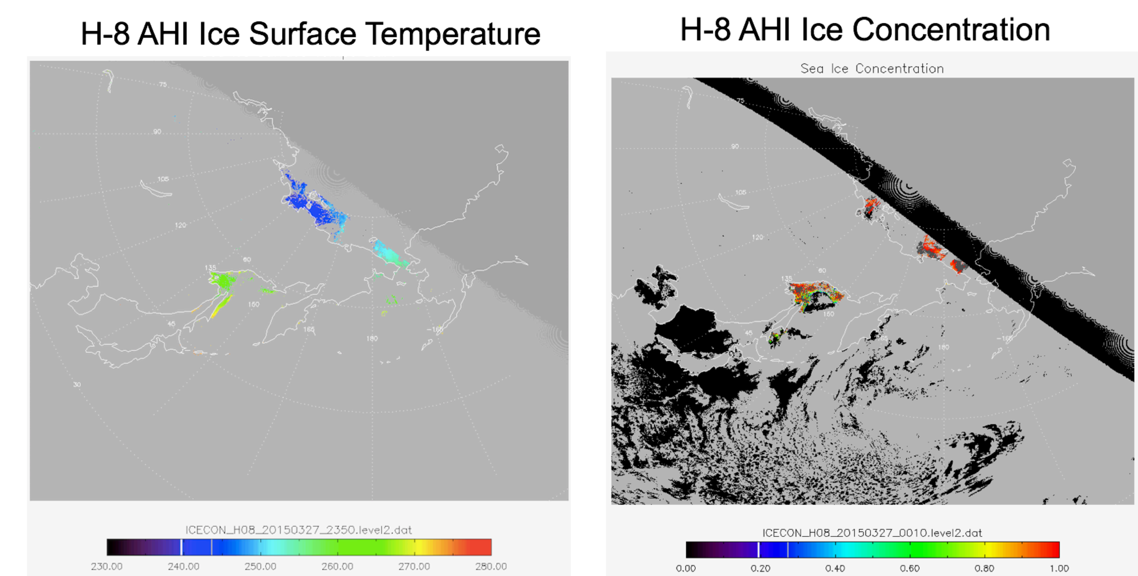

Figure 42. Ice surface temperature and ice concentration using ice algorithm developed for GOES-R ABI with Himawari-8 AHI data as input on March 27, 2015.

Publications

Liu, Y.; Key, J.; Tschudi, M.; Dworak, R.; Mahoney, R.; Baldwin, D. Validation of the Suomi NPP VIIRS Ice Surface Temperature Environmental Data Record. Remote Sens. 2015, 7, 17258-17271.

Y. Liu, J. Key and R. Mahoney: Sea ice concentration from VIIRS on Suomi NPP and the future JPSS Satellites. Submitted to Remote Sensing.

11. GOES-R Future Capability: SO_2 Detection
CIMSS Task Leader: John Cintineo
CIMSS Support Scientist: Justin Sieglaff
NOAA Collaborator: Mike Pavolonis

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

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 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
- *Continue to evaluate the upgraded GOES-R SO_2 detection capability*
  The VOLCAT spatial detection techniques designed for volcanic ash clouds will be leveraged for detecting SO_2 plumes, especially low-level SO_2 plumes. This technique has been successful in capturing low-level volcanic ash clouds that would otherwise go

undetected with ash spectral signatures alone. In addition, VOLCAT cloud object tracking techniques designed for ash clouds can be directly leveraged for SO_2 clouds, which is especially important for larger scale eruptions with long-lived SO_2 clouds.

- *Apply upgraded algorithm to Himawari-8 and validate results.*
  Work is ongoing to collect SO_2 examples from Himawari-8 imagery to be potentially used for additional training for next-generation satellites (Himawari-8 is very similar to GOES-R) and for validation of the SO_2 detection algorithm.

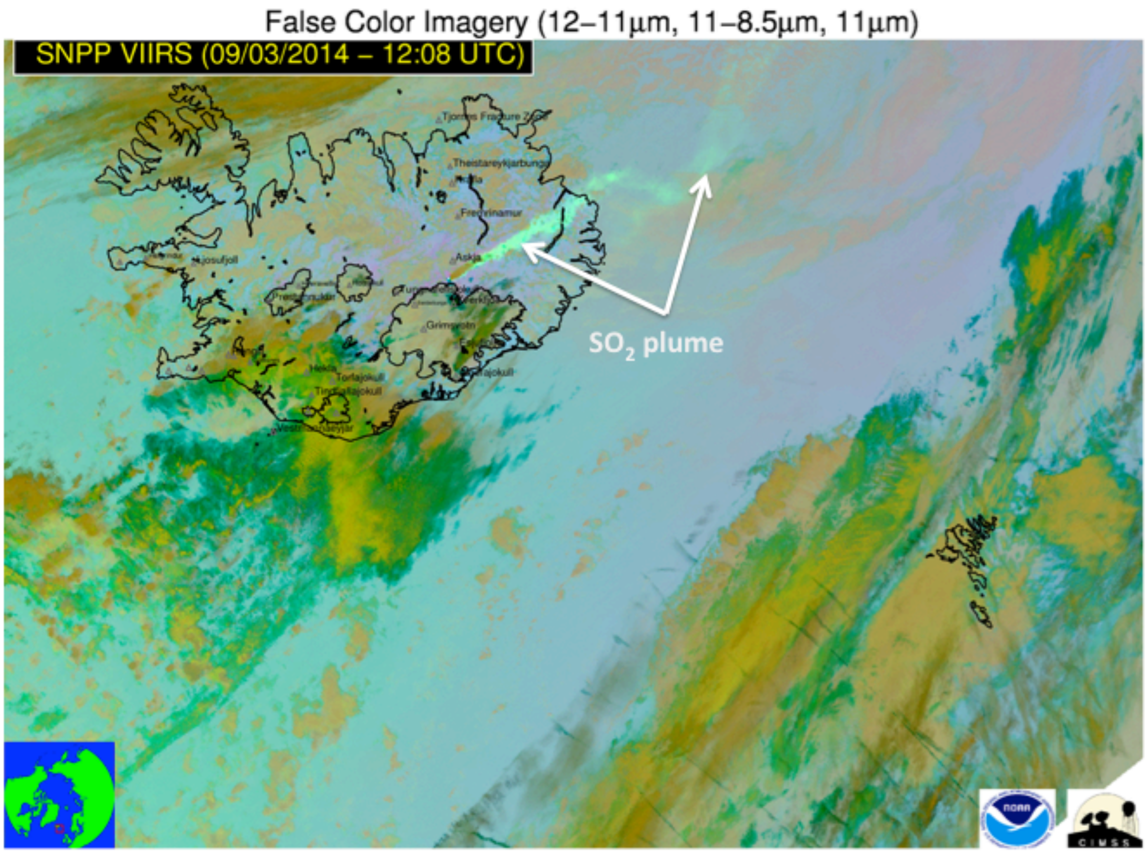

Figure 43. This SO_2 plume from NPP VIIRS false color imagery is an example where spatial methods applied to volcanic ash clouds may also be successful in detecting SO_2 plumes.

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., J. Sieglaff, and J. Cintineo, 2014a: Spectrally Enhanced Cloud Objects (SECO): A generalized framework for automated detection of volcanic ash and dust clouds in satellite imagery, Part I: Multi-spectral Analysis, Submitted to *J. Geophys. Res. Atmos*.

Pavolonis, M.J., J. Sieglaff, and J. Cintineo, 2014b: Spectrally Enhanced Cloud Objects (SECO): A generalized framework for automated detection of volcanic ash and dust clouds in satellite imagery, Part II: Cloud Object Analysis and Global Application, Submitted to *J. Geophys. Res. Atmos*.

12. Identification of GOES-R Storm Top Features
CIMSS Task Leader: Pao K. Wang
NOAA Collaborators: Steve Goodman

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

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.

Milestones with Summary of Accomplishments and Findings
We have identified a unique feature called "gullwing cirrus" feature in the CALIPSO image of a storm system (Figure 44). Although this is not the same satellite as GOES, the understanding of this phenomenon can contribute to deeper understanding of GOES-R images of storms. We believe this is due to the gravity wave breaking in the stratosphere, a good indication of the presence of clear air turbulence (CAT).

Figure 44 shows the CALIPSO CALIOP 532 nm lidar backscattering coefficient profile, a cross-section acquired along a line cutting through a thunderstorm in Agentina. The focus of our study is the gullwing-shaped thin cirrus layer indicated by the white arrows, called "gullwing cirrus" because of their shape. The first gullwing cirrus (left) labeled "E" seems to rise from an already heightened block of cloud materials.

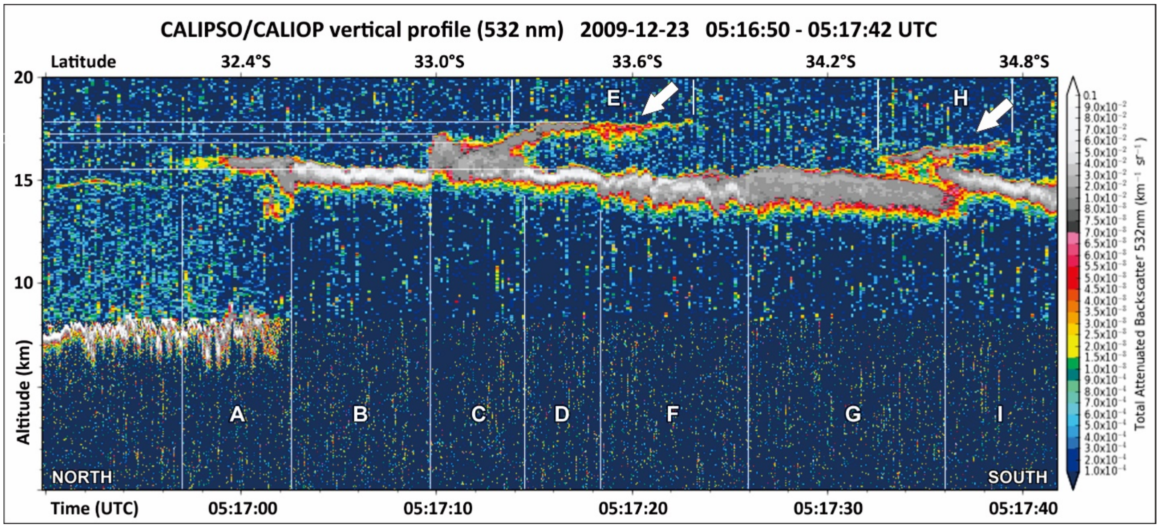

Figure 44. The gullwing feature (indicated by white arrows) of two storm systems in a CALIPSO image.

We performed numerical model studies to show that such gullwing cirrus are indeed due to internal gravity wave breaking and carries moisture into higher part of the stratosphere. Figure 45 shows an example of the model simulation:

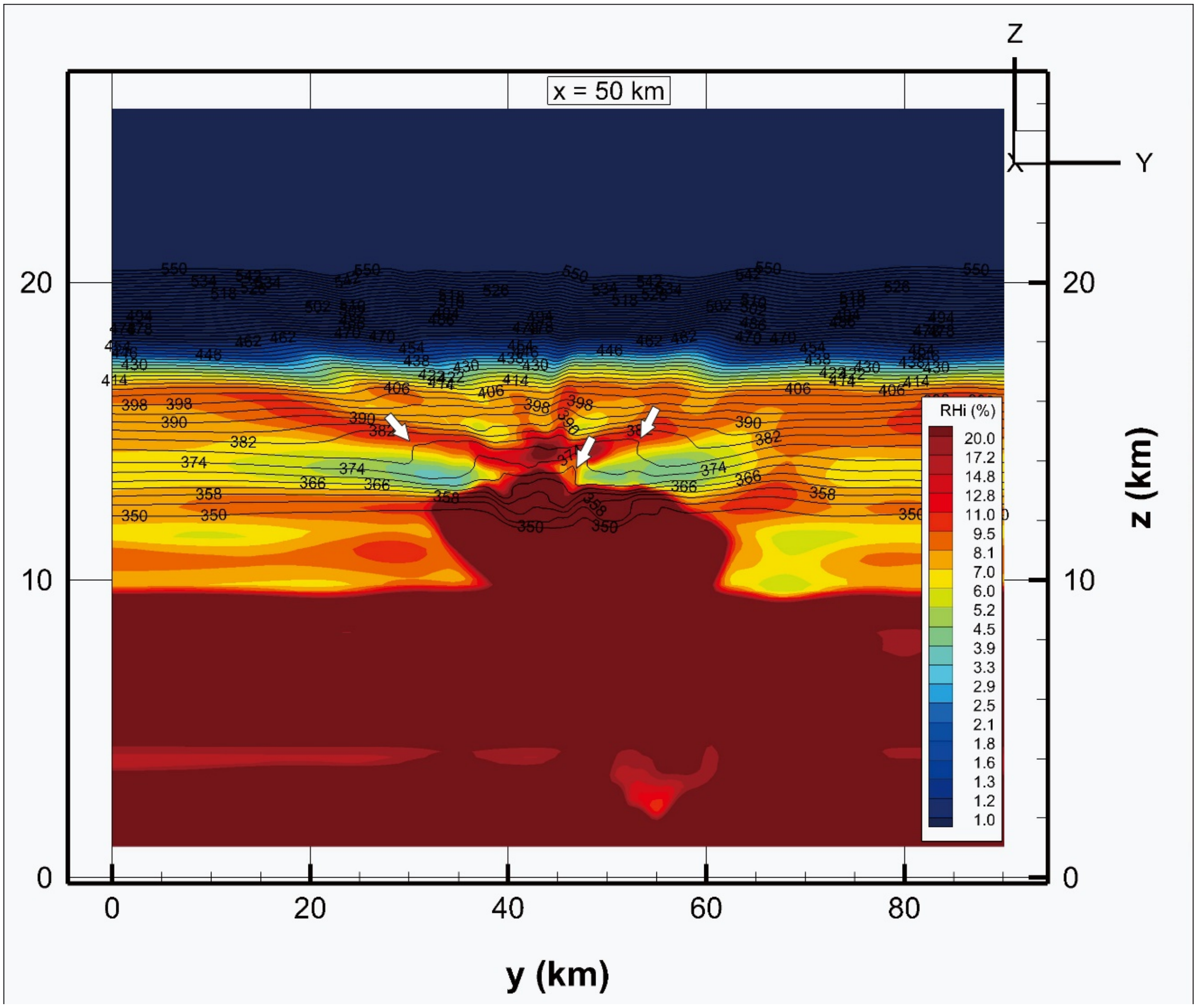

Figure 45. The north-south cross-section at x=50km of the RHi field at a randomly chosen time of the simulated CCOPE supercell showing similar gullwing-shaped plumes in the stratosphere. White arrows indicate locations where wave breaking is occurring.

The presence of gullwing-shaped cirrus is evidence that storm materials can be transported into the stratosphere via the gravity wave breaking process to levels much higher than previously thought. Given the important role played by water substance in the stratosphere, it is clearly of some importance to investigate this process further. It is highly likely that other trace chemicals (both trace gases and aerosol particles) of tropospheric origin can also be transported this way.

The wave breaking occurs at points where the vertical gradient of the equivalent potential temperature is negative ($\partial\theta_e / \partial z < 0$). Figure 46 shows an example of the wave breaking region of the simulated storm top:

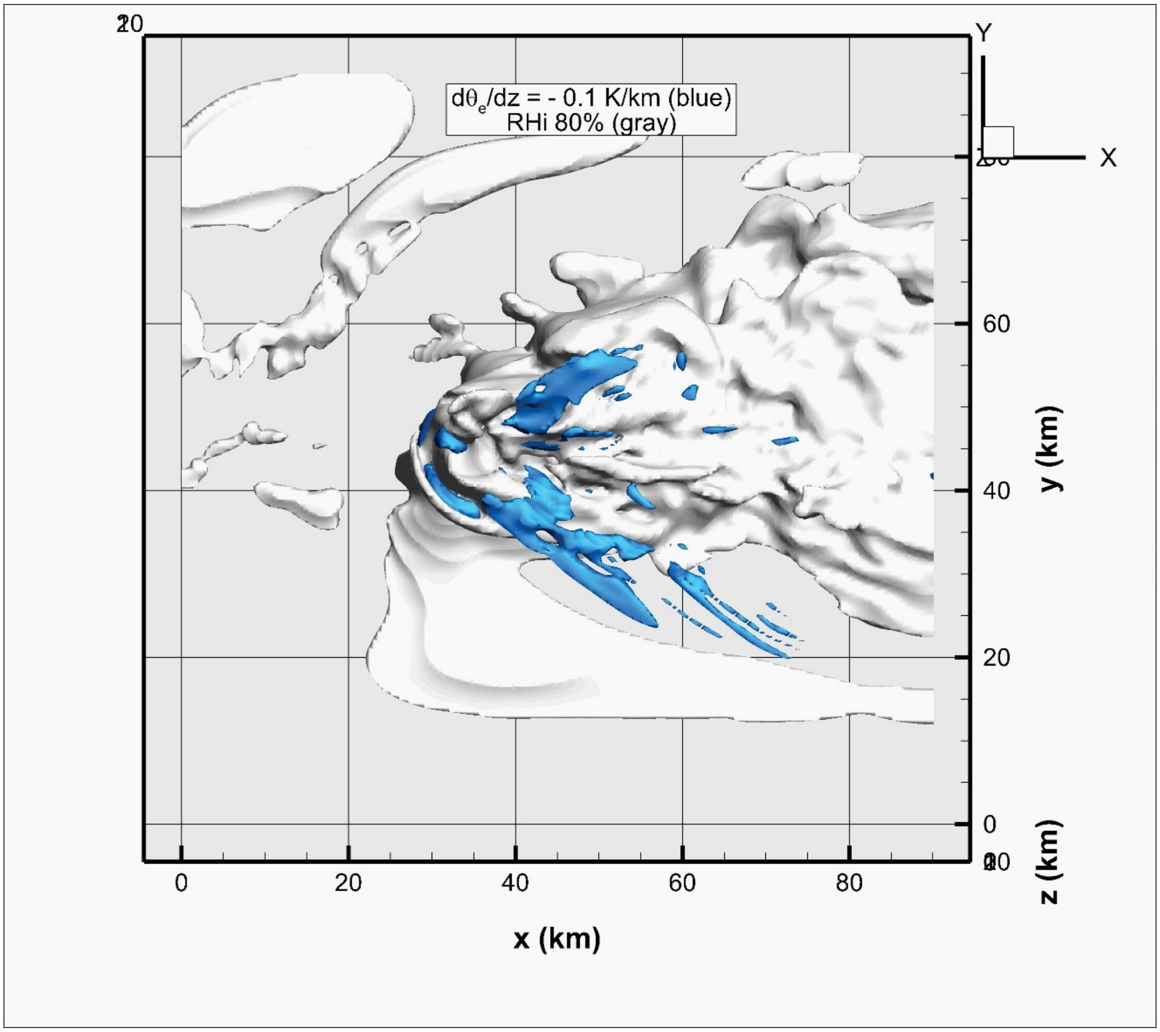

Figure 46. Top view of the simulated CCOPE storm at the same time frame as in Figure 47 showing the regions where ***∂θe∂z=-0.1K/km*** **(blue). The gray color represents the RHi=80% isosurfaces used to represent the approximate cloud boundaries.**

The blue regions in Figure 46 also represent where clear air turbulence (CAT) are generated since wave breaking must generate turbulence. Figure 47 shows a side-view of the wave breaking regions.

This understanding can be utilized for GOES-R' future projects in detecting CAT. We have summarized the results into a paper (Wang et al., 2016) and submitted to *J. Geophys. Res.* which is now accepted for publication.

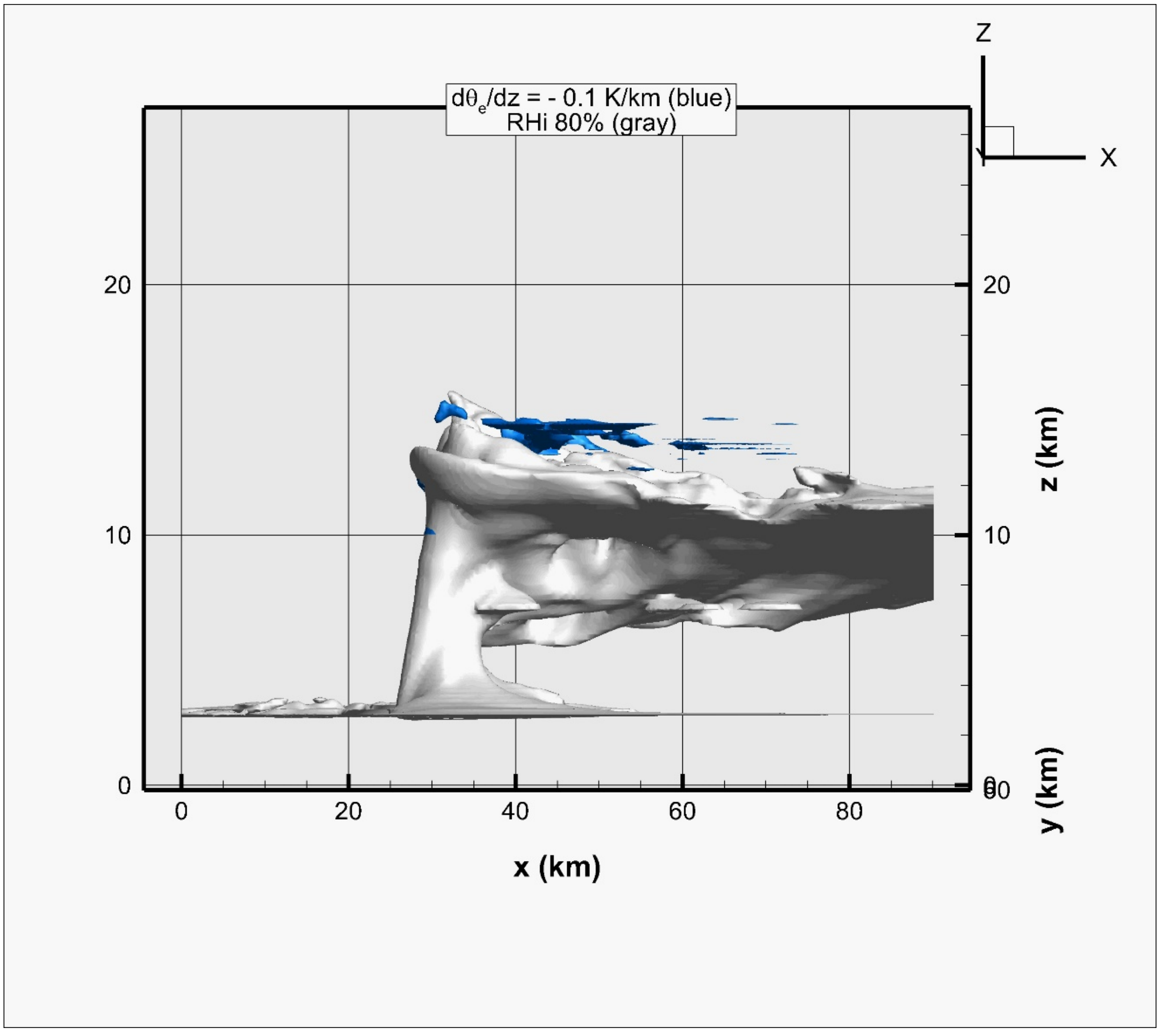

Figure 47. East-west view of the simulated CCOPE storm at the same time frame as in previous figure showing the regions where *∂θe∂z=-0.1K/km* (blue). The gray color represents the RHi=80% isosurfaces used to represent the approximate cloud boundaries.

Publications and Conference Reports

Wang, P. K., K. Y. Cheng, M. Setvak, and C. K. Wang, 2016: The origin of the gullwing-shaped cirrus above an Argentinian thunderstorm as seen in CALIPSO images. *J. Geophys. Res.* (accepted for publication)

Wang, P.K., and K.Y. Cheng, 2015: Physical Processes Responsible for Storm Top IR Features Observed by Satellites. EUMETSAT Meteor. Satellite Conf., 21-25 September 2015, Toulouse, France.

Wang, Pao K., 2015: High Time Resolution Physics and Dynamics of the Top of Simulated Severe Thunderstorms, *Taipei Severe Weather and Extreme Precipitation Workshop*, 25-27 May 2015.
Cheng, K. Y., and Pao K. Wang, 2015: A Numerical Study on the Growth of Large Falling Hydrometeors, *Taipei Severe Weather and Extreme Precipitation Workshop*, 25-27 May 2015.

13. Development of a Geostationary Community Satellite Processing Package (CSPP)

CIMSS Task Leaders: Liam Gumley (PI), Graeme Martin (PM)
CIMSS Support Scientists: Nick Bearson, Jessica Braun, Geoff Cureton, Ray Garcia, Tommy Jasmin, Scott Mindock, Kathy Strabala.
NOAA Collaborators: Steve Goodman, Satya Kalluri, Andrew Heidinger, Michael Pavolonis

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

Project Overview

The CSPP Geo project develops and distributes software that allows users to process geostationary satellite data received at direct broadcast stations. The software is free to download and easy to install and run, with support provided by the CSPP Geo team. The primary goal is to support processing of GOES Rebroadcast (GRB) data from the GOES-R mission, and additional goals are to provide support for processing direct broadcast data from the current GOES and Japanese Himawari-8 missions.

As of this reporting period, the following software is available for public download via the CSPP Geo website: 1) the **GVAR package**, capable of processing current GOES imager data in real-time as received via the GVAR data stream, and 2) the **GRB package**, capable of processing GOES-R instrument data in real-time as it will be received via the GRB stream. The GRB packages supports four of the six GOES-R instruments, with support for the remaining instruments to be added in a future release.

Software packages are currently being developed at CIMSS/SSEC to generate Level 2 products using research versions of algorithms developed under GOES-R AWG. Initially, support will be offered for current GOES Imager data, with support for the Advanced Himawari Imager (AHI) and the Advanced Baseline Imager (ABI) to be added later. By allowing users to run algorithm software developed for GOES-R on currently available data from other instruments, we hope to familiarize users with the software and products before the launch of GOES-R, improve the quality of the software and products, and to provide products that are themselves useful in forecasting and other applications.

The target user base encompasses the U.S. and international community of direct broadcast users within the receiving area of the supported instruments. This includes the National Weather Service and other government users, vendors of satellite receiving stations, international meteorological offices and the research community. Potential applications of the data products include forecasting, data assimilation, hazard detection and environmental monitoring.

Milestones with Summary of Accomplishments and Findings

The CSPP GEO team at CIMSS/SSEC made significant progress on several tasks during the reporting period, including:

- Developing and releasing software to process current GOES Imager data received via the GVAR stream;
- Developing and releasing software to process data that will be received from the GOES-R satellite via the GRB stream;
- Planning and developing software to process data from the AHI instrument on the Japanese Himawari-8 satellite;
- Algorithm integration and software scripting infrastructure development for the GEOCAT Level 2 software to process data from multiple instruments, and maintenance of a public-facing ancillary data server;
- Cross-cutting activities related to software development;
- Testing the Harris GRB simulator, including data gathering and chaining with the Quorum demodulator and our GRB software; and
- Interactions with users, potential users and vendors, as well as development and maintenance of the CSPP Geo website

CSPP Geo GVAR Software

Version 1.0 of the CSPP Geo GVAR software package was released on April 9, 2015. This initial software release performs the primary functions of reading GVAR data as received on an antenna at a direct broadcast site, remapping GOES Imager data to a common projection, and writing the output to McIDAS AREA files. The GOES-13 and GOES-15 imagers are supported in this release. The output is suitable for use in the future GEOCAT Level 2 processing software, or by other applications that can read AREA files.

CSPP Geo GRB Software

Prototype version 0.2 of the GRB software package was released on June 5, 2015. This is a critical piece of infrastructure that will allow users to process the CADU-framed CCSDS packets that make up the GRB stream, generating Level 1 products from the ABI and space weather instruments, and Level 2 Geostationary Lightning Mapper (GLM) products. The software was developed in accordance with the GRB specification in the GOES-R Product Definition and Users' Guide (PUG), and was tested on the most up-to-date GRB proxy data available.

This version of the software added support for the Magnetometer (MAG) and Space Environment In-Situ Suite (SEISS) instruments, in addition to the ABI and GLM instruments that were supported in the initial release. Other new features in this version were support for processing UDP datagrams containing CADU frames over dual sockets, as the data will be received from a demodulator in a GRB receiving system.

A test data package was provided to users containing a mix of data captured from the GRB simulator and DOE-1 data captured from tests of the operational ground system, along with a sender script that frames data as CADUs and streams it over dual sockets, simulating the GRB data stream.

An updated version of the CSPP Geo GRB Interface Control Document describing the upstream and downstream interfaces was provided along with the software.

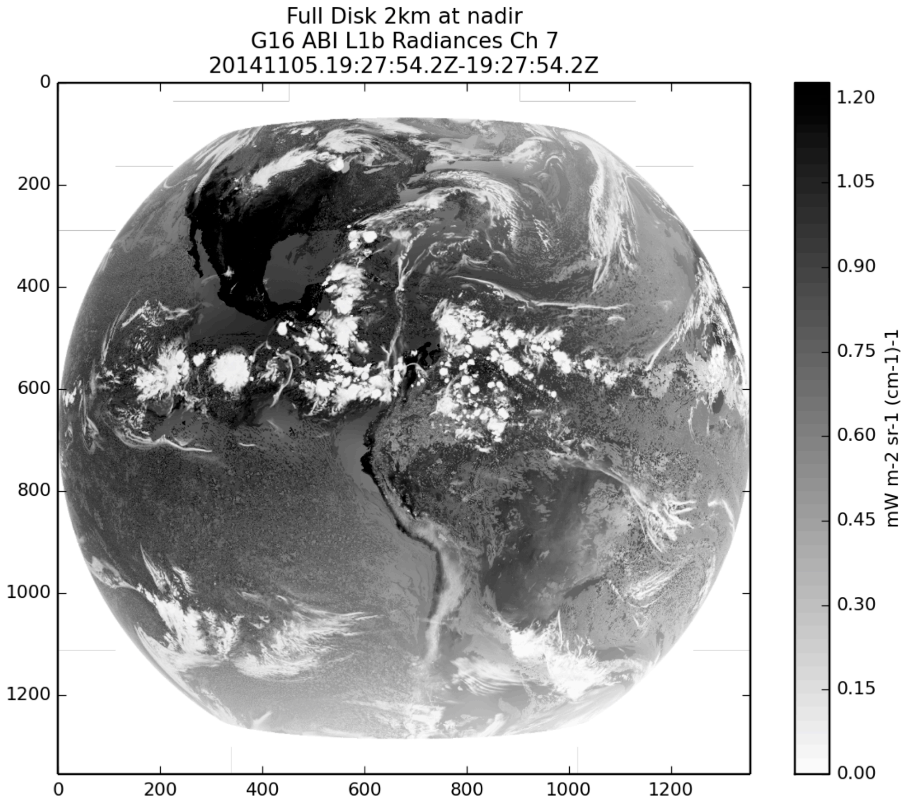

Figure 48. Quicklook image of the radiance product from the GRB v0.2 prototype software package (ABI proxy data, band 7)

Himawari AHI Planning and Software Development

During this period work was begun on planning and developing software to support processing of AHI data. Software will be provided to allow users to process AHI data in both the full-resolution HSD format that is distributed by the JMA via the cloud, and the lower resolution HimawariCast data format that is distributed via direct broadcast. During the reporting period we began receiving and working with HSD data from NOAA STAR, as well as understanding the requirements and designing software to process HimawariCast data, in consultation with the vendor of the required proprietary upstream processing software, KenCast. We also began developing AHI ingest code, leveraging and contributing to the libHimawari ingest library that was being developed at CIMSS/SSEC under separate funding.

Geocat Level 2 Software

The CSPP Geo team worked with the AWG cloud and fog teams to integrate and test updated versions of science algorithms in the Geostationary Cloud Algorithm Testbed (GEOCAT), and to verify output products. The goal is to release an initial version of the GEOCAT package that processes current GOES Imager data, and later add support for the AHI and ABI instruments, as well as additional product algorithms. Work was begun on developing scripting infrastructure for job sequencing, handling temporal data dependencies, ancillary data download and data caching, error handling and logging. We implemented a software chain consisting of the GVAR and prototype GEOCAT software running in real-time on GOES imager data received on an antenna at SSEC, allowing us to evaluate the robustness of the software and the quality of the products.

The CSPP Geo team maintained a public-facing ancillary data distribution server, routinely posting the NWP and other dynamic ancillary data required by GEOCAT.

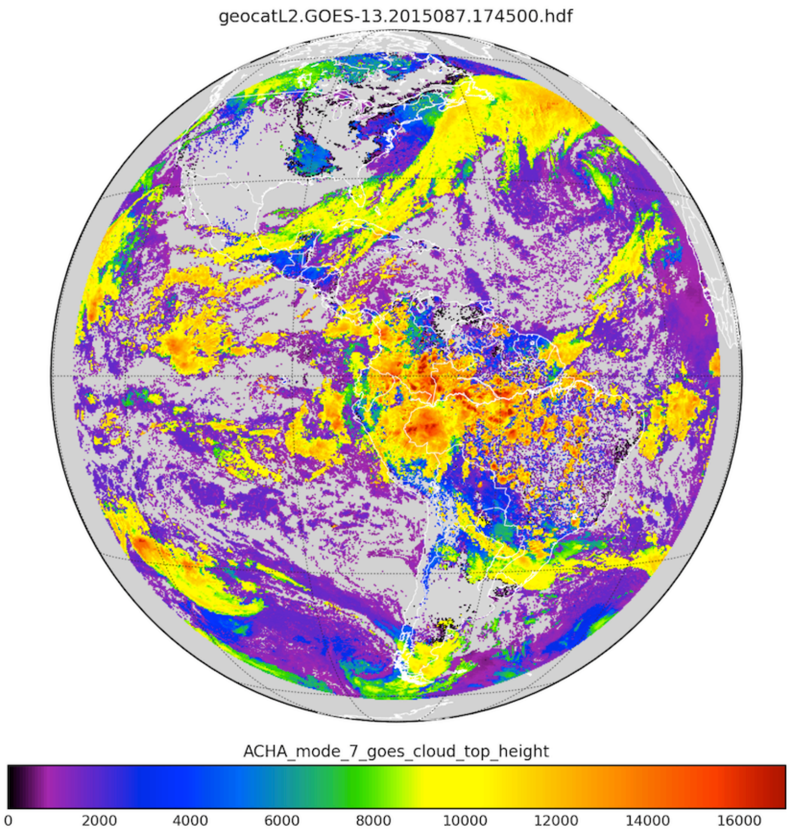

Figure 49. Plot of cloud top height product generated by the prototype GEOCAT Level 2 software package (GOES-13, 28 Mar 2015 1745 UTC)

Cross-cutting Software Development Activities

We made progress on various tasks related to software development and spanning multiple software packages, including: developing "quicklook" image plotting software and other common utilities; developing testing infrastructure; static build and bundling of third-party COTS libraries; developing packaging tools and processes; and evaluation, implementation and maintenance and of third-party productivity tools. For many of these tasks we leveraged code and processes that had been developed by the CSPP project under separate funding.

Working with the Harris GRB Simulator

The CSPP Geo team continued to work with the GRB simulator, on loan from Harris Corporation. A processing chain representing a realistic approximation of a GRB receiving system was demonstrated, consisting of the GRB simulator, a prototype demodulator on loan from Quorum Communications, and the prototype CSPP Geo GRB software.

User Interactions and Public Relations

The CSPP Geo team connected with users and potential users during this period, answering questions regarding the capabilities and hardware requirements future software packages, and helping the users with their planning for GOES-R and Himawari data reception and processing. Presentations and software demos were given at the 2015 NOAA Satellite Conference in

Washington, DC, and the CSPP Users' conference in Darmstadt, Germany. We interacted with individuals in the National Weather Service, Environment Canada, Australian Bureau of Meteorology, INPE, MeteoFrance, JMA and KMA, as well as vendors of receiving systems and researchers at universities within the United States.

The CSPP Geo website was maintained as a point of distribution for new software, documentation and information regarding the project and future plans. Software releases were also announced to the public on the NOAA GOES-R website. A profile of the CSPP Geo project was published on the CIMSS/SSEC website.

