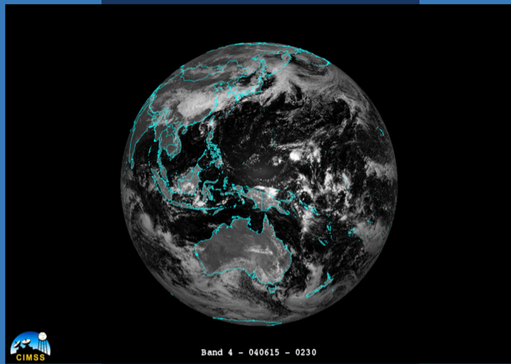

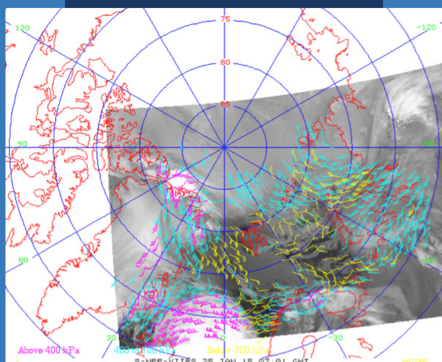

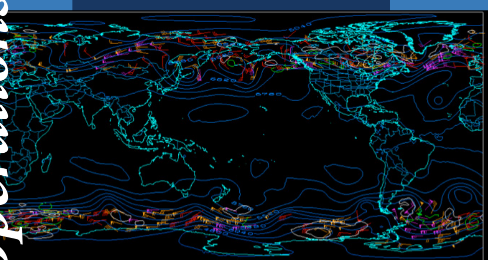

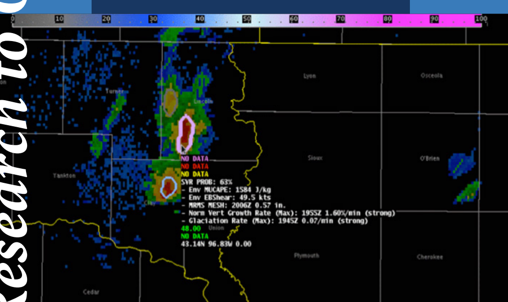

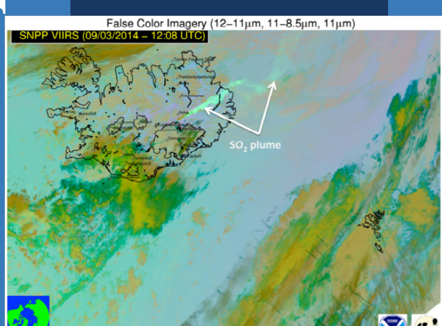

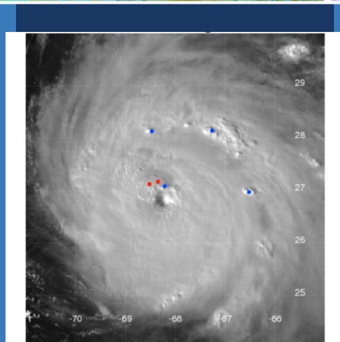

Research to Operations

CIMSS Cooperative Agreement Annual Report

for the period
1 April 2014 to 31 March 2015

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

April 2015

THE UNIVERSITY of WISCONSIN MADISON

CIMSS

University of Wisconsin–Madison

Cooperative Institute for
Meteorological Satellite Studies (CIMSS)

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

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

1 April 2014 to 31 March 2015

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I. Director's Executive Summary

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) is a collaborative relationship between the National Oceanic and Atmospheric Administration (NOAA) and the University of Wisconsin–Madison (UW–Madison). This partnership 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 noted in the recent 5-year review panel, 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 scientists, in collaboration with ASPB and other scientists, 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 GOES Imager and Sounder data. 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. CIMSS scientists continue to collaborate with ASPB scientists in assessing new and current satellite instruments. For example, 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. This group developed and hosts volcanic cloud alerts and associated imagery (http://volcano.ssec.wisc.edu). Operational meteorologists at the Anchorage Volcanic Ash Advisory Center (a-VAAC) are using the volcanic cloud website during ash events. The group is now collaborating with the FAA to develop satellite-based data sets for model verification of volcanic ash dispersion forecasts. CIMSS and ASPB scientists are currently evaluating the feasibility of merging the current state of the Volcano Cloud Analysis Toolkit (VOLCAT) into the CLAVR-X/AIT framework for operationally processing AVHRR data within NESDIS operations.

The CIMSS has a long collaboration with ASPB in developing analysis methods for the polar and geostationary satellite Sounder observations. This support is for both quality assurance and for application sciences. The GOES-14 satellite was operated in Super Rapid Scan Operation for GOES-R (SRSOR) mode on several days during 2014 for the purpose of demonstrating the value of high temporal observations (1-minute intervals) from GOES which will become available regularly with GOES-R. All gaps in NOAA's Comprehensive Large Array-data Stewardship System (CLASS) data archive for GOES-14 SRSOR data were filled by the SSEC Data Center. GOES-14 SRSOR data were supplied to CLASS for dates in June 2013 and May 2014.

CIMSS' scientists continue to work with NOAA in providing science input to the future NOAA satellite missions. For example, Effective fire detection and characterization was a consideration during ABI's design, and CIMSS was involved in developing the specifications for the 4 and 11 μm bands.

The GRAFIIR team at CIMSS has been an active participant with the government's ABI waiver response team. GRAFIIR has been an integral part of the plan for assessing the potential impact of certain ABI waivers on Level-1B and Level-2+ products. The GRAFIIR team has helped the government respond to 12 ABI instrument waivers or deviations to date. This project supports the GOES-R Data Operations Support Team (DOST) by extending our current real-time proxy effort to provide real-time Full-Disk (East and West) and CONUS (East and West) 16-band ABI imagery for GOES-R ground system testing and validation activities. The real-time full-disk proxy data will utilize full-resolution (T1534L64, an effective grid point spacing of about 13 km), GFS model meteorological (temperature, humidity, pressure, surface temperature, cloud water, and cloud ice) and RAQMS $1^o x 1^o$ aerosol/ozone forecasts to provide input for CRTM 16-band radiance calculations. Realistic noise will be added using GOES-R Analysis Facility for Instrument Impacts on Requirements (GRAFIIR) capabilities. The CIMSS/ASPB team developed an automated way of delivering simulated ABI imagery (in Fixed Grid Format) to the AIT in real-time for testing the algorithm framework.

CIMSS also has a strong partnership with NOAA through the GOES-R program.

- 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. At least, 27 NWS WFOs are utilizing the FLS products in operations.
- 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. The SO_2 detection algorithm utilized infrared channels that are sensitive to SO_2 absorption,
- The GOES-R Tropical Overshooting Top (TOT) product is an algorithm designed to identify convective updrafts and overshooting tops in tropical environments, specifically tropical cyclones (TCs). 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) field experiment for the past 3 Atlantic hurricane seasons.
- The Fire Detection and Characterization Algorithm (FDCA) utilizes the improved fire monitoring capabilities on GOES-R and contains updates to the modules that identify and characterize sub-pixel fire activity. For this year, the work on the FDCA focused on

providing continued support to the implementation team at the AIT and Ground Segment Contractor as well as refinement of the validation software and preparation for using AHI on Himawari-8 as a proxy for ABI.

- The AWG Imagery Team has developed the format for ABI data which includes the fixed grid format and GRB-like data structure. The team also wrote the ATBD covering how to convert between counts and radiance, radiance and physical units (brightness temperature or reflectance factor), and how to generate brightness values to be displayed. Now in the validation phase, the next steps are to develop better methods by which ABI imagery will be quality controlled. Past efforts have primarily been theoretical approaches to data validation and now the project will move into practical applications of validation, including testing on current GOES.
- One of the principle benefits expected from GOES-R is the improvement in temporal sampling of images from the ABI, enabling 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. A 'Benchmark' AMV dataset for Hurricane Sandy was produced using the traditional derivation practices and settings/tuning based on previous research. The Hurricane-WRF (HWRF) team at NCEP-EMC is interested in evaluating the impacts of assimilating GOES-derived Atmospheric Motion Vectors (AMVs) in collaboration with the AMV development and applications team at CIMSS.
- The GOES Surface and Insolation Project (GSIP) has been the operational NESDIS cloud processing system for the GOES Imager. Integration of the updated GOES-R cloud algorithms into GSIP was performed in early 2015 and is currently being tested. In addition, the updated GOES-R cloud algorithms have been successfully integrated into the NOFS (NESDIS Operational Framework System).
- The CIMSS/SSEC Algorithm Integration Team (AIT) handles aspects of computer science cross-cutting AWG algorithm development teams at CIMSS/SSEC, and works in cooperation with the NESDIS AIT leadership in software development practices, software process management, documentation, testing and automation, infrastructure, general computing assistance, and systems design and optimization.
- CIMSS, and ASPB scientists have long collaborated on 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 team has developed five algorithms that generate fourteen independent cloud products: 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.
- CIMSS continues to support to the NOAA GOES-R Proving Ground in testing and validating 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, CIMSS scientists help in evaluating the GOES-R Algorithm Working Group by demonstrating algorithms and decision support products, testing enhancements and providing user assessments and feedback to the product developers.
- CIMSS scientists have established strong collaborations with NWS offices in Alaska and Honolulu that have led to focus area fact sheets about ABI and improved capability of AWIPS-II. CIMSS continue 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 2014 NOAA Hazardous Weather Testbed (HWT) Spring Experiment.

CIMSS also has a long collaboration with NOAA scientist in conducting research and developing applications with NOAA's polar orbiting platforms. We have several projects that make use of instruments on the Suomi NPP platform. There are many activities, as described below, where NOAA support is provided to CIMSS researchers to support the JPSS program. Some examples include:

- CIMSS scientists continue to support the JPSS project as a member of the Algorithm Development Library (ADL) Team. In addition to algorithm development, we work 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. The ADL website (https://jpss-adl-wiki.ssec.wisc.edu/) includes documentation and user instructions, and the ADL Forum for user interaction.
- We are developing and generating new JPSS ice products from VIIRS for evaluation at the National Ice Center (NIC) as part of the Proving Ground program. The work aims to improve two ice products (ice concentration and ice thickness) and create two new ice products (ice concentration under all-weather conditions by blending VIIRS and AMSR-2 observations and a sea ice fracture product).
- The implementation of the CIMSS GOES-R AWG Cloud Algorithms is being transferred to the Suomi NPP Visible Infrared Imaging Radiometer Suite (VIIRS) for a consistent data set. A cloud team is developing cloud algorithms for Cloud Optical Properties (COP)
- A research team is helping to assess the JPSS aerosol product in evaluating the global aerosol product from VIIRS with a focus on collocating the NASA's Earth Observing System (EOS) MODIS (MODerate resolution Imaging Spectroradiometer) aerosol products to support VIIRS aerosol product maturity.
- Researchers are leading efforts to assess CrIS through calibration and validation activities related to the CrIS SDRs, including a range of CrIS performance issues including noise performance, principle component analysis, radiometric calibration, radiometric nonlinearity, and lineshape and spectral calibration.
- 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 greatly enhance regional weather prediction capabilities. To encourage the operational use of hyperspectral retrieval data in NWS (National Weather Service) forecasting offices the value that hyperspectral infrared sounder retrievals add to forecasting applications is demonstrated by means of case studies in the Alaskan Region (AR) as well the CONUS area. Furthermore, selected retrieval products are prepared for near real-time viewing and analysis through the Advanced Weather Interactive Processing System (AWIPS). This will add new meteorological data to forecasting activities by NWS users.
- A team is demonstrating the efficient processing of VIIRS data that is physically consistent with those from GOES-R. This project involves the implementation of the CIMSS GOES-R AWG Cloud Algorithms to the data from the Suomi NPP VIIRS, including: ABI cloud mask, the ABI cloud height algorithm and the daytime cloud optical and microphysical properties algorithm. Implementation support is also provided for the nighttime cloud optical and microphysical properties algorithm. The JPSS AIT-MW supports the NOAA JPSS AIT toward implementation of pseudo-operational product generation, validation, and visualization capabilities for SNPP and follow-on polar satellites.

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 and ASPB scientists continue to work side-by-side in assessing satellite instrument calibrations. 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. For CrIS on Suomi NPP, this included various studies to support the transition to full spectral resolution mode which occurred in December 2014, continuing studies of the "spectral ringing" artifacts and investigations into correction modules and improved calibration equation methods to remove this artifact, and continuing calibration/validation efforts using intercomparisons with various other data sources to monitor and assess the Suomi NPP CrIS spectral radiance product. The validation of derived products is also critical and CIMSS scientists conduct validation efforts of SNPP CrIMSS atmospheric temperature and water vapor retrieved profiles, as well as the observed infrared radiances. 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. Several field campaigns are also planned to support validation of GOES-R and JPSS derived products.