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

14.1 VIIRS Cloud Mask Validation and Tool Development, Cloud Mask Tuning and Software Support

CIMSS Task Leader: Andi Walther
CIMSS Support Scientists: Denis Botambekov, Rich Frey, Christine Molling
NOAA Collaborator: Andrew Heidinger (NOAA/STAR/NESDIS)

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

Project Overview

The main idea of this project is a support of the JPSS VIIRS Cloud Mask (VCM) Cal/Val Team. Different tools are used to validate and tune the cloud mask. The Suomi-NPP/VIIRS was launch in November 2011. This work is also coordinated with other members at other.

We leverage our efforts within the existing NASA Atmosphere SIPS (former NPP PEATE) located at the University of Wisconsin. Through this project, we intend to continue to interact with our colleagues the Air Force Weather Agency (AFWA) in Omaha, Nebraska (Tom Kopp), NOAA STAR JPSS Algorithm Integration Team (AIT) (Walter Wolf). At this moment VCM is in the stage called "Block 2", and all tuning and code changes are not possible. However, we are intended to continue to improve the algorithm and apply changes when it would be allowed.

Task List

- *Validation Tool Development*
  Our developed tools allow validating VCM globally and by individual granules.
- *NOAA/NASA Cloud Mask Comparison*

Using our tools we are able to compare other developed cloud masks (NASA and NOAA) to VCM. These are run at the CIMSS in Madison, Wisconsin (UW). The tools allow creating match-ups between VCM and MODIS (MYD35) cloud masks.

- *NOAA Match-ups with CALIOP*
  Data from CALIPSO is considered as "truth", and match-ups with VCM, or any other cloud mask, allow validating and tuning the algorithm. These tools run at the SSEC in Madison, Wisconsin (UW). The easily identified errors lead to better understanding of cloud detection, and improving of the cloud mask.

Milestones with Summary of Accomplishments and Findings

Developed at the SSEC in Madison, Wisconsin (UW) Long-Term Monitoring (LTM) website (http://cimss.ssec.wisc.edu/patmosx/ltm/monitor.html) continues to function, but it is focuses only at a small 20x20 degrees box in North Pacific off the California Coast. In addition using CIMSS tools daily global images (Cloud Mask, Cloud Optical Depth, Cloud Top Temperature, and False Color RGB) are created and posted on the NOAA STAR LTM webpage (http://www.star.nesdis.noaa.gov/jpss/EDRs/products_clouds.php). Figure 50 shows Global VCM performance from February 5th, 2016, Ascending node.

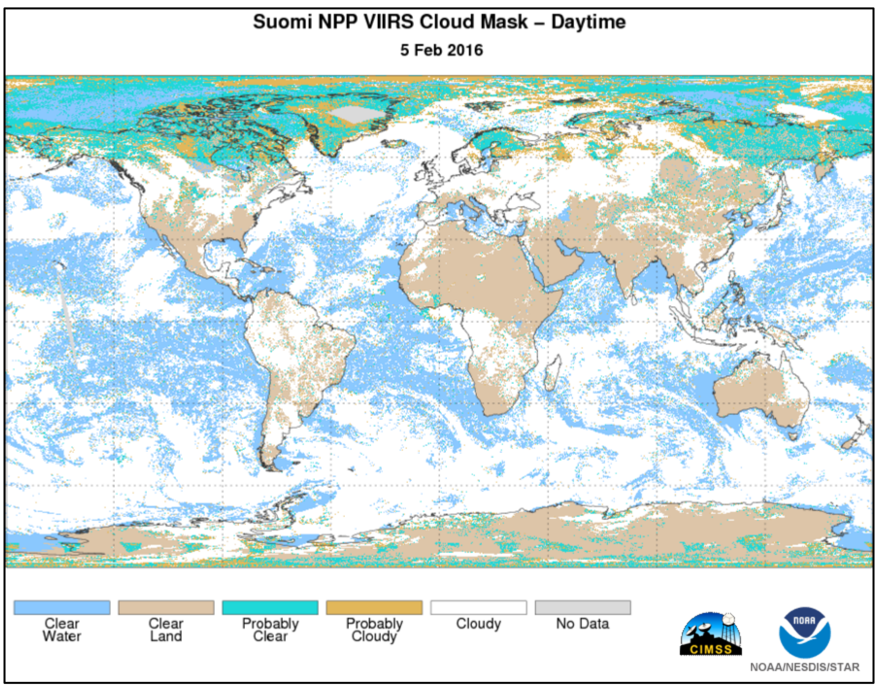

Figure 50. Global VCM performance, 5 February, 2016, Ascending node.

14.2 VIIRS Cloud Phase Algorithm

CIMSS Task Leader: Corey Calvert
CIMSS Support Scientist: Justin Sieglaff
NOAA Collaborator: Michael Pavolonis

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

Project Overview

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

Milestones with Summary of Accomplishments and Findings

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

Initial validation results indicate the VIIRS cloud phase product determined the same phase as CALIOP for about 80% of the pixels validated. After further investigation it was found that a large majority of VIIRS pixels that did not match the CALIOP cloud phase distinction occurred because the VIIRS cloud type algorithm returned a water phase category when the CALIOP algorithm returned ice phase. Looking at a sample granule it appears that several glaciated convective clouds were being misclassified as mixed phase (generally classified as water phase for this validation) instead of ice phase. The top panel in Figure 51 shows a VIIRS false color image where bare land appears green, ice clouds look bright pink and water clouds are yellowish in color. Focusing on the red-circled area there are several convective clouds that appear bright pink on the false color image. These are opaque ice clouds from the tops of growing thunderstorms. However, the bottom left panel of Figure 51 shows the VIIRS cloud type algorithm erroneously classified these clouds as mixed phase (green) instead of opaque ice (yellow).

Among others, the VIIRS cloud type algorithm uses a test based on the relationship between the 11μm brightness temperature and the 8.5μm – 11μm brightness temperature difference (BTD) to differentiate between ice and water clouds. This test, called the infrared cloud phase discrimination test, was determined to be the source of the majority of misclassified VIIRS pixels. When this test is applied, a threshold function is used to differentiate water clouds from ice clouds. However, the original threshold function was not calculated using VIIRS data because the instrument was not launched until after the algorithm was developed. Instead, the threshold function was initially chosen based on the modeling of single-layer water and ice clouds (Pavolonis et al., 2005). Now that VIIRS data are available, a new threshold function can be calculated to improve the performance of the infrared cloud phase discrimination test, and therefore, the overall performance of the VIIRS cloud type algorithm. The bottom right panel in Figure 51 shows the VIIRS cloud type algorithm applied using the newly calculated threshold function. Note that the convective cloud tops in the red-circled area are now correctly identified as opaque ice clouds instead of mixed phase. Early validation results are encouraging, but further evaluation and modifications are likely necessary to ensure the VIIRS cloud type algorithm performs dependably at a high level.

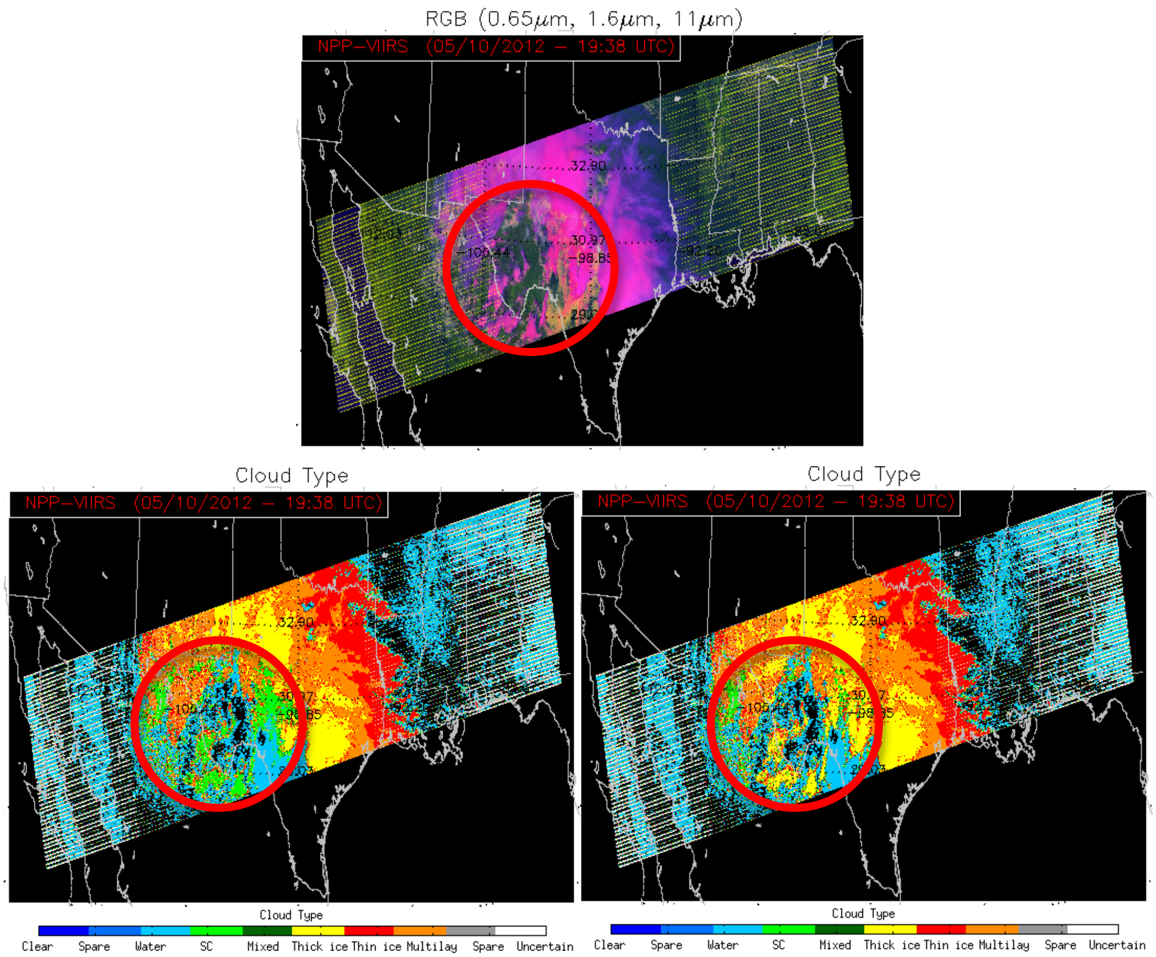

Figure 51. A daytime VIIRS scene over Texas on May 10, 2012 at 1938Z. The top panel is a false color image where ice clouds appear pink and water clouds appear yellowish. The bottom left panel is the VIIRS cloud type product with the original infrared cloud phase discrimination threshold function. The bottom right panel is the VIIRS cloud type product in the updated threshold function.

References

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

14.3 Cloud Optical Property Algorithm
CIMSS Task Leader: Andi Walther
NOAA Collaborator: Andrew Heidinger

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

Project Overview
This project aims to evaluate and improve the Cloud Optical Properties (COP) products of the JPSS VIIRS team using the Daytime Cloud Optical and Microphysical Properties (DCOMP) retrieval. We have been working on further retrieval developments and validating against other algorithms and sensors products and against independent data.

DCOMP generates estimates of cloud optical thickness and effective radius and ice/water path during daylight conditions [Walther and Heidinger, 2012]. Descriptive technical details for DCOMP algorithm are provided in the corresponding algorithm technical basis document (ATBD; Walther et al., 2015). The algorithm is based on bi-spectral approach with pre-computed forward operator stored in look-up-tables. DCOMP is performed within an optimal estimation framework, which allows physically based uncertainty propagation. Atmospheric-correction and forward-model parameters, such as surface albedo and gaseous absorber amounts, are obtained from numerical weather prediction reanalysis data and other climate datasets. DCOMP is set up to run on sensors with similar channel settings (e.g., MODIS, SEVIRI, AVHRR, VIIRS and Suomi NPP) and has been successfully exercised on most current meteorological imagers.

Milestones with Summary of Accomplishments and Findings
The focus in this period lied in implementation work into NOAA AIT Framework and further evaluation of cloud products. The project successfully implemented the DCOMP retrieval in AIT processing framework and passed Algorithm Readiness Review (ARR). We provided NOAA AIT and scientific public with a corresponding ATBD, and started drafting an OAD.

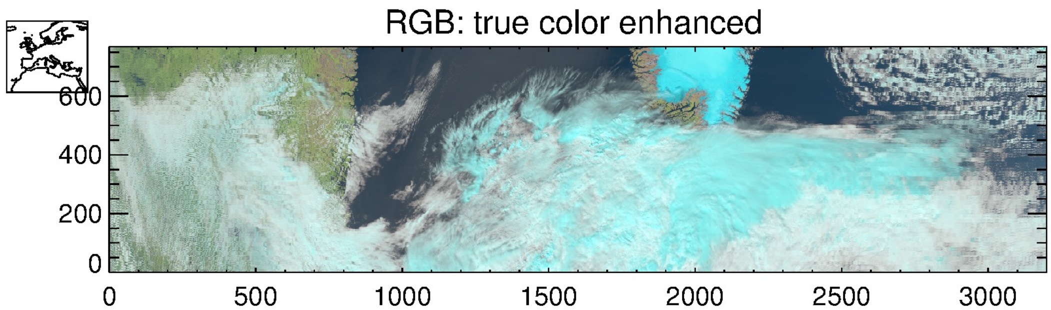

Figure 52. Enhanced RGB composite of VIIRS granule 19 Aug 2013 15:46 UTC.

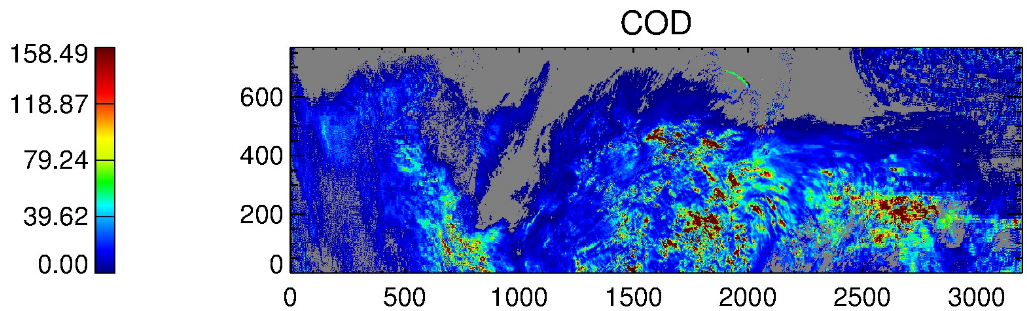

Figure 53. Corresponding Cloud Optical Thickness.

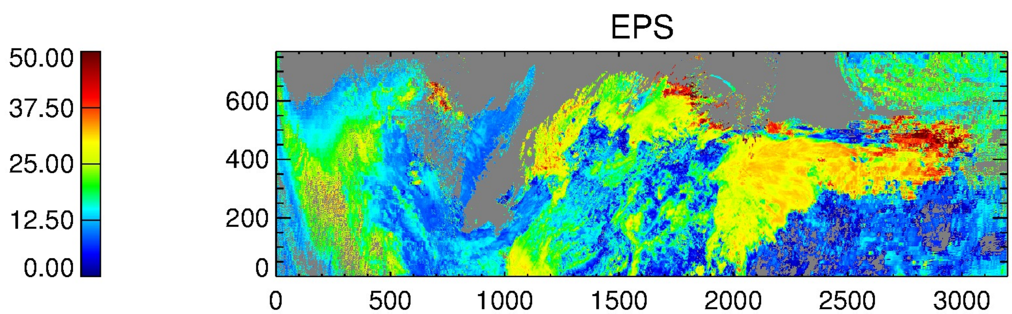

Figure 54. Corresponding Effective Particle Size (aka Effective Radius).

Publications and Conference Reports

Walther, Andi and William Straka, 2015: DCOMP ATBD.

References

A Walther, AK Heidinger 2012: Implementation of the daytime cloud optical and microphysical properties algorithm (DCOMP) in PATMOS-x, Journal of Applied Meteorology and Climatology, 2012.

14.4 Cloud Top Properties Algorithm

CIMSS Task Leader: Yue Li
CIMSS Support Scientist: Steve Wanzong
NOAA Collaborator: Andrew Heidinger

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

Project Overview
This project aims to evaluate and improve the Cloud Top Products (CTP) from S-NPP VIIRS generated using the ABI Cloud Height Algorithm (ACHA). We have been constantly working on improving the height retrieval by identifying coding bugs, introducing better algorithms, and validating against products from other satellites and algorithms, primarily the CALIPSO Lidar product.

Milestones with Summary of Accomplishments and Findings
Due to the absence of CO_2 absorption channels, the retrievals of high ice cloud height are more challenging from VIIRS than its heritage sensor MODIS. We have developed the capability to use the CO_2 channel information from S-NPP Sounder CrIS to improve the ice cloud height retrieval. By including sounder information, it benefits the ice cloud height retrieval by both capturing the fine structure and improving the general accuracy and precision. Figure 55 shows an example of the improvement through a comparison to CALIPSO. Note that the retrieval uncertainty is also largely reduced.

We also improved the ice cloud height retrieval by developing a new ice cloud model for ACHA optimal estimation algorithm based on radiometric consistency. This model proves to be effective in reducing the high bias of VIIRS ice cloud height in comparison to CALIPSO (Figure 56).

Other accomplishments include:
- The ACHA algorithm has been fully incorporated into NOAA AIT FRAMEWORK and passed the Algorithm Readiness Review;
- The ACHA ATBD was submitted to NOAA AIT;
- The Cal/Val plan for JPSS-1 was submitted; and
- ACHA paper on infrared-derived cirrus cloud properties was published.

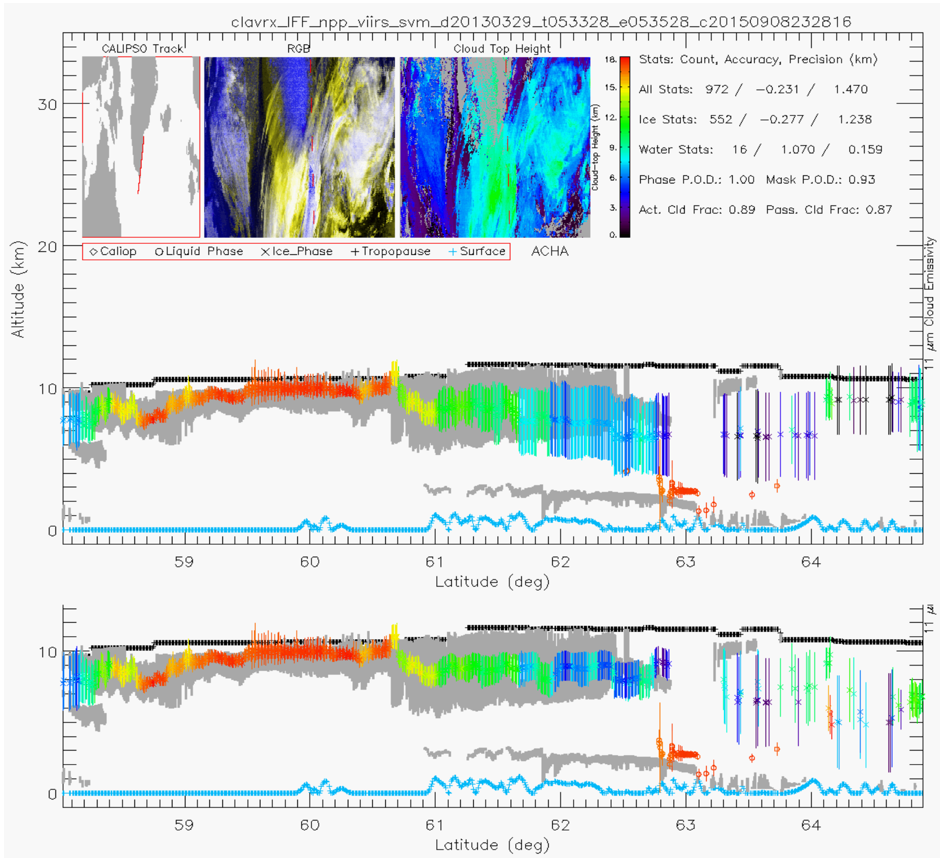

Figure 55. An example showing the improved height retrieval for high altitude ice clouds. The upper portion of the image illustrates the CALIPSO track, the RGB image and the retrieved cloud height of the selected granule, as well as some statistics against CALIPSO. The center image shows the retrieved cloud height along the lidar track by only using VIIRS data. Vertical bars indicate retrieval uncertainty. The bottom portion shows similar image but using both VIIRS and CrIS data.

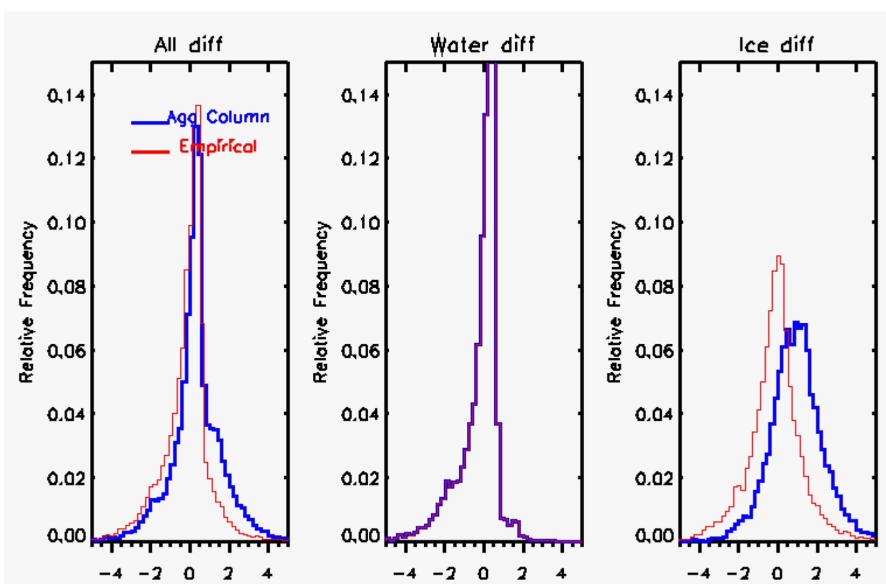

Figure 56. Histogram showing differences between ACHA cloud top height, using two different ice models - Aggregate Column and Empirical, and CALIPSO. One day of MODIS 5km data are used and run at a mode to mimic VIIRS.

14.5 CSPP Support
CIMSS Task Leader: Denis Botambekov
CIMSS Support Scientists: Andi Walther, Yue Li
NOAA Collaborator: Andrew Heidinger (NOAA/STAR/NESDIS)

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

Project Overview

The number of CSPP CLAVR-x users is constantly increasing all around the world. It is not surprising because the system is a convenient way to process received satellite data in a near real-time to level 2 cloud products. Our group is working with needs of the CSPP CLAVR-x users by answering questions, and explaining the results. The feedbacks allow us to modify algorithms to meet users' expectations. This work is coordinated with other research group members at CIMSS (Liam Gumley, Kathy Strabala, and Nick Bearson). The new version of CSPP CLAVR-x 2.0 is scheduled to be released in 2016.

Task List

- *CSPP CLAVR-x Users Support*
  Clear answers and timely responds to all CSPP CLAVR-x users' questions are important for keeping users satisfied with a quality of cloud products. Outreach other possible users.
- *CSPP CLAVR-x Algorithms Improvement*
  Algorithms code improving is an essential task based on the users' feedback (bug fixing, new algorithms developing, existing algorithms improvement). Prepare new releases of CSPP CLAVR-x that would satisfy users' needs.

Milestones with Summary of Accomplishments and Findings

In November 2015 Denis Botambekov participated at the 6th Asia/Oceania Meteorological Satellite User's Conference in Tokyo, Japan. It allowed outreaching and increasing number of users, and meeting in person with current users. The Japan Meteorological Agency (JMA) has launched the new geostationary satellite – Himawari-8, with the Advanced Himawari Imager (AHI) on its board. AHI is very similar to the Advanced Baseline Imager (ABI), which will be launched on board of GOES-R later in 2016. CSPP CLAVR-x among many other sensors supports AHI (and will support ABI). A problem that was widely discussed at the meeting is that many users don't have abilities to receive level 2 cloud products from JMA, and CSPP CLAVR-x in this situation is a huge help for them.

As an example, in addition to the Siberian Regional Center (Novosibirsk, Russian Federation), the Far East Regional Center of "Hydro-Meteorology from Space, Science-Research Center – PLANETA" (Khabarovsk, Russian Federation) started to actively use CSPP CLAVR-x. Also they agreed to participate in validation of betta version of CSPP CLAVR-x 2.0 planned to be released in 2016. This center is one of three ground complex systems, which are receiving, process, and provide satellite data to Hydro-Meteorological Service of Russia, and other organizations and companies. The daily results of cloud algorithms are published on their webpage (http://www.dvrcpod.ru/index.php). Regional Cloud Top Height (CTH) image from September 30th, 2015, AVHRR NOAA-19 is shown in Figure 57.

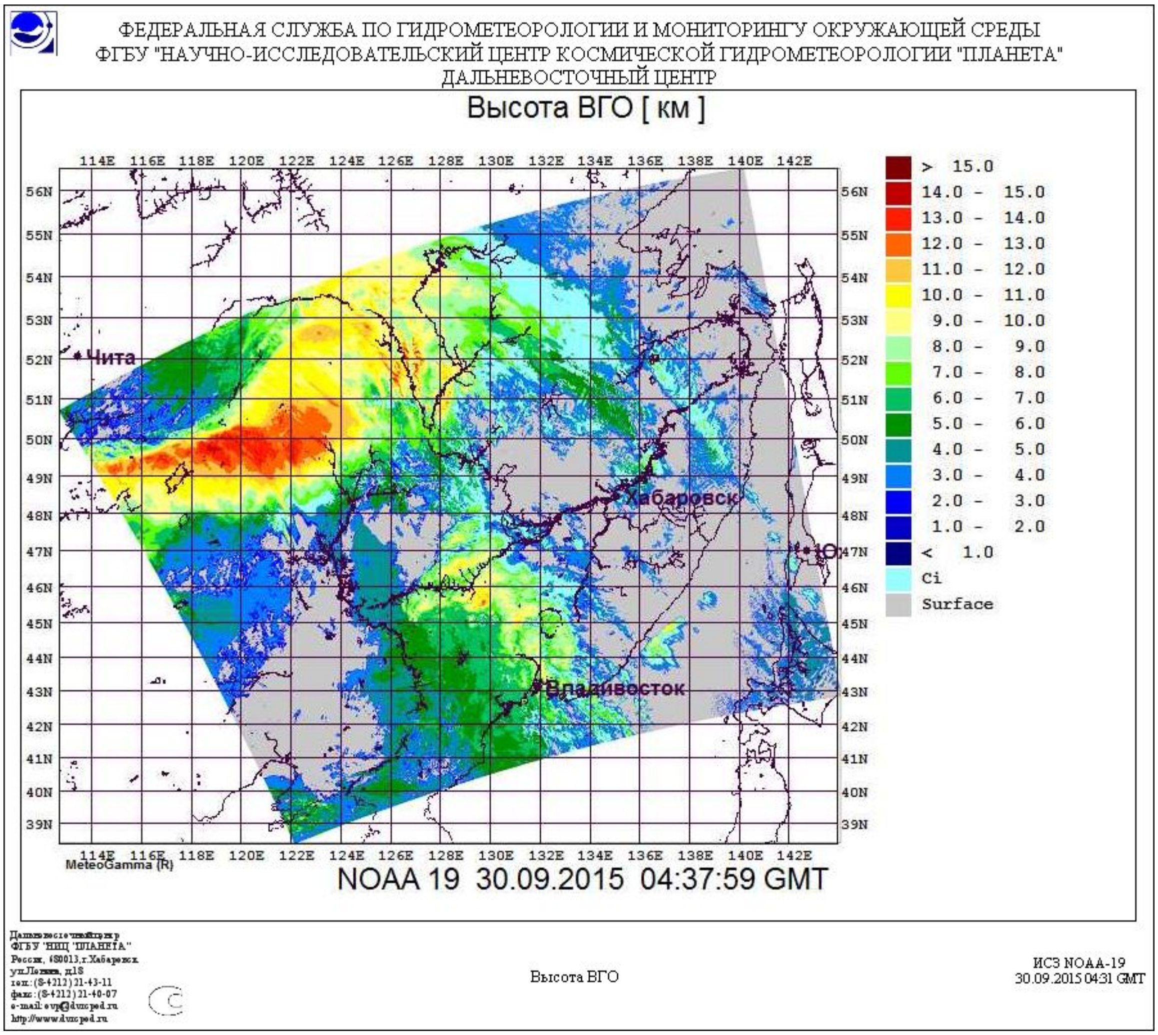

Figure 57. Cloud Top Height - CTH, CSPP CLAVR-x, NOAA19, September 30, 2015

At this moment a new release of CSPP CLAVR-x 2.0 is in the testing stage. It includes improvements to the previous release algorithms, new added algorithms (for example Cloud Base Height), increase of the code structure effectiveness and processing stability.

Publications and Conference Reports

Bearson N. "CSPP / CLAVR-x". The CSPP/IMAPP User's Group Meeting in Darmstadt, Germany, April 14-16, 2015.

Heidinger A. "New Features in the Upcoming CLAVR-x". The CSPP/IMAPP User's Group Meeting in Darmstadt, Germany, April 14-16, 2015.

Botambekov D. "Cloud Products From CSPP-CLAVR-x". The Sixth Asia/Oceania Meteorological Satellite Users' Conference, 9 - 14 November, 2015, Tokyo, Japan.

Planning to participate at the 1st Workshop of the International Cloud Working Group (ICWG), 17 - 20 May 2016, Lille, France.

Planning to participate at the Joint AMS-7th Asia-Oceania Satellite Meteorology Users Conference, October/November 2016, South Korea.

14.6 VIIRS Aerosol Evaluation Using Satellite Observations

CIMSS Task Leader: Robert Holz
NOAA Collaborator: Andrew Heidinger
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

- Satellite Meteorology Research and Applications

Project Overview

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

Milestones with Summary of Accomplishments and Findings

We completed a significant milestone this year with the completion of the JPSS cloud assessment report which was delivered to the JPSS program. This project supported both the evaluation and report preparation. Our work has identified and corrected two issues during this first year. First, the team identified an error in the COP lookup table interpolation. Second, the team developed an improvement to the height assessment of low level clouds that will impact the accuracy performance. The second fix has not been implemented into the IDPS yet.

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

- Low convergence rates for cloud retrievals. For example, roughly 60% of cloudy pixels have IP COP results classified as successful;
- Cloud top heights are severely underestimated in general for most transmissive high-level clouds (i.e., cirrus), especially in the Tropics, but can also exhibit a tendency for severe over-estimation at times when solutions appear to follow the Tropopause Level;
- Though this issue will be addressed in a future IDPS release, low-level CTH are too high, often by as much as 2-3 km. This is most evident over oceans in areas of widespread stratocumulus decks;
- The inference of cloud base height is challenging for a passive VIS/IR sensor such as VIIRS. The cloud base height product depends critically the performance of the CTH and cloud phase, among other things, as input. Comparisons with the active radar of CloudSat indicate that there is very limited accuracy obtained at this time. The product demonstrates less accuracy for thin cirrus than water cloud layers;
- For most of the first year, COP exhibited erroneous distributions of optical thickness and particle size due to problems associated with the look-up tables (LUTs). Earlier analyses led to an updated LUT being developed for IDPS;
- With the updated LUT that went into IDPS operations, the COP does not return a valid result for about a third of the cloudy pixels, a much higher number than other operational algorithms;
- The accuracy specification is met for some of the COP parameters for some phases. The precision specification is generally not met;
- With the updated LUT that went into IDPS operations on 5 September, 2012, there are still indications of LUT-related issues. The COP comparisons relative to NOAA and NASA results indicate a large scan angle dependence that hints at continued flaws in the COP LUTs. Discontinuities in the distributions of the latest COP results also indicate remaining issues with the COP convergence method;
- The team has found difficulty in using the quality flags and has found them to be generally inadequate. The quality flags are designed for analysis to determine specification compliance. Their use by the community will be problematic. The team has made suggestions for additions to the COP quality flags to address these issues; and
- Taken together, some issues such as QA flags could be resolved given sufficient resources. However, the COP and CTP/CTH/CTT algorithms suffer from a lack of operational maturity. The ADL may lack the necessary ancillary datasets required to help improve products over land surfaces.

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

14.7 McIDAS Support for VIIRS Imagery and Data Analysis
CIMSS Task Leaders: Tom Rink, Tommy Jasmin
NOAA Collaborator: Don Hillger (RAMMB/CIRA)

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

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.

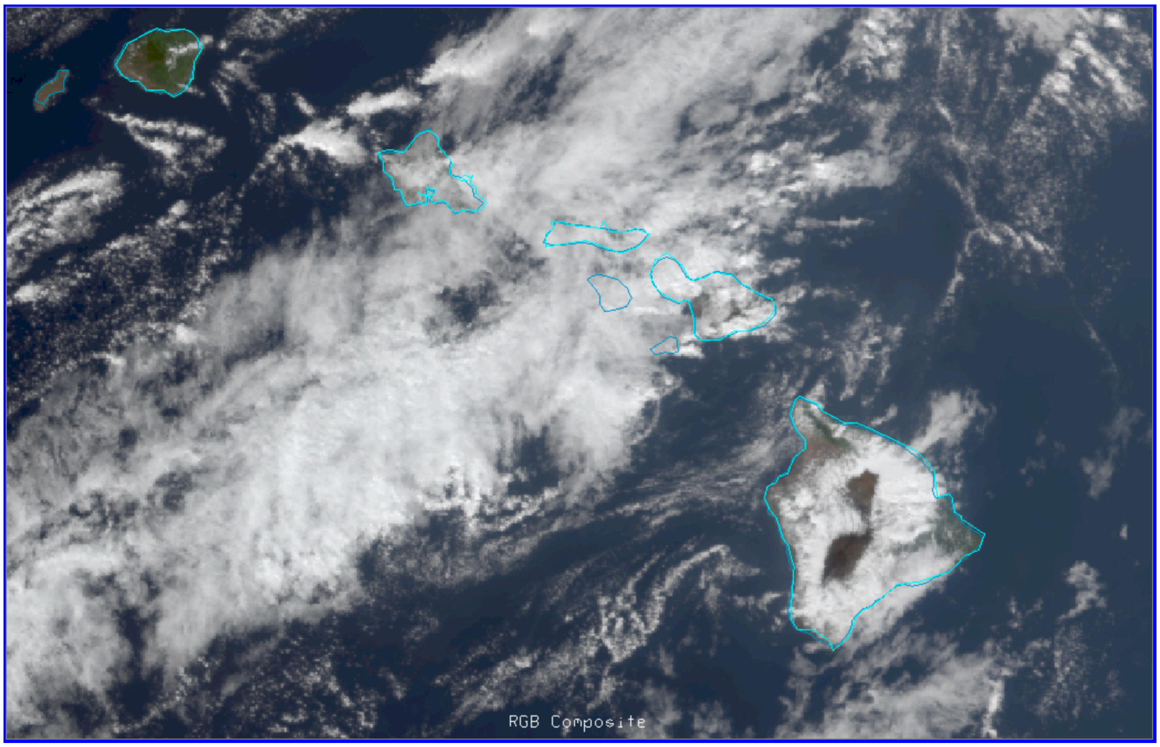

Figure 58. VIIRS True Color Image from NASA L1B data rendered in McIDAS-V.

In 2015 it was announced that the SSEC Atmosphere SIPS (http://sips.ssec.wisc.edu) would be transitioning from ingesting, archiving, and providing access to NOAA Suomi NPP products, to providing only NASA VIIRS L1B products. As a result the primary focus of this task shifted to developing support for the NASA VIIRS data in McIDAS-V. This code has been developed and is available in the McIDAS-V nightly builds, based on preliminary, Release Candidate 2 data from SIPS. The primary VIIRS-related McIDAS-V goals for 2016 will extensive testing and completion of support for visualizatioin and analysis of NASA L1B products, and resolving outstanding high priority feature requests and bug reports in time for the next stable McIDAS-V release, version 1.6.

Additional Planned Development for 2016

- *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.

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

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

CIMSS Task Leader: Dave Tobin
CIMSS Support Scientists: Joe Taylor, Robert Knuteson, Lori Borg, Dan DeSlover, Graeme Martin, Aronne Merrelli, Tom Greenwald, Hank Revercomb
NOAA Collaborators: Yong Han

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 is to perform analyses of the JPSS-1 Thermal Vacuum test data and to perform a characterization of the spectral and radiometric performance of the sensor.

Project Overview

For the past period of performance, efforts of this project have focused on four main areas: 1) Support of CrIS SDR related reviews and meetings, 2) continued Cal/Val analyses of the Suomi-NPP CrIS SDR data, 3) CrIS SDR algorithm assessment and refinement for Suomi-NPP and JPSS-1, and 4) Analysis of the JPSS-1 TVAC CrIS test data.

Milestones with Summary of Accomplishments and Findings

We have had numerous accomplishments and findings associates with the goals of this project. Titles of various topics are listed below:

1. JPSS-1 CrIS TVAC: Imaginary Radiance and Phase Residual Analysis,
2. JPSS-1 CrIS TVAC: Gas Cell Spectral Interfov Analysis,
3. CrIS FIR Filter Normalization and the Nonlinearity DC level model,
4. CrIS FSR to LSR interferogram truncation,
5. Pre-launch JPSS1 CrIS Radiometric Uncertainty estimates for ECT view data,
6. CrIS Radiometric Uncertainty and Uncertainties in the predicted ECT view radiances,
7. Suomi-NPP LW FOV5 Cold Scene Anomaly,
8. CrIS FIR Normalization and Convolution Correction,
9. Assessment of Candidate Calibration Algorithms using Clear Sky Obs-Calcs,
10. Comparisons of S-NPP and JPSS-1 Responsivities and "True Ringing,"
11. FIR Filtering and Aliasing,
12. CrIS/VIIRS comparisons,
13. Inputs to JPSS1 CrIS Cal/Val Plan,
14. CrIS Polarization and Analysis of CrIS Pitch Maneuver Data,
15. Suomi-NPP CrIS Midwave a_2 adjustments,
16. Hyperspectral Radiance Trend Investigations,
17. XSR Phase and Truncation study,
18. FIR Convolution Correction applied to S-NPP XSR Earth view data,
19. Implications of NIST TXR results on ECT and ST characterization, and
20. UW CCAST mods/status.

Due to space limitations the details of these studies are not provided here. But as one example, the time series of the CrIS/VIIRS comparisons are described briefly here. As one way to assess the CrIS radiometric calibration, routine comparisons of CrIS and VIIRS are performed daily using global CrIS and VIIRS data. The figure below shows the daily mean differences versus time with data through April 2016, including 4 full years of comparisons. The top panel shows the differences for bands M13, M15, and M16, and the bottom panel shows the same data but with the mean biases (over all times) subtracted off. Deviations from the mean biases over time are less than (roughly) +/- 0.01 K. The larger outliers are due to the VIIRS nonlinearity tests which are performed quarterly. Excluding these data, the biases are very stable with time, with linear trends and 1-sigma trend uncertainty of: M13: -2.6359 +/- 0.1015 mK/yr, M15: -1.4741 +/- 0.1011 mK/yr, M16: -2.6229 +/- 0.0969 mK/yr.

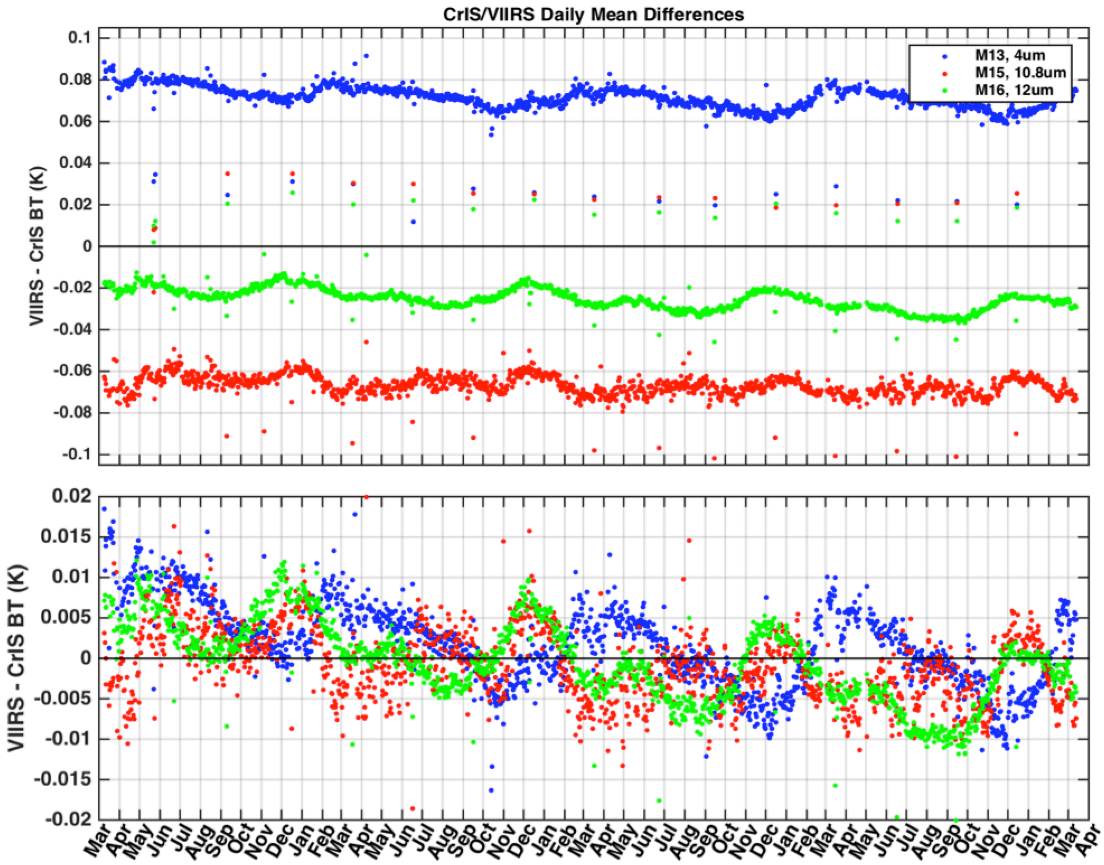

Figure 59. Daily mean differences between CrIS and VIIRS from March 2012 to July 2015.

Publications and Conference Reports

Imaginary Radiance and Phase Residuals, J1 TVAC, CrIS SDR telecom, 27 January 2015.

J1 CrIS TVAC Gas Cell Data Spectral Inter-FOV Analysis: Evaluation of Exelis Draft ILS Parameters, CrIS SDR telecom, 25 February 2015.

FIR Filter Normalization and Nonlinearity DC Level Model, CrIS SDR telecom, 25 February 2015.

Tobin, D. C., H. Revercomb, R. Knuteson, J. Taylor, L. Borg, D. H. DeSlover, G. Martin, A. Merrelli, and T. Greenwald Suomi-NPP Cross-track Infrared Sounder (CrIS): Radiometric Calibration and Validation, *Proceedings from the 95th American Meteorological Society Annual Meeting, Joint session of the 11th Annual Symposium on New Generation Operational Environmental Satellite Systems and the 20th Conference on Satellite Meteorology and Oceanography,* Phoenix, AZ, January 2015.

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"CrIS LW FOV5 Cold Scene Anomaly", *Knuteson_LW_FOV5_coldScene_anomaly_29Apr2015.pdf, presented at 4/29 SDR telecon.*

"Obs – Calc results from NOAA FSR test data", *UW_FSR_obscalc_results_2015_04_29.pdf, presented at 4/29 SDR telecon.*

"Comparison of S-NPP and JPSS-1 Responsivities and differences in "True Ringing", *j1_and_snpp_responsivities.pptx, presented at 5/27 SDR telecon.*

"Preliminary results from the 2015 S-NPP Aircraft Campaign", *SHIS_Greenland2015_20150527.pptx, presented at 6/10 SDR telecon.*

"S-NPP LW FOV5 Cold Scene Anomaly", Dave Tobin, 05 August 2015 CrIS SDR telecon presentation, UW_LW_FOV5_Cold_Scene_Anomaly_20150805.pptx

"CrIS Calibration Bias due to Polarization", Joe Taylor, 16 September 2015 CrIS SDR telecon presentation, UW_CrIS_Polarization_2015-09-15.pdf

"Adjustment to S-NPP MW FOV7 quadratic nonlinearity coefficient", Dave Tobin and Jon Gero, 16 September 2015 CrIS SDR telecon presentation, uw_SNPP_MW7_a2_adjustment_20150918.pptx

"J1 CrIS Radiometric Calibration", Dave Tobin, 2015 JPSS Science Team Annual Meeting, College Park, MD, 26 August 2015.

"Detecting Climate Trends with High Spectral Resolution Infrared Satellite Radiances", Daniel DeSlover, 2015 EUMETSAT Meteorological Satellite Conference, September 2015.
"JPSS-1 CrIS" Pre-launch Characterization of the Radiometric Calibration", David Tobin, 15 EUMETSAT Meteorological Satellite Conference, September 2015.

"UW Assessment of CrIS FIR Filter Requirements", Robert Knuteson, 14 Oct 2015 CrIS SDR telecom presentation.

"Adjustment to S-NPP Midwave band quadratic nonlinearity coefficients (Update to 16 Sept 2015 presentation)", David Tobin, 14 Oct 2015 CrIS SDR telecom presentation.

"Phases of NSR, FSR, XSR Complex Spectra and Truncation to NSR", David Tobin, 18 November 2015 CrIS SDR telecom presentation.

"FIR Convolution Correction: First look at XSR data", Robert Knuteson, 18 November 2015 CrIS SDR telecom presentation.

"FIR Aliasing Update: NPP Earth Diagnostic Mode", Robert Knuteson, 01 December 2015 CrIS SDR telecom presentation.

"UW-SSEC Polariza/on Analysis of CrIS Pitch Maneuver Data", Joe Taylor, 03 February 2016 CrIS SDR telecom presentation.

"Recent Insights into the CrIS FOV5 anomaly: CrIS/IASI SNOs", Robert Knuteson, 17 February 2016 CrIS SDR telecom presentation.

"CrIS FOV-5 Artifact: Beamsplitter Channeling as a Possible Mechanism", 16 March 2016 CrIS SDR telecom presentation.

15.2 VIIRS SDR Calibration/Validation
CIMSS Task Leader: Chris Moeller
CIMSS Support Scientist: Dan LaPorte
NOAA Collaborator: Changyong Cao

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

Project Overview
This task includes participation on the VIIRS SDR Team, activities associated with SNPP VIIRS on-orbit performance, and JPSS-1 pre-launch performance characterization in preparation for the launch of JPSS-1.

SNPP VIIRS SDR Performance
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 contributing to investigations of known and revealed on-orbit performance issues and adjustments to the SDR calibration algorithm either in response to performance anomalies or through improved understanding of instrument performance (e.g. bias corrections). Along with satellite-satellite radiometric intercomparisons, this subtask also includes radiometric validation using aircraft.

JPSS-1 VIIRS Pre-Launch Test Program Performance Characterization
Through participation in the JPSS-1 Pre-TVAC, TVAC, and Post-TVAC phases of the pre-launch test program, UW-Madison has gained deep knowledge and insight into the test program data quality. This expertise is applied to performance analysis and LUT generation to support the JPSS-1 at-launch SDR algorithm readiness. This subtask has its primary focus on the JPSS-1 spectral characterization but also includes other performance elements such as response vs scan, radiometric calibration, and crosstalk, all in support of the on-orbit SDR algorithm.

Support STAR and SDR Team Meetings and Activities
The VIIRS SDR Team meets to discuss timely matters of SNPP and JPSS-1 VIIRS and to plan path forward. Under this subtask, 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.

Milestones with Summary of Accomplishments and Findings

SNPP VIIRS On-Orbit Performance Evaluation
Wisconsin has continued activities begun under Cal/Val tasks RAD-01, RAD-04, RAD-12(A,B) and RAD-21. These activities are adding to the body of documentation of SNPP VIIRS on-orbit

performance. These tasks and data vigilance have supported investigations into the following highlighted performance aspects:

- Daily global SNPP VIIRS-CrIS spectral radiance comparisons and SNPP VIIRS-IASI SNO comparisons continue to show that VIIRS radiometric performance in thermal emissive bands is stable with small biases. Cold scene calibration bias continues to be within specification for all bands although it exceeds 1 K at 220 K for MWIR bands.
- During the SNAP2015 deployment, the NASA ER-2 aircraft flew missions over the cold scenes of the ice covered Greenland interior. Two missions, March 28 and March 29, 2015 have been prioritized due to favorable earth scene conditions. Along track profiles of VIIRS and SHIS show generally consistent features observed by the two instruments (Figure 60). Biases are consistently within +/- 0.2 K (3-sigma uncertainty on SHIS calibration of about +/- 0.12 K) for LWIR bands M14-M16, I5 for cold scenes (~230 K); for MWIR bands (M12, M13, I4) the biases vary over a larger range, likely due to the effects of transient surfaces and angular dependence of light reflected from those surfaces at MWIR wavelengths. These findings largely corroborate findings from VIIRS comparisons to CrIS and IASI at cold scenes.
- SNPP VIIRS band M6 performance continues to be monitored for digital fold-over in tropical bright cloud scenes. Digital fold-overs continue to occur above the out-of-range flagging threshold as expected, meaning these occurrences will be appropriately flagged as poor quality. It is also observed however that because of ongoing RTA degradation, the frequency of M6 radiance saturation occurrences (> 60 W/m2 sr um) is increasing in the SDR product, primarily in detectors 13-16 (sensor order). An increase of the M6 saturated radiance level in the SDR algorithm processing would be needed to restore these saturated observations to the true signal level of the earth scene.

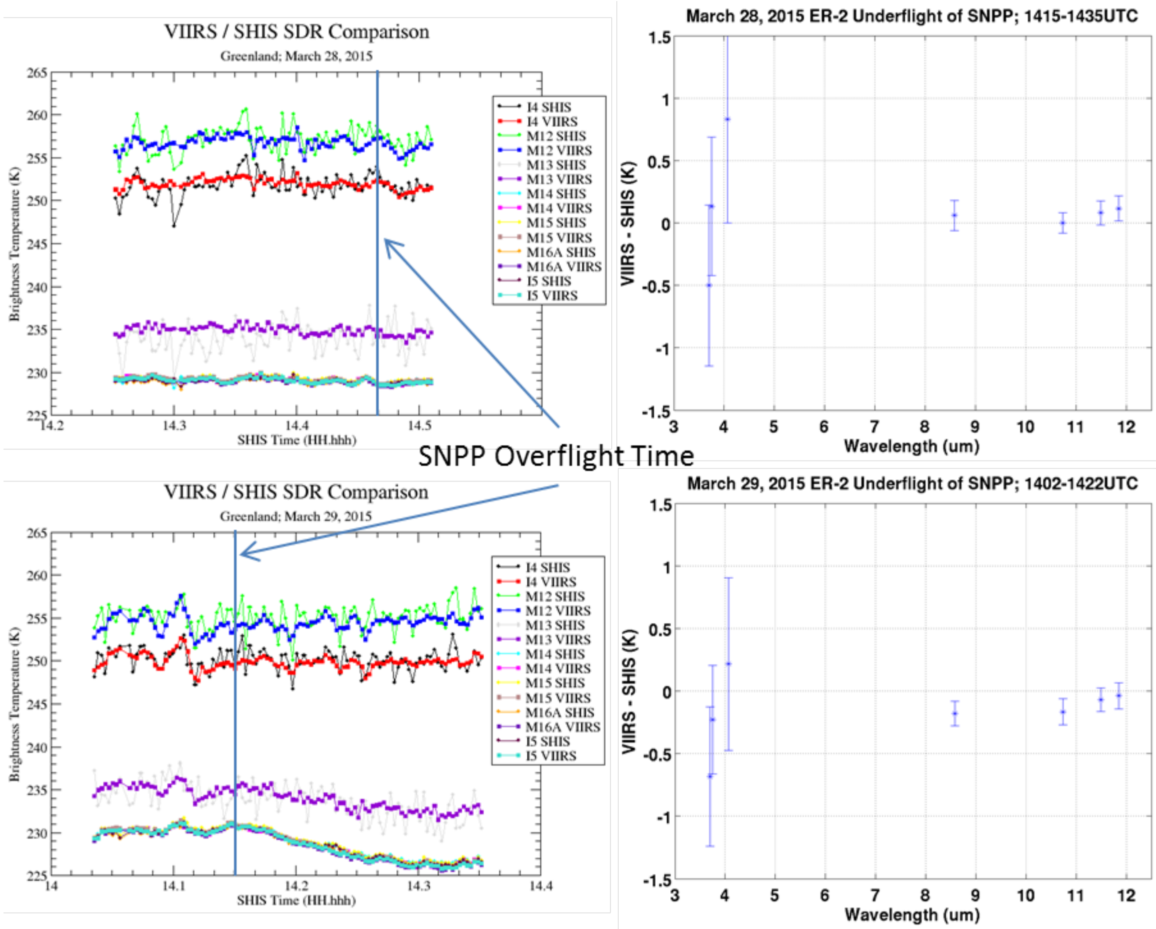


Figure 60. SHIS and VIIRS co-incident profiles (left column) and resulting averaged bias with standard error whiskers (right column) for March 28, 2015 (top row) and March 29, 2015 (bottom row).

JPSS-1 VIIRS Pre-launch Performance Characterization

The effort on JPSS-1 VIIRS has focused primarily on spectral characterization leading to a Version 1 RSR product releases to the VIIRS user community.

- The Govt. analysis and review of the JPSS-1 VIIRS Version 1 (V1) RSR has been completed and released to the password protected NASA eRooms at https://jpss-erooms.ndc.nasa.gov/eRoom/JPSSInstruments/VIIRSF2_JPSS1/0_35d0f. The V1 Release RSR consist of detector and band average (over all detectors) RSR for all VIIRS bands measured during the test program, i.e. M1-M16A,B, I1-I5, DNBLGS, DNBMGS) and replaces the V0 (Beta) Release of February 2015. Band average RSR include data quality filtering, with low quality (i.e. noise-driven) assigned a response of 1E-10. Detector RSR retain the measured low quality response for informational purposes.
- The Version 1 RSR have been used to populate a JPSS-1 SDR RSR LUT for SDR algorithm testing under the Flight project. The LUT uses the RSR at native sampling (i.e. non-uniform), allowing all native RSR information to be retained in the LUT.
- JPSS-1 VIIRS RSB RSR (Version 1) were used with forward model output (desert, blue ocean, grassland) to compare spectrally driven differences in SNPP and JPSS-1 top of atmosphere (TOA) reflectances. Relative differences (relative to scene reflectance) exceed 1% for most VisNIR bands, largely a result of the significant out-of-band signal reduction in JPSS-1; but with a few minor exceptions, absolute TOA reflectance changes

are < 0.1% for all bands. Spectrally driven relative changes in SWIR band TOA reflectances are less than 1%.

- TOA brightness temperatures using JPSS-1 VIIRS TEB RSR (Version 1) were compared to the same using S-NPP VIIRS TEB RSR. The simulation used IASI observations. For all bands except M12, the JPSS-1 VIIRS simulated TOA brightness temperature is within 50 mK of S-NPP. For M12, the difference is a little larger at about 150 mK. These differences are considered to be small and negligible given the high quality spectral characterization of S-NPP and JPSS-1.
- Wisconsin continued to work with VCST to ensure a high quality water vapor correction of M9 RVS characterization, leading to an "at-launch" quality characterization and LUT for JPSS-1.

Publications and Conference Reports

G. Moy, F. DeLuccia, and C. Moeller, "Modification of VIIRS Sensor Data Record Operational Code for Consistency of Data Product Limits". IGARSS 2015, July 26-31, 2015, Milan, Italy.

Moeller, C., T. Schwarting, J. McIntire, and D. Moyer, "JPSS-1 VIIRS Pre-launch Spectral Characterization and Performance", SPIE Vol. 9607, 960711S, doi:10.1117/12.2188658, (2015).

Moeller, C., T. Schwarting, J. McIntire, and D. Moyer, "JPSS-1 VIIRS Version 2 At-launch Relative Spectral Response Characterization", submitted for presentation at the EOS XXI conference of the August 2016 SPIE annual meeting in San Diego, CA.

Robert A. Barnes, Steven W. Brown, Keith R. Lykke, Bruce Guenther, James J. Butler, Thomas Schwarting, Kevin Turpie, David Moyer, Frank DeLuccia, and Christopher Moeller, "Comparison of two methodologies for calibrating satellite instruments in the visible and near-infrared," Appl. Opt. **54**, 10376-10396 (2015).

Chris Moeller attended the STAR JPSS-1 August 2015 Annual Science Team meeting in College Park, MD and presented a talk titled "J1 VIIRS Spectral Characterization and Performance".

15.3 CrIMSS EDR Cal/Val: ARM Site Support
CIMSS Task Leader: Lori Borg
CIMSS Support Scientist: David Tobin
NOAA Collaborators: Tony Reale, Quanhua (Mark) Liu, Nicholas Nalli

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

Project Overview

The goal of this task is to prepare for and to conduct efforts for the critical validation of S-NPP CrIMSS atmospheric temperature and water vapor retrieved profiles and observed infrared radiances. In order to assess the soundings on the 1K/km level and to establish a long-term set of well-characterized sounding products an accurate and on-going validation data set is required. The Atmospheric Radiation Measurement (ARM) program field sites provide such data. In this arrangement, radiosondes are launched from ARM sites coincident with the satellite overpasses of the sites. Analysis is then performed, by UW-Madison personnel, comparing the radiosonde and CrIMSS EDR products, to assess the accuracy 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. It is hoped that this effort will be repeated throughout or periodically during the S-NPP mission.

Milestones with Summary of Accomplishments and Findings

This effort has involved the continuing coordination of radiosonde launches at the Eastern North Atlantic (ENA), North Slope Alaska (NSA), and Southern Great Plains (SGP) ARM sites coincident with overpasses of the S-NPP satellite. Phase-3 of this effort, which began in February 2015, was concluded in September 2015, during which a total of 38/46/53 overpasses were targeted at the ENA/NSA/SGP sites respectively. Phase-4 of this effort began in October 2015 and is ongoing with the expectation to target approximately 90 overpasses at each site. The ARM Program has been extremely supportive of this work and has donated spare radiosondes from the closure of the Tropical West Pacific – Manus (TWP) site to this effort. This influx of radiosondes has allowed for additional dual-sonde launches at NSA and SGP during Phase-4. See Table 2 for additional information on the radiosonde launch efforts during each phase.

Table 2 CrIMSS EDR radiosonde launch efforts: July 2012 – March 2016. * = ongoing efforts.

Radiosonde Launch Efforts						
Phase	**Site**	**Start**	**Stop**	**nOverPasses**	**nSingle**	**nDual**
1	NSA	Jul12	Dec12	90	--	90
	SGP		Jan13	89	--	89
	TWP		Jun13	94	94	--
2	NSA	Jun13	Sep14	124	68	56
	SGP		Sep14	129	31	98
	TWP		May14	79	79	--
3	ENA	Feb15	Sep15	38	38	--
	NSA			46	23	23
	SGP			53	23	30
4	ENA	Oct15	Sep16*	37*	37*	--
	NSA			41*	28*	13*
	SGP			33*	17*	16*

In addition to the radiosonde launch coordinating activites, assessments of the radiosonde quality, creation of BEs of the atmospheric state, and comparisons with retrievals have been underway. Best Estimates of the atmospheric state are created by interpolating the radiosondes onto a common pressure grid, applying precipitable water vapor scaling to the relative humidity and water vapor mixing ratio using microwave radiomater data, and then interpolating to the overpass time. Comparisons are then made between the BE of the atmospheric state, retrievals from the Global Data Assimilaton System (GDAS), and NOAA Unique CrIS ATMS Processing System (NUCAPS) as implemented under the Community Satellite Processing Package (CSPP). Temperature retrieval comparisons are shown in Figure 61 for each ARM site and for all-sky conditions. In general there is very good agreement between the GDAS and BE (blue). This is expected given that the GDAS products are heavily weighted by synoptic sondes. Further efforts are ongoing to assess what is happening near the surface at NSA and SGP causing large RMS errors between the NUCAPS and BE products (black).

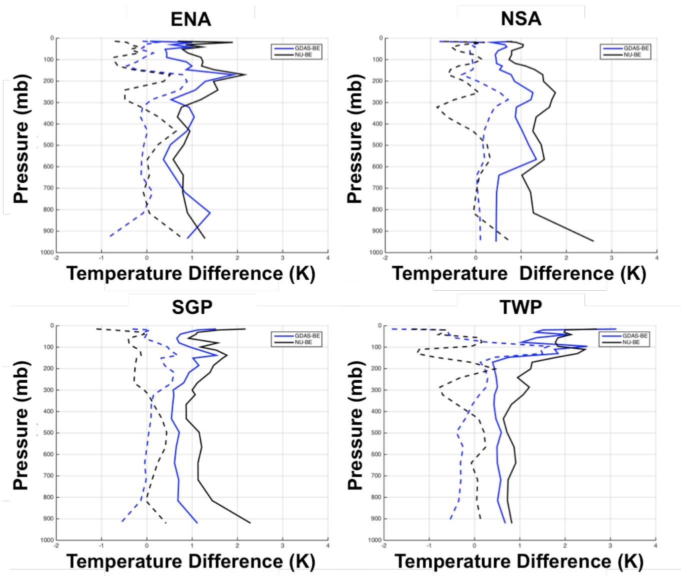


Figure 61. Temperature differences: GDAS - BE (blue) and NUCAPS - BE (black) at ENA, NSA, SGP, and TWP. Mean bias (dashed) and RMS error (solid).

Publications and Conference Reports

Borg, Lori and Knuteson, B. Ground-based measurements for T,q profiles and TCWV (Oral presentation). UK MetOffice, Exeter. ISSWG-2 12th meeting, 03-04 December 2015.

Borg, Lori, Tobin, D., Reale, T., Liu, Q., Nalli, N., Holdridge, D.; and Mather, J. Validation of S-NPP CrIMSS atmospheric temperature and water vapor retrievals using coordinated ARM site radiosondes (Poster presentation). Toulouse, France. European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2015, P-1: Current and future satellites, instruments and their applications.

Feltz, M., R. Knuteson, L. Borg, S. Ackerman, and D. Tobin. Comparisons of IR Sounder and COSMIC RO Temperatures: Guidance for CrIS NUCAPS Validation (Oral Presentation). Proceedings of the 20th International TOVS Study Conference. Lake Geneva, Wisconsin, USA. 2015. Oral Presentation.

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.

16 CIMSS Participation in the JPSS Algorithm Continuity Risk Reduction Program for 2015

16.1 NOAA Algorithm Continuity – Ice surface Temperature, Concentration, and Characterization

CIMSS Task Leader: Yinghui Liu
CIMSS Support Scientist: Xuanji Wang
NOAA Collaborator: Jeffrey Key

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
- 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

Project Overview

The goal of this task is to modify the ice surface temperature (IST), ice concentration, and ice age/thickness (or "characterization"; Wang et al., 2010) algorithms that CIMSS developed for the GOES-R Advanced Baseline Imager (ABI) so that they can be applied to data from the NPP Visible Infrared Imager Radiometer Suite (VIIRS). These and other state-of-the-art products have been developed for the ABI instrument but, due to budgetary considerations, will not initially be generated for GOES-R.

Using these algorithms to generate VIIRS products will bring continuity to the NOAA product suite over time. Equally importantly, the current VIIRS products may not meet the needs of users, so these NOAA-unique products will provide alternatives to the industry-developed VIIRS products. The algorithms are mature and have been extensively tested on Moderate Resolution Imaging Spectrometer (MODIS) and other satellite data, and have been shown to meet the GOES-R requirements for accuracy and precision.

Milestones with Summary of Accomplishments and Findings

GOES-R algorithms have been modified to run using VIIRS data. Differences between ABI and VIIRS are taken into account, particularly the number and characteristics of the spectral bands of GOES-R ABI and VIIRS. Parameters related to the sensor characteristics have been updated in the algorithm. The latest algorithm has been transferred to the Algorithm Integration Team (AIT) with test cases.

We continued to make improvements to OTIM for better and more accurate sea ice thickness and age products. This year we have focused on the validating OTIM by comparing it with other satellite retrieved sea ice thickness products of ICESat, CryoSat-2, SMOS, the IceBridge airborne measurements, and the PIOMAS(Pan-Arctic Ice Ocean Modeling and Assimilation System) model simulation results. Below are some results of the comparisons of the OTIM with other sea ice thickness datasets. Figure 62 shows the comparison of sea ice thickness between OTIM and ICESat. Figure 63 shows the comparison of sea ice thickness between OTIM and CryoSat-2. Figure 64 shows the comparison of sea ice thickness between OTIM and IceBridge. The overall accuracy and uncertainty of the OTIM are 0.20 m and 0.54 m, respectively.

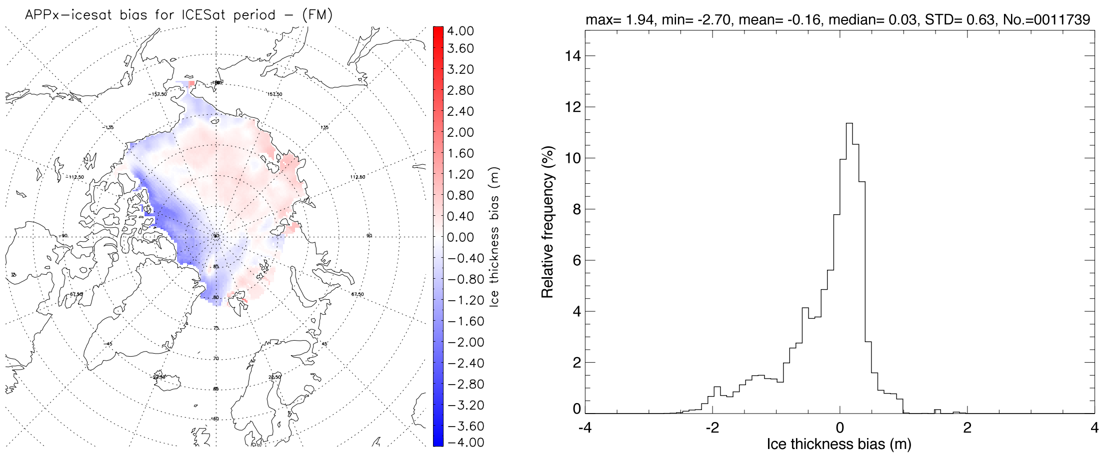


Figure 62. Comparison in sea ice thickness between OTIM and ICESat for the cold period (Feburary + March) over 2003-2008. The bias image between them is shown on the left, and the bias histograms is shown on the right.

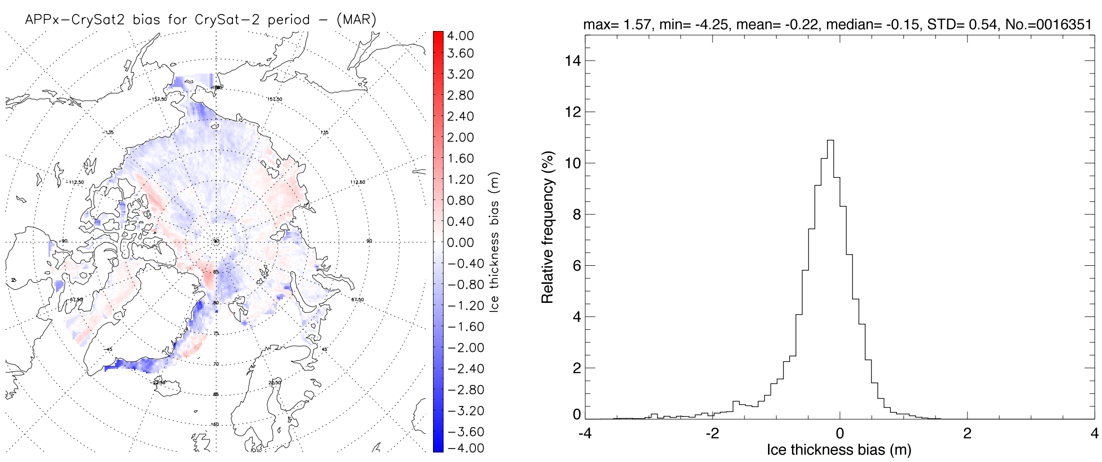


Figure 63. Comparison in sea ice thickness between OTIM and CryoSat-2 for the cold period (March) over 2011-2013. The bias image between them is shown on the left, and the bias histograms is shown on the right.

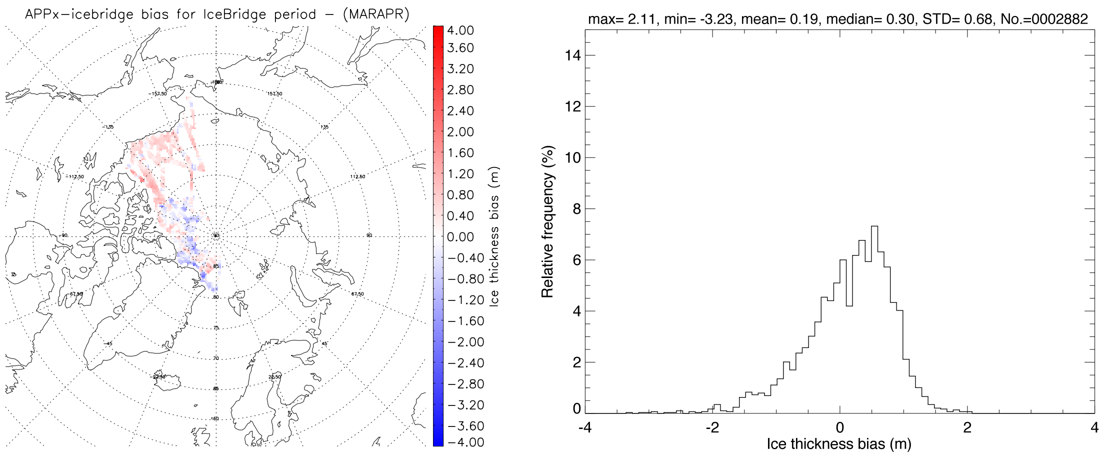


Figure 64. Comparison in sea ice thickness between OTIM and IceBridge for the cold period (March+April) over 2011-2013. The bias image between them is shown on the left, and the bias histograms is shown on the right.

Ice Surface Temperature (IST) retrieval algorithm coefficients have been updated based on the Northrop Grumman Band Averaged Relative Spectral Response used operationally for VIIRS. The updated algorithm is being applied by the Team in near-real time. Validation study using the operational VIIRS IST EDR and the CIMSS algorithm have been updated with IceBridge KT-19 for 2014 over the Arctic. Results show good performance as shown below in Figure 65. Ice concentration algorithm has been updated and validated using observations from Landsat 8 and SSMIS as shown in Figure 66. Validation results with Landsat 8 show that VIIRS has an overall bias of 1.35% compared to Landsat 8 ice concentration, with a precision 8.9%.

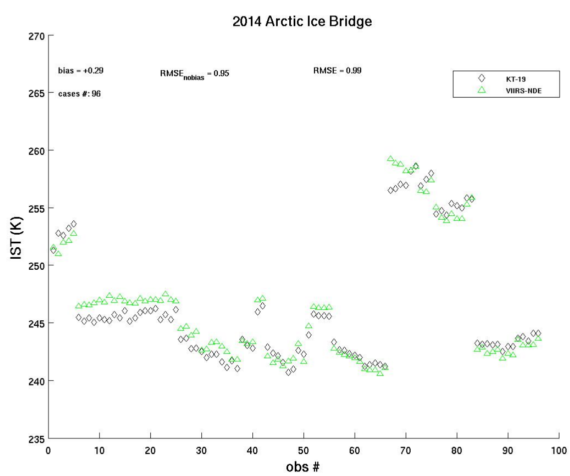


Figure 65. Ice surface temperatures from the IceBridge KT-19 instrument in 2014.