CIMSS continues to support NOAA's goal for infrared sounding 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, 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. The assimilation experiments are implemented in the Data Assimilation Research Testbed (DART) system. Modifications were made to DART so that the Community Radiative Transfer Model (CRTM) can be used for both clear and cloudy grid points in the model domain. 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.

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.

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). This project has been extends to include delivery to present day, incorporating a continuing near real-time delivery of data, and expanding the Fundamental CDR (FCDR) to include the brightness temperature from the AVHRR infrared channels. 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). The primary CIMSS products developed under that project are the AVHRR Polar Pathfinder (APP) and the extended APP (APP-x). APP is essentially an FCDR; APP-x is a TCDR.

Within CIMSS, several cloud climate data sets are generated, including the AVHRR Polar Pathfinder Extended (APP-x), the UW HIRS data set and the Pathfinder Atmospheres Extended (PATMOS-x), GOES imager and sounder cloud products and the MODIS cloud properties. Assessing some of these data sets requires the user community to expend significant effort and investment in data storage. To avoid this CIMSS is developing a climate data portal that would allow users to subset the data by time, space and parameter and allow for efficient access to the data. PATMOS-x is serving as the initial data set for development of the CIMSS climate portal but the goal is to extend this to all other CIMSS cloud climate data sets.

CIMSS sponsored many national and international visitors during this time (Appendix 5). For example: **Louis Uccellini**, NOAA/National Weather Service, **Yasuhiko Sumida**, Japanese Meteorological Agency (JMA), **Johannes Schmetz**, EUMETSAT, **Aku Riihela**, Finnish Meteorological Institute, **Lisa Milani**, Institute for the Sciences of the Atmosphere and Climate, National Council of Research, Rome, Italy, **Leon Majewski**, Australian Bureau of Meteorology, **Ahreum Lee**, Seoul National University, **Burcu Kabatas**, University of Istanbul, **Xiaohui Gao**, Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences, **Barbara Arvani**, University of Modena, **Pete Francis**, UK Met Office, **Christopher Hughes**, University of Buffalo, NY, and **Terhikki Manninen**, Finnish Meteorological Institute.

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

CIMSS continues to support NOAA's education goals. These activities span the landscape of education involving participation in include K-12, undergraduate, graduate and professional training. To improve coordination of these activates we established the CIMSS Education and Public Outreach Office. The new office reports to the CIMSS Director, allowing the engagement function to be infused throughout the institute.

NOAA and NASA grants support CIMSS graduate students in the UW–Madison Department of Atmospheric and Oceanic Sciences (see Appendix 4). 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.

We work in collaboration with NOAA and other cooperative institutes in developing training resources for NOAA. The CIMSS involvement in the CIMSS will further develop the Satellite Hydro-Meteorology (SHyMet) training course through close collaboration with experts at the CIRA. CIMSS has assisted in the development of the previous five SHyMet courses: Intern, Tropical, Forecaster, Severe and Water Vapor Channels. Planning and coordination efforts for a new GOES-R Course, an Aviation Course and a Winter Weather Course are continuing. 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. See, for example, http://cimss.ssec.wisc.edu/goes/blog/archives/15086 for Winter Weather and http://cimss.ssec.wisc.edu/goes/blog/archives/17681 for Aviation training. Training material more specific to the GOES-R Fog/Low Stratus products continues to be added at http://fusedfog.ssec.wisc.edu/ . These case studies can easily be mined for relevant examples to be used for SHyMet.

SHyMet has also supported AWIPS (and AWIPS-II) capabilities that have been further refined at CIMSS. A stable AWIPS-II platform at CIMSS allows for manipulation of CIMSS-produced datasets into formats that are compatible with AWIPS-II formats. Thus, the production at CIMSS of products that forecasters wish to see (for example, GOES-R Fog/Low Stratus Products) can continue into the AWIPS-II era.

CIMSS supported the expanding use of satellite-based weather products through having 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. CIMSS hosted a very successful and exciting Satellites & Education XXVII Conference (http://cimss.ssec.wisc.edu/meetings/27sated/) from July 30 through August 1 2014. In attendance were members of the Satellite Educators Association (SEA), middle and high school science teachers from Wisconsin and beyond, broadcast meteorologists, University of Wisconsin faculty and students, National Weather Service (NWS) meteorologists, Science On a Sphere (SOS) docents, and NOAA and NASA science communicators. The conference featured the formal launch of 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 also launched a new twitter account in late August 2014 (@UWCIMSS), mentioned by the popular Rachel Maddow blog due to high interest in the CIMSS TPW product. 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 4,400 followers.

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:

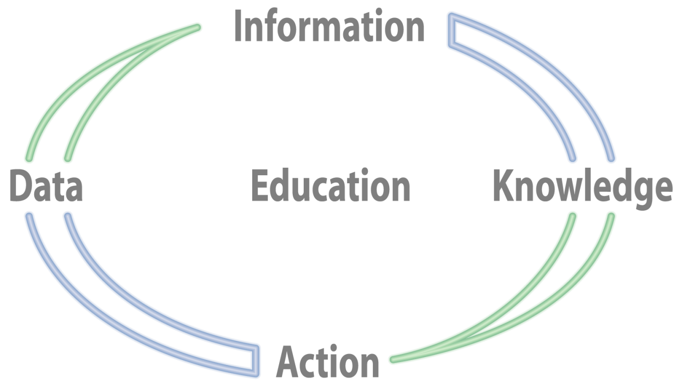
- Foster collaborative research among NOAA, NASA, and the University in those aspects of atmospheric and earth system science that exploit the use of satellite technology;
- Serve as a center at which scientists and engineers working on problems of mutual interest can focus on satellite-related research 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:

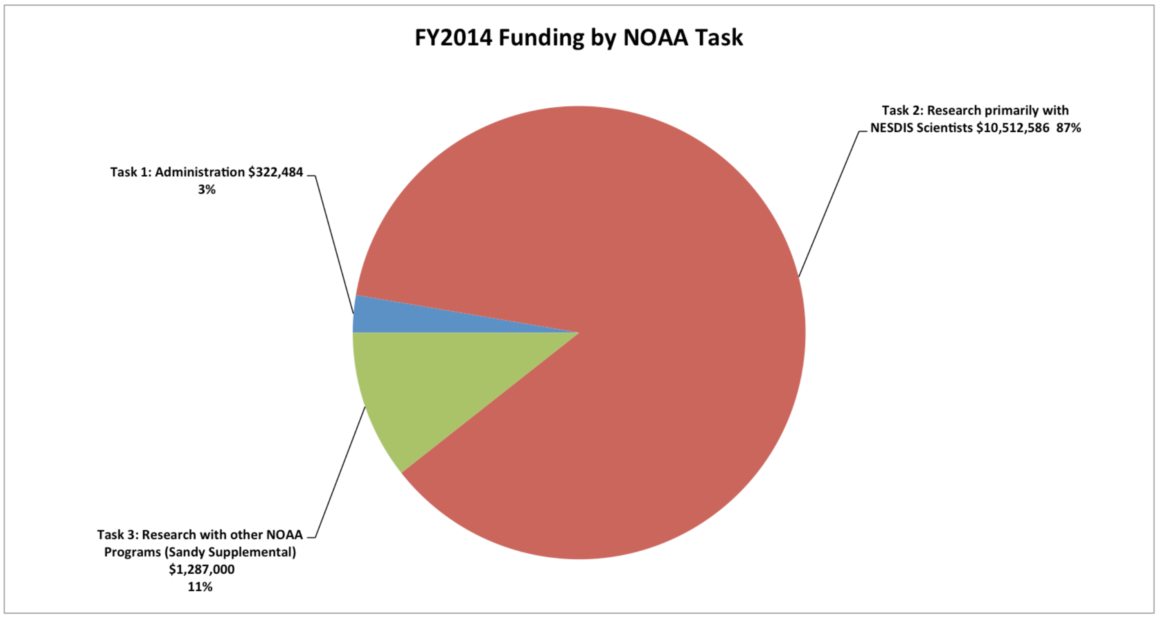
- **Administrative support**
  The administrative support team includes approximately 14 full-time staff and several students providing services that include human relations, proposal processing and publishing, grant and contract management, accounting, financial programming, purchasing and travel.
-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



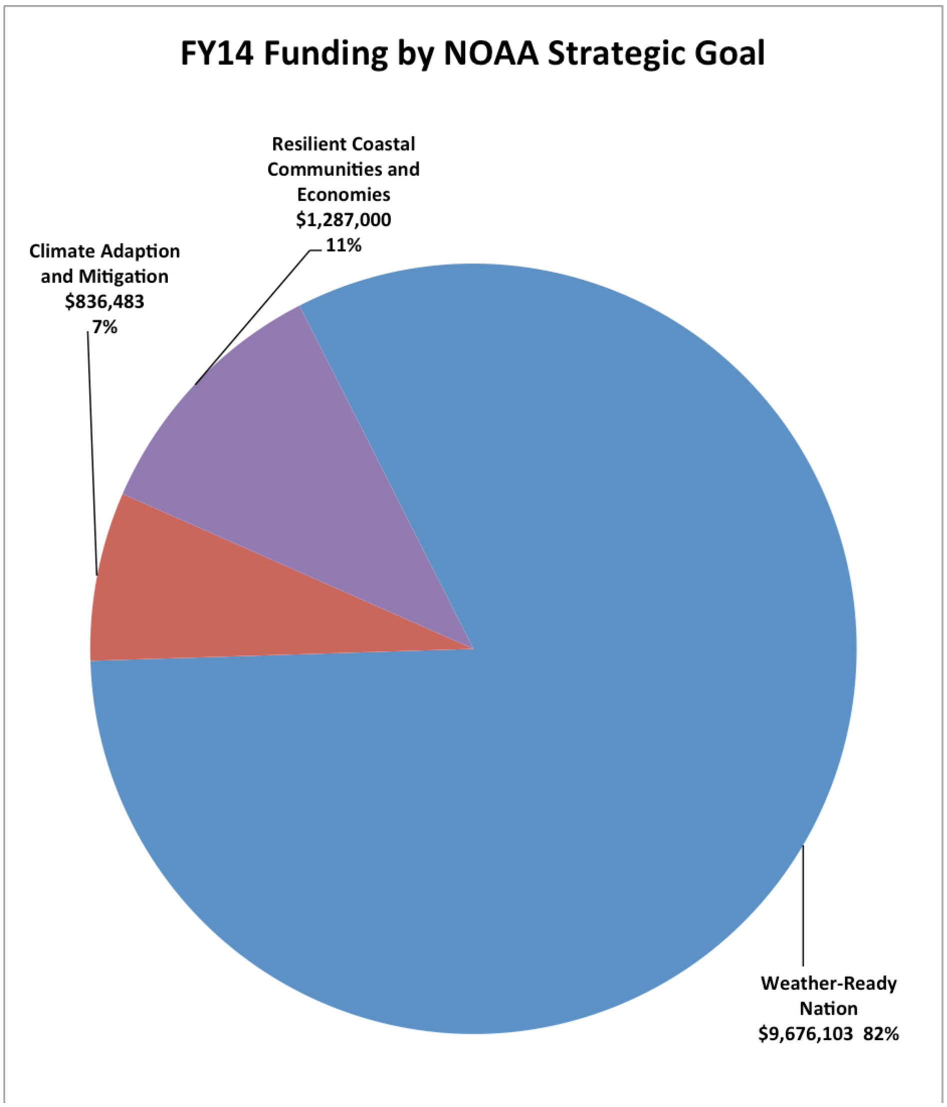
Nearly 90% of CIMSS funding is for Task 2 (69 FTEs) and is research conducted with ASPB scientists.