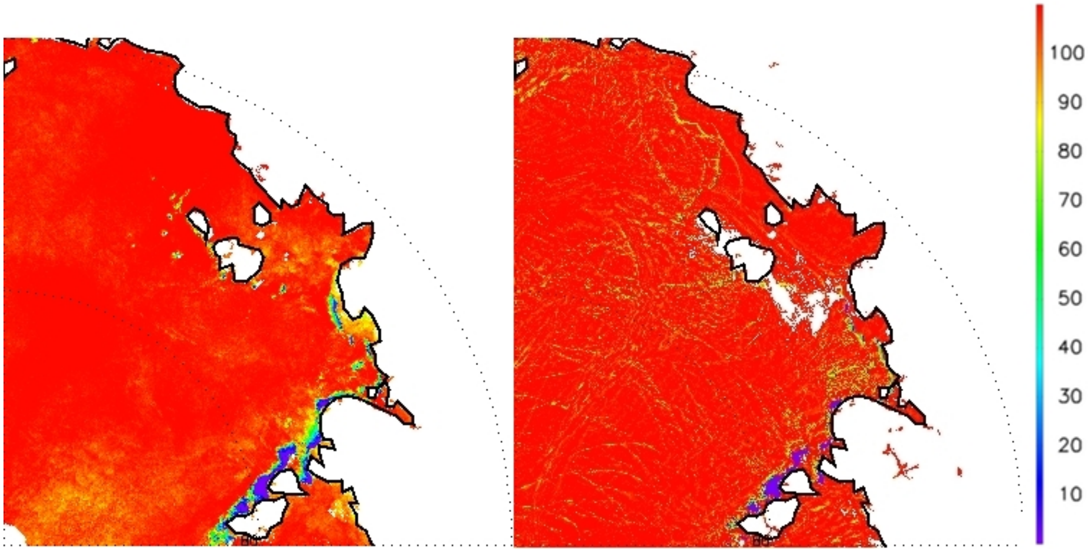


Figure 66. Ice concentration from SSMIS (left), and from VIIRS daily composite over portion of the Arctic (longitude: 90 – 180, latitude: 70 – 90) on February 20, 2015. The North Pole is in the lower left corner.

Publications

Liu, Y.; Key, J.; Tschudi, M.; Dworak, R.; Mahoney, R.; Baldwin, D. Validation of the Suomi NPP VIIRS Ice Surface Temperature Environmental Data Record. Remote Sens. 2015, 7, 17258-17271.

Y. Liu, J. Key and R. Mahoney: Sea ice concentration from VIIRS on Suomi NPP and the future JPSS Satellites. Submitted to Remote Sensing.

Y. Liu, J. Key, M. Tschudi, R. Dworak, and D. Baldwin: Calibration and validation of the Suomi NPP ice surface temperature environmental data record. 2015 AGU Fall Meeting, 14–18 December, San Francisco, CA, USA

16.2 Transition of GOES-R AWG Cloud Algorithms to VIIRS/JPSS

CIMSS Task Leaders: Andi Walther, William Straka III
CIMSS Support Scientists: Pat Heck, Denis Botambekov, Yue Li, Steve Wanzong
NOAA Collaborators: Andrew Heidinger, Michael Pavolonis

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

Project Overview

This project involved the implementation of the GOES-R AWG Cloud Algorithms to the data from the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard both Soumi-NPP and the future JPSS satellites. Specifically, this project covers the implementation of the Enterprise Cloud Mask (ECM), the ABI Cloud Height Algorithm (ACHA), the Daytime Cloud Optical and Microphysical Properties (DCOMP) Algorithm and the Nighttime Cloud Optical and Microphysical Properties (NCOMP) Algorithm. The motivation for this project is the demonstration of efficient processing of VIIRS data with NOAA and the generation of a set of products from VIIRS that is physically consistent with those from GOES-R as well as other sensors.

ECM

The function of Enterprise Cloud Mask (ECM) is to provide the official binary clear-sky mask (clear or cloudy). In addition to this official product, the ACM also provides a 4-level cloud mask (clear, probably clear, probably cloudy and cloudy) as well as cloud probabilities. The 4-level mask is an intermediate product and is generated for those algorithms and users who are familiar with the 4-level masks currently generated by NASA and NOAA.

The ECM uses 12 spectral bands. Its cloud detection is based on spectral, and spatial signatures. The imager specific thresholds used were derived from analysis of space-borne Lidar with co-located imager data. The cloud tests were chosen to provide each algorithm a wide range of cloud detection options. The ECM is designed to allow algorithms and users to ignore certain tests and to efficiently re-compute the cloud mask as well as providing a probability of cloud for a given pixel. The ECM design concept allows for easy expansion to include other tests as warranted. The current tests have their heritage in the cloud masks run operationally by NOAA, NASA and EUMETSAT.

ACHA

The ABI Cloud Height Algorithm (ACHA) is an infrared-only retrieval that uses an analytical forward model in an optimal estimation framework to estimate cloud temperature, emissivity and β (an IR microphysical parameter). Cloud height and pressure are derived from the temperature and knowledge of the atmospheric profiles from the NWP ancillary data. For JPSS, ACHA is also required to estimate the cloud-base height and the development of this technique is included in this project. VIIRS does not offer the same set of IR channels as offered by the GOES-R ABI. In the ABI version of ACHA, the 11, 12 and 13.3 μm channels are used. On VIIRS, only the 8.5, 11 and 12 μm channels are available (Heidinger et al., 2010). ACHA uses scattering models of each channel within its forward model. Using the same methods employed on the ABI, the VIIRS channels will be incorporated. The ACHA results from VIIRS are critical since they are used by other products including the DCOMP and NCOMP cloud algorithms, and the GOES-R Derived Motion Wind (DMW) algorithms.

DCOMP

One other crucial component is the daytime cloud optical and microphysical properties (DCOMP) algorithm, which generates estimates of cloud optical thickness, cloud effective radius and ice/water path during daylight conditions [Walther and Heidinger, 2012]. DCOMP was developed with support from the NOAA Geostationary Operational Environmental Satellite R Series (GOES-R) Algorithm Working Group (AWG) to be the official algorithm for the Advanced Baseline Imager (ABI). Descriptive technical details for the DCOMP algorithm for GOES-ABI are provided in the corresponding algorithm theoretical basis document (ATBD; Walther et al., 2011). The algorithm is based on bi-spectral approach with pre-computed forward operators stored in look-up-tables. DCOMP is performed within an optimal estimation framework, which allows physically based uncertainty propagation. Atmospheric-correction and forward-model parameters, such as surface albedo and gaseous absorber amounts, are obtained from numerical weather prediction reanalysis data and other climate datasets. DCOMP is set up to run on sensors with similar channel settings (e.g., MODIS, SEVIRI, AVHRR, VIIRS, ABI and AHI) and has been successfully exercised on most current meteorological imagers.

All products were extensively validated against all available independent data sets during the EUMETSAT cloud retrieval evaluation workshops [http://www.icare.univlille1.fr/crew/index.php/Welcome] and for validation projects in the framework of GOES-ABI retrieval development.

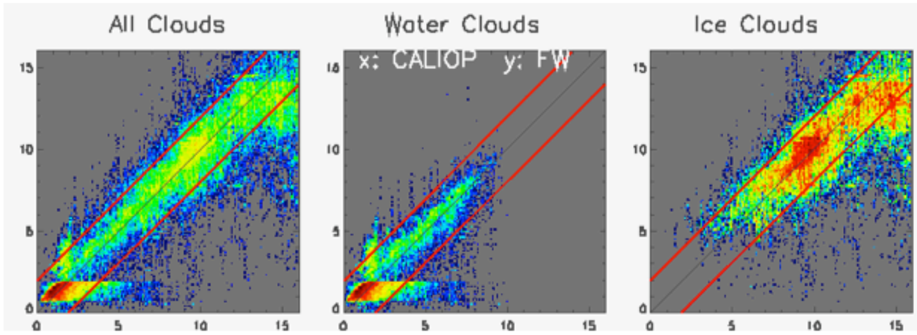
DCOMP can be run with multiple modes, and are determined by channel availability for each sensor. VIIRS on JPSS will provide the full range of DCOMP modes on a very high spatial resolution. The recently launched Suomi NPP satellite allows us using its results as proxy data for the JPSS program. It gives us the opportunity to extend and improve the current retrieval for all possible modes before launch. The higher spatial resolution (750 m in contrast to 1 km for MODIS) will allow us to study finer cloud features.

NCOMP

The final algorithm which is part of the project is the nighttime cloud optical and microphysical properties (NCOMP). NCOMP is a thermally based algorithm, which generates estimates of cloud optical thickness, cloud effective radius and ice/water path during nighttime conditions. NCOMP was developed with support from the NOAA Geostationary Operational Environmental Satellite R Series. The only change to support VIIRS and other sensors, was updating the lookup tables used to determine the nighttime optical properties.

Milestones with Summary of Accomplishments and Findings

This project successfully completed the integration of the of the GOES-R ABI cloud algorithms for VIIRS in to the STAR Algorithm Processing Framework (SAPF). The completion of this task resulted in a successful Test Readiness Review in early 2015 and Algorithm Readiness Review in late 2015. In addition, the SAPF running on the cloud algorithms was installed at CIMSS, resulting in the ability to run and evaluate the output from the SAPF. A demonstration of the performance of the AWG Cloud Height Algorithm (ACHA) implemented in the AIT Framework, the equivalence of one day's worth of data (~1000 granules) that are collocated with CALIPSO over all seasons is shown Figure 67. Performing this validation demonstrates the compliance of the CTH output with the requirements for this project. The stripe parallel to the x-axis is primarily due to low level temperature inversions. Due to the limitation of the passive sensor's sensitivity to high thin ice clouds, in particular when low level clouds are present beneath, the within spec percentages are lower for ice phase clouds as expected. This evaluation of the SAPF output was performed as part of the Algorithm Readiness Review. The updated algorithms were initially delivered to OSPO in December 2015 with an update performed in February 2016.



CTH Statistics (Framework vs CALIPSO)					
Type	Bias(km)	StanDev(km)	Counts	Within Specs - Accuracy	Within Specs - Precision
All clouds	-0.29	1.57	176867	68.9%	68.8%
Water	-0.04	1.10	88454	79.3%	79.5%
Ice	-0.55	1.90	88413	58.5%	55.6%

Figure 67. The GOES-R CTH as applied to VIIRS, compared with CALIPSO for ~1000 granules over all seasons.

Publications and Conference Reports

Heidinger, Andrew K.. Applicability of GOES-R AWG cloud algorithms for JPSS/VIIRS. Annual Symposium on Future Operational Environmental Satellite Systems, 7th, Seattle, WA, 23-27 January 2011. American Meteorological Society (AMS), Boston, MA, 2011, abstract only.

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Heidinger, Andrew K.; Evan, Amato T.; Foster, Michael J. and Walther, Andi. A naive Bayesian cloud-detection scheme derived from CALIPSO and applied within PATMOS-x. *Journal of Applied Meteorology and Climatology*, Volume: 51, Issue: 6, 2012, pp.1129-1144.

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Walther, Andi; Heidinger, Andrew and Park, Chang-Hwan. Sources of error in satellite derived cloud products. 2011 EUMETSAT Cloud Retrieval Evaluation Workshop, 3rd, (CREW-3), Madison, WI, 15-18 November 2011.

Walther, Andi; Straka, William and Heidinger, Andrew K.. Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document for Daytime Cloud Optical and Microphysical Properties (DCOMP) Version 2.0. NOAA, NESDIS, Center for Satellite Applications and Research, 2011.

16.3 Delivery of VIIRS Cloud Phase and Volcanic Ash Algorithms to NESDIS Operations

CIMSS Task Leader: Corey Calvert
CIMSS Support Scientist: Justin Sieglaff
NOAA Collaborator: Mike Pavolonis

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

Project Overview

The goal of this project is to develop cloud phase and volcanic ash algorithms for the VIIRS instrument on the JPSS platform that provide continuity with the GOES-R algorithms. These algorithms will be delivered to the NOAA/NESDIS/STAR Algorithm Integration Team (AIT) and STAR will work with NDE through the SPSRB to deliver these algorithms to operations within two years of the start of the project. This effort will help ensure that JPSS products will benefit from the cutting-edge algorithm development conducted in preparation for GOES-R. In addition, this project will benefit the many users already familiar with the GOES-R cloud phase and volcanic ash products through Proving Ground demonstrations by providing consistent JPSS products. The current JPSS cloud phase and volcanic ash products are NOT consistent with the GOES-R products and are generally less useful and accurate.

Milestones with Summary of Accomplishments and Findings

- *Deliver second version of cloud phase algorithm for implementation into AIT Framework (January, 2016)*
  We have delivered the second version updates of the Enterprise cloud phase algorithm code (single set of code for use with GOES-R ABI, current GOES and JPSS VIIRS) to the AIT.
- *Cloud phase Algorithm Readiness Review (ARR) (December, 2015)*
  We have successfully completed the cloud phase ARR. The VIIRS cloud phase and type products were validated against the cloud phase/type products derived from spacebourne lidar measurements from CALIOP. Validations were performed for a large global sampling of VIIRS data as well as separate categories based on geography, solar viewing angle and optical depth. The results show the JPSS/VIIRS implementation falls within the accuracy specifications (80% detection) for all categories.
- *Deliver second version of volcanic ash algorithm for implementation into AIT Framework (April, 2015)*
  We have delivered the second version updates of the Enterprise volcanic ash algorithm code (single set of code for use with GOES-R ABI and JPSS VIIRS) to the AIT.
- *Volcanic ash Algorithm Readiness Review (ARR) (August, 2015)*
  We have successfully completed the volcanic ash algorithm ARR. One highlight of the ARR was validating the ash cloud height and mass loading algorithms with the more limited VIIRS channel availability (Figure 68). The validation shows the JPSS/VIIRS implementation is well within algorithm specifications.

References

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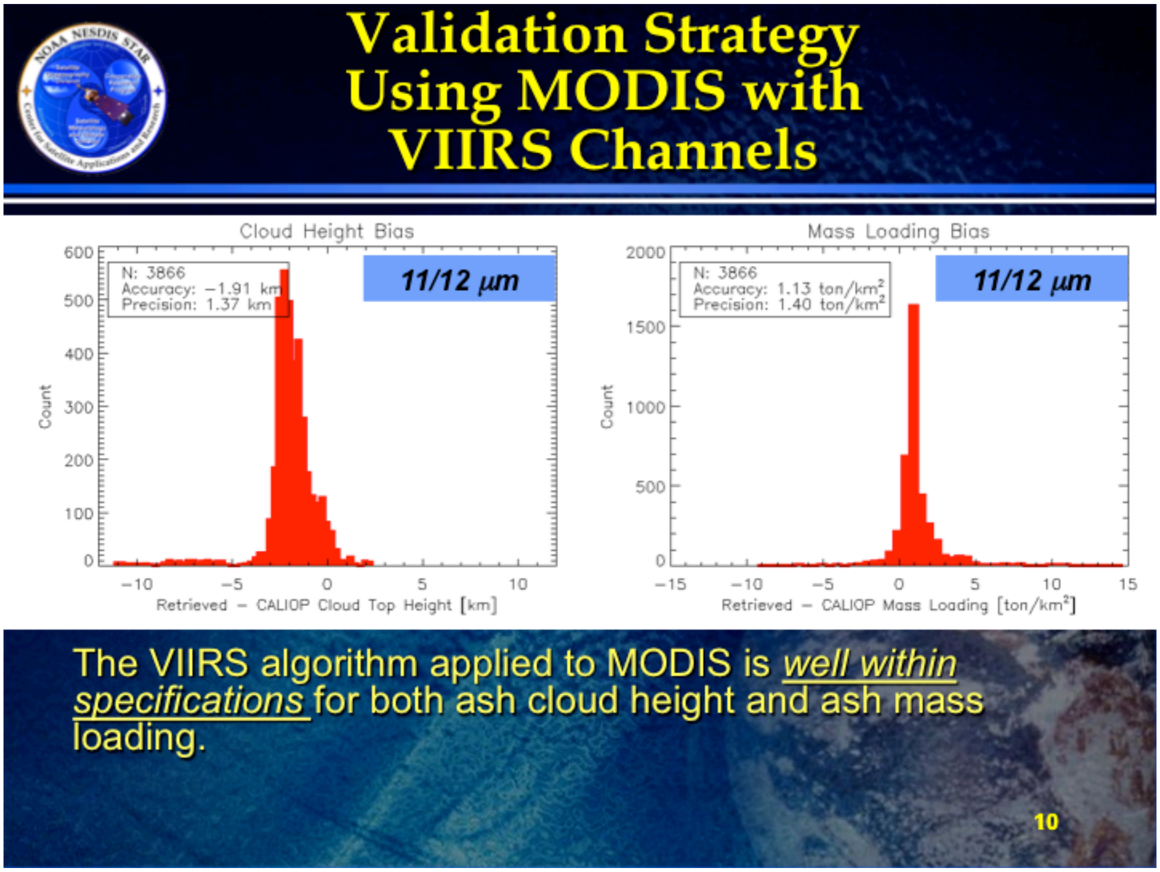


Figure 68. Enterprise volcanic ash algorithm validation using VIIRS channel availability (using MODIS data) for a variety of volcanic ash and dust clouds. The use of MODIS data, but with only VIIRS channels is employed because the number of matchups of VIIRS observations of volcanic ash clouds with CALIOP truth data is too few. The results indicate the ash cloud height (left) and mass loading (right) are well within specifications.

16.4 JPSS Risk Reduction Algorithm Integration Team Midwest

CIMSS Task Leader: R. Garcia
CIMSS Support Scientists: W. Straka, G. Martin
NOAA Collaborator: W. Wolf

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

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 reference framework 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

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

Milestones with Summary of Accomplishments and Findings

- Integrated and verified the CIMSS JPSS Risk Reduction 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-RR algorithm developers.
- Participated and supported the Critical Design Review (CDR) for CIMSS JPSS-adapted algorithms.
- 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.

17. CIMSS Participation in the JPSS Risk Reduction Program for 2015

17.1 Near Real-time Assimilation System Development for Improving Tropical Cyclone Forecasts with NPP/JPSS Soundings

CIMSS Task Leader: Jun Li
CIMSS Support Scientists: Jinlong Li, Kevin Baggett, and Pei Wang
NOAA Collaborators: Mark DeMaria, John L. Beven, Vijay Tallapragada, and Tim Schmit

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

Project Overview

The work is to use the regional numerical weather prediction (NWP) models (WRF - Weather Research and Forecasting, and/or HWRF – Hurricane WRF) and the advanced data assimilation methodologies (GSI, EnKF, DART). CIMSS scientists will develop a near real time assimilation system (SDAT – Satellite sounder data assimilation for Tropical storm forecasts) based on the combination of community GSI (Gridpoint Statistical Interpolation) assimilation system and WRF, and use NPP/JPSS sounder measurements from Community Satellite Processing Package (CSPP) or NOAA data ports (IDPS and NDE), or Global Telecommunication System (GTS), to serve as an application demonstration system on the utilization of JPSS sounder measurements for TC forecasting.

Milestones with Summary of Accomplishments and Findings

Real Time Validation of SDAT Forecasts with GOES Imager (April 2015 – May 2015)

As a useful validation tool, GOES realtime observations have been added into SDAT website since March 2015. The realtime GOES 13 Imager channel 3 (10.7 µm) and channel 4 (6.5 µm) data are plotted in the same way as that of the WRF forecast data. Due to the observational data are not available for the latest forecasts, we link the realtime GOES observations backward to all historically corresponding forecasts. In this way, users can easily compare the forecasted and available observed GOES images and get a confirmation and adjustment for future forecast results.

Improving Resolution of SDAT (April 2015 – June 2015)

During last couple of months we also worked hard trying to increase the model horizontal resolution while still meeting the forecast latency requirement. It is found that the GFS/GDAS data ingest takes a lot of time during the system run. Current data ingest are run in a series from GDAS analysis/observations to GFS forecast/observations. After careful analysis, we found there are time gaps between these data available. So we separate the data ingest into three parts, each representing GDAS data, GFS observation and GFS forecast. In this way we can save 50% data ingest time. Along with other script improvements, the model horizontal resolution has been upgraded from 36 km to 27 km since 18 June 2015. The preliminary system tests don't show any latency issue even considering the incoming tropical storm data processing. We are also working to test using the earlier forecast data to see the time and results impacts. If successful, we can further increase model horizontal resolution to 18 km.

CrIS Cloud Detection with Collocated VIIRS Cloud Mask Algorithm Tested in Radiance Assimilation (June 2015 – March 2016)

Followed the successful demonstration by AIRS/MODIS, we have implemented CrIS sub-pixel cloud detection using collocated high spatial resolution VIIRS. CrIS has the overall best signal-to-noise ratio among the three advanced IR sounders: AIRS, IASI and CrIS. However, the assimilation of CrIS in NWP so far has not outperformed AIRS and IASI, one possible reason is that the correlated (channel-to-channel) observation error needs to be taken into account in radiance assimilation appropriately, another possible reason is cloud detection, since CrIS has a little coarser spatial resolution (14 km at nadir) than AIRS (13.5 km at nadir) and IASI (12 km at nadir), CrIS footprints might be more easyeasier to be cloud contaminated than AIRS and IASI.

Applying the same technique we have done developed for AIRS/MODIS to CrIS/VIIRS might be helpful for eliminating the cloud contaminated radiances in assimilation. Figure 69 shows the clear-sky data locations for CrIS channel 96 (709.37 cm^{-1}) at 06 UTC on 25 October 2012 with stand-alone cloud detection scheme from GSI (upper) and VIIRS cloud detection technique (lower), respectively, overlaying on the GOES-13 IR (10.7µm) brightness temperature (K) image for Hurricane Sandy (2012) case. Results show promising on improving CrIS radiance assimilation with collocated high resolution VIIRS cloud mask.

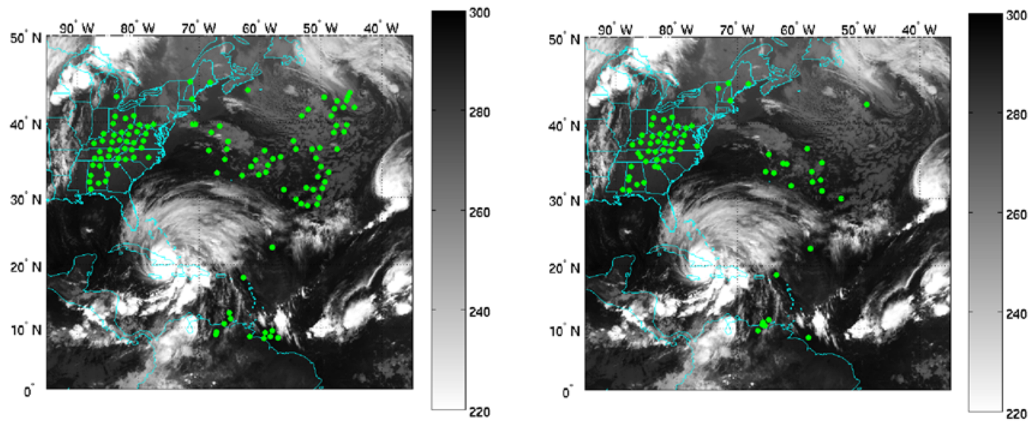


Figure 69. The clear-sky data locations for CrIS channel 96 (709.37 cm^{-1}) at 06 UTC on 25 October 2012 with stand-alone cloud detection scheme from GSI (upper) and VIIRS cloud detection technique (lower), respectively, overlaying on the GOES-13 IR (10.7µm) brightness temperature (K) image for Hurricane Sandy (2012) case.

Publications and Conference Reports

Wang, Pei, Jun Li, M. Goldberg, et al., 2015: Assimilation of thermodynamic information from advanced IR sounder under partial cloudy sky conditions in regional NWP, Journal of Geophysical Research – Atmosphere, 120, 5469 - 5484DOI: 10.1002/2014JD022976.

17.2 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 Leaders: Ralph A. Petersen, Lee Cronce
CIMSS Support Scientists: Richard Dworak, Nadia Smith, Elisabeth Weisz
NOAA Collaborators: Robert Aune (NESDIS), Bill Line (CIMMS), Carven Scott (AR)

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

Project Overview

This work is being performed in coordination with the National Weather Service (NWS) Alaska Region (AR) with the goal of increasing the operational utility of Low Earth Orbit (LEO) satellite soundings to forecasters and to help fill the large data gaps that exist between the sparse conventional observations and radar sites in AR. The long-term project objectives include: 1) assessing and validating various LEO sounder moisture products for use in very-short-range forecasting, 2) testing the impact of LEO-retrieval based NearCasts on improving a variety of AR operational very-short-range forecast products specifically designed for the Alaska Region (AR) forecasting needs, and 3) determining the optimal information contained in both hyperspectral and microwave LEO moisture retrievals using a variety of algorithms. Initial seed funding was received in mid-2013 with the first year of full project funding was made available in mid-2014. A test version of the NearCast system is running in real time over the AR, however real-time data access currently limited product. Efforts to expand data coverage are ongoing.

Milestones with Summary of Accomplishments and Findings

Forecasters in the Alaska Region have requested that short-range NearCasting techniques (developed for using GOES soundings over the CONUS) be applied to hyper-spectral sounder products generated from the multiple Low Earth Orbiting (LEO) satellites that make frequent overpasses at high latitudes (e.g., CrIS, IASI and AIRS). The hope is that these data will help fill the space and time gaps between sparse RAOB reports available there.

Recent efforts focused on demonstrating the potential of new short-range forecaster tools designed to use otherwise underutilized hyperspectral soundings in AR. Although these observations lack the special and temporal detail of GOES data, the increased vertical sounding resolution should be especially important both in areas with limited radar coverage or other asynoptic observations and when conventional NWP guidance is questioned.

Forecasters have also noted the need for short-range guidance using full resolution satellite observations in cloudy conditions (not included in IR-only satellite products) for a variety of problems, especially those related to heavy precipitation events and oceanic weather systems. To address this need, NearCasts generated using combined IR/microwave retrievals are also presented to illustrate how these data can add short-range forecast information in areas where IR instruments are 'blind'. These observationally driven short-range projections could also provide a unique LEO/GEO synergy by filling spatial gaps in future high-time frequency GOES-R IR products and displays. In particular, we:

1. Studied the accuracy of several POES retrieval systems over Alaska
2. Demonstrated the NearCast using IASI data over Europe, using 2 different retrieval systems.
3. Showed an example of a high-impact aviation event over Alaska (shown here).
4. Identified several outstanding data access issues.

Co-location comparisons with GPS-TPW observations over Alaska showed:

- Consistent dry Bias in the majority of Dual-Regression (DR) retrievals
- Dry Bias increases through the summer (Jun-Aug) for DR.
- SD difference is higher for UW-DR, possibly due to higher spatial resolution.
- IASI DR data had the smallest bias and SD
  - NOAA IASI retrievals had the smallest SD
  - EUMETSAT IASI had the smallest Bias.
- Bias related in part to differences between retrieval surface pressures and GPS sites
  - Also affected by of cloud-clearing process

As an example of the utility of CrIS and IASI retrievals through NearCast analyses and forecast depictions is shown in Figure 70 for a case in which commercial aircraft were at risk of mechanical fuel availability problems due to 'gelling' which can occur at temperatures < -70C.

For the case, NearCasts analyses showed:

- The need to include real-time retrievals from BOTH CrIS and IASI from central data collection/processing sites in order to provide sufficient areal data coverage and full product coverage throughout the day.
- An extended areas of extremely cold air (~ -70oC) near 200 hPa before 1200 UTC Barrow and Fairbanks RAOBS were available, including extension over Arctic Ocean
- But indicate some inconsistency between nadir and limb retrievals – Feedback for satellite product developers

NearCast Projections agreed well with 1200 UTC Barrow and Fairbanks RAOBS and showed:

- Show slow progression of cold pool to north and east
- And would have been useful in determining air routes to avoid

Milestones

Major efforts will continue to acquire real-time CrIS and IASI retrievals. Contacts have been made with NESDIS and NCEP regarding possible data sources. NUCAPS/CrIS data for Alaska are now available with ~90 minute delay, which is acceptable. Modification of NearCast display systems will continue to be refined to accommodate gaps in NUCAPS analyses and NearCasts along limbs of satellite paths. Alternative sources of real-time NUCAPS IASI retrievals continue, since the lack of this observations source is expected to degrade the effectiveness/utility of the NearCast system. Due to these real-time data access problems, Milestones for future tasks are being delayed until data acquisition issues are resolved, but these delays should have only minor affect on project budget. This project number has terminated. Subsequent efforts are described under a subsequent project number.

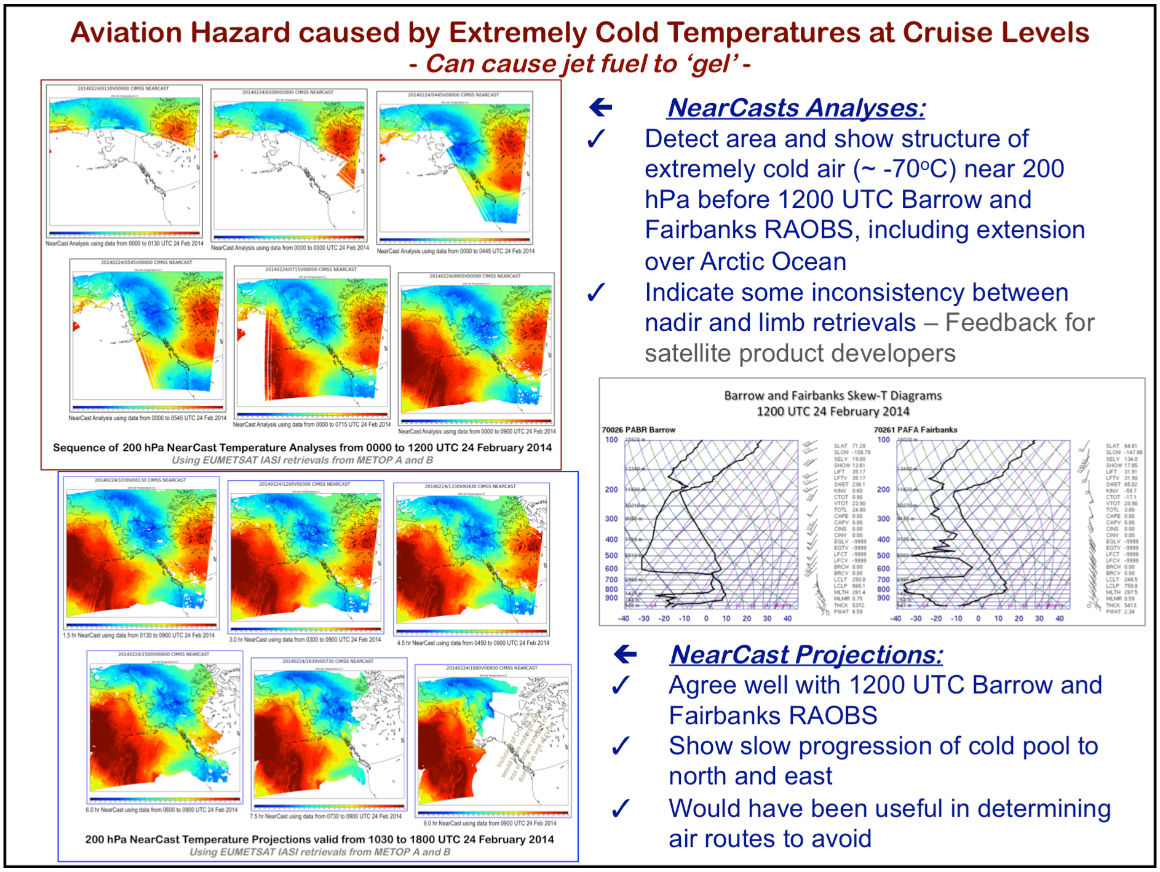


Figure 70. Case study of extreme cold temperatures at flight levels that posed a threat of restricting flow of jet fuel. Successive NearCast Analyses in upper left, NearCast Predictions in lower left and available RAOBs in center right.

Publications and Conference Reports

Presentations:

- Petersen et al. at NOAA Satellite Conference (April 2015)
- Petersen et al. at Alaska Weather Symposium (May 2015)
- Petersen et al. at EUMETSAT Users Conference and Conf. Report (Sept. 2015)
- Petersen et al. at European Conference on Severe Storms (Sept. 2015)

References

August, T., 2014: Presentation and Conference Report, EUMETSAT Users Conference, Geneva.

17.3 Development, Generation, and Demonstration of New Ice Products in Support of a National Ice Center JPSS Proving Ground and Risk Reduction Activity

CIMSS Task Leader: Yinghui Liu
CIMSS Support Scientist: Xuanji Wang
NOAA Collaborator: Jeffrey Key

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
- 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

Project Overview

In this project we are developing and generating new Joint Polar Satellite System (JPSS) ice products for evaluation at the National Ice Center (NIC) as part of the Proving Ground program. The work aims to improve two ice products and create two new ice products. Ice products to be improved are (1) the current Visible Infrared Imager Radiometer Suite (VIIRS) ice concentration intermediate product (IP), and (2) ice thickness estimation with the One-dimensional Thermodynamic Ice Model (OTIM) (Wang et al. 2010) that we developed for the GOES-R Advanced Baseline Imager. New ice products will be (1) ice concentration under all-weather conditions through the optimal blending of high spatial resolution VIIRS ice concentration with ice concentration from passive microwave observations, e.g. Advanced Microwave Scanning Radiometer -2 (AMSR2), and (2) optionally (due to a budget reduction), a VIIRS sea ice leads (fractures) product. The new/improved products will be generated near real-time and provided to the National Ice Center for evaluation. We will work with the NIC Science and Operations as well as NWS Alaska Ice Desk personnel to implement these products on their systems for operational evaluation.

Milestones with Summary of Accomplishments and Findings

The OTIM has been further improved by adding the sea ice growth/melt thermodynamic adjustment function in terms of time and latitude and the physical dynamic behavior adjustment factor along the Canadian Archipelago. Though the algorithms in the OTIM for retrieving daytime and nighttime ice thickness are different because of solar radiation involved in daytime retrieval, their retrieved ice thickness is very consistent in value except that dim area where solar zenith angle between 88 ~ 90 degrees has poor retrieved ice thickness because of poor cloud and surface albedo retrievals. The OTIM retrieved sea ice climatology in the Arctic area north of 70^{o}N has been generated to show the time dependent sea ice growth and melt dynamic process over a year for climate study. S-NPP/VIIRS ice thickness/age product has been validated against aircraft measurements from the NASA IceBridge campaign. The Statistical results of the comparison in sea ice thickness between S-NPP and IceBridge for matched locations (S-NPP pixels) has been done to show the overall good match in value (< 5% percent bias in terms of IceBridge measurements).

Blended Ice Concentration

We proposed to optimize all-weather ice concentration and cover from microwave observations, here AMSR-2, and clear-sky ice concentration and cover with very high spatial resolutions from visible/infrared observation, here the Suomi NPP VIIRS, to monitor the ice characteristics effectively in real time under all-weather conditions. The Best Linear Unbiased Estimator is applied to derive the final ice concentration under clear sky conditions:

$$ICE\_CONC = \left(\frac{\sigma_2^2}{\sigma_1^2+\sigma_2^2}\right)\times(ICE\_CONC_1 - D_1) + \left(\frac{\sigma_1^2}{\sigma_1^2+\sigma_2^2}\right)\times(ICE\_CONC_2 - D_2) \qquad (1)$$

where ICE_CONC, ICE_CONC1, and ICE_CONC2, are optimized ice concentration, and ice concentrations from the two products; D1 and D2 are measurement accuracy; σ1 and σ2 are the measurement precision. For the pixels under cloudy conditions, the resultant ice concentration is determined as the ice concentration from the microwave observations with bias correction. The final product has the same spatial resolution as VIIRS with ice product from microwave observations interpolated to the VIIRS spatial resolution. Figure 71 shows the blended daily sea ice concentration on June 14, 2015 using AMSR-2 and the Suomi NPP daily composite sea ice concentration. This product is being produced daily at CIMSS.

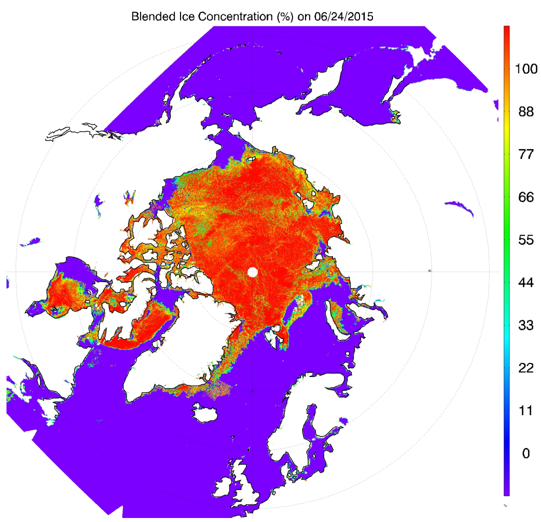


Figure 71. Blended sea ice concentration at 1 km resolution on June 24, 2015 using AMSR-2 and the Suomi NPP VIIRS products.

References

Wang, X., J. Key, and Y. Liu, 2010, A thermodynamic model for estimating sea and lake ice thickness with optical satellite data, J. Geophys. Res.-Oceans, 115, C12035, doi:10.1029/2009JC005857.

Y. Liu, and J. Key: A Blended Ice Concentration Product based on Visible/infrared and Microwave. 12th Annual Symposium on New Generation Operational Environmental Satellite Systems, 96th American Meteorological Society Annual Meeting, 10-14, January 2016, New Orleans, LA, USA

17.4 Hyperspectral Retrievals from Polar-Orbiting Sounders for Use in NWS Alaska Region Forecasting Applications
CIMSS Task Leader: Elisabeth Weisz
CIMSS Support Scientists: William L. Smith, Nadia Smith
NOAA Collaborator: Mitch Goldberg

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

Project Overview

Hyperspectral retrieval data, derived from CrIS (Cross-track Infrared Sounder), AIRS (Atmospheric Infrared Sounder) and IASI (Infrared Atmospheric Sounding Interferometer) radiance measurements has the potential to improve regional weather monitoring and prediction. To increase the operational use of hyperspectral retrieval data in NWS forecasting offices the value that hyperspectral infrared sounder retrievals add to forecasting applications in the CONUS area and the Alaskan Region (AR) is demonstrated. Retrieval products are also prepared for near real-time viewing through the Advanced Weather Interactive Processing System (AWIPS), and new applications are investigated.

Milestones with Summary of Accomplishments and Findings

The study and analysis of AR and CONUS weather systems indicate the capability of hyperspectral sounder retrievals to provide independent and detailed information about the atmospheric vertical structure, clouds and surface. Continued discussion with GINA (Geographic Information Network of Alaska)/UAF (University of Alaska Fairbanks) scientists and AR NWS forecasters about the optimal use of hyperspectral satellite data in their real-time applications emphasized the need for accurately detecting cold air layers aloft over the Arctic. This is important for NWS aviation safety, since extremely low air temperatures (below minus 60 degrees Celsius) may cause the fuel of commercial airlines on transpolar flights to jellify. Currently only a few in-situ measurements and model profiles are used to detect cold air aloft (CAA). We were able to confirm the capability of hyperspectral satellite sounders to detect these upper tropospheric cold air layers (Stevens et al. 2015) by using the UW/CIMSS Dual-Regression (DR) retrieval algorithm (Smith et al. 2012, Weisz et al. 2013) to derive the temperature fields. A new NOAA JPSS funded project has been established to make this novel product operationally available. Based on the CSPP (Community Satellite Processing Package) -'polar2grid' software the CAA team is preparing the AWIPS II display of the direct-broadcast NUCAPS (NOAA Unique CrIS/ATMS Processing System) temperature retrievals. Figure 72 shows NUCAPS and DR CrIS temperature retrievals at the 200-hPa pressure level for all available Suomi-NPP overpasses on March 1, 2015. The cold air layer seen over Alaska was part of a four-day CAA event, which in turn was the first of two events occurring in March 2015.

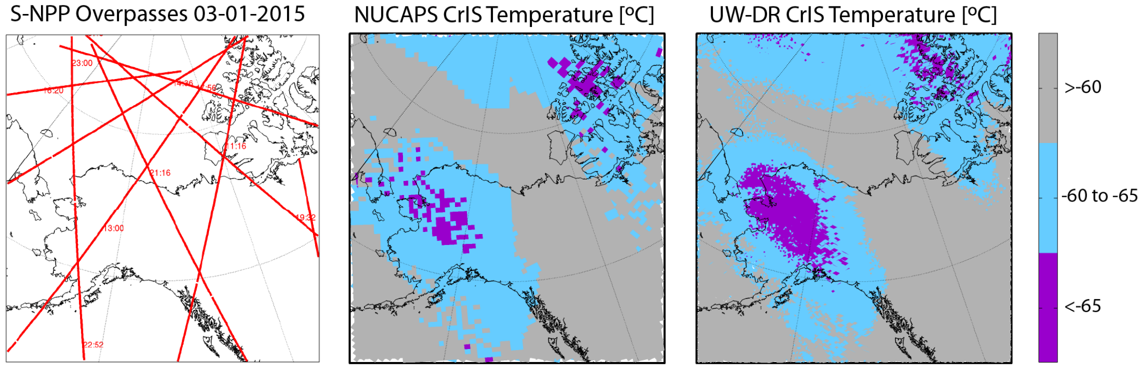


Figure 72. Suomi-NPP orbital nadir tracks for 03-01-2015 (left); retrieved 200-hPa temperatures using the NUCAPS (middle) and the UW/CIMSS dual-regression (right) retrieval method.

Publications and Conference Reports

Stevens, E., E. Weisz, K. Nelson, J. Zhu, "Using Hyperspectral Sounders to Detect Cold Air Aloft over Alaska", 95th AMS Annual Meeting, 5-8 January 2015, Phoenix, Arizona.

Smith Sr., W. L., A. M. Larar, B. Pierce, H. E. Revercomb, N.Smith, J. Taylor, E. Weisz, M. Yesalusky , "Satellite, Airborne, and Ground-based Remote Sensing Techniques", OSA FTS and HISE Topical Meeting, 1 – 4 March 2015, Lake Arrowhead CA.

References

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*.

17.5 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

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

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.

The investigators will expand on extensive TC intensity analysis work done using the above sensors, with many of the methods already being utilized operationally by NOAA. Specifically, we plan to test, demonstrate and evaluate an innovative weighted consensus approach that takes advantage of the strengths of each individual satellite-based approach, and mitigates the weaknesses, making use of statistical performance in given situations.

Milestones with Summary of Accomplishments and Findings

Milestone 1. ATMS data was collected during TCs in 2015. Overpasses coincident with aircraft observations were used to perform an independent validation of the ATMS TC intensity algorithm. ATMS TC overpasses were matched to aircraft reconnaissance observations (within three hours of the ATMS pass) in the Eastern/Central Pacific and Atlantic for a total of 43 cases. An independent test was conducted by including the 2015 cases in the training sample, then using 2012-2015 data and a “leave every 4^{th} case out” approach to re-derive the regression equations and then test against the independent data. Results for the dependent and independent tests are shown in Table 3 and Table 4, respectively.

Milestone 2. In order to incorporate ATMS into SATCON, three types of weights are needed. The first two weights define the contribution of the ATMS estimates in the SATCON estimate at the time of the ATMS pass. These weights are defined in the SATCON algorithm by the RMSE for ATMS Minimum Sea Level Pressure (MSLP) and Maximum Sustained Winds (MSW). Table 3 and Table 4 show the aggregate ATMS performance for the periods shown. The RMSE can be stratified using TC eye size to indicate cases where ATMS estimate errors tend to be lower (large TC eyes greater than 40 km in diameter) and higher (eyes smaller than 45 km in diameter). The RMSE for eye sizes smaller than 40 km increases 12.0 knots. Therefore ATMS estimates for TC eyes with a diameter less than 40 km get less weight in SATCON. SATCON uses interpolated microwave estimates to increase the number of matches to the infrared-based Advanced Dvorak Technique and also to improve smoothness of the plots. Temporal variability and occasional large time gaps from microwave-based estimates require that those estimates have a limited range of influence with respect to time in SATCON. This problem defines the third weight. A weighting function was created that weights the interpolated microwave estimates (interpolated between each estimate as a post-processing step) based on estimate age. Beyond three hours, the estimate influence decays by the square of the distance in time between estimates resulting in the least amount of weighting at the mid-point.

Milestone 3. CIRA MIRS-based ATMS estimates are now available in near real-time. A complete evaluation of the CIRA ATMS estimates using cases from 2012-2015 is ongoing to determine inclusion in SATCON. CIRA ATMS estimates are now being plotted on the CIMSS SATCON plots for reference with the other objective intensity estimates.

Table 3. CIMSS ATMS-derived TC intensity estimates: Dependent results from 169 TC cases in 2012-2015 as compared to operational Best Track estimates. MSLP is estimated TC minimum sea-level pressure, and MSW is estimated maximum sustained 1-min. surface winds. DVK MSW is the average of all available coincident operational Dvorak estimates.

N=169	ATMS MSLP (hPa)	ATMS MSW (kts)	DVK MSW (kts)
Bias	-0.2	0.1	-2.7
Abs Error	5.6	8.8	7.7
RMSE	7.1	11.0	10.0

Table 4. As in Table 3, except for independent sample of 58 cases from 2012-2015.

N=58	ATMS MSLP (hPa)	ATMS MSW (kts)	DVK MSW (kts)
Bias	0.2	2.2	-4.4
Abs Error	5.3	7.5	8.7
RMSE	7.2	9.5	10.4

Publications and Conference Reports

Velden, C., D. Herndon and T. Olander, 2015: Estimating Tropical Cyclone Intensity in the GOES-R/JPSS Era. *2015 NOAA Satellite Science Week,* 23-28 February, 2015, Boulder, CO.

17.6 Ongoing Investigations in support of the JPSS Program
CIMSS Task Leader: W. Paul Menzel
CIMSS Support Scientist: Elisabeth Weisz
NOAA Collaborator: Mitch Goldberg

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

Project Overview

Achieving the stated objective involves reducing the high spectral resolution CrIS/IASI data to resemble the HIRS broad band spectral coverage and using the resulting broad convolved radiances to estimate the cloud top pressures and effective emissivities. Co-located HIRS and IASI data from MetOp have been used to provide proof of concept. Application to CrIS data from SNPP is now being pursued. Additionally, the high spectral resolution data is being investigated to characterize the uncertainties in the broad band cloud products.

Milestones with Summary of Accomplishments and Findings

A combination of the CO2 slicing and IRW techniques (Menzel et al., 2008) for deriving cloud top pressures (CTPs) was applied to HIRS and HIRS-IASI (high spectral resolution IASI measurements were convolved to broad band HIRS spectral response functions). Cloud phase (determined using the tri-spectral technique, Strabala et al (1995)) was used to guide application of IRW for water and CO2 slicing for ice clouds. Results for a granule from 19 January 2009 were compared. IASI with 12 km FOVs at nadir samples 4 FOVs every 50 km while HIRS samples with 10 km FOVs every 20 km cross-track and 40 km along track; IASI has a higher density of samples with a larger footprint than HIRS/4. These scan and FOV differences cause HIRS to find fewer clouds at 77% than HIRS-IASI at 82%; a cloud is determined if at least 15% of the AVHRR FOVs within the HIRS or HIRS-IASI FOV are cloudy. Table 5 has the break out by thin, thick, and opaque versus high middle, and low. Overall, there is good agreement. HIRS-IASI finds more high thick clouds at the expense of low and middle clouds. HIRS-IASI provides continuity for the HIRS cloud record, understanding that FOV size and sampling differences will adjust cloud detection percentages.

Table 5. Classification (in percentage of all observations) of HIRS (and HIRS-IASI in parentheses) cloud determinations.

	Thin (NE<0.5)	Thick	Opaque (NE>0.95)	Total
Hi (CTP<440 hPa)	10 (11)	14 (19)	01 (01)	28 (32)
Mid	09 (10)	10 (11)	07 (04)	26 (24)
Lo (CTP>660 hPa)	04 (05)	07 (08)	12 (14)	23 (26)

References

Menzel, W. P., R. A. Frey, H. Zhang, D. P. Wylie., C. C. Moeller, R. A. Holz, B. Maddux, B. A. Baum, K. I. Strabala, and L. E. Gumley, 2008: MODIS global cloud-top pressure and amount estimation: algorithm description and results. Jour of App Meteor and Clim., 47, 1175-1198.

Strabala, K. I., S. A. Ackerman, and W. P. Menzel, 1994: Cloud Properties Inferred from 8-12 micron Data. Jour. Appl. Meteor., 33, 212-229.

18. 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, Hong Zhang

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

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

The NASA GMAO GEOS-5 Nature run (G5NR) (http://gmao.gsfc.nasa.gov/projects/G5NR/) had been selected from three different nature runs available to represent the true atmospheric state for this study. It had the highest spatial and temporal resolution at 7km globally and 30 minute output. A version of T1534 GFS was put on S4 and was ready for use in October 2015. Modifications were made to the code to remove conventional data quality control so as to maintain the same data usage for both real world and OSSE. The data quality control for conventional data was based on NCEP archived files for the real world. Multiple real world data denial experiments were conducted. Their statistics will be used as a reference for OSSE calibration. The OSSE is calibrated so that its performance is similar to assimilation performance in the real world, before the impact of the potential observing system is assessed.

The OSSE assimilates observations from the current existing network at the same time and location as in the real world. Various simulators to generate these observations from the nature run need to be created. Two simulators (conventional and GPSRO data) had been completed. Time and location were extracted from real data files. Observations were simulated from the nature run via interpolation for conventional data and a bending angle forward model provided by EMUMETSAT for GPSRO. A total of 5 different sensors on 7 different satellites (including a potential CrIS at half the current spatial resolution) will be required for this OSSE. Since this study will be conducted at the global scale, and due to the large number of sensors/satellites used, the creation of an orbit simulator was initiated. The orbit simulator generates simulated satellite orbits that are comparable to that of the real world. Figure 73 and Figure 74 show examples for CrIS and ATMS.

Progress of the project ending June 30 2015 is shown in Figure 75. Various different components are still in progress. Leveraging on another OSSE project, which had developed a satellite radiance simulator for geostationary hyperspectral sounder; capability to simulate satellite radiances for the 5 sensors needed using satellite geometry from the orbit simulator will be added. The assimilation system ingests observations in the BUFR format. An encoder to convert simulated radiances from netcdf format to BUFR format will be required. As simulated observations are noise free, a noise simulator following that described by Erico et al (2013). This noise simulator will be used to adjustment of the errors during the calibration step.

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.

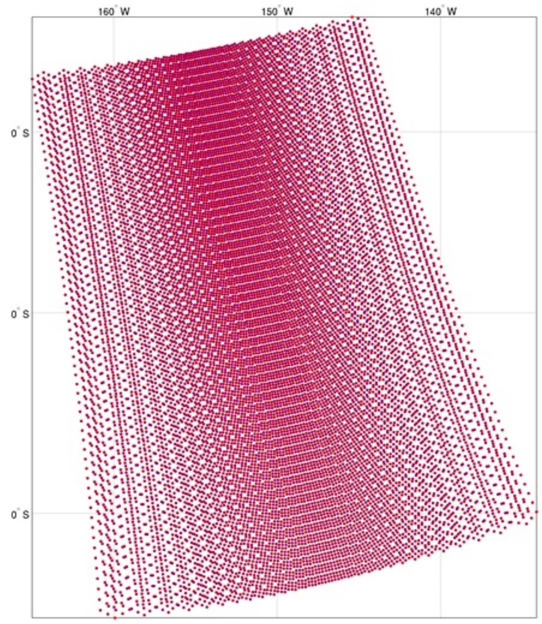


Figure 73. Comparison between spatial coverage of satellite orbits in the real world (blue) and that generated by the orbit simulator (red) for S-NPP CrIS.

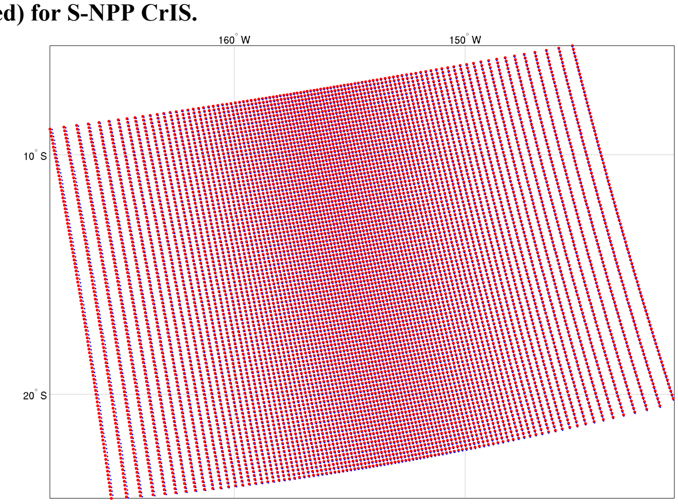


Figure 74. Comparison between spatial coverage of satellite orbits in the real world (blue) and that generated by the orbit simulator (red) for S-NPP ATMS.

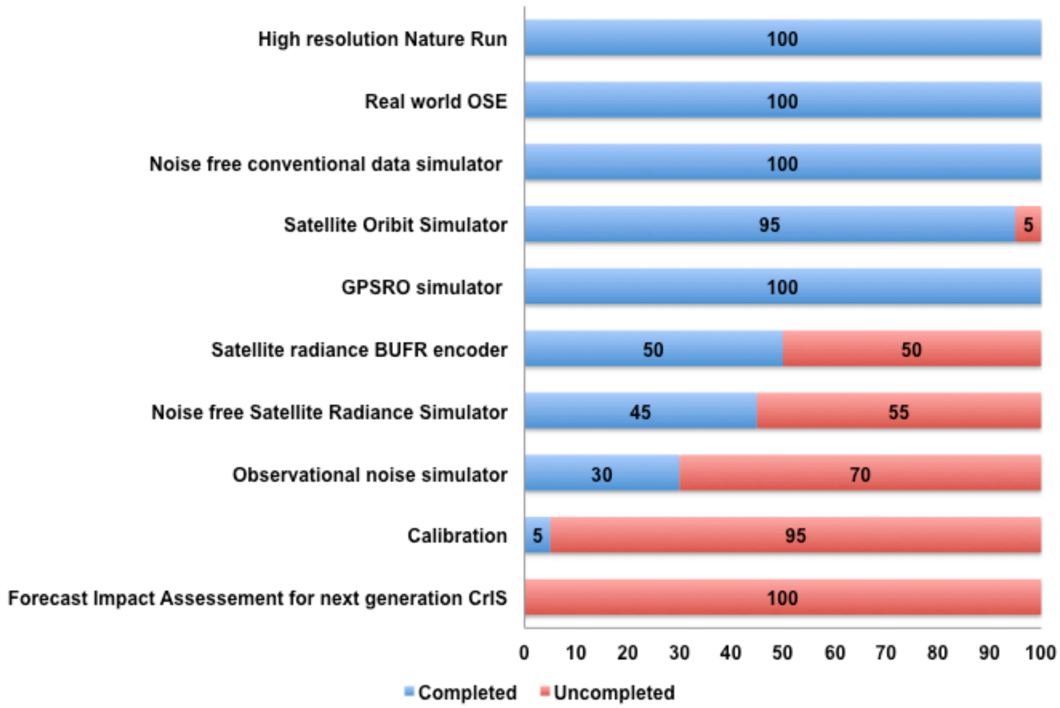


Figure 75. Status of OSSe ending 30 June 2015.

Publications and Conference Reports

Agnes Lim, Zhenglong Li, James Jung, Allen Huang, Jack Woollen, Greg Quinn, FW Nagle, Jason Otkin & Mitch Goldberg, Impact Analysis of LEO Hyperspectral Sensor IFOV size on the next generation NWP model forecast performance, NOAA Satellite Conference, April 27 - May 1, 2015

Lim, Agnes; Jung, J. A.; Huang, H. L.; Li, Z.; Otkin, J. and Goldberg, M. Impact analysis of LEO hyperspectral sensor IFOV size on the next generation NWP model forecast performance. Boston, MA, American Meteorological Society, 2015

References

Errico R.M., R. Yang, N. Prive, K-S Tai, R. Todling, M. E. Sienkewicz and J. Gao, 2013: Development and validaton of observing system simulation experiments at NASA Global Modelling and Assimilation Office, Q. J. R. Meteorol. Soc., 139, 1162-1178.

19. The Development of a Community Satellite Processing Package (CSPP) in Support of Suomi NPP/JPSS Real Time Regional (RTR) Applications

CIMSS Task Leaders: Allen Huang (PI), Liam Gumley (PM)
CIMSS Support Scientists: Scott Mindock, Ray Garcia, Graeme Martin, Geoff Cureton, Kathy Strabala, Nick Bearson, Jim Davies, Jess Braun
NOAA Collaborator: Mitch Goldberg

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

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
The CSPP suite includes software for generating the following products on CentOS 64-bit Linux for Intel platforms:

1. SDR	VIIRS, CrIS, and ATMS geolocated and calibrated earth observations.
2. VIIRS EDR	VIIRS imager cloud mask, active fires, surface reflectance, vegetation indices, sea surface temperature, land surface temperature, and aerosol optical depth.
3. HSRTV	Hyperspectral infrared sounder retrievals of temperature and moisture profiles, cloud properties, total ozone, and surface properties.

4. Polar2grid	Reprojected imagery (single and multi-band) in GeoTIFF and AWIPS formats.
5. Hydra	Interactive visualization and interrogation of multispectral imagery and hyper spectral soundings.
6. MIRS	Microwave sounder retrievals of temperature and moisture profiles; surface properties; snow and ice cover; rain rate; and cloud/rain water paths.
7. CLAVR-x	Multispectral imager retrievals of cloud properties; aerosol optical depth; surface properties; ocean properties.
8. NUCAPS	Combined hyperspectral infrared sounder and microwave sounder retrievals of temperature and moisture profiles, cloud cleared radiances, and trace gases.
9. IAPP	Combined infrared sounder and microwave sounder retrievals of temperature and moisture profiles, water vapor, total ozone, and cloud properties.
10. ACSPO	Multispectral imager retrievals of sea surface temperature.
11. Sounder Quicklook	Quickook images (maps and Skew-T plots) from CSPP temperature and moisture profile products.

The CSPP SDR and VIIRS EDR software for Suomi NPP is based on the Algorithm Development Library (ADL) developed by Raytheon and the JPSS project. This means that the CSPP software is the same software that runs in the operational processing facility at NOAA/NESDIS. SSEC has packaged the software to run from the Linux command line in real-time direct broadcast mode, however the underlying processing software, algorithms, and data formats are unchanged. The output files from the CSPP SDR processing software are identical in naming, format, and structure to the corresponding files from NOAA/NESDIS. The native format for NPP SDR products is HDF5, and descriptions of the NPP file formats are available in the "Common Data Format Control Books."

CSPP also distributes a number of third-party software packages developed by NOAA and the DB community, including the SSEC/CIMSS Dual Regression Retrievals, NOAA Microwave Integrated Retrieval System, and Hydra2 Multispectral Data Analysis Toolkit.

The CSPP project created the following software releases and updates during the reporting period:

- *December 14, 2015: CSPP NUCAPS CrIS/ATMS EDR Retrieval Software Version 1.1.* Updated release of the of the NOAA NESDIS Center for Satellite Applications and Research (STAR) NUCAPS EDR software providing retrievals of atmospheric temperature, moisture and trace gasses as well as cloud-cleared radiances from input Suomi-NPP CrIS and ATMS SDR data files. This version provides support for the 7 Field-Of-View direct broadcast CrIS files that began downlink on 18 August 2015.
- *October 12, 2015: CSPP Polar2Grid Reprojection Software Version 2.0.* Update to the software that enables users to create reprojected VIIRS SDR GeoTIFF, and AWIPS NetCDF files as well as 24 bit True Color and False Color imagery in a selection of projections or grids for entire swaths of data or covering a user defined region. This

version includes updates that allow the creation of VIIRS, MODIS and AVHRR KMZ, Binary and HDF5 output data formats as well.

- *October 9, 2015: CSPP Microwave Integrated Retrieval System (MIRS) Software Version 2.0.*
  Update to the CSPP release of the NOAA NESDIS Center for Satellite Applications and Research (STAR) Microwave Integrated Retrieval System (MIRS) software in support of the ATMS instrument onboard S-NPP, and the AMSU-A and MHS instruments onboard NOAA-18, NOAA-19, Metop-A and Metop-B satellites. This update includes the base NOAA software upgraded to version 11.1, and the creation of NOAA-18, -19, Metop-A and-B products at the resolution of the MHS instrument.
- *September 29, 2015: CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software Version 2.1.1 Patch.*
  This update is required for users to continue to process CrIS data after the transition to extended spectral resolution data. This update is distributed as a patch rather than a full software release.
- *July 16, 2015: CSPP Sounder Quicklook Software Version 1.0.*
  First release of a software package that can create navigated pressure level plots of temperature and moisture as well as Skew-T Thermodynamic diagrams of atmospheric Level 2 retrievals from the following software packages:
    - CSPP-NOAA Unique CrIS/ATMS Processing System (CSPP-NUCAPS),
    - CSPP Hyperspectral Sounder Retrieval (Dual Regression) (HSRTV),
    - CSPP-Microwave Integrated Retrieval System (CSPP-MIRS), and
    - CSPP-International ATOVS Processing Package (CSPP-IAPP).

An update to the CSPP SDR package supported the transition to CrIS extended spectral resolution in October 2015. A later update to the CSPP SDR software supported the transition to VIIRS auto calibration mode in December 2015. The current version of CSPP SDR is synchronized with the version running in NOAA IDPS operations (Mx 8.11).

The CSPP team worked with algorithm developers at NOAA/NESDIS to release updates to the NUCAPS, CLAVR-x, ACSPO, and MIRS software packages.

The CSPP team, in collaboration with EUMETSAT, hosted a combined CSPP/IMAPP Users Group meeting at EUMETSAT headquarters in Darmstadt, Germany from 14-16 April, 2015. The meeting was attended by more than 70 participants and featured oral and poster presentations over 3 days. The full meeting program and presentations are available at http://www.ssec.wisc.edu/meetings/cspp/2015/program.html

Figure 76. Attendees at the 2nd CSPP/IMAPP Users Conference, 14-16 April 2015, at EUMETSAT in Darmstadt.

20. SSEC/CIMSS Participation on the Algorithm Development Library (ADL) Team

CIMSS Task Leader: Liam Gumley
CIMSS Support Scientists: Scott Mindock, Ray Garcia, Graeme Martin
NOAA Collaborator: Pat Purcell

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

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;
- Verifying compatibility with RDRs from Direct Broadcast sources;

- Checking compatibility of Direct Broadcast produced SDRs with the corresponding IDPS SDRs; and
- Verifying robustness of ADL distributions before public release.

SSEC works closely with the Raytheon ADL development team and the JPSS project to ensure that ADL meets the needs of users who wish to execute and modify IDPS PRO algorithms outside the operational IDPS environment.

Milestones with Summary of Accomplishments and Findings

SSEC provided support to the JPSS community for ADL 4.2 and ADL 5.0 during 2015. The JPSS MX builds associated with this release included 5.8.06 (Feb 2015) to 5.8.11 (Jan 2016) and Block 2 releases to 2.0.00.00.16 (March 2016). Each of these MX releases initiated several activities at SSEC. These activities included:

- Staging of ADL release DVD contents,
- Updates of installation scripts for ADL and COTS,
- Testing of installation scripts on several platforms,
- Updates to ADL installation instructions including COTS version updates,
- Building and testing ADL using a variety of compiler versions on supported platforms,
- Identification and ingest of ancillary data required for SDR algorithms, including calibration LUTs.
- Improvements to ancillary ingest QC
- A CSPP SDR version based on ADL 4.2 mx 5.8.11was developed and tested, and released in early April 2016.

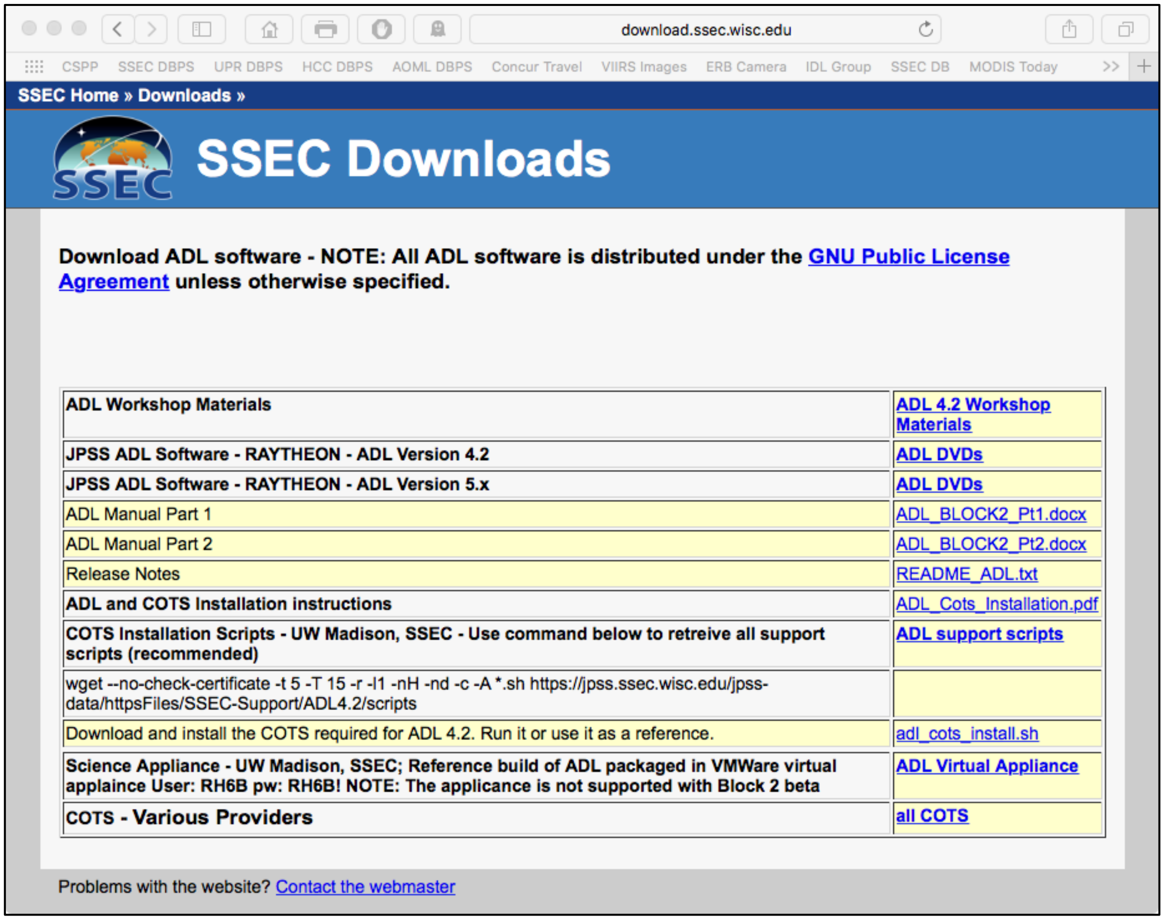
SSEC provided distribution of ADL and end-user support at https://jpss.ssec.wisc.edu/ (Figure 77). The ADL website includes information on ADL Software and Downloads, Installation Instructions, Scripts and Helper Applications, ADL Virtual Appliance, HOWTOs, Add-Ons, and a link to the ADL help desk email address. The website also contains links to the ADL ancillary data website.

SSEC continued to host and support the online ADL User Forum available at https://forums.ssec.wisc.edu/viewforum.php?f=23 (Figure 78). The ADL forum allows ADL users to interact directly with the development team, and each other, with or without the involvement of SSEC. Raytheon has proven to be especially helpful and diligent in monitoring and answering ADL user questions on the forum site.

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.



Download ADL software - NOTE: All ADL software is distributed under the GNU Public License Agreement unless otherwise specified.

ADL Workshop Materials	**ADL 4.2 Workshop Materials**
JPSS ADL Software - RAYTHEON - ADL Version 4.2	**ADL DVDs**
JPSS ADL Software - RAYTHEON - ADL Version 5.x	**ADL DVDs**
ADL Manual Part 1	ADL_BLOCK2_Pt1.docx
ADL Manual Part 2	ADL_BLOCK2_Pt2.docx
Release Notes	README_ADL.txt
ADL and COTS Installation instructions	ADL_Cots_Installation.pdf
COTS Installation Scripts - UW Madison, SSEC - Use command below to retreive all support scripts (recommended)	**ADL support scripts**
wget --no-check-certificate -t 5 -T 15 -r -l1 -nH -nd -c -A *.sh https://jpss.ssec.wisc.edu/jpss-data/httpsFiles/SSEC-Support/ADL4.2/scripts	
Download and install the COTS required for ADL 4.2. Run it or use it as a reference.	adl_cots_install.sh
Science Appliance - UW Madison, SSEC; Reference build of ADL packaged in VMWare virtual applaince User: RH6B pw: RH6B! NOTE: The applicance is not supported with Block 2 beta	**ADL Virtual Appliance**
COTS - Various Providers	**all COTS**

Problems with the website? Contact the webmaster

Figure 77. SSEC ADL Website showing ADL installation instructions.

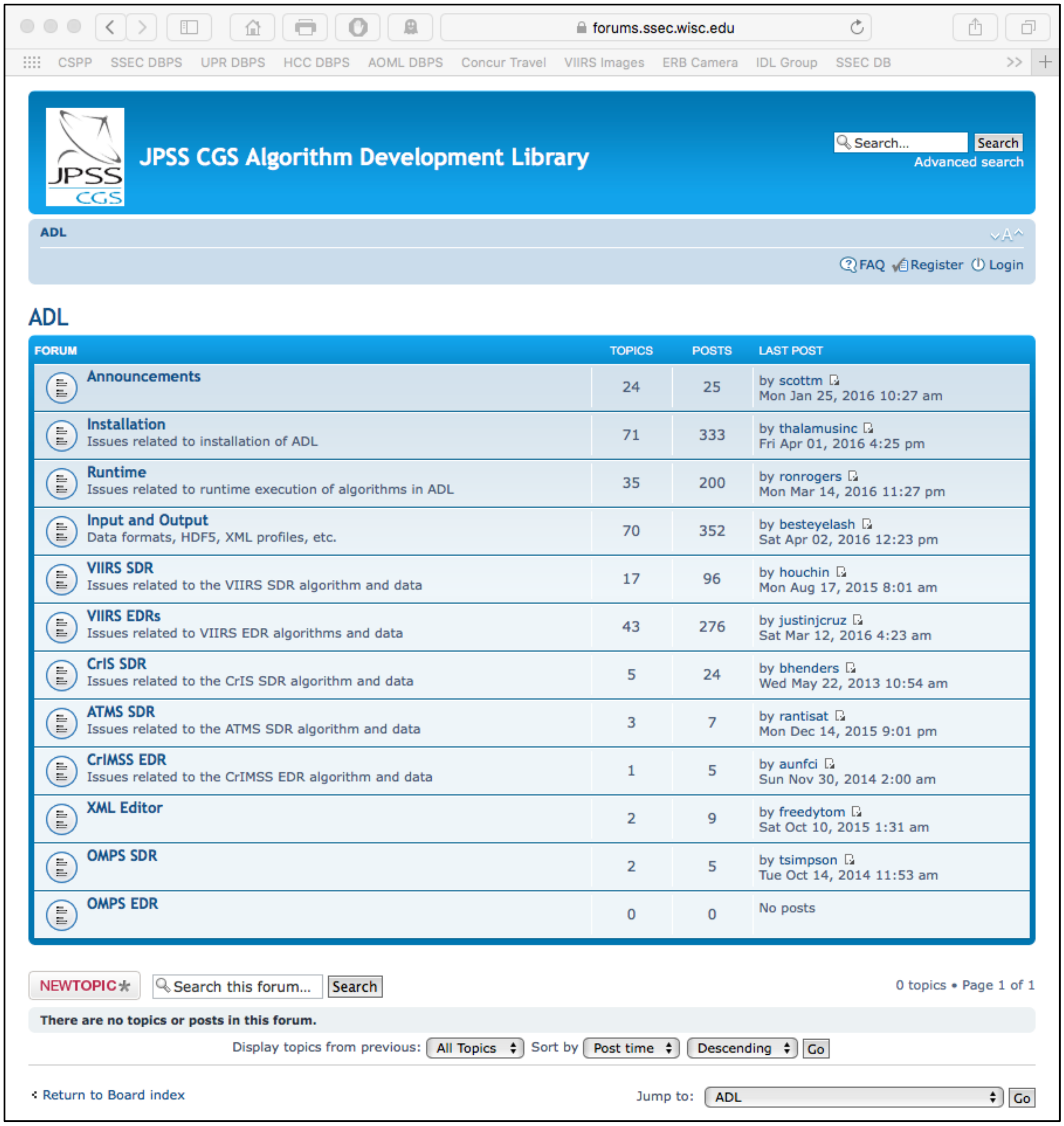


Figure 78. SSEC Forum for ADL.

21. Science and Management Support for NPP VIIRS Snow and Ice EDRs in 2015

CIMSS Task Leader: Yinghui Liu
CIMSS Support Scientists: Xuanji Wang, Richard Dworak
NOAA Collaborator: Jeffrey Key

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

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

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, 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.

Ice Surface Temperature (IST) retrieval algorithm coefficients for the algorithm developed by the Cryosphere Team at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) have been updated based on the Northrop Grumman Band Averaged Relative Spectral Response used operationally for VIIRS. This algorithm is also for the NASA Moderate Resolution Imaging Spectroradiometer (MODIS) product. The updated algorithm is being applied by the Team in near-real time.