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*	

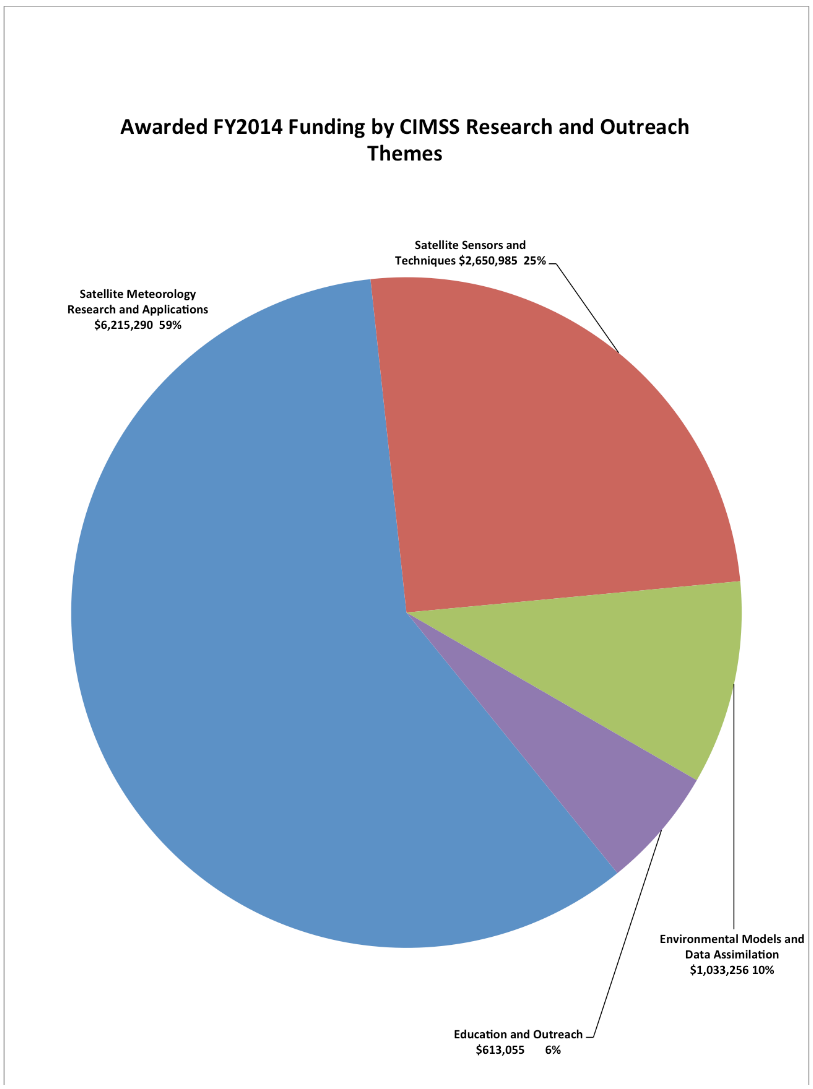
* - does not include the Task 1 funding but include Sandy Supplemental research funding



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

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

NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

NOAA Strategic Goals:

- Provide critical support for the NOAA mission

CIMSS Research Themes:

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

Project Overview

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

Summary of Accomplishments and Findings

The CIMSS Task I funds continue to support the administrative needs for the CIMSS Director, the CIMSS Executive Director - Science and the CIMSS Staff Program Assistant Maria Vasys provides that support and is also supported by student hourly employees to maintain a consistent presence in the CIMSS administrative office. SSEC administration provides the majority of administrative support for CIMSS contracting, accounting, purchases, human resources and travel at no cost to Task 1 funding.

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

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

2. CIMSS Task 1B Support

CIMSS Task Leaders: Margaret Mooney and Steve Ackerman
CIMSS Support Scientists: Scott Bachmeier and Rick Kohrs
NOAA Collaborators: Tim Schmit, Gary Wade, Nina Jackson, LuAnn Dahlman, Marcia Cronce, Louis Uccellini and 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

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.

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. In 2014 this was followed by the Satellites & Education XXVII conference which made its Midwest debut at CIMSS in late July. Sharing satellite imagery is a priority in all CIMSS outreach endeavors; at campus events we utilize a Magic Plant sphere for this, which is similar but smaller than NOAA Science on a Sphere (SOS).

In the fall, CIMSS presented and participated in the 10th annual Cooperative Research Program (CoRP) Science Symposium in New York. Year-round, CIMSS researchers and staff conduct numerous in-person presentations at formal and informal venues.

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 launched a new twitter account in late August 2014 (@UWCIMSS), mentioned by the popular Rachel Maddow blog due to high interest in the CIMSS TPW product.

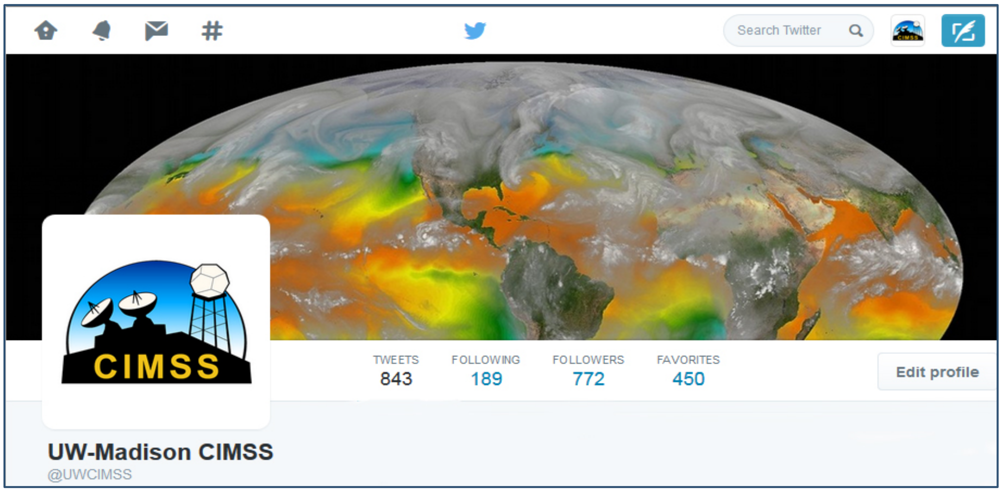


Figure 1. CIMSS Twitter Account.

In addition, the CIMSS Facebook page fans nearly doubled last year.

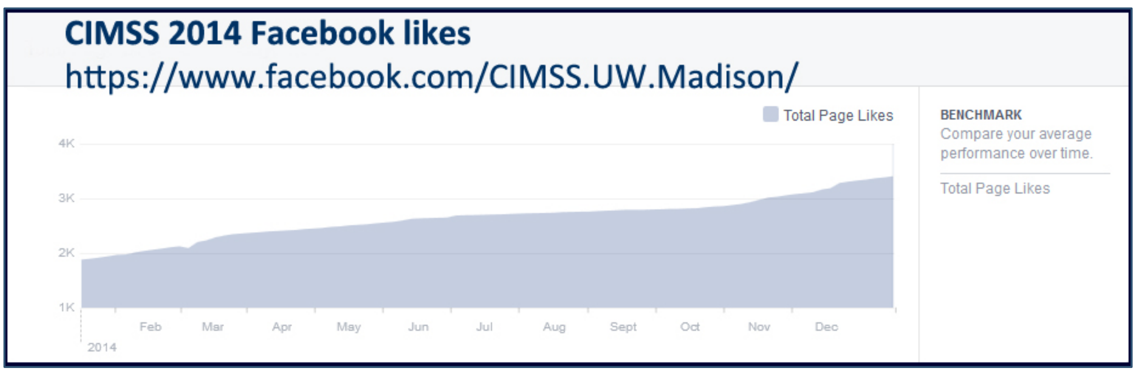


Figure 2. CIMSS Facebook likes.

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.

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 4,400 followers.

The GOES-R Education Proving Ground (http://cimss.ssec.wisc.edu/education/goesr/) led by CIMSS, made great strides in 2014 at the Satellites & Education XXVII conference. This initiative involves three teams of two teachers from Wisconsin, New Jersey and Florida working with CIMSS scientists and staff on the development of lesson plans and webapps related to the GOES-R launch and satellite series.

Figure 3. GOES-R Education Proving Ground Team.

Publications and Conference Reports

Mooney, Margaret and Ackerman, S., On-line Education Initiatives to Galvanize Climate Mitigation in the Great Lakes Region., AGU Fall Meeting, 15-19 December 2014, American Geophysical Union, San Francisco, CA, 2014

Mooney, Margaret; Schmit, T. J. and Ackerman, S. GOES-R Education Proving Ground., Symposium on Education, 24th, Phoenix, AZ, 4-8 January 2015. American Meteorological Society, Boston, MA, 2015

3. CIMSS Participation in the Product Systems Development and Implementation for 2014

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 micron 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.

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. Furthermore, as of January 29, 2015 the NESDIS VIIRS winds are also available via the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) EUMETCast Europe system. EUMETCast is a broadcast system for environmental data that uses commercial telecommunication geostationary satellites to multicast files (data and products) to a wide user community. EUMETCast is primarily intended for the distribution of image data and products from EUMETSAT's fleet of geostationary and polar satellites, but also provides access to data from some external sources, such as NESDIS. To obtain EUMETCast data, users must have a EUMETCast reception station.

Also, the VIIRS Polar Winds are now generated at two Direct Broadcast (DB) sites: 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 these 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.

The latest wind images from Sodankyä (Figure 4) are available at http://stratus.ssec.wisc.edu/db/sodankyla and for Fairbanks at http://stratus.ssec.wisc.edu/db/fairbanks.

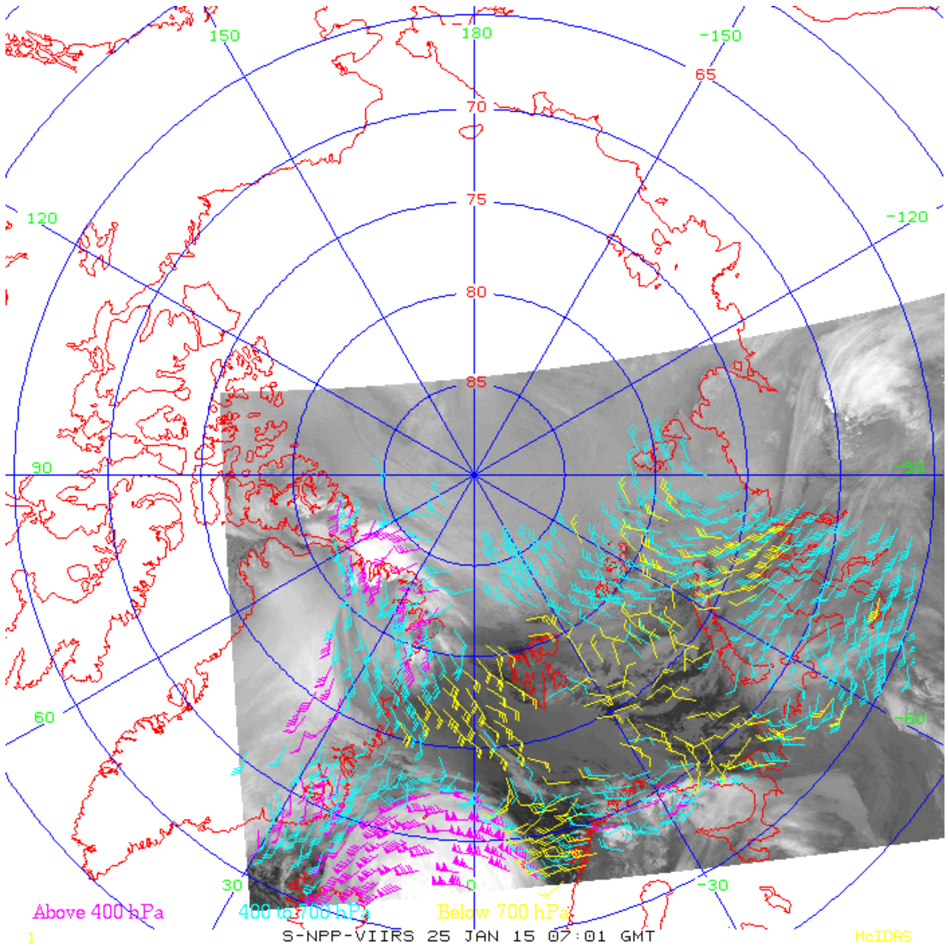


Figure 4. VIIRS polar winds generated at Sodankyä, Finland for one pass on 25 January 2015.

Publications and Conference Reports

Key, Jeff; Daniels, Jaime; Bailey, Andrew; Wanzong, Steve; Qi, Hongming; Breskey, Wayne; Santek, David and Velden, Christopher. Status of VIIRS polar winds. International Winds Workshop, 12th, Copenhagen, Denmark, 15-20 June 2014. University of Copenhagen, Copenhagen, Denmark.

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.

Summary of Accomplishments and Findings
The CIMSS team has been working with STAR scientists and contractors as well as the STAR Algorithm Integration Team (AIT) in the planning to implement of nested tracking code for MODIS and AVHRR polar winds. However at this time, the transition to operations has been delayed due to scheduling and funding issues. The current plans are:
- May 2015: Pre-operational Phase Begins
  - Aug 2015: Pre-operational product output evaluated & tested
  - Oct 2015: Code transitions to operations; all documentation is complete
- Nov 2015: Operational Phase Begins
  - Nov 2015: SPSRB declares product operational
- Nov 2015: Retirement Phase Begins for legacy polar wind products
  - Nov 2015: Send initial announcement to users
  - Jul 2016: Send final announcement to users
  - Sep 2016: Retire product

Note: The nested tracking algorithm has been applied to MODIS data by AIT in preparation for the VIIRS winds implementation. Additional validation activities will occur at CIMSS during the pre-operational phase.