Validation study using the operational VIIRS IST EDR and the CIMSS algorithm have been updated with all available IceBridge KT-19 for 2014 over the Arctic and Antarctic. Results show good performance of the IST EDR as shown below in Figure 79. Validation is also planned for comparisons with multiple datasets, including NASA IceBridge measurements, air temperature from Arctic drifting ice buoys, Moderate Resolution Imaging Spectroradiometer (MODIS) IST, MODIS IST simultaneous nadir overpass (SNO), and surface air temperature from the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis.

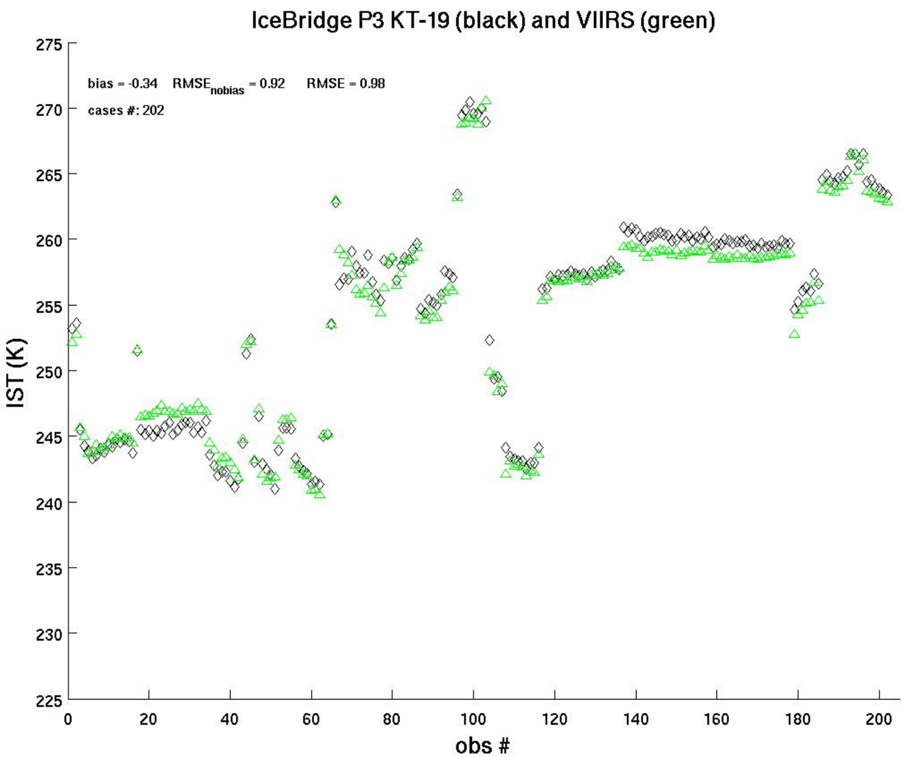


Figure 79. VIIRS IST (green) and KT-19 IST (black) for all coincident IceBridge flights with cloud-free observations over the Arctic (March-May 2014) and Antarctic (October-November 2012-13).

All the sea ice concentration products are being compared with microwave ice concentration products, and archived daily, weekly and monthly animations of ice concentration and ice surface temperature products for Arctic and Antarctic available at https://stratus.ssec.wisc.edu/ice-products/anibrowser/index.php. One example is shown in Figure 80. Validation of VIIRS and passive microwave-derived sea ice concentration has been done by using high-resolution Landsat data. Biases and uncertainties (precision) are relatively small for all bins. The overall bias is 0.74% with precision 12.2%.

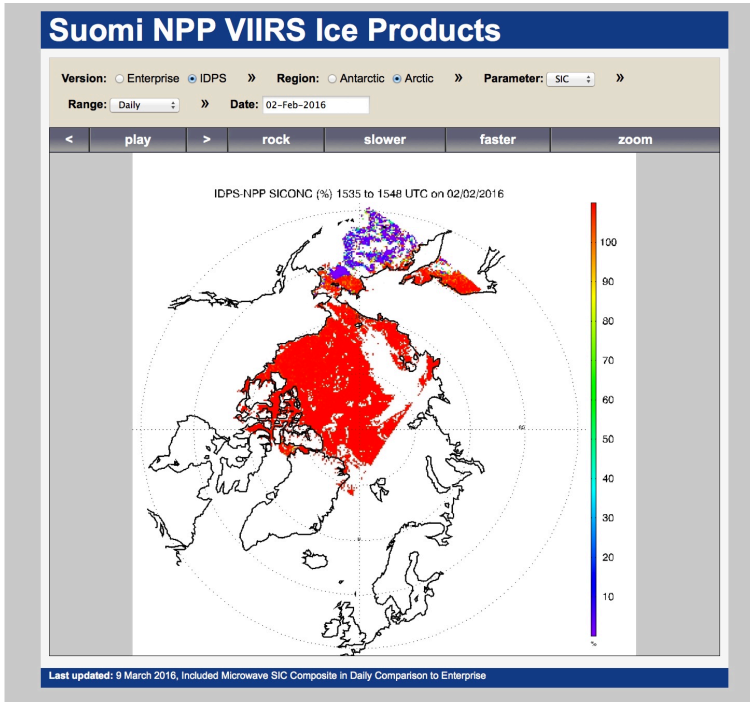


Figure 80. Suomi NPP VIIRS Ice Products Web.

NPP/VIIRS ice thickness/age product has been validated against aircraft measurements from the NASA IceBridge campaign. (The IceBridge data in about 7 m resolution were grouped up in S-NPP 750 m resolution box, and then averaged to match S-NPP 750 m pixel size sea ice thickness for comparison.) There were no significant differences between the results generated by the Framework and our locally-generated results. Table 6 lists statistical results of the comparison in sea ice thickness between S-NPP and IceBridge for matched locations (S-NPP pixels).

Table 6. Statistical results of the comparison in sea ice thickness.

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.; Tschudi, M.; Dworak, R.; Mahoney, R.; Baldwin, D. Validation of the Suomi NPP VIIRS Ice Surface Temperature Environmental Data Record. Remote Sens. 2015, 7, 17258-17271.

Y. Liu, J. Key and R. Mahoney: Sea ice concentration from VIIRS on Suomi NPP and the future JPSS Satellites. Submitted to Remote Sensing.

Y. Liu, and J. Key: A Blended Ice Concentration Product based on Visible/infrared and Microwave. 12th Annual Symposium on New Generation Operational Environmental Satellite Systems, 96th American Meteorological Society Annual Meeting, 10-14, January 2016, New Orleans, LA, USA.

Y. Liu, J. Key, M. Tschudi, R. Dworak, and D. Baldwin: Calibration and validation of the Suomi NPP ice surface temperature environmental data record. 2015 AGU Fall Meeting, 14–18 December, San Francisco, CA, USA.

Xuanji Wang, Jeffrey Key, Ron Kwok, Jinlun Zhang: Comparison of Sea Ice Thickness from Satellites, Aircraft, and PIOMAS Data. Submitted to Remote Sensing.

22. CIMSS Visiting Scientist on Tropical Cyclone Monitoring and Predicting with Satellite Measurements

CIMSS Task Leader: Jun Li
CIMSS Support Scientist: Hyojin Han
NOAA Collaborator: Mitch Goldberg

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

Project Overview

In order to understand the better use of satellite data for tropical cyclone (TC) forecasts, a Postdoc scientist is proposed to work at the Cooperative Institute for Meteorological Satellite Studies

(CIMSS) at the University of Wisconsin-Madison on the application of S-NPP/JPSS sounder (CrIS, ATMS) data for Hurricane and Typhoon forecast improvement, CIMSS Satellite Data Assimilation for Tropical Storm forecasts (SDAT) with domain over Pacific Ocean will be used as the testbed, focus will be on the use of dynamic and thermodynamic information from S-NPP/JPSS for Typhoon Haiyan (2013) forecast improvement. Since Typhoon Haiyan is considered the strongest landed Typhoon even in the history; this research is expect to maximize the benefit of satellite data in monitoring and predicting strong TCs such as Haiyan (2013).

Milestones with Summary of Accomplishments and Findings

ATMS Cloud Screening with VIIRS Cloud Product Tested with SDAT as Testbed (April 2015 – March 2016)

Cloud screening is one of the most important steps in microwave sounder radiance assimilation, To enhance the accuracy of cloud screening and improve ATMS radiance assimilation for tropical cyclone (TC) forecasts, ATMS measurements are collocated with high spatial resolution VIIRS cloud products, and cloud-screened ATMS radiance measurements are assimilated for Hurricane Sandy (2012) and Typhoon Haiyan (2013) forecasts using SDAT as testbed. Experiments are carried out to determine the thresholds of VIIRS cloud fraction (CF) and cloud top height (CTH) for distinguishing the cloud affected and unaffected ATMS radiance measurements. The results indicate that the use of VIIRS high spatial resolution cloud products can improve the accuracy of hurricane forecasts by correctly eliminating cloud contaminated ATMS pixels. For example, cloud detection with VIIRS, ATMS radiance assimilation improves the Hurricane Sandy (2012) forecasts by 8.6 – 38.0 km for the track and 0 – 2.5 hPa for SLP (Figure 81). The sub-pixel cloud detection also reduces the track error of the Typhoon Haiyan (2013) forecast, up to 60 km (Figure 82). Results also show that ATMS performs better than AMSU-A on Aqua (solid lines versus dashed lines in Figure 81 and Figure 82).

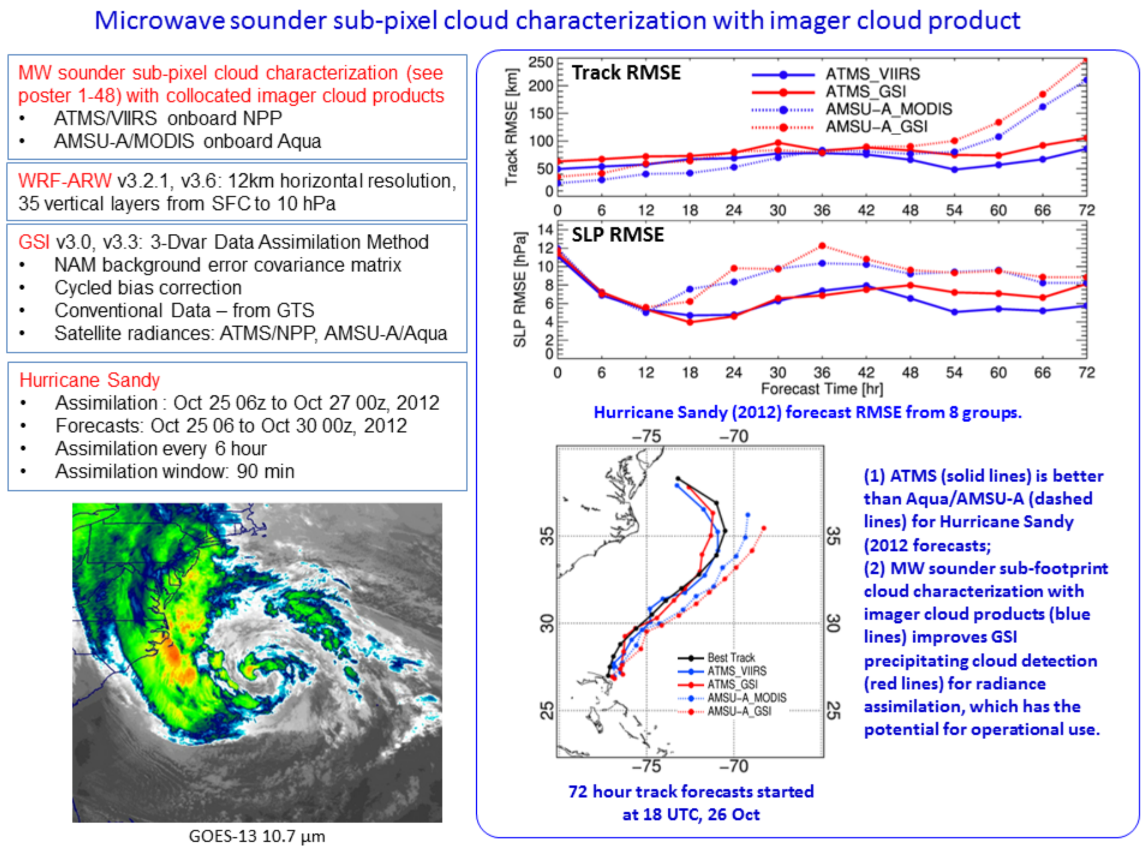


Figure 81. The track and SLP RMSEs of the Hurricane Sandy (2012) forecasts for AMSU-A_MOD (blue dotted line), AMSU-A_GSI (red dotted line), ATMS_VIIRS (blue solid line), and ATMS_GSI (red solid line). One An example of 72-hour track forecasts along with the observations are is also shown in the lower right panel.

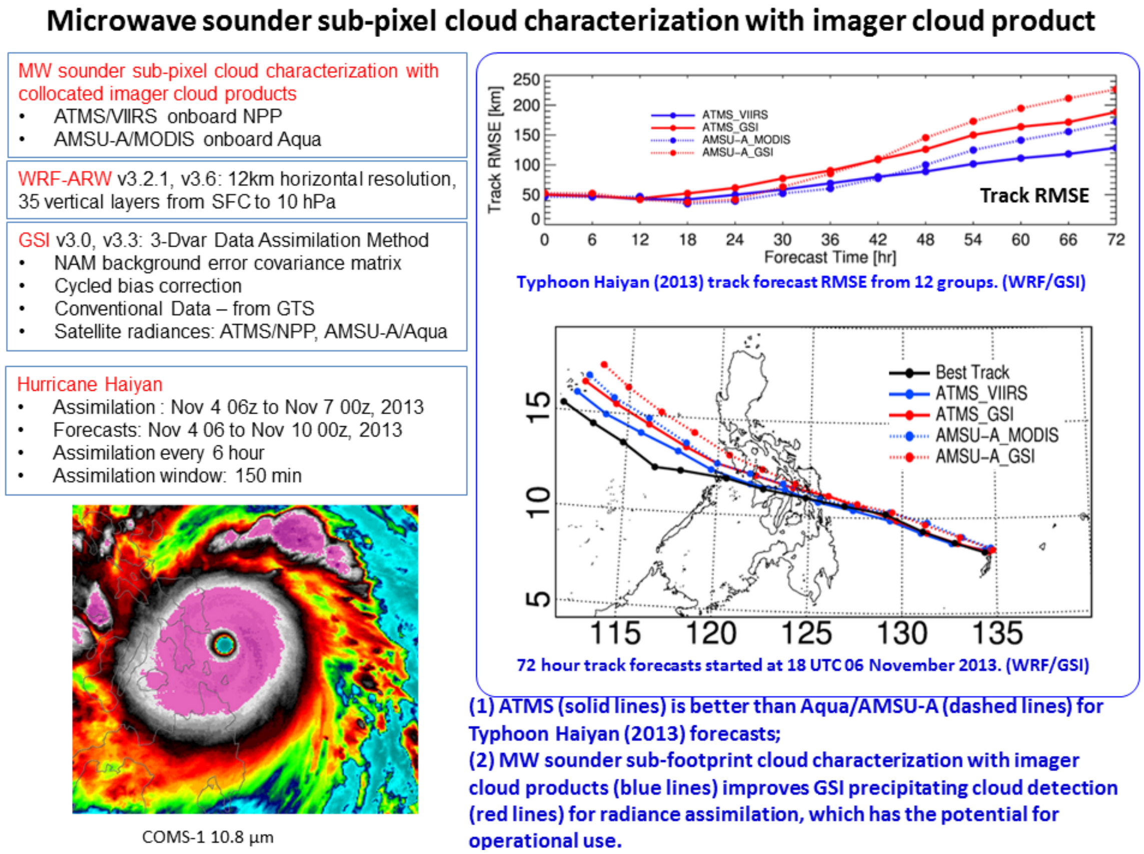


Figure 82. The track and SLP RMSEs of the Typhoon Haiyan forecasts for AMSU-A_MOD20 (blue dotted line), AMSU-A_MOD90 (blue dot-dashed line) AMSU-A_GSI (red dotted line), ATMS_VIIRS (blue solid line), and ATMS_GSI (red solid line). An example of 72-hour track forecasts along with the observations isare also shown in the lower right panel.

Publications and Conference Reports

Han, Hyojin, Jun Li, Mitch Goldberg, Pei Wang, Jinlong Li, Zhenglong Li, B.-J. Sohn, and Juan Li, 2015: Microwave sounder cloud detection using a collocated high resolution imager and its impact on radiance assimilation in tropical cyclone forecasts, Journal of Geophysical Research – Atmosphere (under revision).

Han, Hyojin, Jun Li et al. 2015: Improving tropical cyclone forecasts by assimilating microwave sounder cloud-screened radiances and the GPM precipitation measurements, ITSC20, 28 October – 03 November 2015, Lake Geneva, Wisconsin, U.S.A.

23. Implementation of GCOM-W1 AMSR2 Snow Products

CIMSS Task Leader: Yong-Keun Lee

NOAA and other collaborators: Jeffrey R. Key and Cezar Kongoli (CICS)

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

Project Overview

Snow cover is one of the most dynamic hydrological variables on the Earth's surface and it plays a key role in the global energy and water budget. The ability to detect global snow cover and measure snow depth in nearly all weather conditions has been shown using satellite passive microwave measurements such as the Scanning Multi-channel Microwave Radiometer (SMMR), the Special Sensor Microwave Imager (SSM/I), and the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E). Unfortunately, AMSR-E on NASA's Aqua satellite effectively stopped functioning on October 4, 2011. 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. From an operational and functional perspective, it has replaced the AMSR-E instrument. 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 objective of this project is to assess the suitability of heritage snow algorithms, algorithm selection/ implementation with AMSR2 data.

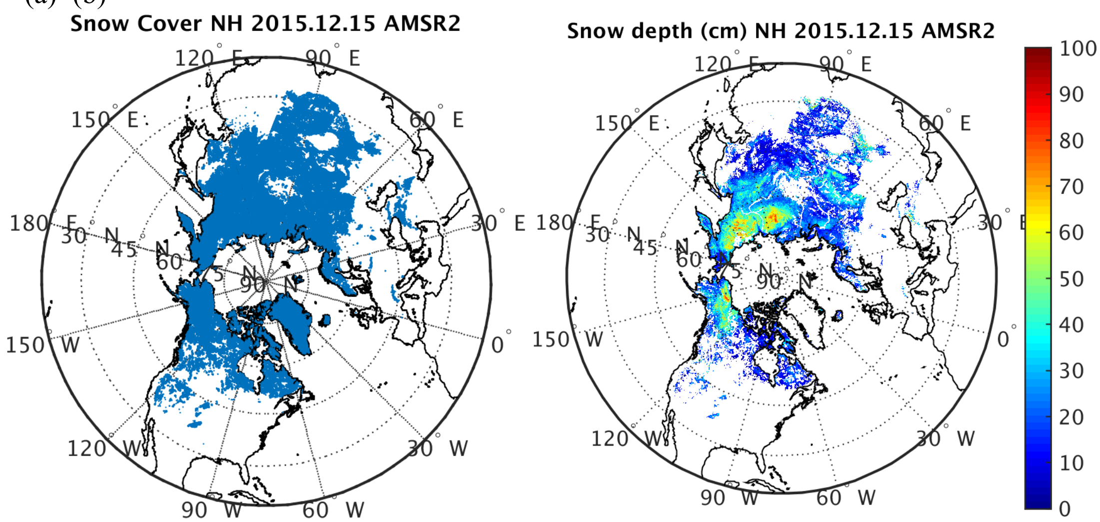
The objectives of this project include assessing the suitability of heritage snow algorithms, algorithm selection, implementation, testing and validation, and routine product generation with AMSR2 data. The selected heritage algorithms are being modified as necessary. The assessment of the algorithm performance as well as the development of the data processing and product generation system are being conducted using observations from AMSR-E onboard Aqua as a proxy for GCOM AMSR2.

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. 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 the routine generation of snow products through the application of the developed snow detection, snow depth, and snow equivalent algorithms to AMSR2 measurements and the delivery of the algorithms to NOAA for the operational use. Figure 83 gives a qualitative comparison of snow cover detection with Grody's algorithm (Grody, 1991; Grody and Basist, 1996), snow depth with the Kelly (2009) algorithm and the corresponding snow water equivalent. Snow depth and snow water equivalent are related through the snow density and climatological snow density data (Sturm et al., 1995; Brown and Mote, 2009) are used. Spatial patterns in the three products are similar.

(a) (b)



(c)

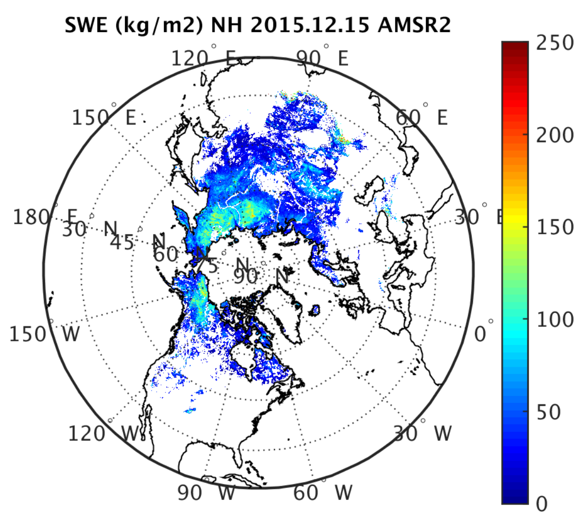


Figure 83. (a) Snow cover from Grody's algorithm, (b) Snow depth from AMSR2 (Kelly's algorithm), and (c) snow water equivalent on 15 December 2015. Three products using AMSR2 show similar spatial patterns and variability.

Publications and Conference Reports

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.

References

Brown, R. D. and P. W. Mote, (2009), The Response of Northern Hemisphere Snow Cover to a Changing Climate. *J. of 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.

Sturm, M, J. Holmgren, and G. E. Liston, (1995), A seasonal snow cover classification system for local to global applications, *J. of Climate*, 8, 1261-1283.

24. CIMSS Participation in VIIRS Cloud Products Using DNB the JPSS Risk Reduction Program for 2015

CIMSS Task Leader: Andi Walther
NOAA Collaborator: Andrew Heidinger

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

Project Overview

In this JPSS risk-reduction proposal the principal emphasis is on realizing the full potential of VIIRS through innovative research and algorithm development. The notional beneficiaries of this research are many-varied, and include all downstream developers of EDRs reliant on accurate nighttime cloud masking, the operational end-users of these VIIRS EDR products (e.g., forecasters), the climate research making use of VIIRS information, distillers of this information in connection with IGPCC, and ultimately policy makers.

This project aims to use moonlight visible reflectance derived from measurements by the VIIRS Day/Night Band to improve cloud property and cloud mask retrievals during nighttime. The new algorithms are being developed as a part of an existing cloud processing system: CLouds from AVHRR-eXtended (CLAVR-x).

Milestones with Summary of Accomplishments and Findings

Efforts in this period focused on writing *Algorithm Theoretical Basis Documents (ATBD), which is intended to describe physical and mathematical description of the Nighttime Lunar Cloud Optical and Microphysical Properties retrieval (NLCOMP).* One major part of the ATBD is validation and evaluation section, for which we processed long-term runs of NLCOMP.

After finishing the core retrieval developments we focused on development of meteorological applications, such as rain rate and icing threat. Figure 84 illustrates the consistency of rain rate product from NLCOMP to its daytime equivalent.

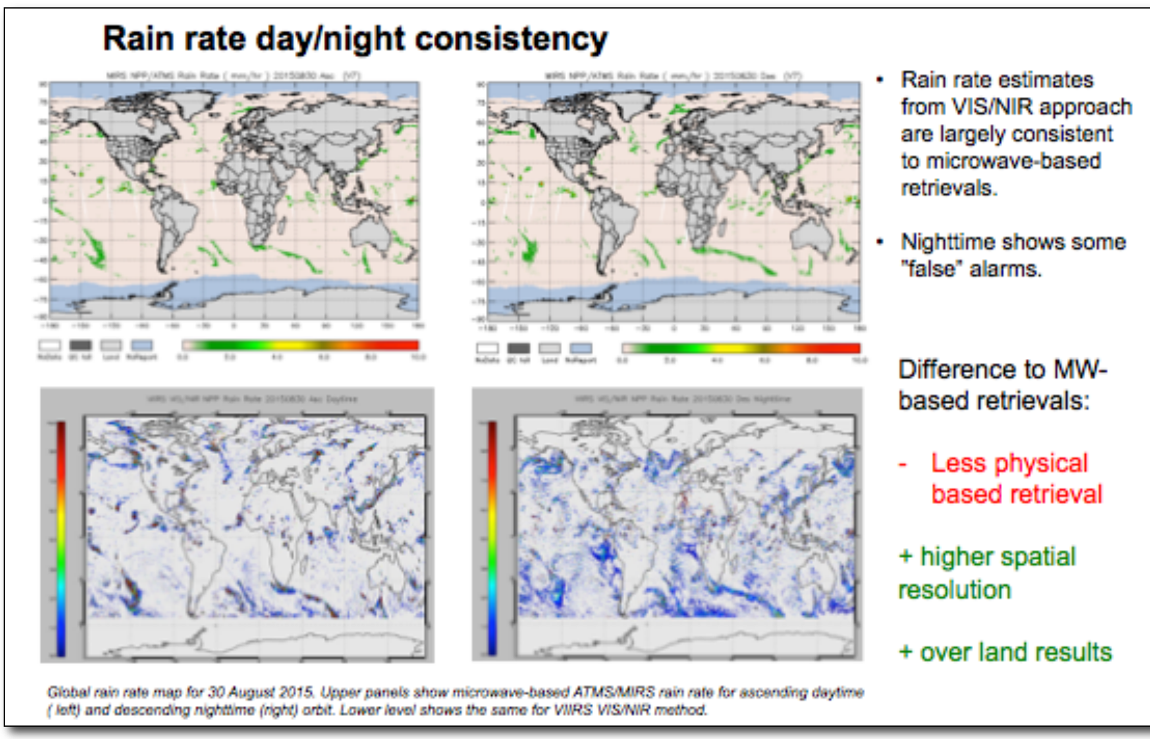


Figure 84. Part of awarded poster "Consistency of reflected moonlight based nighttime precipitation product with its daytime equivalent" at ITOVS conference in Lake Geneva, WI: Application for rain rate estimate algorithm from NLCOMP and daytime equivalent DCOMP.

Major milestones for this period were complement of NLCOMP retrieval development and adding application developments to existing processing system.

Publications and Conference Reports

- Andi Walther presented NLCOMP algorithm at the CSPP meeting in Darmstadt/ Germany in April 2015.
- Andrew Heidinger presented cloud mask improvements at the same conference.

- Andi Walther presented NLCOMP algorithm at EUMETSAT conference in Toulouse, at ITOVS conference in Lake Geneva, WI and at AGU Fall meeting in San Francisco Dec 2015.
- Andrew Heidinger presented cloud mask improvements at the same conference.
- Andi Walther presented new applications at TOVS conference at Lake Geneva, Wisconsin in October 2015.

25. Support CIMSS JPSS and AWIPS II OCONUS Satellite Liaison

CIMSS Task Leader: Jordan Gerth

NOAA Collaborators: Bill Ward and Eric Lau, National Weather Service Pacific Region Headquarters, and Carven Scott, National Weather Service Alaska Region Headquarters

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
- Education and Outreach

Project Overview

The scientist funded under this project is responsible for:
- Coordinating, facilitating, and participating in the development of satellite program data products and techniques into technical systems, such as the Advanced Weather Interactive Processing System (AWIPS) II;
- Communicating development statuses to NWS Pacific Region office staff and headquarters, and Geostationary Operational Environmental Satellite R-Series (GOES-R) and Joint Polar Satellite System (JPSS) management, staff, and liaisons;
- Traveling to Outside CONtiguous United States (OCONUS) for interactions with forecasters and Information Technology Officers (ITOs), and to CONUS locations for personal skill development and/or technical interchange with AWIPS II system developers;
- Leading office and program technical interchange meetings/forums and training where applicable;
- Facilitating scientific and operational initiatives seeking to optimize the current and future use of satellite data in NWS Pacific Region and NWS Alaska Region;
- Developing a portfolio of current JPSS science products that have value to operational meteorology in NWS Pacific Region and NWS Alaska Region, and demonstrating capabilities of those with the most potential;
- Providing technical expertise and scientific consultation for the NWS Operational Advisory Team (NOAT);

- Analyzing leading research and presenting initiative results through actively participating in scientific and professional conferences and workshops pertaining to satellite meteorology and operational meteorology;
- Maintaining essential knowledge and skills related to cutting-edge scientific tools, techniques, and advances in the meteorological field through relevant professional development opportunities; and
- Engaging with NWS Pacific Region and NWS Alaska Region Environmental and Scientific Services Divisions (ESSDs), as well as Meteorologists-In-Charge (MICs) and Science and Operations Officers (SOOs), to determine potential blended and/or decision support products.

Milestones with Summary of Accomplishments and Findings

The major milestones and related accomplishments between 1 April 2015 and 31 March 2016 are indicative of the value of this project. Specifically, the scientist:

- Monitored the status of JPSS science initiatives for their operational viability and made recommendations to Bill Ward for prospective visiting scientists of value to interact with NWS Pacific Region;
- Assisted fellow liaisons Carl Dierking and Eric Stevens in Alaska with proving ground activities related to integration of polar-orbiting satellite imagery and products into NWS Alaska Region operations;
- Envisioned a training course and visualization tool for Himawari to ready NWS meteorologists in Guam for the transition;
- Supported other scientists at CIMSS in making their scientific products ready for demonstration to operational meteorologists via visualization in AWIPS;
- Helped to devise and implement a strategy to process and deliver Himawari, and other future weather satellite, imagery to forecast offices in NWS Pacific Region, with Eric Lau;
- Produced a JPSS-specific training plan for NWS meteorologists, with Bill Ward;
- Developed content for the Advanced Baseline Imager (ABI) band fact sheets, with Tim Schmit, Bill Ward, Carven Scott, and Ken Johnson;
- Assisted with planning for L/X-band antennas in Puerto Rico and Guam; and
- Assisted with the planning and installation of a new L/X-band antenna at Ford Island in Pearl Harbor, Hawaii.

The scientist attended the following meetings during the award period:

- Community Satellite Processing Package Users' Group Meeting (Darmstadt, Germany)
- NOAA Satellite Conference (College Park, Maryland)
- Satellite User Readiness Meeting (Kansas City, Missouri)
- GOES-R/JPSS OCONUS R2O Interchange Meeting (Anchorage, Alaska)

In addition, the scientist made four trips to Honolulu, Hawaii, during the award period, with efforts pursuant to the aforementioned tasks.

Publications and Conference Reports

Why the OCONUS is ready for the new generation of environmental satellites
Talk, Joint JPSS/GOES-R Science Seminar (Remote)
June 29, 2015

Nowcasting Applications
Talk, JPSS Science Team Meeting (College Park, Maryland)
August 25, 2015

26. JPSS Ground Project Field Terminal Node Support 2015

CIMSS Task Leader: Liam Gumley
CIMSS Support Scientists: Scott Mindock, Ray Garcia, Graeme Martin, Kathy Strabala, Jess Braun
NOAA Collaborator: Mitch Goldberg

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

Project Overview
CIMSS/SSEC supports JPSS FTS by providing algorithm and software integration services to enable users to integrate the algorithms into their remote terminals 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.

On 29 September 2015, CSPP SDR v2.1.1 was released. This update is required for users to continue to process CrIS data after the transition to extended spectral resolution data. This update is distributed as a patch rather than a full software release, therefore users must first install SDR 2.1, then install the SDR 2.1.1 patch. In extended spectral resolution mode, extra data points are transmitted from the CrIS instrument. These points may be used by a future SDR algorithm version to reduce ringing artifacts that are visible in certain channels. While the SDR 2.1.1

software will not make use of the extra points, the 2.1.1 update is needed to continue generating a valid product. This software update is backward compatible, so that it can be installed prior to the transmission change. Users who have applied the CSPP SDR v2.1.1 patch should see no change in the output SDR product after the change to CrIS extended spectral resolution. The CSPP SDR V2.1.1 patch includes an updated ADL Leap Second file from 1 July 2015.

The CSPP team performed exhaustive quality control checks on the VIIRS, CrIS, and ATMS SDR products from the CSPP SDR package, to verify that they were in agreement with the same products from IDPS.

CIMSS/SSEC produced VIIRS imagery throughout the reporting period and provided it in real time to the National Weather Service for display in AWIPS.

CIMSS/SSEC continued to maintain and enhance the website for the CSPP software packages. CSPP registration statistics and download statistics via the website were collected throughout the reporting period.

CIMSS/SSEC continued to ingest 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 PEATE for this purpose.

CIMSS/SSEC provided prompt support to CSPP users throughout the reporting period, successfully resolving various installation and operational issues at DB sites around the world including NRL Monterey, NRL Stennis, EUMETSAT, FMI, and University of Alaska.

Publications and Conference Reports

"CSPP Polar Orbiting Satellite Software and Products" was presented at the CSPP/IMAPP Users Group meeting at EUMETSAT in Darmstadt Germany by Liam Gumley in April 2015.

"Community Satellite Processing Package (CSPP): Support for multiple satellites and sensors for real-time decisions" was presented at the American Meteorological Society Annual Meeting in New Orleans by Liam Gumley in January 2016.

27. NOAA Hurricane Forecast Improvement Program: Assimilation of GOES High-Resolution AMVs in HWRF

CIMSS Task Leader: Chris Velden
CIMSS Support Scientist: Will Lewis
NOAA Collaborator: Vijay Tallapragada (NCEP/EMC)

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

Project Overview

The Hurricane-WRF (HWRF) team at NCEP-EMC is interested in evaluating the impacts of assimilating high-resolution GOES-derived Atmospheric Motion Vectors (AMVs) in collaboration with the AMV development and applications team at CIMSS. The NOAA Hurricane Forecast Improvement Project (HFIP) Vortex-scale Data Assimilation strategic team and Satellite Data Assimilation tiger team support this effort as a near-term priority towards the development and improvement of the HWRF performance.

We have prepared high-resolution AMV datasets for selected TC cases and tested the assimilation methodologies in the HWRF system by assessing the impact on TC intensity and track forecasts. The AMV datasets have been examined through a set of experiments using the latest available data assimilation system (hybrid, with rapid cycling) supporting the HWRF model. Testing and evaluation was conducted in collaboration with EMC and HFIP guidance.

Milestones with Summary of Accomplishments and Findings

Milestone 1. GOES-13 AMV datasets were reprocessed, quality-controlled, and completed for 3 selected tropical cyclones: Sandy (2012), Edouard (2014) and Gonzalo (2014), using two different processing algorithms (‘Heritage’ and ‘GOES-R’).

Milestone 2. HWRF Data assimilation experiments were conducted for both processing methodologies, and also for varying levels of quality control. Further details were given in the previous report. The results are presented in the figures below for the 3 tropical cyclone events and compared to Control forecasts without the enhanced AMVs as well as the corresponding operational HWRF forecasts. Our findings indicate that the high-resolution AMVs have an overall modest positive impact on HWRF forecasts, but the impact magnitudes are 1) dependent on the availability of rapid-scan imagery used to produce the AMVs, 2) the degree of quality control employed in the assimilation, and 3) likely constrained by the degree to which spurious unbalanced states are allowed to enter the model analyses (an ongoing issue in atmospheric data assimilation).