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 NESDIS Operational Framework System (referred to NOFS in this proposal). The goal of this project is to assist NESDIS in transitioning CLAVR-x functionality into the NOFS

Summary of Accomplishments and Findings

The updated GOES-R cloud algorithms which run on AVHRR have been successfully integrated into the NOFS. Code detailing the ingest of AVHRR data has been provided to NESDIS to be integrated into the NOFS. Currently we are awaiting the integration of AVHRR within the NOFS so that comparison tests can be performed.

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.

Summary of Accomplishments and Findings

We are currently evaluating the feasibility of merging the current state of the Volcano Cloud Analysis Toolkit (VOLCAT) into the CLAVR-X/AIT framework for operationally processing AVHRR data within NESDIS operations. Upon completion of our assessment we will work with the STAR AIT to determine the best path to migrate the VOLCAT products using AVHRR into NESDIS operations.

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 Imager. With the advent of the NESDIS Framework, NESDIS desires that all operational processing occur with the NESDIS Operational Framework System (referred to NOFS in this proposal). The goal of this project is to first update GSIP with the latest algorithms and then assist NESDIS in transitioning GSIP functionality into the NOFS

Summary of Accomplishments and Findings
Integration of the updated GOES-R cloud algorithms into GSIP was performed in early 2015 and is currently being tested. In addition, the updated GOES-R cloud algorithms have been successfully integrated into the NOFS. Currently we are awaiting test cases from current GOES calculated from the NOFS to perform comparisons.

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.

Summary of Accomplishments and Findings
We are currently working with the STAR AIT to update the framework to provide necessary ancillary and model data sets required by the GOES-R FLS algorithm. It is of critical importance that high spatial resolution meso-scale model information, such as the Rapid Refresh (RAP), be available for the FLS algorithm to function with the quality that the NWS is currently expecting. Once the framework has incorporated all the necessary components we will deliver the GOES-R FLS algorithm to the AIT. After delivery we will continue to help evaluate the products in preparation for the transition to operations.

4. CIMSS Participation in the GOES-R Algorithm Working Group (AWG) for 2014

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 Collaborator: 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 project supports the GOES-R Data Operations Support Team (DOST) by extending our current real-time proxy effort to provide real-time Full-Disk (East and West) and CONUS (East and West) 16-band ABI imagery for GOES-R ground system testing and validation activities. The real-time full-disk proxy data will utilize full-resolution (T1534L64, an effective grid point spacing of about 13 km), GFS model meteorological (temperature, humidity, pressure, surface temperature, cloud water, and cloud ice) and RAQMS $1^o x 1^o$ aerosol/ozone forecasts to provide input for CRTM 16-band radiance calculations. Realistic noise will be added using GOES-R Analysis Facility for Instrument Impacts on Requirements (GRAFIIR) capabilities. In addition, we will continue providing the GOES-R Algorithm Integration Team (AIT) with real-time GOES-R ReBroadcast (GRB) NetCDF files for AIT algorithm testing and collaborate with AIT to validate Baseline algorithm implementation within the AIT Framework through comparison with products produced at CIMSS using GEOCAT. ABI GRB files will be run in real-time as

needed to support Proving Ground activities through generation of red-green-blue (RGB) imagery and GEOCAT Baseline products.

Summary of Accomplishments and Findings

- In our continuing efforts to make available model-derived products within the Advanced Weather Interactive Processing System (AWIPS), we tested and verified the display of RGB Air Mass images overlaid with quantitative information in AWIPS II. Python and XML code was developed to scale our simulated ABI data to fit within the GOES-11 GRIB2 conventions and unpack in the AWIPS II environment for visualization. A sample RGB Air Mass image is shown in Figure 5. Other GOES-R products, including simulated ABI imagery, convective available potential energy, total precipitable water, and cloud thermodynamic phase, have been displayed within AWIPS II but using a remapping tool that we developed in IDL to convert the NetCDF files to GRIB2 (Greenwald et al., 2015).
- We collaborated with CIRA and SPoRT to develop a unified GRIB2 package for ingesting model products into AWIPS II. Kaba Bah attended the first joint CIMSS/CIRA/SPoRT RGB visiting scientist meeting at the *NOAA Center for Weather and Climate Prediction* and presented our progress in importing simulated ABI RGB products into AWIPS II via a unified GRIB decoder. The title of the talk was "CIMSS/ASPG Metrics: Real-time ingest of CIMSS Proxy RGB Air Mass product with quantitative overlay within NCWCP AWIPS environment and forecaster training sessions."
- We supported the NWS through Joe Zajic's RaFTR (Resample and Format, Timed Release) effort by providing real-time simulated full-disk imagery produced by the S4 for the ABI at different satellite subpoints and the Himawari-8 Advanced Himawari Imager (AHI) to address the integration of these data into AWIPS. These data will be used for GOES-R Ground System integration and end-to-end validation testing, as well as ongoing AWIPS II development. Tom Greenwald, Brad Pierce and Joe Zajic contributed a summary of this effort to a BAMS article on the S4 and its role in research-to-operations/operations-to-research (Boukabara et al., 2015).
- Kaba Bah participated in the National Weather Association 39th Annual Meeting in Salt Lake City Utah, October 18th-23rd. He helped to operate a CIMSS/SSEC booth where AWIPS-II products were demonstrated, including some of our proxy ABI datasets, to NWS personnel, students and other attendees. The feedback we received was very promising.
- We developed an automated way of delivering simulated ABI imagery (in Fixed Grid Format) to the AIT in real-time for testing the algorithm framework. We also made separate deliveries to them for our ABI-West simulation imagery centered instead at 89.5^{o} W longitude, since that is the location where GOES-R may be put into storage soon after launch, and for the visible bands centered at 137^{o} W. The latter datasets were passed on to the ground system team for testing purposes.
- WRF-Chem was run for the 2013 Yosemite Rim Fire for improving our fine particle and ozone emissions simulations through comparisons to flight and ground-based measurements. We developed IDL data analysis and deep dive tools for analyzing the simulations. These tools are important for improving and fine-tuning the emission settings in our WRF-Chem runs.
- We worked with Louis Grasso (CIRA) to incorporate GOES WF-ABBA fire detections into the CONUS-East simulated radiances for ABI bands 7 (3.9 µm) and 13 (10.35 µm).
- We developed an IDL true color capability that is similar to CIRA's RGB lookup table (LUT) approach but utilizes a year's worth of our in-house simulated ABI-like 0.55 µm green band to build the LUT instead of using the MODIS green band. An example of this

capability for visualizing smoke in true color imagery is shown during the 2014 Pacific Northwest wildfires (Figure 6).

- We submitted an article to the Bulletin of the American Meteorological Society that describes the system we use to generate real-time proxy GOES-R ABI data and how these data are used for user preparedness and product evaluation (Greenwald et al., 2015). The article is in the final stages of review.

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, 2015: Real-time Simulation of the GOES-R ABI for user readiness and product evaluation. Bull. Amer. Meteor. Soc., provisionally accepted.

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, 2015: S4: An O2R/R2O infrastructure for optimizing satellite data utilization in NOAA numerical modeling systems, A significant step toward bridging the valley of death. Bull. Amer. Meteor. Soc., submitted.

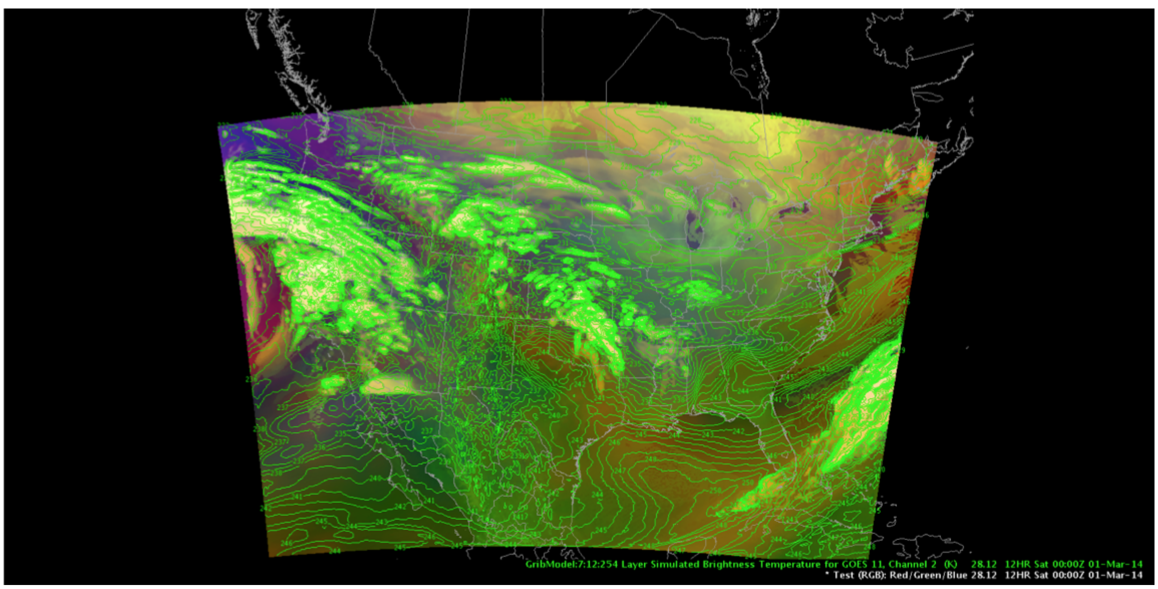


Figure 5. Screenshot of a simulated Red-Green-Blue Air Mass image for 00 UTC 1 March 2014 within AWIPS II. ABI band 8 (6.19 µm) brightness temperature contours are shown to highlight the driest air mass.

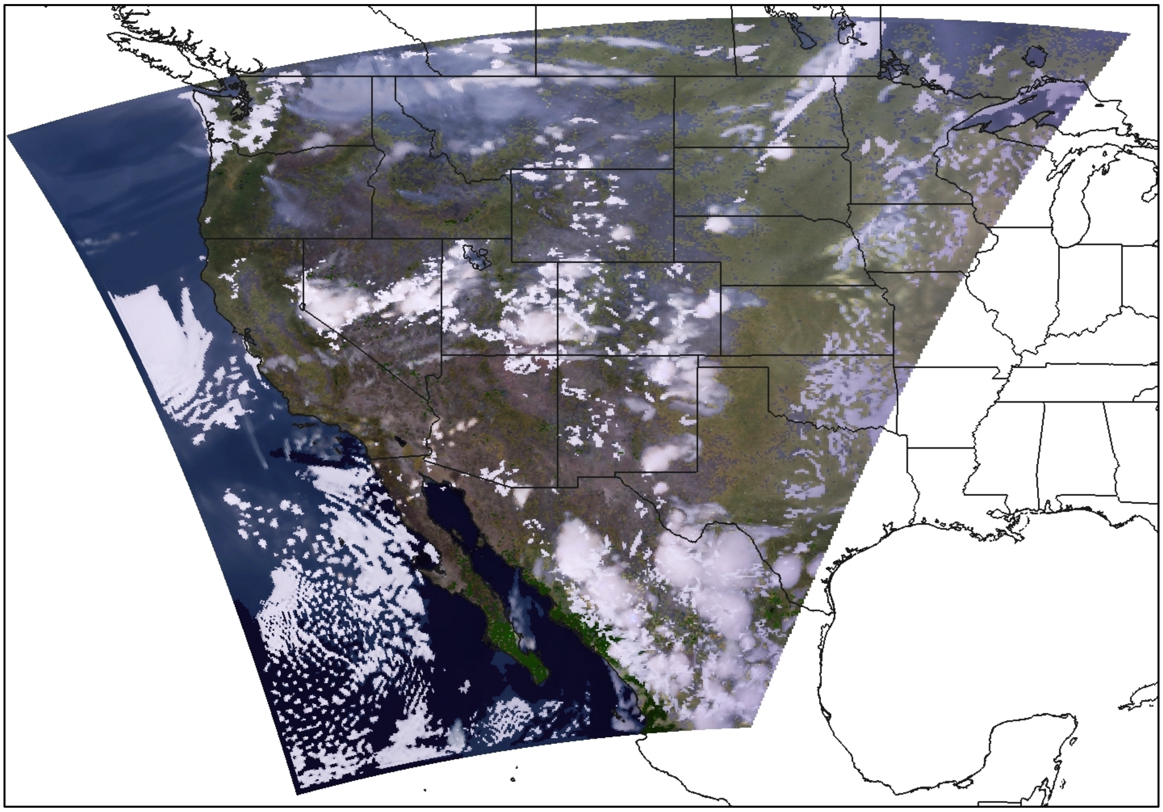


Figure 6. Simulated ABI red-green-blue (RGB) true color imagery for the Pacific Northwest wildfires at 0100 UTC 19 July 2014.

4.2 GOES-R Analysis Facility Instrument for Impacts on Requirements
CIMSS Task Leaders: Mathew Gunshor, Allen Huang
CIMSS Support Scientist: Hong Zhang
NOAA Collaborator: Timothy J. Schmit

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 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 using GRAFIIR's existing capability. Additionally, the CIMSS GRAFIIR team interfaces with the government's GOES-R Product Working Group (PWG), or similarly tasked groups, to assist the government's efforts

with ABI waiver analysis and response. In the past, the PWG has requested specific tasking for the AWG which has primarily been addressed by the CIMSS GRAFIIR team.

Summary of Accomplishments and Findings

The GRAFIIR team at CIMSS has been an active participant with the government's ABI waiver response team. A cross-agency committee, the GOES-R Product Working Group (PWG) is charged with assessing the government's ability to respond to instrument waivers put forth by the GOES-R instrument vendors. This assessment has included creating an inventory of current capabilities, generating a list of needed capabilities, pointing out areas in which there are gaps in capability (in a simulation, not everything is feasible or worth doing), and formulating a plan for the government's response to a waiver to aid the decision making process. GRAFIIR has been an integral part of the plan for assessing the potential impact of certain ABI waivers on Level-1B and Level-2+ products. The GRAFIIR team has helped the government respond to 12 ABI instrument waivers or deviations to date.

In FY14 the GRAFIIR team continued to make adjustments to meet changing program needs. As the AWG Imagery team adjusted to meet the program's needs on file format and content, GRAFIIR has adjusted to use those files as well. GRAFIIR has kept pace with the continued development of GEOCAT as well. New proxy data from the AWG Proxy team (using WRF-Chem and CRTM) produced in near-real-time from NWP has been incorporated.

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

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

Other select accomplishments in 2014 include:

- 0.47um "blip" waiver issue
    - Comparison study of ABI aerosol products: http://www.ssec.wisc.edu/grafiir/GOES_ABI/0.47um/
- Worked on getting GEOCAT to run on a new laptop.
- Demonstrated that GEOCAT could be installed on a Mac laptop and generate products with ABI proxy data and GOES-13 real-time data.
    - http://www.ssec.wisc.edu/grafiir/Demo_case_ABI/.
    - http://www.ssec.wisc.edu/grafiir/GOES_13_GEOCAT/
- Presented a talk at the 2014 EUMETSAT Meteorological Satellite Conference in Geneva, Switzerland: "GRAFIIR and JAFIIR – Efficient End-to-End Semi Automated GEO and LEO Sensor Performance Analysis and Verification Systems." 22-26 September, 2014.

- Presented a poster at the AMS Annual Meeting: "GRAFIIR and JAFIIR: Efficient End-to-End Semi-Automated GEO and LEO Sensor Performance Analysis and Verification Systems" 95th AMS Annual Meeting; 11th Annual Symposium on New Generation Operational Environmental Satellite Systems; Phoenix, AZ; 4-8 January 2015.

Publications and Conference Reports

- Presented a talk at the 2014 EUMETSAT Meteorological Satellite Conference in Geneva, Switzerland: "GRAFIIR and JAFIIR – Efficient End-to-End Semi Automated GEO and LEO Sensor Performance Analysis and Verification Systems." 22-26 September, 2014.
- Presented a poster at the AMS Annual Meeting: "GRAFIIR and JAFIIR: Efficient End-to-End Semi-Automated GEO and LEO Sensor Performance Analysis and Verification Systems" 95th AMS Annual Meeting; 11th Annual Symposium on New Generation Operational Environmental Satellite Systems; Phoenix, AZ; 4-8 January 2015.

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 included:

- Profile reference algorithm implementations and explore performance, accuracy, and reproducibility improvements.
- Review and update software and deliverables with CIMSS science staff.
- Maintain, expand, and deploy 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.
- Continue refactoring and migration of science software toward framework- and platform-agnostic software interfaces in order to simplify existing code and provide new avenues for rapid algorithm development.
- Add Himawari-8 (AHI) 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.

Summary of Accomplishments and Findings

- Continued work on integration and verification testing of updated CIMSS reference algorithms in NOFS (NESDIS Operational Framework System, nee AIT Framework) for use at NOAA.
- Made improvements to Glance verification toolset, responding to AWG team requests and objectives.
- Supported Harris test product verification, providing necessary feedback.
- Conducted preliminary assessment of Harris/AER operational code algorithm samples.
- Made 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 NOFS, 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.
- Integrated libHimawari into GEOCAT, and rapid NetCDF transcoding capability provided for imagery and CLAVR-X rapid validation using AHI data.
- Provided technical and product feedback on AHI to JMA through NOAA channels.

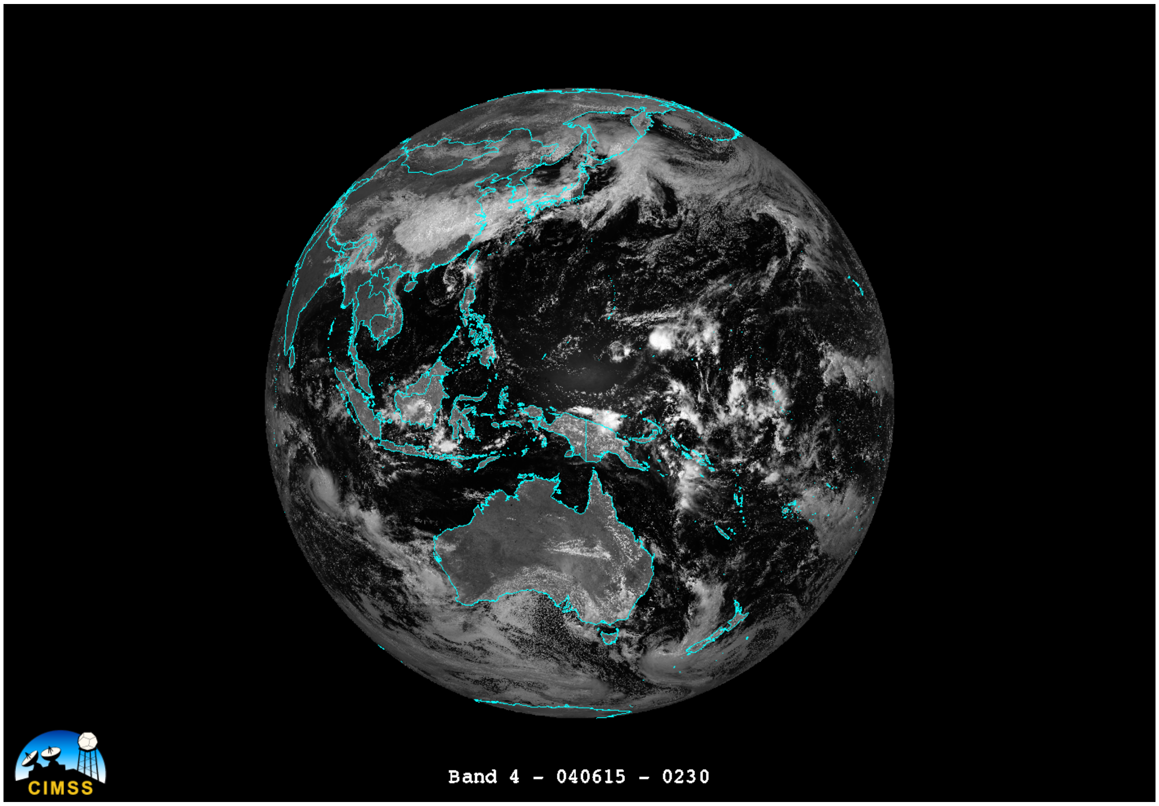


Figure 7. Himawari Full Disk sample imagery.

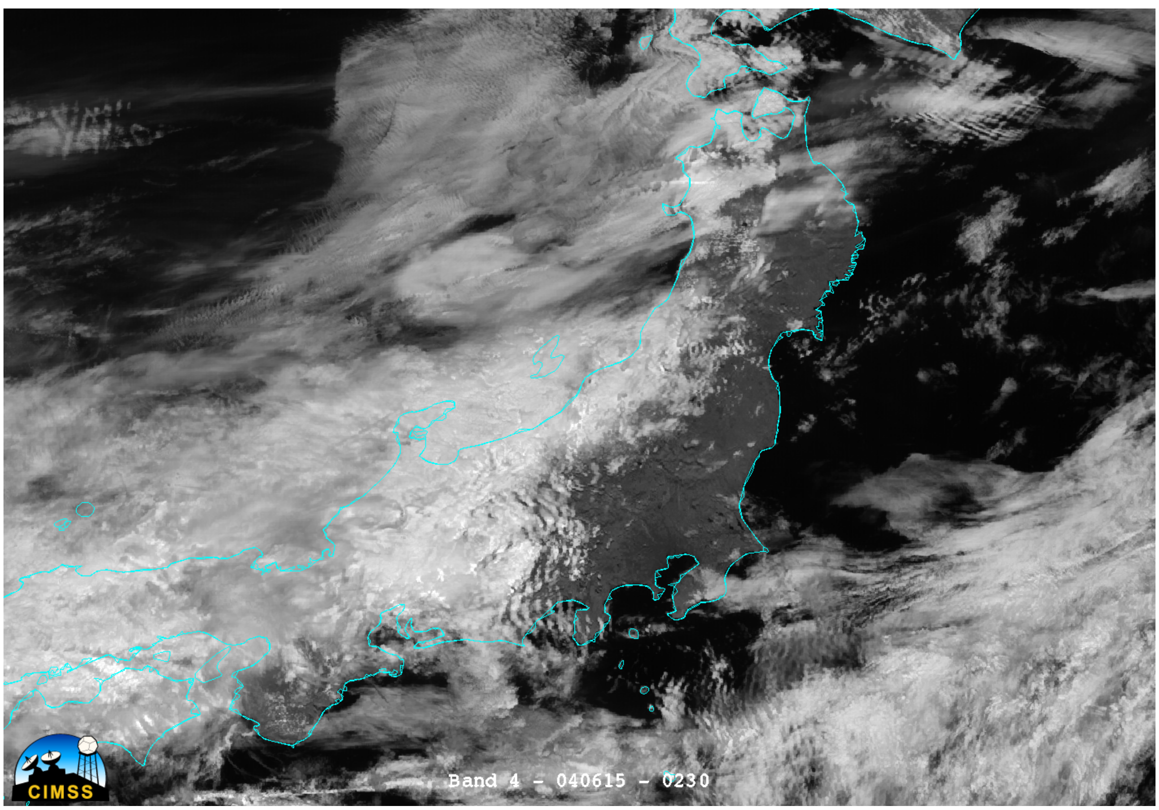


Figure 8. Himawari imagery detail examining registration of coastlines.

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

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

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

CIMSS Research Themes:
- Satellite Sensors and Techniques

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 geo-stationary instruments. As will be presented, the GOES-R AWG project has provided the support to greatly expand these tools to support the AWG calibration and validation efforts enabling months or years of data to quickly be collocated and compared for statistical analysis and long term monitoring. As part of the GOES-R AWG effort, the collocation project supports the following goals:
- Develop a maintainable and extensible toolkit capable of orbital analysis (overpass calculations for satellite-to-satellite or satellite-to-ground) and pixel-to-pixel collocation for both GEO and LEO instruments. This effort involves development of new techniques and algorithms in addition to refactoring and organizing legacy code.
- Support the collocation needs of GOES-R AWG teams as they work to validate their algorithms. The collocation toolkit will become part of a standard validation framework being developed by the AIT.
- Leverage the collocation tools to build an inter-calibration system to allow near real-time monitoring of instrument performance and long-term analysis of radiometric trends.

Both the inter-calibration and validation features have been integrated into a system that allows for near real-time processing using a compute cluster. Thus as instrument data is made available, inter-calibration data or validation results can be made available within hours.