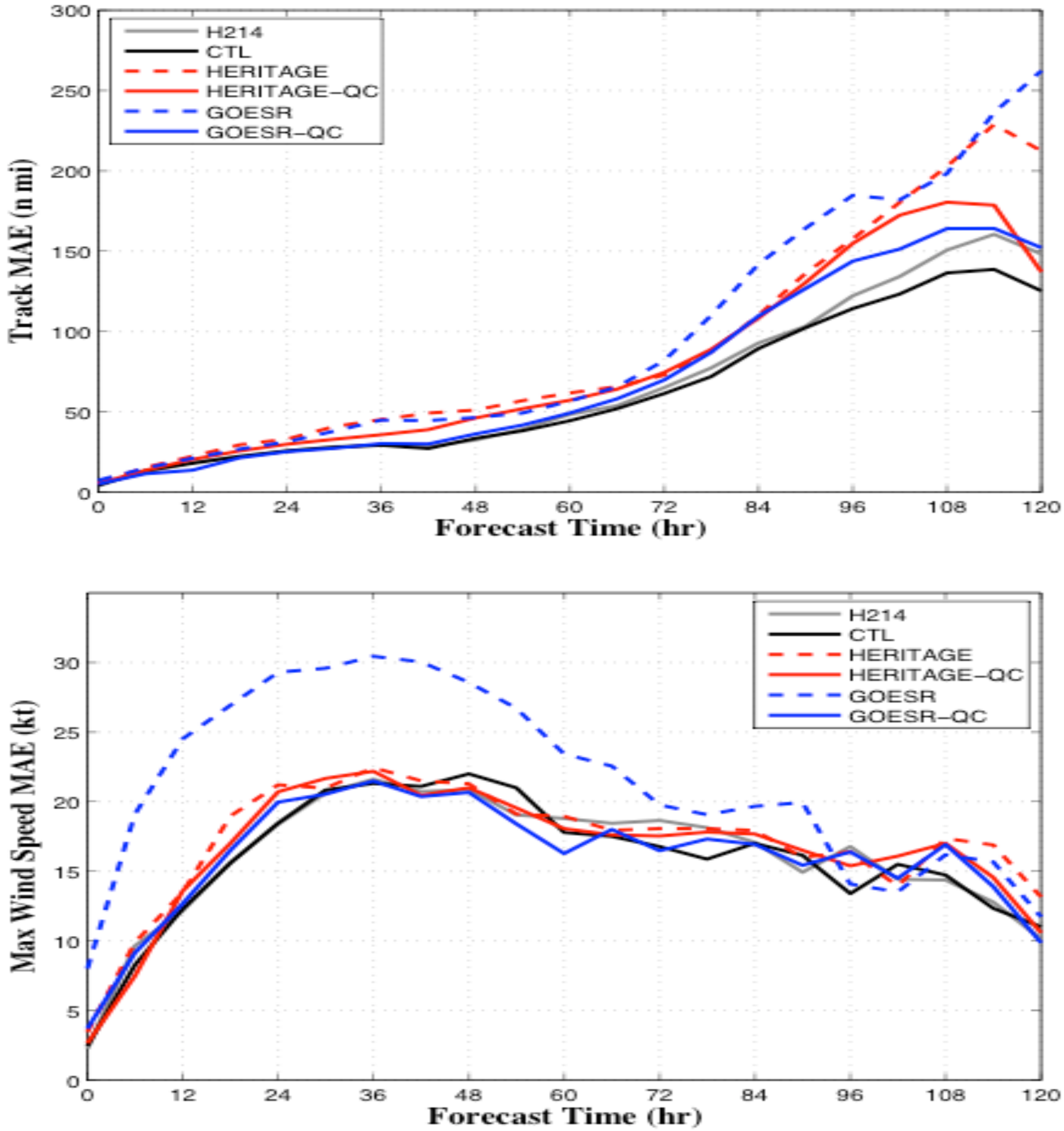


Figure 85. Results of HWRF forecast impact experiments for the combined 3 TC cases, where MAE is the Mean Absolute Error. CTL is our experiment Control run with only radiosondes assimilated. H214 is the operational HWRF run with full complement of data including reconnaissance aircraft dropsondes and radar wind data (but no AMVs in core region). 'Heritage' is the CTL plus AMVs assimilated and processed with the heritage algorithm. 'GOES-R' represents the runs with AMVs processed using the new GOES-R algorithm. QC refers to runs when the GSI quality control was enabled.

Publications and Conference Reports

Velden, C., W. Lewis, D. Stettner, W. Bresky, and J. Daniels, 2016: Assimilation of High-Resolution Satellite-Derived Atmospheric Motion Vectors: Impact on HWRF Forecasts of Tropical Cyclone track and Intensity. Manuscript in preparation.

28. Implementation of Advanced Data Assimilation Techniques and Performance of Forecast Impact Assessment Experiments

CIMSS Task Leader: James Jung
NOAA Collaborators: Mitch Goldberg, John Derber, Andrew Collard

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

Project Overview

The National Center for Environmental Prediction's (NCEP) Global Data Assimilation System/Global Forecast System (GDAS/GFS) has a cold bias in the stratosphere. The analysis is generally correct but the forecast has a cold drift with time. A portion of this problem has been traced back to the concentration of water vapor in the stratosphere. The GFS atmosphere is too wet in the stratosphere and the upper troposphere. As part of our previous work, a reduction in water vapor in the stratosphere has helped to reduce the cold drift. NCEP/EMC has requested that we help in developing techniques to reduce this problem.

Milestones with Summary of Accomplishments and Findings

We have recommended two procedures as a beginning to resolve this problem. The GFS atmosphere is too wet. To resolve this, we suggested a onetime initialization (reset) of the specific humidity to a climatological average. In order to maintain these lower concentrations of water vapor, we recommended decreasing the background error to allow only minimal changes to the field. Initial tests show promise and a more complete parallel test is being designed. A longer term solution will involve the use of more water vapor channels and the potential use of a physical and statistical constraint.

We also suggested putting a maximum allowable concentration of water vapor in the stratosphere. Several papers have been published on the correlation between water vapor and methane in the stratosphere. In short, $2[CH_4] + [H_2O] = 7$ ppmv. Several Numerical Weather Prediction Centers have incorporated similar relationships into their models including the Navy (McCormack et al. 2008) and the European Center for Medium Range Forecasting (Monge-Sanz et al. 2013). This would eliminate the wet bias in the stratosphere.

We also reviewed the ozone assimilation. There are several problems but the largest one seems to be the relaxation to climatology with time in the forecast model. The analysis of ozone seems reasonable and creates a minimal temperature drift. With time the temperature drift gets worse, as the ozone concentrations are relaxed to climatology. We recommended the ozone concentrations in the stratosphere be reviewed and be adjusted to the measured concentrations.

References

McCormack, J. P., K. W. Hoppel and D. E. Siskind 2008: Parameterization of middle atmospheric photochemistry for high-altitude NWP and data assimilation, *Atmos. Chem. Phys*., **8**, 7519-7532.

Monge-Sanz, B.M., M.P. Chipperfield, A. Untch, J.-J. Morcette, A. Rap and J. Simmons 2013: On the uses of a new linear scheme for stratospheric methane in global models: water source, transport tracer and radiative forcing, *Atmos. Chem. Phys*., **13**, 9641-9660.

29. Contributions from NSSL to the Observing System Simulation Experiment (OSSE) Testbed

CIMSS Task Leader: Jason Otkin
CIMSS Support Scientist: Rebecca Cintineo
NOAA Collaborator: Steve Koch

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

Project Overview

In collaboration with the National Severe Storms Laboratory and the Cooperative Institute for Mesoscale Meteorological Studies at the University of Oklahoma, Observing System Simulation Experiments (OSSEs) will be performed using convection allowing numerical weather prediction (NWP) models to assess the potential for satellite observations to improve the characterization of storms within model analyses and forecasts. Satellite data are available in many formats, including temperature and humidity retrievals from hyperspectral sounders, cloud property retrievals, and raw infrared observations. Assimilating these datasets into NWP models poses many challenges due to observation uncertainties and how these errors are correlated to model state variables. The OSSE framework used during this study provides a useful means to investigate their impact on NWP in a controlled manner.

Milestones with Summary of Accomplishments and Findings

A new OSSE study is currently being performed to evaluate the potential impact of assimilating clear and cloudy sky GOES-R ABI brightness temperatures and Doppler radar reflectivity and radial velocity observations at convection-resolving resolutions. Synthetic satellite and radar observations were created using output from a 2-km resolution truth simulation of a severe thunderstorm event that occurred across eastern Kansas and northern Missouri on 04 June 2005. Radar observations at all scan angles were generated for three radar locations (Wichita, Topeka, and Kansas City, KS), whereas satellite observations were generated for the entire model domain. The synthetic satellite and radar observations were subsequently assimilated at 5-minute intervals during a 2-hr assimilation period using the Weather Research and Forecasting (WRF) model and the Data Assimilation Research Testbed (DART) ensemble data assimilation system. Numerous assimilation experiments using different combinations of satellite and radar observations were performed using a 50-member ensemble with 4-km horizontal resolution and 52 vertical levels. We are currently examining the impact of various assimilation settings, such as the observation error and covariance localization radius, on the analysis and forecast results.

The impact of the satellite and radar observations on the simulated cloud and water vapor fields by the end of the 2-hr assimilation period is shown in Figure 86. The upper left panel shows the truth simulation, the upper right panel shows the control case without data assimilation, and the bottom two panels show the satellite and radar only assimilation cases. Clear and cloud sky ABI 6.19 μm (band 8) brightness temperatures were assimilated during the satellite assimilation case, whereas Doppler radar reflectivity and radial velocity observations were assimilated during the radar case. In the truth simulation, a line of deep convection extends across eastern Kansas and northern Missouri. During the Control case, the southern end of this line is located too far to the east, whereas the northern end is located too far to the west. When the satellite observations were assimilated, the spatial extent of the thunderstorms was much more accurately depicted. This includes the localized areas of very cold brightness temperatures over northeastern Kansas and northeastern Missouri, and the cluster of small convective cells across south-central Kansas. Finally, when the radar observations were assimilated, the thunderstorms were more accurately depicted across northeastern Kansas; however, the thunderstorms were poorly depicted over northern Missouri and the small convective cells are missing over southeastern Kansas. The main reason for the poor performance over northern Missouri is that this region is located within a small gap in the Doppler radar observing network, especially in the lower troposphere, which demonstrates that satellite observations have the ability to fill in observing gaps even in data rich locations such as the central United States. Extensive analysis is currently underway to better understand the impact of the satellite and radar observations on the assimilation results.

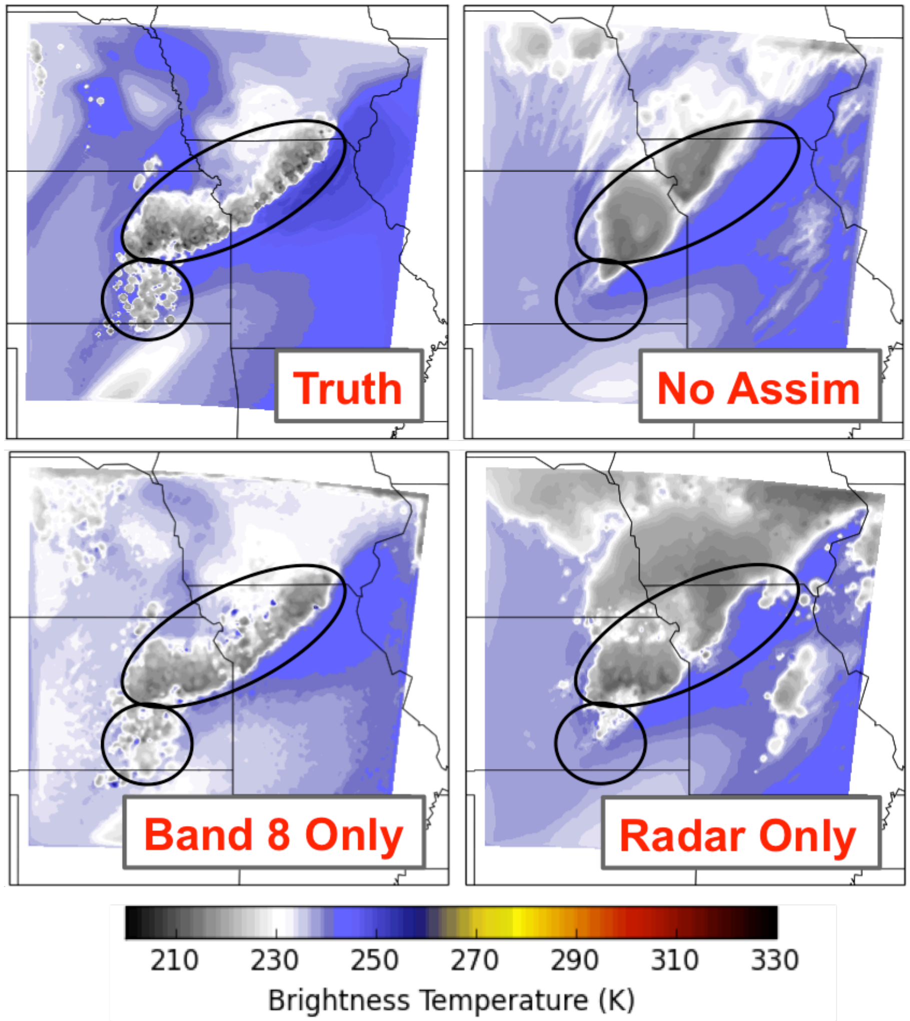


Figure 86. Simulated 6.19 µm brightness temperatures at the end of the 2-hr assimilation period from the (a) truth simulation, (b) control case without data assimilation, and from the (c) satellite-only and (d) radar-only assimilation cases.

Publications and Conference Reports

Cintineo, R. M., **J. A. Otkin**, T. A. Jones, S. Koch, L. J. Wicker, and D. J. Stensrud, 2015: Assimilation of GOES-R ABI satellite and WSR-88D radar observations during a convection-resolving Observing System Simulation Experiment. *19th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface*, Phoenix, AZ.

Cintineo, R., **J. A. Otkin**, T. Jones, S. Koch, L. Wicker, and D. Stensrud, 2014: Assimilation of satellite and radar observations during a convection-resolving Observing System Simulation Experiment. *27th Conference on Severe Local Storms*, Madison, WI.

Cintineo, R., **J. A. Otkin**, M. Xue, and F. Kong, 2014: Using synthetic satellite observations to evaluate the performance of PBL and cloud microphysical parameterization schemes. *World Weather Open Science Conference*, Montreal, Canada.

Cintineo, R., **J. A. Otkin**, T. Jones, S. Koch, L. Wicker, and D. Stensrud, 2014: Assimilation of satellite and radar observations during a convection-resolving Observing System Simulation Experiment. *6th EnKF Workshop*, Buffalo, NY.

30. CIMSS Cal/Val Activities in Support of the Calibration Work Group

CIMSS Task Leader: Mathew Gunshor
CIMSS Support Scientist: Jim Nelson
NOAA Collaborator: Tim Schmit

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

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, would be 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. CIMSS also proposed to continue to provide assistance to CWG analyzing JMA's AHI calibration and navigation.

Milestones with Summary of Accomplishments and Findings

Proposed activities for this project year were:

1. Assist CWG in preparation for ABI PLT:
   a. Consult on the development of McIDAS for ABI applications and facilitate its utilities at CIMSS and STAR.
   b. Analyze JMA's AHI data and report on
      i. AHI performance and, by analogy, what can be expected for ABI.
      ii. Based on AHI experience, what to watch out for during ABI PLT.
2. Assist CWG in analysis of calibration and navigation issues:
   a. Support GOES-R ABI INR efforts.
   b. Support GOES-R ABI calibration efforts.
   c. Support analysis of the impacts of L1b issues on L2 products
3. Communicate with CWG:
   a. Report via PSE Weekly when appropriate;
   b. Regularly attend CWG meetings via phone/internet;
   c. Report on findings when appropriate, e.g., issues addressed by CIMSS that affect current GOES radiance quality.

CIMSS has had a representative at most Calibration Working Group (CWG) monthly meetings (teleconferences). There have been various presentations from CIMSS periodically at these meetings. Topics have covered ABI, AHI, and current GOES, all with the focus on preparing for GOES-R. When appropriate, information was submitted to the CWG weekly status report to relay information about the team's activities.

This year there were new simulated ABI files produced by the official ground system software that were available for testing. This allowed for comparisons between actual file contents and expectations based on documentation. There were files available from multiple tests, including ones dubbed the Final Product Set (FPS), the Data Operations Exercise (DOE), and Ground Readiness Exercise (GRE) tests. Issues that were of interest to the CWG included discrepancies in the conversion between radiance and either reflectance factor or brightness temperature, the radiance ranges of the L1b data, and the brightness temperature ranges for the L2 products. These tests have allowed the team to update validation tools and better prepare for the GOES-R post-launch test period to provide timely information on data status.

Analysis of these files has revealed Program plans to limit the output L2 imagery files in both reflectance factor and brightness temperature to ranges that do not make use of the entire range of radiance data. In order to help highlight why this is a bad idea, CIMSS showed some AHI data with reflectance factors (or albedos) that exceeded the ABI maximum value of 1 (or 100%). Figure 87 shows an AHI visible image with albedos that exceed 100% (maximum in the image is 119%) enhanced such that the detail in the clouds can be seen. If only a maximum value of 100% were allowed, the details in the clouds in that image are lost (Figure 88).

In preparation for the ABI Post Launch Test (PLT), the McIDAS ADDE server was tested for accuracy in converting radiance to brightness temperature. Also, AHI data and performance was analyzed. The impacts of L1b data issues on L2 products were discussed as well.

Other accomplishments reported to CWG, either via Weekly Report or meetings:

- Analysis of AHI 2km vs 1km data which revealed a shift in navigation for 2km files.
- Testing of the McIDAS AHI and ABI ADDE servers.
- Reports to the CWG on ABI FPS (Final Product Set) L1b radiance files analyses where inconsistencies in the conversion from radiance to reflectance factor or brightness temperature were reported.
- Calculation of min and max brightness temperatures for ABI based on valid radiance ranges (which differs from min/max values in PUG).
- Analysis of 3.9um band rollover issue on current GOES.

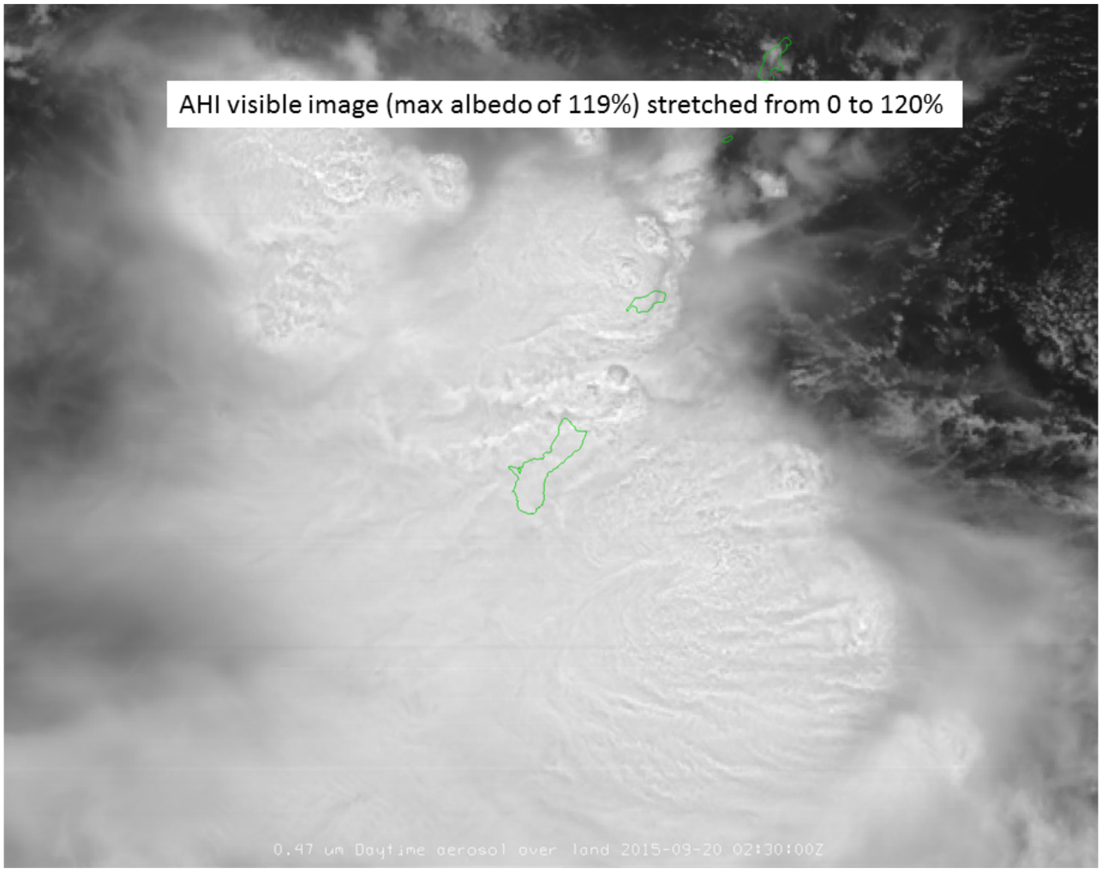


Figure 87. AHI Visible image from September 20, 2015 at 02:30 UTC. Parts of the image exceed 100% albedo because of light reflected off of a bright surface (clouds). Image is enhanced so that the details in the clouds can still be seen, even though they exceed 100% albedo.

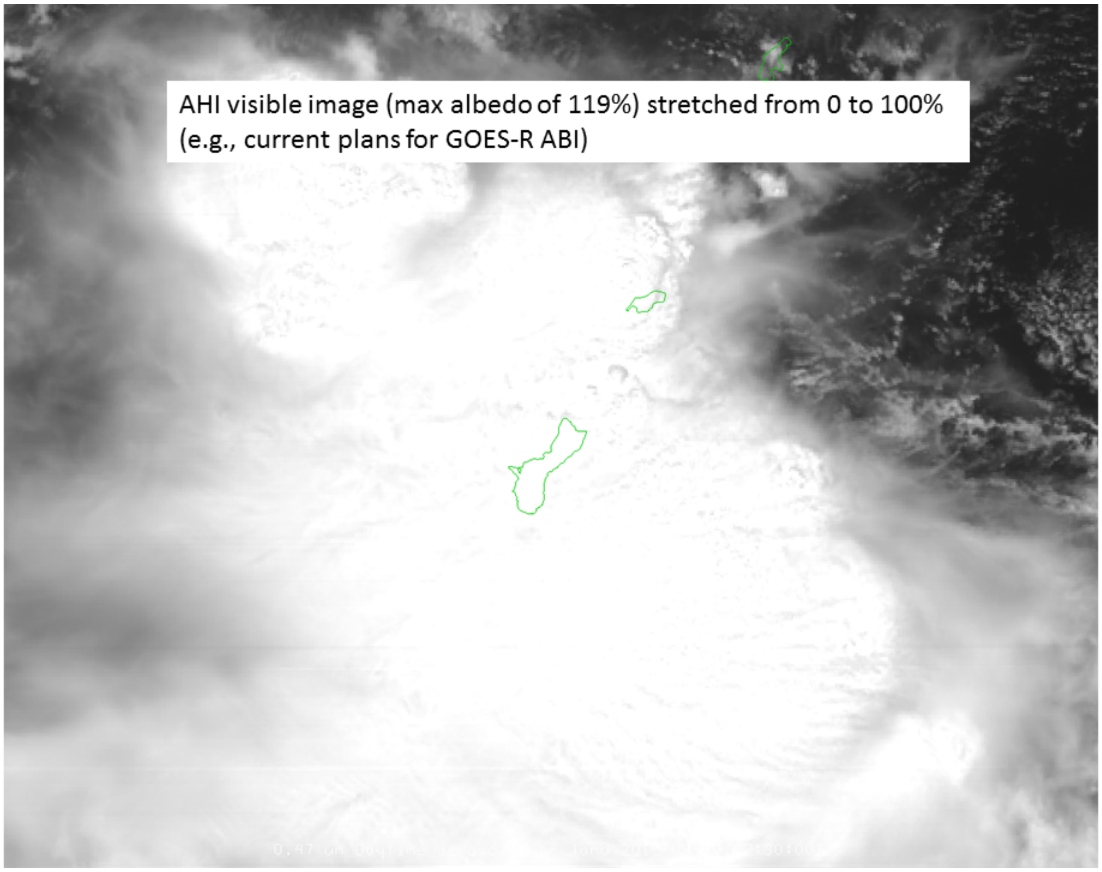


Figure 88. AHI Visible image from September 20, 2015 at 02:30 UTC, same as Figure 87. Parts of the image exceed 100% albedo because of light reflected off of a bright surface (clouds), but the enhancement employed stops at 100% so that the effects of limiting the range can be seen. Note how "washed out" the clouds appear.

31. Consistent Cloud Thematic Climate Data Records from Historical, Current, and Future +NOAA POES Sensors

CIMSS Task Leader: Michael Foster
CIMSS Support Scientist: Michael Hiley
NOAA Collaborator: Andrew Heidinger

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

Project Overview

This project supports research-to-operations for the NOAA's National Climatic Data Center's (NCDC's) Climate Data Record (CDR) program. The goal for this project is to develop consistent sets of cloud properties based on the Advanced Very High Resolution Radiometer (AVHRR) and the High Resolution Infrared Radiometer Sounder (HIRS). These sensors are flown onboard the NOAA Polar Orbiter Environmental Satellite (POES) series and European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) MetOp polar orbiter satellite series. While ongoing efforts with each sensor are providing valuable decadal records of cloud parameters, further improvements can be obtained by merging the products from the two sensors. The primary goal is to address historical shortcomings in AVHRR spectral information, specifically in those areas where the AVHRR does not produce sufficient radiometric contrast between clouds and surface. Two examples where HIRS will supplement the AVHRR record are in polar regions and in the detection/placement of semitransparent ice clouds.

Milestones with Summary of Accomplishments and Findings

Successful completion of the tasks outlined herein will result in generation of complete 0.1^{o} equal-angle global gridded archive that will provide consistent global cloud products and their associated errors from merged PATMOS–x and HIRS products. The major tasks can be described as follows:

1. Collocation of HIRS and AVHRR measurements and products;
2. Modification of the clavr-x processing system to process HIRS data;
3. Negotiation of the differing footprint and measurement spacing of the AVHRR and HIRS sensors;
4. Integration of the HIRS information into the AVHRR-based cloud detection and height algorithms; and
5. Generation of a full level2b merged AVHRR/HIRS record spanning 1979 – present.

Tasks 1 and 2 were completed and reported upon in previous periods of performance. During this period of performance progress has been made in each of these tasks.

Task 3 (complete): A HIRS mask has been created that shows where HIRS observations are located on the level2b grid as well as the line and element indices for the native HIRS product; this was necessary to interpolate HIRS FOVs to the AVHRR resolution grid. The interpolation scheme chosen minimizes 11-micron brightness temperature differences between HIRS and AVHRR at the AVHRR-pixel level by comparing all adjacent HIRS FOVs. We find this method is a significant improvement on a simple nearest-neighbor scheme (See Figure 89).

Task 4 (complete): Several years of the merged AVHRR/HIRS PATMOS-x record have been processed, using HIRS data to inform the cloud detection and height algorithms.

Task 5 (not yet complete): We are in the process of analyzing the merged AVHRR/HIRS PATMOS-x record from Task 4 with the goal of characterizing the results and identifying shortcomings to be addressed. We expect this to be an iterative process whereas the end results is a consistent record spanning 1979 – present.

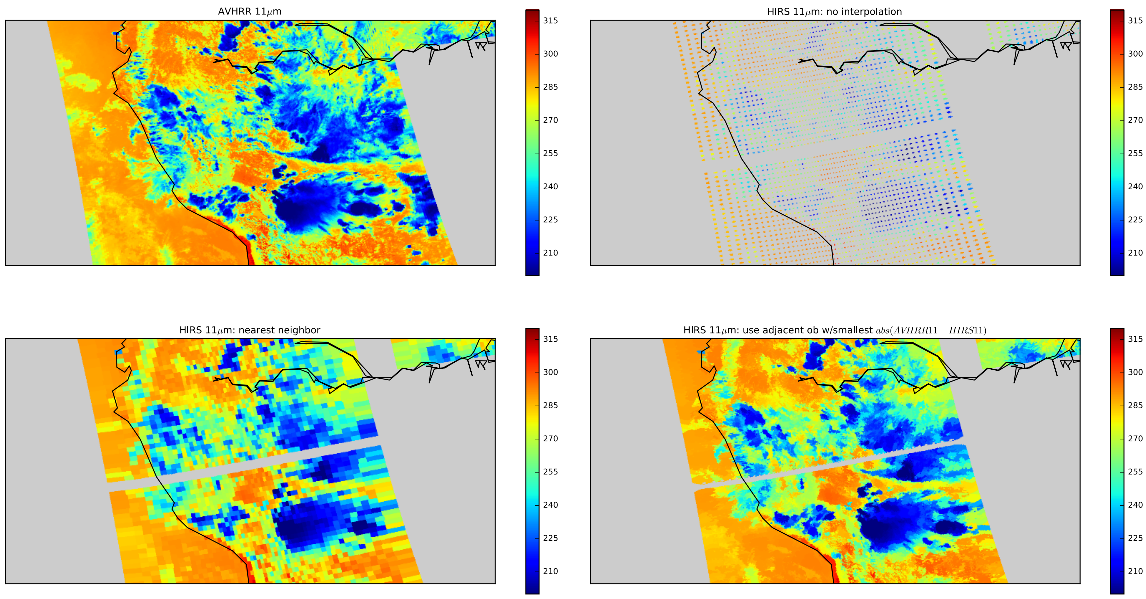


Figure 89. (Top left) – AVHRR measurement coverage; (Top Right) – HIRS measurement coverage for the same area with no interpolation scheme applied; (Bottom Left) – HIRS coverage with a nearest neighbor interpolation scheme applied; (Bottom Right) – HIRS coverage with an interpolation scheme that minimizes the AVHRR/HIRS 11-micron brightness temperature difference.

Publications and Conference Reports

Foster, M. J., A. K. Heidinger, M. Hiley, S. Wanzong, A. Walther and D. Botambekov, 2016: PATMOS-x Cloud Climate Record Trend Sensitivity to Reanalysis Products. *Remote Sensing – Submitted.*

Heidinger, A. K., M. J. Foster, D. Botambekov, M. Hiley, Y. Li and A. Walther, 2016: Using the NASA EOS A-Train to Probe the Performance of the NOAA PATMOS-x Cloud Fraction CDR. *Remote Sensing - Submitted* .

"Characterizing Long-Term Stability in the PATMOS-x Record," EUMETSAT conference, Toulouse, France, September, 2015.

References

Heidinger, A. K., M. J Foster, A. Walther and X. Zhao, 2013: The Pathfinder Atmospheres Extended (PATMOS-x) AVHRR Climate Data Set. *"]. Bull. Amer. Meteor. Soc*, doi: http://dx.doi.org/10.1175/BAMS-D-12-00246.1

32. Support for the NOAA Cloud Climate Data Records

CIMSS Task Leader: Michael Foster
CIMSS Support Scientist: Michael Hiley
NOAA Collaborator: Andrew Heidinger

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

Project Overview

The main goal of this project is to support the NOAA's National Climatic Data Center's (NCDC's) CDR program. Specifically, the Pathfinder Atmospheres – Extended (PATMOS-x) CDR, which is composed of both the AVHRR Reflectance – PATMOS-x Fundamental CDR (FCDR) and the AVHRR Cloud Properties – PATMOS-x Thematic CDR (TCDR) along with supporting documentation and source code. The AVHRR Reflectance – PATMOS-x FCDR was initially delivered in 2010, while this was the first delivery of the AVHRR Cloud Properties – PATMOS-x TCDR. In addition the FCDR was expanded from the AVHRR visible reflectance channels to include infrared brightness temperature channels.

Milestones with Summary of Accomplishments and Findings

During previous reporting periods tasks were primarily focused on bulk delivery of the PATMOS-x CDRs, along with accompanying code and documentation, and automation of the near real-time update process. These deliveries are now complete. During this reporting period the primary task was performing a calibration procedure using the methods described in Heidinger et al. (2010). After calibration a re-delivery of CDR files most affected by the calibration occurred. These files are considered to be in a stable calibration state and therefore had the 'preliminary' designation removed from the name. The calibration method involves stable earth targets, AVHRR-to-AVHRR SNOs, and AVHRR-to-MODIS SNOs. The calibration process for this reporting period was particularly significant as it was the first time the MODIS Collection 6 products were used in lieu of Collection 5. This caused some noticeable improvements in calibration, particularly for the most recent two or three years (See Figure 90).

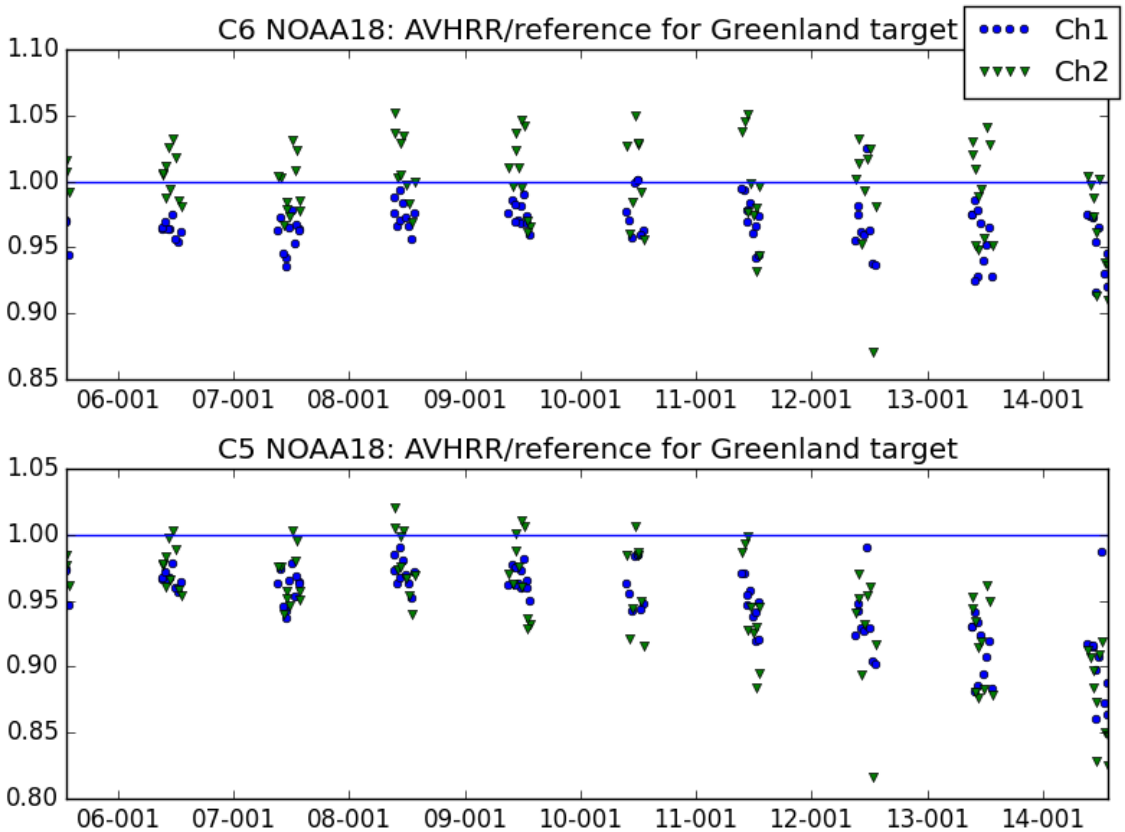


Figure 90. Plot showing coincident and collocated ratios of Channel 1 (blue) and Channel 2 (green) for AVHRR/reference, where for the top panel the reference is AQUA/MODIS Collection 6 while for the bottom channel the reference is AQUA/MODIS Collection 5. The AVHRR measurements are from NOAA-18.

Publications and Conference Reports

Foster, M. J., A. K. Heidinger, M. Hiley, S. Wanzong, A. Walther and D. Botambekov, 2016: PATMOS-x Cloud Climate Record Trend Sensitivity to Reanalysis Products. *Remote Sensing – Submitted.*

Heidinger, A. K., M. J. Foster, D. Botambekov, M. Hiley, Y. Li and A. Walther, 2016: Using the NASA EOS A-Train to Probe the Performance of the NOAA PATMOS-x Cloud Fraction CDR. *Remote Sensing – Submitted.*

"Characterizing Long-Term Stability in the PATMOS-x Record," EUMETSAT conference, Toulouse, France, September, 2015.

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Heidinger, A.K., Straka III, W.C., Molling, C.C., Sullivan, J.T. and Wu, X., 2010, Deriving an inter-sensor consistent calibration for the AVHRR solar reflectance data record. *International Journal of Remote Sensing.*

33. CIMSS Support for Aura Chemical Reanalysis in Support of Air Quality Applications (NASA)

CIMSS Task Leader: Allen Lenzen
CIMSS Support Scientist: Monika Harkey
NOAA Collaborator: R. Bradley Pierce (NOAA/NESDIS)

NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation
- Resilient Coastal Communities and Economies

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

Project Overview

We will provide the air quality community with a multi-year global chemical and aerosol reanalysis using NASA Aura and A-Train measurements. We will also conduct regional chemical data assimilation experiments to quantify the influences of changes in NOx emissions on US air quality during the Aura period.