Summary of Accomplishments and Findings
A major effort of the collocation project is the development of an integrated validation system which will provide the AWG teams access to global, quantitative, inter- comparisons between GOES-R products and both active (CALIPSO and CloudSat) and passive (MODIS, VIIRS, CrIS, IASI) Cloud, Aerosol, Sounding observations. As part of this effort a centralized web interface has been developed (http://kepler.ssec.wisc.edu) allowing both viewing of imagery and access to

Match files that provide the collocated data products. Future work will focus on integrating the JPSS products allowing the JPSS teams to easily inter-compare the polar (JPSS) and GOES-R products. We are also working on adding radiance level inter-calibration. The system is designed to automatically identify when there is coincident observations between the geo and leo observations. Once identified the system automatically processes the collocation and inter-comparison software providing about a 15 min delay between when the data is ingested and the inter-comparison products are produced. This capability will support monitoring of the AWG products. The foundation for this system is the collocation and navigation tools presented in the previous section. We now present the components of this system.

Flo processing

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

Match Files

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

Validation Results and Imagery

A recent advance of this project is the development of python software that utilizes an oblique Mercator projection for displaying the imagery which can be applied to both GEO and LEO observations. The oblique Mercator projection is a cylindrical projection where the cylinder intersects the earth along an arbitrary great circle. The benefits of this projection is that images from both LEO and GEO observations can be viewed in a rectangular which is not rotated as they would be with a orthographic projection. Due to the earths rotation and satellite motion granules near the equator take on a parallelogram shape. This capability will be used to generate consistent quick look product images for both AHI and ABI which can be directly inter-compared with SNPP VIIRS retrievals. An example of these tools applied to the AWG cloud algorithms on SNPP is presented in Figure 9.

We have also implemented the corrected reflectance true color [R,G,B], snow/ice [0.86, 1.6, 2.25 um], and natural color [1.6, 0.86, 0.67um] color composite imagery. For daytime observations these images are valuable for algorithm developers to help differentiate liquid from ice clouds and snow or ice surfaces, see Figure 10.

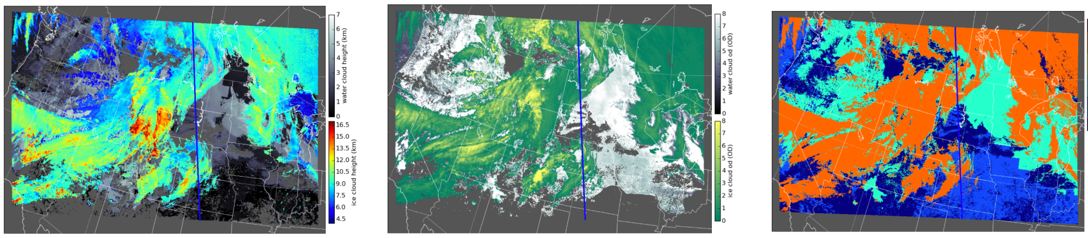


Figure 9. From left to right: AWG cloud algorithms applied to VIIRS data for retrieved cloud top altitude, effective radius, and cloud mask. Blue line is CALIPSO ground track.

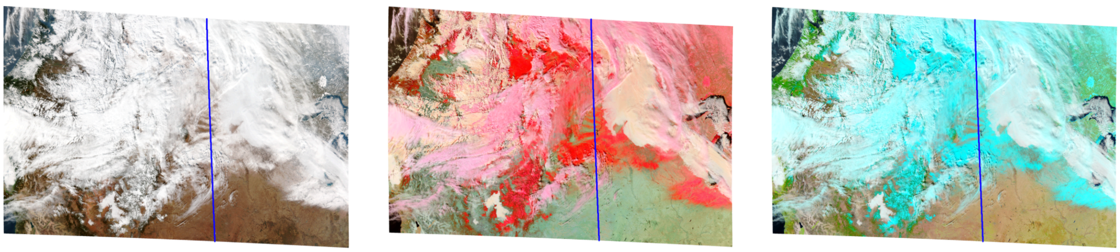


Figure 10. From left to right: True color, snow/ice composite, natural color. Blue line is CALIPSO ground track.

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

Publications and Conference Reports

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

4.5 ABI Cloud Products

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

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.

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; 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 both GOES-R and Himawari-8, which both contain ABI or ABI-like instruments.

Validation of the current and updated algorithms is important to making sure 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 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 11 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.

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 the 2015, the Cloud AWG will continue 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 will evaluate both the baseline and update algorithms using 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.

References

Monette, Sarah A.; Velden, C. S.; Heidinger, A. K.; Zipser, E. J.; Cecil, D. J.; Black, P. G. and Braun, S. A.. Validation of Automated Cloud Height Algorithm (ACHA) cloud top heights in tropical cyclones using observations from the NASA Global Hawk. Boston, MA, American Meteorological Society, 2014, abstract only.

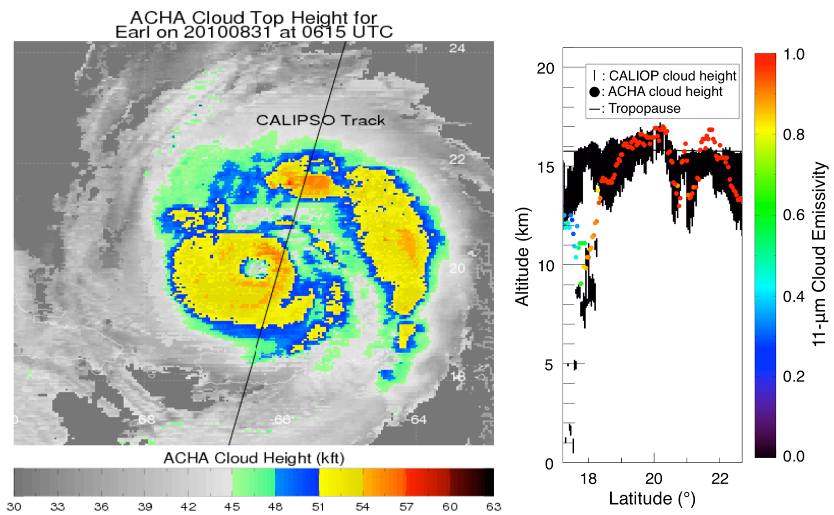


Figure 11. Post hurricane analysis of category 4 Hurricane Earl comparing ACHA cloud heights with CALIPSO. ACHA cloud heights match CALIPSO well in the convective eyewall and outer band.

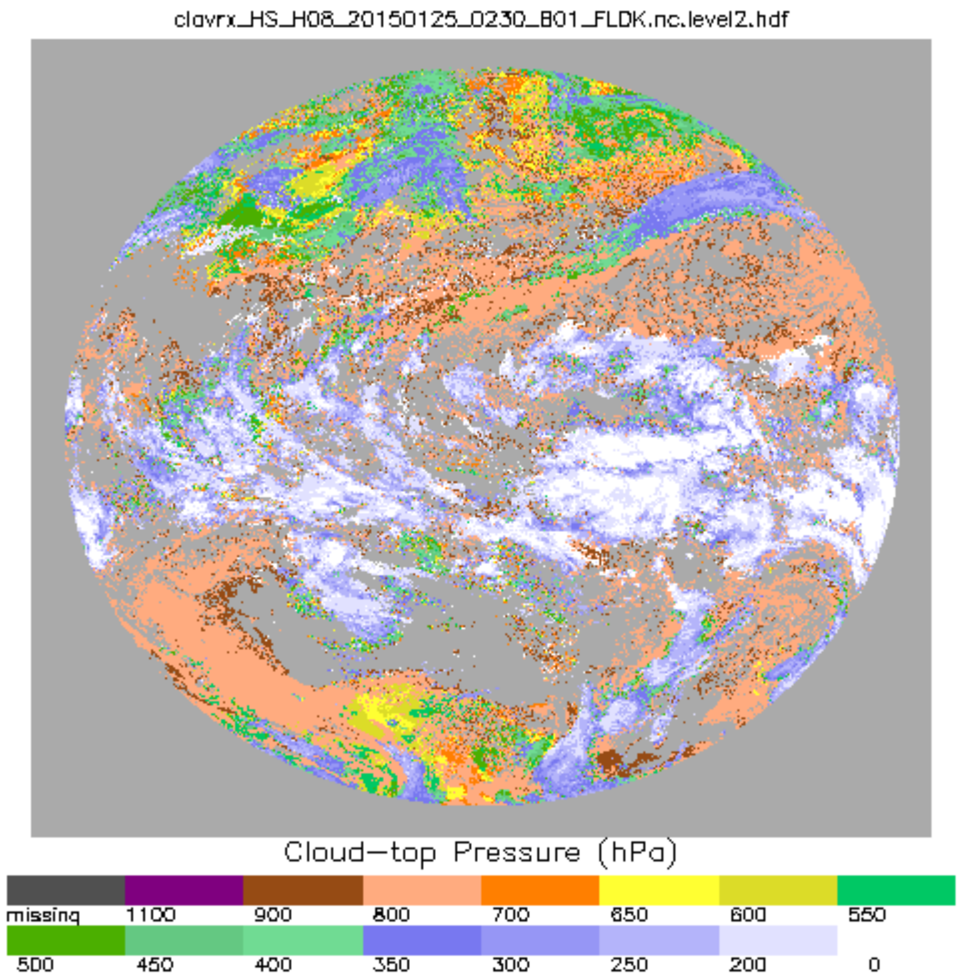


Figure 12. Example ACHA cloud top pressure product derived from Himawari 8 AHI observations.

4.6 Active Fire/Hot Spot Characterization

CIMSS Task Leader: Chris Schmidt

CIMSS Support Scientists: Jay Hoffman, Elaine Prins (UW–Madison/CIMSS-Contractor)

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

Fire detection and characterization with the current generation of GOES takes advantage of bands that were included on the GOES-8 through -15 Imager for other purposes. Effective fire detection and characterization was a consideration during ABI's design, and CIMSS was involved in developing the specifications for the 4 and 11 μm bands. This meant having a sufficiently high 4 and 11 μm saturation temperatures for the footprint, low noise equivalent detector radiance (NEDR), good co-registration between the 4 and 11 μm bands, and a good understanding of the bands' point spread function (PSF). CIMSS adapted the current GOES Wildfire Automated Biomass Burning Algorithm (WFABBA), building on its historical and current expertise in fire algorithm development for the GOES Imager and the global geostationary fire observation network. The Fire Detection and Characterization Algorithm (FDCA) utilizes the improved fire monitoring capabilities on GOES-R and contains updates to the modules that identify and characterize sub-pixel fire activity. For this year, the work on the FDCA focused on providing continued support to the implementation team at the AIT and Ground Segment Contractor as well as refinement of the validation software and preparation for using AHI on Himawari-8 as a proxy for ABI. Additionally, outreach was expanded to the broadcast meteorology community.

Summary of Accomplishments and Findings

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 will primarily be a manual process as the high resolution data matchups will be 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; Google Earth will be primary tool as it 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. The infrastructure for this process is largely complete.

Himawari-8 carrying AHI has been launched. Data is available but the Geocat software that runs the CIMSS implementation of the FDCA was not ready during this reporting period. Visual inspection of AHI images was conducted to assess instrument performance. JPEGs of the bands from an early AHI image were made available to the team in December and it was found that fires had "ringing" artifacts. This is almost certainly due to the remapping algorithm. Figure 13 shows an example from Eastern China, fires are dark and the "ringing" is visible as lighter pixels on either side of the fire pixels. Later example images did not seem to contain the "ringing", however further assessment is needed of a number example images. Such ringing has been commonly seen with data from Korea's COMS, which also remaps its data to a perfect geostationary projection, as AHI does and ABI will. Issues with remapping and its impact on fire detection and characterization were identified very early in the GOES-R ABI development process. Remapping modifies the radiances, which alters the determination of fire characteristics.

Outreach for the FDCA (and WFABBA) was extended to the broadcast meteorology community in 2014. CIMSS presented the science behind the algorithm and sample outputs, including 1 minute data, at the 42nd Conference on Broadcast Meteorology in June. That presentation and a presentation on GOES-R's products led to an invitation to do a GOES-R short course at the 43rd Conference on Broadcast Meteorology in Raleigh, NC in June 2015. The team received invaluable feedback on how to best present satellite fire data to garner the interest of the broadcast community. 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.

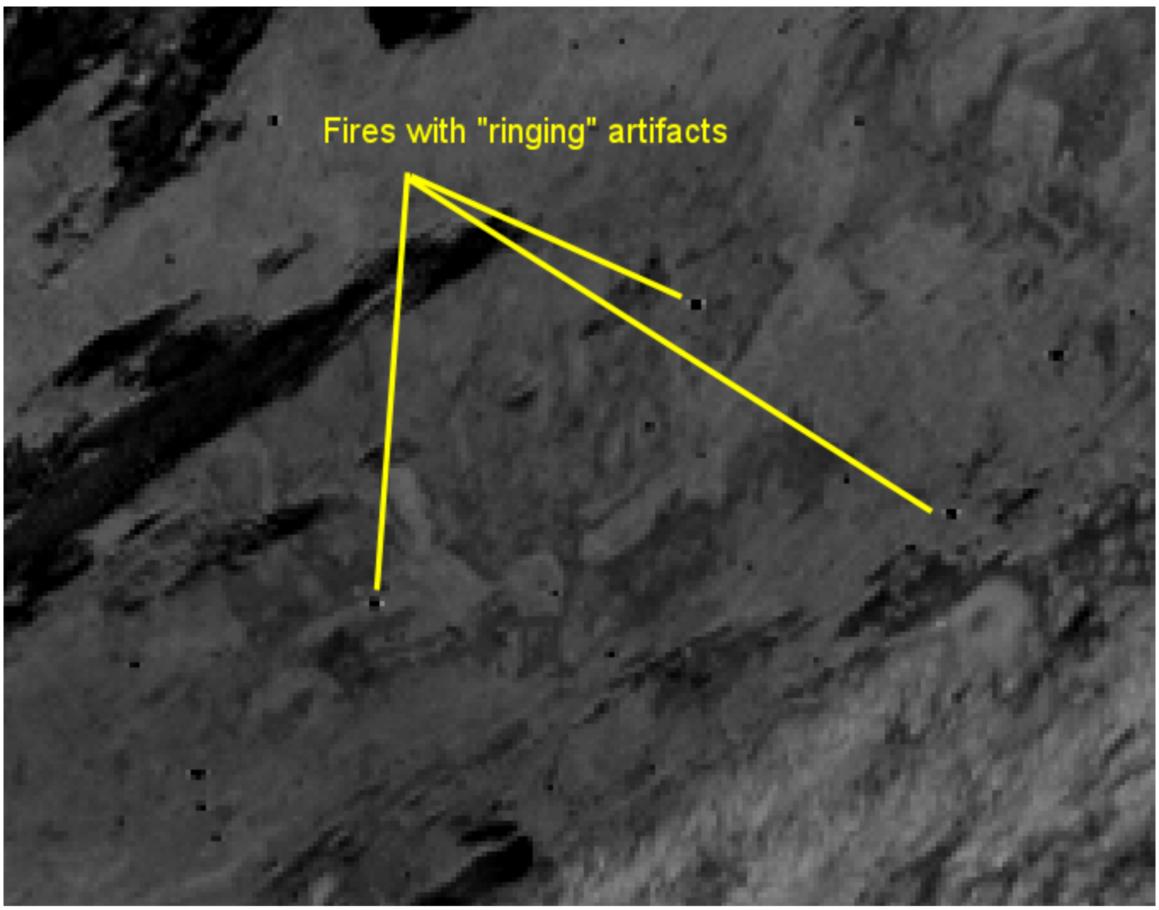


Figure 13. Early Himarwari-8 AHI image from Eastern China, December 2014. Fires are dark pixels against the lighter background. "Ringing" is visible as lighter pixels on either side of the fire pixels, some of which are highlighted. This data was preliminary data posted to JMA's website, later imagery did not show such pronounced artifacts.

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

CIMSS Task Leader: Jun Li
CIMSS Support Scientists: Zhenglong Li, Jim Nelson, Yong-Keun Lee, Richard Dworak, Jinlong Li
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

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.

Summary of Accomplishments and Findings

Summary of FY 2014 accomplishments and findings include:

- The GOES-R LAP algorithm for GOES-15 Sounder has been implemented in CIMSS GEOCAT for real time LAP product generation;
- The GOES-15 Sounder real time LAP products from GEOCAT have been converted to AREA format that GOES-R proving ground (PG) uses;
- Initial evaluation on GOES Sounder LAP products from CIMSS GEOCAT shows better accuracy for TPW than the GOES Sounder from McIDAS. McIDAS processing uses the NOAA current operational GOES sounding algorithm while GEOCAT processing uses GOES-R LAP algorithm;
- RAP surface analysis has been integrated into GOES-15 Sounder real time processing in GEOCAT;
- Near real time (NRT) online validation tool is being developed for GOES-15 Sounder LAP product monitoring and validation at CIMSS;
- GOES-R LAP algorithm has been applied to AHI; and
- Harris/AER were assisted in solving issues found in the LAP operational software.

Real Time GOES-15 LAP with GOES-R Algorithm from GEOCAT

During the past year CIMSS sounding team worked on GOES Sounder real time processing with GOES-R legacy atmospheric profile (LAP) algorithm in CIMSS GEOCAT frame. The goals are to (a) develop a research testbed in GEOCAT to generate real time GOES Sounder LAP product with GOES-R LAP algorithm for Proving Ground (PG) related GOES-R demonstrations and applications; (b) to serve as pre-launch validation for GOES-R LAP algorithm with GOES Sounder radiance measurements; (c) to prepare for post-launch validation for GOES-R LAP product and improve/refine the GOES-R LAP algorithm. The ultimate goal is to replace the McIDAS GOES Sounder real time processing with GEOCAT GOES Sounder (and GOES-R ABI) real time processing at CIMSS for GOES-R LAP validation and applications. The GEOCAT GOES Sounder real time processing involves in the following procedures:

1. GOES Sounder cloud detection in GEOCAT;
2. GOES Sounder real time LAP product generation with GOES-R LAP algorithm;
3. Ingesting NWP and surface T/q observations in GEOCAT GOES sounding processing;
4. Evaluation of GEOCAT GOES Sounder LAP product together with McIDAS GOES Sounder retrievals and NOAA operational GOES Sounder product, using RAOBs as references; and
5. Collaboration with GOES-R PG and HWT (hazards weather testbed) team on using the real time GEOCAT GOES Sounder products with GOES-R LAP algorithm.

Two algorithms are involved in our AWG validation activities: the GOES-R LAP algorithm is able to process SEVIRI, simulated ABI, the current GOES Sounder, MODIS and AHI for LAP product generation, another algorithm is Li-algorithm which has been used by NOAA to generate the operational GOES Sounder product since February 2013 and also used for McIDAS real time GOES Sounder product generation at CIMSS. The GOES-R LAP algorithm has some advantages over the Li-algorithm (Lee et al., 2014).

Currently the step (1) uses GOES-R AWG cloud mask algorithm from cloud team, steps (2) and (3) are finished, and steps (4) and (5) are ongoing.

Routine Evaluation of GEOCAT GOES Sounder Near Real Time (NRT) LAP Products

CIMSS sounding team has started GEOCAT GOES Sounder retrieval validation with RAOB data, GEOCAT GOES Sounder product will be achieved, McIDAS GOES Sounder product has been achieved routinely, the RAOB data is from conventional raob sites available at http://www.esrl.noaa.gov/raobs/. RAOB will be interpolated into retrieval levels – the 101 vertical pressure levels. Currently, for McIDAS-X GOES retrievals, we use the mandatory/significant-level RAOB data from the SSEC Data Center, and then run a program that combines these 2 data sources and produces an output McIDAS MD file. We then use the RAOB data from the new McIDAS MD file to verify the GOES retrievals. For evaluating the GEOCAT GOES Sounder product, we use the RAOBs from ESRL and interpolated to 101 vertical pressure levels. At this moment, only GOES-15 Sounder is processed at GEOCAT, but GOES-13 Sounder will be also running in GEOCAT in NRT in April 2015. The validation tool is being implemented into a web-based tool for GOES-R PLT/PLPT. The online validation tool is being tested with GOES-13/15 Sounder LAP products (using GOES-R LAP algorithm) generated in NRT from CIMSS GEOCAT, along with the NOAA operational GOES-13/15 Sounder products, and can be applied to GOES-R ABI LAP products later. The capabilities include NRT monitoring of GOES/GOES-R LAP products and comparisons with ARM site in-situ measurements, conventional RAOBs over CONUS, GPS TPW over CONUS, GFS products, and AMSR2 TPW over ocean, as well as deep dive tool. The deep dive capability can provide the detailed atmospheric status for a specific case at users' convenience.

GEOCAT LAP Versus McIDAS LAP

The GOES Sounder LAP products from GEOCAT and McIDAS are compared using in-situ measurements as references. GEOCAT LAP is from GOES-R algorithm while McIDAS LAP is from the current operational GOES sounding algorithm. Both algorithm are developed at CIMSS and are well documented. Taking TPW as example, Figure 14 shows the TPW comparisons between GEOCAT (left panel) and McIDAS (right panel) using GPS_Met TPW as reference. It can be seen that both bias and RMSE are smaller in GEOCAT than in McIDAS. The bias and RMSE differences are attributed to the algorithm difference, however, are also attributed to the difference data processing in the two systems, see below for more detailed analysis and investigation.

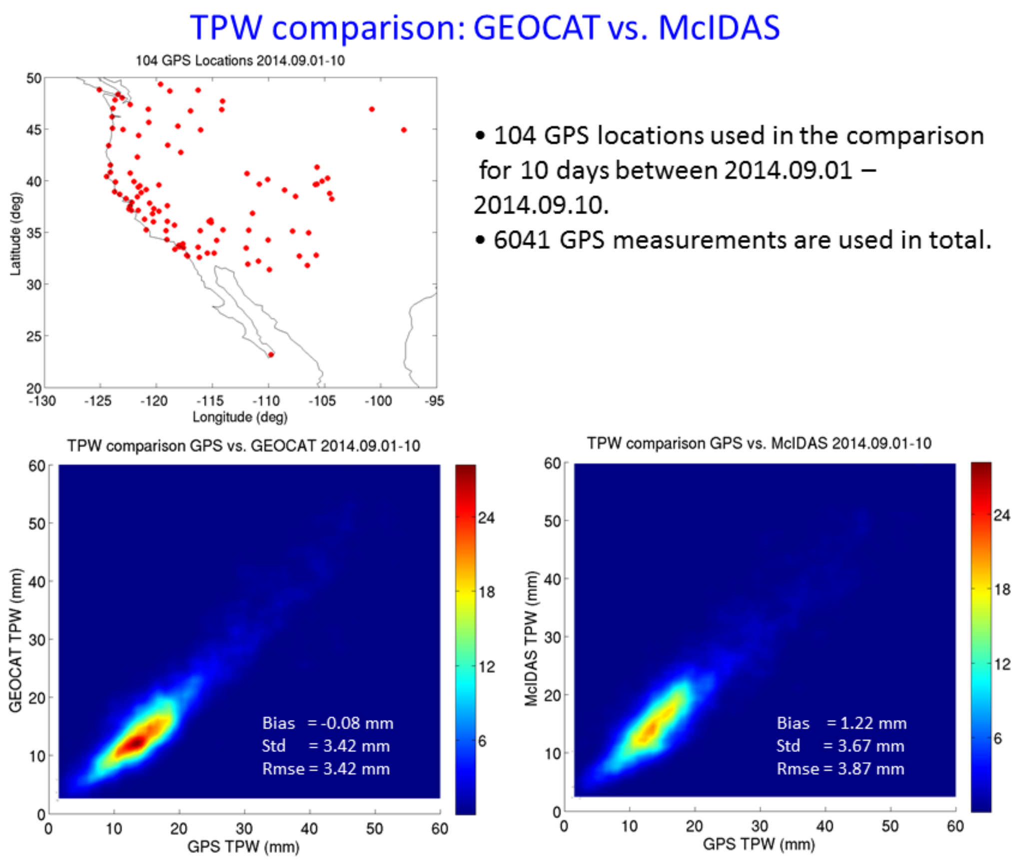


Figure 14. The TPW comparisons between GEOCAT (left panel, GOES-R LAP algorithm) and McIDAS (right panel, operational GOES sounding algorithm) using GPS_Met TPW as reference.

Initial comparison between GEOCAT GOES Sounder LAP product and McIDAS GOES Sounder product shows some difference. After detailed investigation, it was found that the difference was caused by handling surface observation and NWP vertical interpolation in the process. Routine comparisons among the GEOCAT Sounder LAP (with GOES-R algorithm), McIDAS real time product and NOAA operational GOES Sounder product have been started.

The GOES-15 Sounder has been running in real time at GEOCAT with GOES-R ABI LAP algorithm, the GOES-R AWG cloud mask algorithm (daytime) has also been implemented in GEOCAT for GOES Sounder LAP processing. GOES-13 Sounder will also be included in

GEOCAT real time processing in April 2015. Therefore real time sounding products from both GOES East and GOES West with GOES-R LAP algorithm will be available in April 2015 for PG and HWT applications.

For comparisons between GEOCAT (GOES-R algorithm) and McIDAS (operational GOES Sounder algorithm), the spatial (vertical and horizontal) interpolation coding in McIDAS and GEOCAT were confirmed to be very similar or the same except the surface area below 850 hPa and the higher atmosphere above 10 hPa. The current procedure to generate NWP input profile for the sounding retrieval in GEOCAT is fine except the surface area. The NWP input difference near the surface has been resolved by using RAP data instead GFS in GEOCAT for practical reason.