Milestones with Summary of Accomplishments and Findings

- Verified implementation of the OMI observation operator in GSI.
- Tested using the full MLS profile (down to 215mb) in GSI.
- We have ported and tested Version 5.1 of the Community Multi-scale Air Quality (CMAQ) modeling system from the Community Modeling and Analysis System (CMAS) website (https://www.cmascenter.org/cmaq/) on our local computing cluster and are preparing to conduct 2011 regional OMI NO2 data assimilation studies.

Activities during this reporting period focused on data denial studies using the NOAA National Centers for Environmental Prediction (NCEP) Gridpoint Statistical Interpolation (GSI) analysis scheme (Kleist, et al., 2009) within the Real-time Air Quality Modeling System (RAQMS, Pierce, et al., 2007) to optimize assimilation of ozone using measurements from the Aura Microwave Limb Sounder (MLS) and Ozone Monitoring Instrument (OMI). We are using the publically available GSI code from the Developmental Testbed Center (DTC , http://www.dtcenter.org/com-GSI/users/index.php). Status of each of these tasks is summarized below.

Aura MLS/OMI Ozone Assimilation

During this reporting period we conducted a number of data denial experiments using MLS stratospheric ozone profiles and OMI cloud cleared total column ozone retrievals within the RAQMS/GSI analysis system. The MLS experiments were used to test assimilation of the full MLS profile (down to 215mb) and optimize the use of the MLS retrieval errors. Additional experiments were conducted to verify the implementation of the OMI observation operator, which accounts for the vertical profile of the OMI sensitivity to ozone concentrations and the OMI apriori profile, within the RAQMS/GSI analysis system. Figure 91 shows the March-June

2010 mean Tropospheric Ozone Column (TOC) from the Aura Reanalysis including MLS and OMI ozone retrievals. Elevated TOC extends from Southeast Asia out over the central Pacific and wraps around the subtropical high pressure system off the western coast of the US. High TCO also extends from the Eastern US across the Atlantic to Europe.

NOAA CalNex ozonesonde measurements during May-June 2010 provide an opportunity to assess the impact of MLS and OMI O3 assimilation on ozone within the Aura Reanalysis along the California coast (Figure 92). These comparisons show that the Aura Reanalysis has very low (<10%) mean biases with respect to ozonesonde measurements and is able to capture the majority (80%) of the observed variance, which is largest between 200-300mb. These data denial studies demonstrate that the RAQMS/GSI Aura Reanalysis is suitable for use in quantifying the role of intercontinental transport in determining background ozone concentration and can be used as lateral boundary conditions for regional air quality assessment modeling.

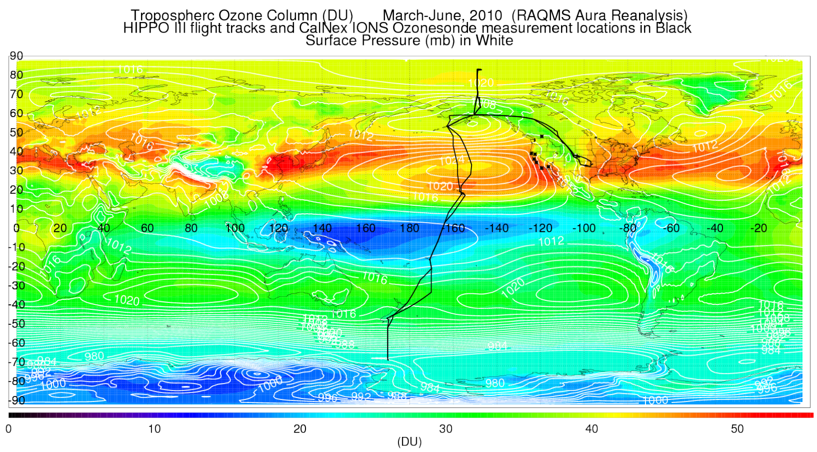


Figure 91. March-June 2010 Tropospheric Ozone Column (DU) from the RAQMS/GSI Aura Reanalysis. White contours show mean sea level pressure. NSF HIPPO III flight tracks and locations of the CalNex IONS ozone sonde measurements are shown in black.

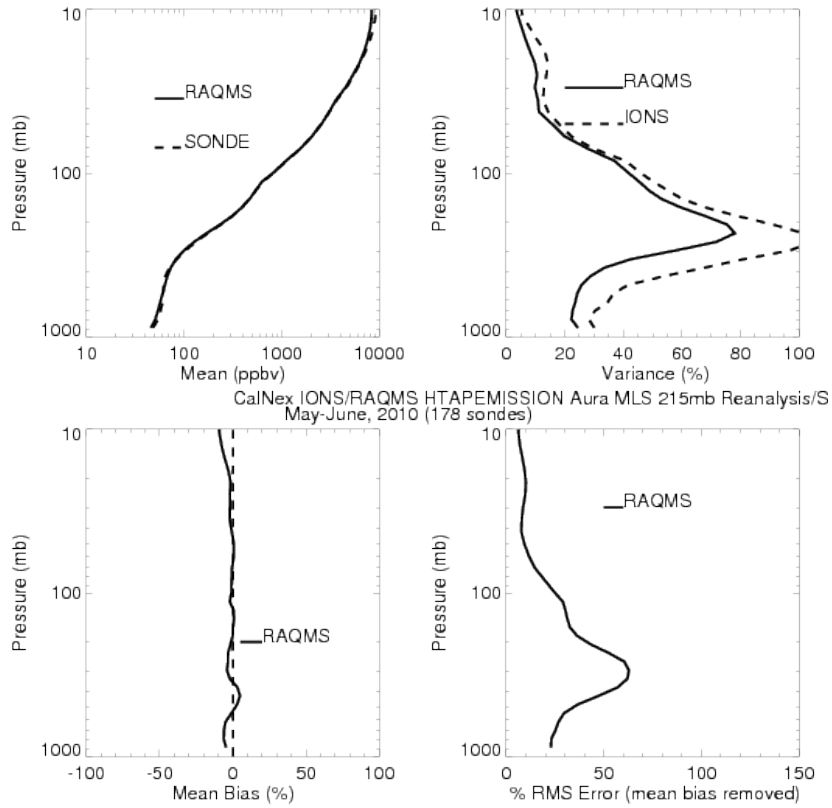


Figure 92. Comparison between RAQMS MLS/OMI Aura Reanlysis (solid) and CalNex ozonesonde measuremenst (dashed) during May-June 2010. Upper panels show mean (left) and percent variance (right). Lower panels show mean percent bias (left) and percent RMS error.

Publications and Conference Reports

"Understanding Background Ozone over the Continental US: A Global Ozone Assimilation Perspective", by Brad Pierce, Todd Schaack, Allen Lenzen, Georg Grell, Steve Peckham, Emma Yates, Laura Iraci, Gail Tonnesen, Patrick Reddy, Dan Jaffe, Pao Baylon, Thierry Leblanc, Tom Mcgee, John Sullivan, Second Annual Tropospheric Ozone Lidar Network (TOLNet) Working Group Meeting, June 16-18, 2015 Boulder, CO

"Aura Chemical Reanalysis in support Air Quality Applications" by Brad Pierce (NOAA/NESDIS), presented by Allen Lenzen (UW-Madison, SSEC) at the 2015 NASA Health and Air Quality Applications Program Review, September 16-17, 2015, Park City, UT

References

Kleist, D. T., et al., (2009) Introduction of the GSI into the NCEP Global Data Assimilation System. Wea. Forecasting, 24, 1691–1705. doi:http://dx.doi.org/10.1175/2009WAF2222201.1

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.

34. CIMSS Participation in SHyMet for 2015

CIMSS Task Leader: Steve Ackerman

CIMSS Support Scientists: Scott Lindstrom, Scott Bachmeier
NOAA Collaborators: Tim Schmit, Tony Mostek, Brian Motta

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

Project Overview
CIMSS will further develop the Satellite Hydrology and Meteorology (SHyMet) training course through close collaboration with experts at the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University, Colorado. 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.

Milestones with Summary of Accomplishments and Findings
CIMSS Scientists have continued working with CIRA scientists in preliminary planning for SHyMet Courses on GOES-R, Aviation Weather and Winter Weather. In addition, the recent change in the Department of Commerce Learning Management System Vendor required a re-tooling (to SCORM files from Quizmaker) of all SHyMet quizzes. This was accomplished in 2015. CIMSS scientists also added a NOAA/CIMSS ProbSevere Product module to the SHyMet Severe Course.

Data for case studies/training modules continues to be placed on CIMSS Satellite Blog (http://cimss.ssec.wisc.edu/goes/blog); entries include data from MODIS and Suomi NPP VIIRS that can serve as a proxy for GOES-R and JPSS. See, for example, http://cimss.ssec.wisc.edu/goes/blog/archives/15086 for Winter Weather and http://cimss.ssec.wisc.edu/goes/blog/archives/14795 or http://cimss.ssec.wisc.edu/goes/blog/archives/20850 for Aviation training. 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.

SHyMet has also leveraged AWIPS capabilities that have been further refined at CIMSS. A stable AWIPS platform at CIMSS allows for manipulation of CIMSS-produced datasets, especially GOES-R Products, into formats that are compatible with AWIPS. This allows quick development of training modules using data as it appears before the forecaster in the National Weather Service Forecast Office.

Publications and Conference Reports
Lindstrom, S. S. and A. S. Bachmeier, 2016: Most Popular Blog posts of 2015 from CIMSS. Oral Presentation at 25th Syposium on Education, American Meteorological Society, New Orleans, LA, 10-14 January 2016.

Lindstrom, S. S., 2015: Fog and Low Stratus Training Resources: Blogs, Videos and Facts sheets (and how they complement each other), NOAA Satellite Proving Ground/User Readiness Meeting, Kansas City, KS, 15-19 June 2015. (Invited)

Lindstrom, S. S. and A. S. Bachmier, 2015: The Use of Blogs, Twitter and YouTube for outreach at CIMSS. Oral Presentation at 24th Symposium on Education, American Meteorological Society, Phoenix, AZ, 4-8 January 2015.

Lindstrom, S. S. and A. S. Bachmeier, 2014: Using a blog to tell short, compelling stories based on satellite observations. 27th Conference on Severe Local Storms. American Meteorological Society, Madison, WI, 3-7 November 2014. (Invited)

35. CIMSS Collaboration with the NWS Training Center

CIMSS Task Leader: Chad Gravelle
CIMSS Support Scientist: Wayne Feltz
NOAA Collaborator: Tim Schmit

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

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:

- Manuscript accepted to the Bulletin of the American Meteorological Society titled "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".
- Operations Proving Ground evaluation on operational applications of high-temporal imagery for the GOES-R era was 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.

Central Michigan University Earth and Atmospheric Sciences Departmental Seminar. Mount Pleasant, MI. *Capabilities of The Next-Generation Geostationary Environmental Satellite System for Operational Meteorology*.17 April 2015.

2015 NOAA Satellite Conference. Greenbelt, MD. *Training Within the Satellite Proving Ground: The Satellite Liaison Perspective*. 30 April 2015.

36. CIMSS Collaboration with the Aviation Weather Center

CIMSS Task Leader: Wayne Feltz
CIMSS Support Scientist: Amanda Terborg
NOAA Collaborator: Jeff Key

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

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.

Milestones with 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;
- Serve as "implementation expert" for selected planned GOES-R 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;
- 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.

Appendix 1: List of Awards to Staff Members

2015

Bob Aune, Brad Pierce: STAR Recognition for 25 Years of Government Service
Fred Best, Bob Holz, Bob Knuteson, Hank Revercomb, Bill Smith, Dave Tobin: NASA Langley 2015 H. J. E. Reid Award
Ankur Desai: AMS Clarence Leroy Meisinger Award
Ankur Desai: AMS Award for Early Career Achievement
Anne Sophie Daloz: WARF Discovery Challenge Research Symposium Award
Jessica Gartzke: Reid Bryson Award Undergraduate Scholarship
Jessica Gartzke: ITSC Silver Award, Poster Presentation
Sarah Griffin, Derrick Herndon, John Sears, Chris Velden: NASA Group Achievement Award
Sarah Griffin, Derrick Herndon, Tim Olander, John Sears, Dave Stettner, Chris Velden, Steve Wanzong, and Tony Wimmers: AMS Special Award for CIMSS Tropical Cyclones website
Allen Huang, James P Nelson III, Tom Rink, Christopher Schmidt, Anthony Schreiner, Kathleen Strabala, and the Data Center: NOAA-CIMSS Collaboration Award: "For outstanding critical support that extended the beneficial life of an aging geostationary weather satellites, greatly improving coverage over South America"
Jim Kossin: Department of Commerce Bronze Medal Award: "For the development and transfer to operations of novel hurricane forecast techniques for eyewall replacement cycles"
Mark Kulie: NASA Group Achievement Award
Mark Kulie: NASA RHG Exceptional Achievement Awards for Science Teams
Jun Li: UW-Madison Chancellor's Award for Excellence in Research as independent investigator
Margaret Mooney: AMS Distinguished Educator Recognition Award for Outstanding Service to Precollege Education
Mike Pavolonis: AMS David Johnson Award
Brad Pierce, Andy Heidinger, Jason Otkin, Todd Schaack: STAR Award for Best Paper
Jacola Roman: ITSC Gold Award, Oral Presentation
Tim Schmit: Department of Commerce Gold Medal Award: For "orchestrating the use of retired geostationary weather satellites for improved coverage of South America. These unique efforts included international agreements, satellite processing research and updates, international training and satellite operations. They took what would have been retired satellites and gained an additional six total satellite years of operations from Geostationary Operational Environmental Satellite (GOES)-10 and then GOES-12 imager and sounders for international and domestic uses"
Christopher Rozoff: NOAA-CIMSS Collaboration Award: "For novel hurricane forecast techniques for eyewall replacement cycles"
Walter Sessions: NASA Group Achievement Award for the SEAC4RS mission (Biomass Forecasting Team)
Chris Velden: AMS STAC Committee on Satellite Meteorology award for outstanding scientific contributions
Pei Wang: AMS Best Oral Presentation
Andi Walther: ITSC Bronze Award, Poster Presentation

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 2013-2015. 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

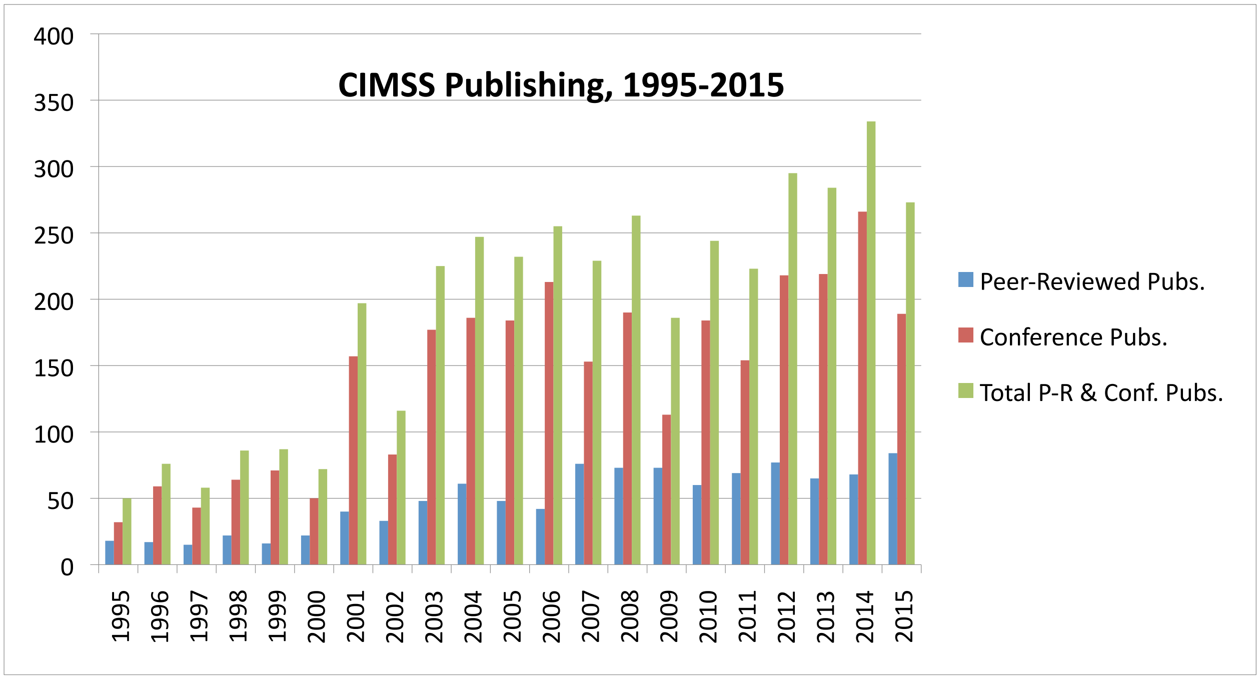
Table 1. Peer Reviewed and Non Peer Reviewed journal articles having CIMSS, ASPB, NOAA or Other lead authors, 2013-2015.

	Inst Lead			ASPB Lead			NOAA Lead			Other Lead		
	2013	**2014**	**2015**	**2013**	**2014**	**2015**	**2013**	**2014**	**2015**	**2013**	**2014**	**2015**
Peer Reviewed	16	21	20	4	1	4	11	4	10	34	42	50
Non Peer Reviewed	2	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, 2013-2015.*

	Institute Co-Author			ASPB Co-Author			NOAA Co-Author		
	2013	**2014**	**2015***	**2013**	**2014**	**2015**	**2013**	**2014**	**2015**
Peer Reviewed	108	91	99	25	17	27	68	23	64
Non Peer Reviewed	1	0	0	2	0	0	1	0	0

Table 3. CIMSS Publishing History, showing peer reviewed and conference publications for the period 1995-2015.



Appendix 3: Employee Support Documentation

Personnel				
Category	Number	B.S.	M.S.	Ph.D.
Research Scientist	1	0	0	1
Visiting Scientist	0	0	0	0
Postdoctoral Fellow	0	0	0	0
Research Support Staff	17	1	13	3
Administrative	0	0	0	0
Total (≥ 50% Support)	18	1	13	4
Undergraduate Students	8			
Graduate Students	10			
Employees that received <50% NOAA Funding (not including students)	96	9	45	41
Located at Lab (include name of lab)	2 AWC, 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

Kaba Bah

Ph.D Thesis topic: This study will focus on using nested global-to-regional air quality forecast and chemical data assimilation models, satellite, airborne and ground based in situ and remote measurements to interpret air quality in the Denver, CO region during the NSF sponsored Front Range Air Pollution and Photochemistry Éxperiment (FRAPPÉ) field campaign (July 2014). CIMSS, in collaboration with the LASP at the University of Colorado- Boulder will be deploying ground based remote sensing instruments during FRAPPE including the SSEC Automated High Spectral Resolution Lidar (AHSRL), Atmospheric Emitted Radiance Interferometer (AERI), and LASP Solar Spectral Flux Radiometer (SSFR) which will be used to provide continuous measurements of clouds, aerosols, ozone, carbon monoxide, and atmospheric temperature and water vapor. These measurements will be assimilated within nested RAQMS/WRF-CHEM.

Michelle Feltz

M.S. Title: "The Use of GPS Radio Occultation and Hyperspectral Infrared Sounder Data in Stratospheric Temperature Monitoring." This research explores the utility of the combination of GPS radio occultation (RO) and hyperspectral infrared sounder data. A sounder and RO profile-to-profile matchup methodology is employed for comparison of the sounder and RO temperature profiles. RO and sounder radiances are computed using a radiative transfer model from the matchup temperature dataset and are compared to the measured IR sounder radiances which can be used as a validation reference due to their low measurement uncertainty. This work focuses on the stratospheric region and is motivated in part by the need for instruments that can provide climate quality datasets.

Amanda Gumber

The research is focused on studying the 3D radiative effects of clouds using MODIS satellite data. Using a timeseries of global MODIS data from both Aqua and Terra, areas will be identified as being susceptible to the influence of internal and external cloud inhomogeneity based on using a spatial heterogeneity index based on the 0.65 mm reflectance, solar zenith angle, and viewing zenith angle. After identifying these regions, perform 3D radiative transfer calculations using a Monte Carlo model and compare the results against plane-parallel calculations for the Independent Column Approximation(ICA) and non-ICA. From this, estimate the magnitude of retrieval bias of the optical properties and the horizontal movement of photons. With those results, identify the magnitude of the visible reflectance measurements that can be attributed to the internal and external inhomogeneity of clouds. Another part of the research is helping produce a MODIS maritime water cloud record which will account for the influence of external and internal cloud inhomogeneity and calculated statistics of in-cloud distributions of cloud properties that conserve solar reflectance.

Kyle Hosley

Research focuses on examining the trajectories of high aerosol optical depth (AOD) signals, as seen by the MODIS satellite, using the Infusing satellite Data into Environmental Applications - International (IDEA-I) software. So far, the Rim Fire from August of 2013 has been analyzed using the forecast trajectories to determine the sphere of influence of trajectories from each day and to determine the cumulative influence on each day from trajectories initiated up to 2 days prior. Future research will include looking at other fires to determine their sphere of influence and looking at similar trajectories for ozone to diagnose stratospheric intrusion events.

Xiaowei Jiang

M.S. Title: "Evaluation of environmental moisture from NWP models with measurements from advanced geostationary satellite imager." The atmospheric moisture in the environment is associated with storm development, and it is important to evaluate the uncertainty of moisture fields in the environment from numerical weather prediction (NWP) models for better understanding the associate of the environmental moisture with storm prediction. This study develop a new methodology on evaluate moisture in environment from NWP models and associated with tropical cyclone forecast. This methodology can be applied to improve the TC forecasts.

Aaron Letterly

Research focuses on using AVHRR sea ice concentrations and ERA-Interim reanalysis output to assess factors contributing to winter sea ice growth. Particularly interested in creating a climatology of winter cloud anomaly and determining its lagged correlation with fluctuations in sea ice area anomaly. The absence of arctic sunlight throughout the winter months doesn't "turn off" the melting of sea ice, but rather sets the stage for longwave re-emission by clouds to dominate the surface energy budget in marginal ice areas (i.e., the Beaufort Sea). Comparing the 32 years of AVHRR-sensed sea ice concentration records in conjunction with anomalously clear or cloudy years allows the determination of just when winter clouds were a major contributor to changes in the sea ice record. Through extensive analysis, would like to determine seasonal cloud amount's role as a predictor on future sea ice area anomaly.

Yue Li

Post Doc Research: We studied the diurnal variations of land surface emissivities (LSE) using geostationary satellite data observations. Better understanding of LSE change can improve the retrieval accuracy from satellite observations and reduce uncertainties in number weather predictions. So the aim of this study is to investigate the magnitude and factors resulting variations of the LSE change.

b. We assessed the quality of CrIMSS post-launch EDR product. This assessment is important to report possible biases and deficiencies prior to the official release of CrIMSS product.

Jacola Roman *(Graduated, started on Ph.D.)*

M.S. Thesis title: "Climatological Analysis and Assessment in Global Climate Models and Observations of Precipitable Water Vapor (PWV) and Sea Surface Temperature (SST)". This study examines regional monthly mean and seasonal trends in PWV using ground-based GPS measurements as well as satellite (AIRS and AMSR-E) observations and reanalysis (NARR). Additionally, the study examines the simulations of the GCMs of SST for two different scenarios (decadal run 1980 and decadal run 2000). A comparison to observations will be done, in an attempt to show which scenario best stimulates the observations from 2000-2010. Once a scenario is distinguished, the assessment of GCMs at simulating the PWV observations will be examined and evaluated, similar to the analysis done on the observations.

Gary Wade

Extending work of Ralph Petersen and Richard J. Dworak (CIMSS), research analyzes the accuracy of the moisture gradients in the GOES (Geostationary Operational Environmental Satellite) Sounder retrieved moisture fields, primarily employing comparison with independent, remotely sensed GPS (Global Positioning System) moisture data. With spatial and temporal scales comparable with GOES, GPS affords a measure of comparison that can be examined for gradients. Although retrieved moisture data from the GOES Sounder, with its limited spectral resolution, have traditionally had small impact and have been underutilized, gradient information avoids the issue of simple biases in the data. As low spectral resolution moisture data from geostationary orbit will continue in the near future with GOES-R, this study remains relevant in attempting to exploit the current and future GOES moisture measurements. As forecasters currently examine and assess the CIMSS GOES Nearcast system, where in one approach GOES layered moisture fields are advected ahead to estimate atmospheric stability, this study may help legitimize how unique and accurate one might consider the Nearcast products.

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.

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. Besides, I have an independent research topic, that is, 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.

<u>Students Funded on other projects than NOAA</u>

David Loveless

M.S. Title: “Composite Bore Analysis Using Ground-based Remote Sensing Instruments during the PECAN Campaign.” 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) and Doppler wind lidars were deployed at both 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.

These instruments will be used to construct a composite analysis of atmospheric bore passages. This work is conducted with the goal of better characterizing bore ducting layers, and understanding the boundary layer evolution during bore passages. By understanding boundary layer evolution during bore passages, the potential role of atmospheric bores in nocturnal convective initiation can be described.

Brent Maddux
Ph.D. Thesis title: "Analyses of the MODIS Global to Regional Cloud Properties and Uncertainty." This study analyzes the MODIS global and regional cloud property data records. Cloud property histograms and statistics are utilized to characterize the global cloud property fields and attribute systematic errors and biases to their source. In conjunction with the GEWEX Cloud Climatology Comparison working group, this effort will help characterize the MODIS data records for future improvement and potential merger with other satellite data records.

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.

Kyle Nelson
M.S. Thesis title: "Optically Thin Liquid Clouds: Detection and Assessment of Contribution to Greenland Melt Events Using Satellite Data." Clouds play a fundamental role in the mass budget of the world's major ice sheets both as a source, via precipitation, and as a sink, via surface melt due to radiative forcing. To understand present and future effects of changes to the world's ice sheets requires a robust understanding of the macro and microphysical properties of polar cloud systems, including their radiative effects on the surface. For this study, the TERRA Moderate Resolution Imaging Spectroradiometer (TERRA-MODIS) is used to diagnose the spatial extent and frequency of occurrence of optically thin, liquid clouds over the Greenland Ice Sheet (GIS). Results from the Integrated Characterization of Energy, Clouds, Atmospheric State and Precipitation at Summit (ICECAPS) campaign noted a historically rare period of extended surface melting observed across the entire Greenland ice sheet in July 2012. A study by Bennartz et al. (2013), using ICECAPS surface instrument data and simple radiative transfer modeling, determined that low-level liquid clouds played a key role in that melt event by helping to increasing surface temperatures above freezing. Preliminary results show similar geographic coverage of thin, liquid clouds in July 2011 and July 2012. A qualitative analysis of low-level

warm air advection for both years will be combined with satellite data and radiative transfer modeling to determine why melting occurred over such a large area in July 2012 as compared to July 2011.

Alexa Ross
Research involves understanding the relationship between cloud ice orientation and precipitation over maritime regions. By examining CloudSat reflectivities and CALIOP depolarization ratios side by side, I hope to confirm whether or not signatures of horizontally oriented ice crystals in low clouds increase the chances of precipitation. The experiment will also look into whether or not there are seasonal and/or geographic dependencies on the correlation of ice orientation and precipitation.

Walter Sessions
M.S. Thesis title: "Exploitation of Hyperspectral Infrared Radiance and Retrieval Product data to improve Numerical Dust Modeling through Ensemble Kalman Filter Assimilation Techniques". Aerosols represent a poorly constrained yet highly influential atmospheric component. With highly discretized sources and sinks, aerosols require as many observation channels as possible. Despite this, many of the current generation of satellite assimilation products rely on the visible spectrum limiting observations to half orbits. We are looking to infrared bands to remove this constraint. The multispectral sensors often used for aerosol retrievals have had limited success with this task. We are first building a database of the spectral signatures of mineral dust in the infrared and using the higher spectral resolution found in hyperspectral sounders (space, aircraft, and ground based), to try and produce an assimilation grade product. Verification and validation will be done through the Naval Research Laboratory's Ensemble Kalman Filter Assimilation System to evaluate efficacy.

Skylar Williams
This research focuses on support for improving the use of airborne observations in daily forecasting within NOAA NWS. Commercial aircraft measurements from the AMDAR dataset include pressure, temperature, and relative humidity allow for a vertical profile of the atmosphere to be created when aircraft takeoff and land. While the Water Vapor Sensing System II (WVSS-II) sensor has been validated against rawinsonde launches during short-term localized validation experiments, this research promises a CONUS-wide comparison of this sensor to balloon-based observations that can account for different seasons and climates. This will allow for a basis to find when aircraft profiles can be used as an alternative to rawinsonde launches.

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
Jay **Cable**	Geographic Information Network of Alaska (GINA), University of Alaska
Yi-Chun **Chen**	JPL/CalTech
Dehui **Cheng**	Chief Engineer, China Meteorological Administration (CMA) Numerical Weather Prediction Center (NWPC)
Carl **Dierking**	Geographic Information Network of Alaska (GINA), University of Alaska
Laura **Dobor**	Eotvos Lorand University, Department of Meteorology, Hungary
Iliana **Genkova**	I. M. Systems Group
Jiandong **Gong**	Deputy Director, China Meteorological Administration (CMA) Numerical Weather Prediction Center (NWPC)
Xinya **Gong**	Institute of Atmospheric Physics, Chinese Academy of Sciences
Kelton **Halbert**	Oklahoma University
Wei **Han**	Deputy Director, Division of Modeling and Data Assimilation, CMA/NWPC
Hyo-Jin **Han**	Seoul National University
Burcu **Kabatas**	Istanbul Technical University
Mike **Kalb**	Acting Director, NOAA/NESDIS/STAR
Satya **Kalluri**	Chief, NOAA/NESDIS/STAR Cooperative Research Program Division
Hye-Sil **Kim**	Ewha Women's University (Korea)
Bo-Ram **Kim**	Ewha Women's University (Korea)
Alexander **Koltunov**	CSTARS, University of California-Davis
Paul **Kucera**	National Center for Atmospheric Research (NCAR)
Juan Li	China Meteorological Administration (CMA) Numerical Weather Prediction Center (NWPC)
Wen **Liu**	Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences
Johannes **Nielsen**	Danish Meteorological Institute
Aku **Riihela**	Finnish Meteorological Institute
Kirsti **Salonen**	European Center for Medium-range Weather Forecasting (ECMWF)
Yasuhiko **Sumida**	Meteorological Satellite Center of the Japan Meteorological Agency (JMA)

David **Turner**	NOAA National Severe Storms Laboratory
Susan **Ustin**	Director, CSTARS, University of California-Davis
Lu **Wang**	Chengdu University of Technology
Tao **Yu**	Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences
Hua **Zhang**	Senior Scientist, China Meteorological Administration (CMA) Numerical Weather Prediction Center (NWPC)
Cong **Zhou**	East China Normal University
Lin **Zhu**	National Satellite Meteorological Center of China Meteorological Administration

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 meets formally approximately once a year to review the policies, research themes, and priorities of CIMSS, including budget and scientific activities. The Board is also responsible for approving the appointment of members to the Science Advisory Council. The most recent Board of Directors meeting was held in July 2014. Current Board of Directors members include:

Marsha Mailick	Associate Vice Chancellor for Research and Graduate Education, UW–Madison
Steven A. Ackerman	Director, CIMSS, UW–Madison
Henry E. Revercomb	Director, SSEC, UW–Madison
Grant Petty	Chair, Department of Atmospheric and Oceanic Sciences, UW-Madison
Steven Volz	Assistant Administrator for Satellite and Information Services, NOAA/NESDIS
Alfred Powell	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 Advisory Council advising the CIMSS Director in establishing the broad scientific content of CIMSS programs, promoting cooperation among CIMSS, NOAA, and NASA, maintaining high scientific and professional standards, and preparing reports of CIMSS activities. The Science Council normally meets every 1-2 years; however, the last Council meeting was held in November 2009. 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
Ralf Bennartz	Professor, Vanderbilt University
Chris Kummerow	Professor, Department of Atmospheric Science, Colorado State University
Steve Goodman	GOES-R Program Scientist, NOAA/NESDIS/ORA
Christopher Brown	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, 2013-2016

CIMSS Peer-Reviewed Publications, 2013-16

2016: In Press, Accepted, or In Review

Boukabara, S., Zhu, T., Hendrik, T., Lord, S., Goodman, S., Atlas, R., Goldberg, M., Auligne, T., Pierce, B., et al. 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 the American Meteorological Society, accepted for publication.

Heymsfield, A., Matrosov, S., and Wood, N. toward improving ice water content and snow rate retrievals from radars, Part I: X and W bands, emphasizing CloudSat. Journal of Applied Meteorology and Climatology, in press.

Hioki, S., P. Yang, B. A. Baum, S. E. Platnick, K. G. Meyer, M. D. King, and J. Riedi, 2015: Inference of the ice cloud particle roughness parameter in polarimetric data. Atmospheric Chemistry and Physics Discussion, in revision.

Kossin, J. P., K. A. Emanuel, and S. J. Camargo, 2016: Past and projected changes in western North Pacific tropical cyclone exposure. Journal of Climate, in review.

Kossin, J. P., K. A. Emanuel, and G. A. Vecchi, 2016: Comment on 'Roles of interbasin frequency changes in the poleward shifts of the maximum intensity location of tropical cyclones'. Environmental Research Letters, in press.

Kulie, M. S., L. Milani, N. Wood, S. Tushaus, and T. L'Ecuyer. A shallow cumuliform snowfall census using spaceborne radar. Journal of Hydrometeorology, in Press.

Menzel, W. P., R. A. Frey, E. E. Borbas, B. A. Baum, G. Cureton, and N. Bearson. Reanalysis of HIRS satellite measurements from 1980-2015: Development of a consistent decadal cloud record. Journal of Applied Meteorology and Climatology, in review.

Miller, D. J., Zhang, Z., Ackerman, S., Platnick, S., and Baum, B.A. The impact of cloud vertical structure on cloud liquid water path retrieval based on the bi-spectral method: A theoretical study based on large-eddy simulations of shallow marine boundary-layer clouds. Journal of Geophysical Research, in press.

Orf, L., Wilhelmson, R., and Wicker, L. Visualization of a simulated long-track EF5 tornado embedded within a supercell thunderstorm. Parallel Computing, in press.

Palerme, C., Genthon, C., Claud, C., Kay, J.E., Wood, N.B., and L'Ecuyer, T. Evaluation of current and projected Antarctic precipitation in CMIP5 models. Climate Dynamics, in press.

Petersen, R.A. On the impact and future benefits of AMDAR observations in operational forecasts. Part 1: A review of the impact of automated aircraft wind and temperature reports. Bulletin of the American Meteorological Society, accepted for publication.

Petersen, R.A., Cronce, R., Mamrosh, R., Baker, R., and Pauley, P. On the impact and future benefits of AMDAR observations in operational forecasting. Part 2: Water vapor observations. Bulletin of the American Meteorological Society, accepted for publication.

Rink, T., Menzel, W.P., Gumley, L., and Strabala, K. HYDRA2 – A multispectral data analysis toolkit for sensors on Suomi NPP and other current satellite platforms. Bulletin of the American Meteorological

Society, accepted for publication.

Wang, X., Key, J., Kwok, R., Zhang, J. Comparison of Sea Ice Thickness from Satellites, Aircraft, and PIOMAS Data. *Remote Sensing,* submitted.

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Anderson, M.C., Zolin, C.A., Sentelhas, P.C., Hain, C.R., Semmens, K., Yilmaz, M.T., Gao, F., Otkin, J.A., and Tetrault, R., 2016. The Evaporative Stress Index as an indicator of agricultural drought in Brazil: An assessment based on crop yield impacts. Remote Sensing of Environment, 174(1): 82-99.

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.

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.

Greenwald, T.J., Pierce, R.B., Schaack, T. , Otkin, J., Rogal, M., Bah, K., Lenzen, A., Nelson, J., Li, J., and Huang, H.-L., 2016. Real-time simulation of the GOES-R ABI for user readiness and product evaluation. Bulletin of the American Meteorological Society, 97(2): 245-261.

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Kossin, J.P. and DeMaria, M., 2016. Reducing operational hurricane intensity forecast errors during eyewall replacement cycles. Weather and Forecasting, 31(2): 601-608.

Kulie, M.S., Milani, L., Wood, N.B., Tushaus, S.A., Bennartz, R., and L'Ecuyer, T., 2016. A shallow cumuliform snowfall census using spaceborne radar. Journal of Hydrometeorology, 17(4): 1261-1279.

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Pettersen, C., Bennartz, R., Kulie, M.S., Merrelli, A.J., Shupe, M.D., and Turner, D.D., 2016. Microwave signatures of ice hydrometeors from ground-based observations above Summit, Greenland. Atmospheric Chemistry and Physics, 16(7): 4743-4756.

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