Evaluation of GOES-R LAP Algorithm with DART and LAPS Assimilation Systems

In addition, in order to further evaluate the GOES-R LAP algorithm, the MODIS TWP research product derived with GOES-R ABI LAP algorithm has been generated and provided to NCAR for assimilation study with WRF/DART, GOES Sounder TPW and LPW research products with GOES-R LAP algorithm have also been generated and provided to ESRL for assimilation experiments in regional NWP models.

CIMSS AWG sounding team have transferred GOES-R algorithm to process MODIS, it has been demonstrated that MODIS TPW has significant improvement over the science product (see our 2013 annual report). The algorithm has been part of the IMAPP for regional MODIS product generation. A manuscript on MODIS is being prepared for publication. The evaluation of MODIS product using the GOES-R retrieval algorithm will be based on the comparison with TPW measurements from microwave radiometer (MWR), GPS over the globe for a year between July 2012 and June 2013. On the other hand MODIS TPW product with GOES-R LAP algorithm has been reprocessed for a tropical cyclone (TC) case (Sinlaku, 2008) over period between September 1 and 14 in 2008, and TPW data are provided to NCAR for assimilation study and evaluation. The area of a TC case covers -5° and 55° in latitude and 90° and 150° E in latitude as shown in Figure 15. Impact of MODIS TPW with GOES-R algorithm has been reported positive from DART.

CIMSS sounding team are also collaborating ESRL on assimilating GOES Sounder moisture products. GOES Sounder radiances, TPW and LPW have been processed and provided to ESRL LAPS team for assimilation analysis, impact results are also expected from LAPS in near future.

GOES-R LAP Algorithm for H-8/AHI

GOES-R LAP algorithm has been applied to the simulated AHI with both PFAAST and CRTM (e.g., use PFAAST to simulate AHI while use CRTM for LAP retrieval from AHI), the GOES-R LAP algorithm is ready for testing real AHI data.

Assist Harris/AER on LAP Software

Some issues such as lat/lon location, pixel index etc. from Harris/AER on software have been solved through efforts of CIMSS LAP team and STAR AIT.

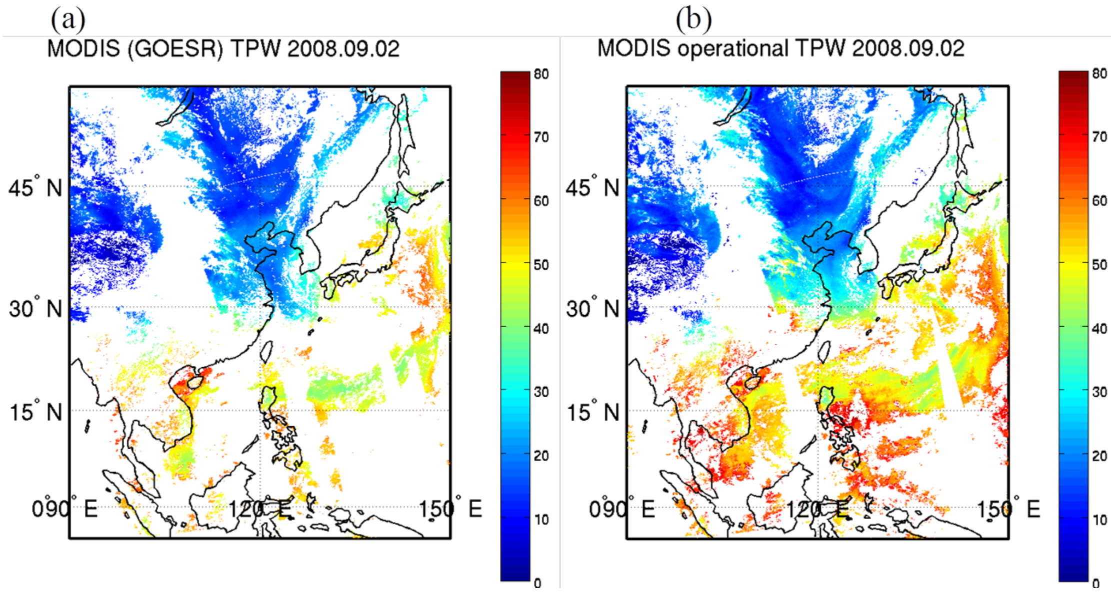


Figure 15. (a) Sample of MODIS TPW with GOES-R ABI LAP algorithm for a tropical cyclone (TC) case, Sinlaku 2008. (b) Corresponding NASA MODIS science TPW product.

Publications and Conference Reports

Lee, Yong-Keun, Zhenglong Li, Jun Li, and, Timothy J. Schmit, 2014: Evaluation of the GOES-R ABI LAP retrieval algorithm using GOES-13 Sounder, Journal of Atmospheric and Oceanic Technology, 31, 3- 19.

Lee, Yong-Keun, Z. Li, E. Borbas, J. Li, and T. J. Schmit, 2015: Validation of GOES-R LAP algorithm with MODIS measurements, 2015 Annual Meeting, 4-8 January 2015, Phoenix, AZ, USA.

4.8 ABI Derived Motion Winds
CIMSS Task Leaders: Chris Velden and Steve Wanzong
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 atmospheric motion vector (AMV) derivation algorithms and using them in demonstration studies. The AMV algorithm development has reached a mature stage and the project is now in a validation mode. The software is being tested in a near real-time demonstration mode using Meteosat-10 SEVIRI data as ABI proxy imagery,

with the resultant AMVs 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 AMV height assignment methodologies have become closely integrated with the developments by the AWG Cloud Team ACHA algorithm.

Summary of Accomplishments and Findings

During this reporting period, the focus of activities was on keeping the AWG cloud team software in sync with the AWG AMV team software. The ACHA software is developed in a different framework (CLAVRx) than the AMV software (GEOCAT), so it is necessary to modify bridge and services software within ACHA for the GEOCAT framework to correctly access the cloud products in the winds code. Testing and modifications to the AMV processing code, along with all validation activities, were dependent on this interaction.

In addition to the AMV code development support, the CIMSS team assisted in several calibration and validation activities. Experimental processing and resultant datasets were produced from Meteosat-SEVIRI and GOES rapid scans. Fine-tuning and optimization of the algorithm performance as well as comparisons with AMV datasets produced from the heritage AMV algorithm have occurred on many fronts involving weather events on several scales (hurricanes, severe weather, etc). Near the end of this reporting period, satellite data from Himawari-8 AHI was supplied to the AMV software.

Publications and Conference Reports

Daniels, J., W. Bresky, S. Wanzong, A. Bailey, C. Velden, and A. Allegrino, 2015: NESDIS' Atmospheric Motion Vector (AMV) nested tracking algorithm: Exploring its performance. Satellite Meteor. and Ocean. Conf., Phoenix, AZ., American Meteorological Society, MA.
Santek, D., C. Velden, I. Genkova, D. Stettner, S. Wanzong, S. Nebuda, and J. Garcia-Pereda, 2014: A new atmospheric motion vector intercomparison study. 12th Inter. Winds Workshop, Copenhagen, Denmark, University of Copenhagen.

4.9 ABI Hurricane Intensity Estimation (HIE)
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 automated tropical cyclone (TC) intensity estimates using the GOES-R Advanced Baseline Imager (ABI) infrared imagery. The ADT was selected due to its longstanding use at several operational TC centers worldwide, and because of its proven record for accuracy and reliability in providing objective TC intensity estimates, especially when aircraft reconnaissance is not available.

Summary of Accomplishments and Findings

During this reporting period, CIMSS scientists continued to support the development of the HIE algorithm into operational code by Harris/AER programmers within their system through documentation review and answering questions raised by code developers and document writers. Questions ranged from those related to simple clarification of what specific variables were used for and what various sections of code performed in the HIE intensity derivation process, to identification of potential logic changes. In addition, clarification of the related sections of the HIE Algorithm Description Document (ADD), based upon the HIE Advanced Theoretical Basis Document delivered previously by CIMSS scientists, were provided to AER/Harris, as necessary. The ATBD was also updated to reflect the ADD modifications and continues to be updated as new questions and clarifications are requested by and provided to AER/Harris programmers.

CIMSS also supported the HIE demonstration in the NHC Proving Ground activities during the Atlantic hurricane season. A version of the ADT was operated on 15-min. Meteosat SEVIRI imagery during eastern Atlantic events as a proxy to GOES-R, and to mimic what the HIE will provide when GOES-R becomes available in 2016. A similar demo is being planned for the upcoming typhoon season in the western Pacific using the new Himawari-8 data.

Publications and Conference Reports

Olander, T. and C. Velden, 2014: New features and capabilities of the Advanced Dvorak Technique. *31st AMS Hurricanes and Tropical Meteorology Conference*, San Diego, CA, March 31-April 4.

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
- Environmental Models and Data Assimilation

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.

Summary of Accomplishments and Findings

We have continued to, when requested, participate in Technical Interchange Meetings and AERs with the ground segment to resolve questions related to the implementation of the GOES-R Volcanic ash algorithm into the GOES-R Ground System.

Additionally, we have continued to monitor the accuracy of the GOES-R volcanic ash cloud heights vs. space-borne lidar (CALIPSO) observations of volcanic clouds over the past year. These analyses continue to indicate the GOES-R algorithm accuracy is well within GOES-R requirements.

Publications and Conference Reports

Pavolonis, M.J., A.K. Heidinger, and J.M. Sieglaff, 2013: Automated retrievals of volcanic ash and dust cloud properties from upwelling infrared measurements. *J. Geophys. Res.*, **118**, 1436-1458.

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, Tom Rink
NOAA Collaborator: Timothy J. 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. The team also wrote the ATBD covering how to convert between counts and radiance, radiance and physical units (brightness temperature or reflectance factor), and how to generate brightness values to be displayed. Now in the validation phase, the next steps are to develop better methods by which ABI imagery will be quality controlled. Past efforts have primarily been theoretical approaches to data validation and now the project will move into practical applications of validation, 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. This free software is available to any scientist, researcher, or educator to analyze, visualize and synthesize with other data, including past and current GOES, common meteorological in-situ observations, model forecast and reanalysis.

McIDAS-V is the fifth generation of McIDAS (the Man-computer Interactive Data Access System), and is a Java-based, open-source, freely available system. The software tool provides a powerful data manipulation and visualization environment to work with a large variety of geophysical data. McIDAS-V contains a flexible, extendable framework for integrating geophysical data into a very interactive 4D visualization and computation environment. This new functionality builds upon 40 years of McIDAS work and 10+ years of VisAD/IDV development. While this project is not the only funding source for McIDAS-V development, many improvements were made to McIDAS-V to meet the needs of the GOES-R Program.

Summary of Accomplishments and Findings

FY14 work is summarized as follows:

- 137W "triplet" datasets delivered
  - Reprocessed, validated, and delivered the 137W PSC simulations containing 7 time periods, all 16 ABI bands and all domains (FD,CONUS and MESO) to the AIT: ftp://ftp.ssec.wisc.edu/ABI/kaba/sim-abi/fgf/GRB/
- GOES-R CONUS domain definition
  - Prepared images containing approximate pixel sizes based on 2km ABI IR band resolution which demonstrated the effect of view angle on resolution.
  - New center points for the CONUS sectors from both West and East satellites were proposed. These proposed sectors take advantage of better view angles inherent in the east and west views. The GOES-West CONUS would be shifted far enough west to include Hawaii. The GOES-East CONUS would be shifted just slightly east to better include Puerto Rico. Images were generated demonstrating the proposed new CONUS sectors.
  - The National Weather Service Operational Advisory Team (NOAT) agreed with this proposal over the original PUG plans.
  - Delivered new CONUS scan files and images to AIT.
    - CONUS files with the new center points from both West and East.
  - Generated new CONUS domain images out of the full disk WRF simulations for one time period and all 16 bands. This was done for both the 75W and 137W simulations. This was done to help the user community better understand spatial gains possible by modifying the CONUS domain for ABI.
- Generated new 89.5W CONUS GRB and VAL files for all 16 ABI bands with 7 time periods each.

- McIDAS-V Improvements / Scripting progress
  - Working toward supporting the latest PUG geolocation file metadata.
  - Verified that Overshooting Tops ASCII product could be displayed in McIDAS-V
    - This is in use with multiple users in Europe.
  - Better integrated support for ABI FGF navigation.
  - Internal validation of new CONUS netCDF files for GOES-West (137-W).
    - Images of 16 bands for 22UTC generated with McIDAS-V scripts.
  - Fixed McIDAS-V problem with above datasets so that all resolutions can be visualized.
  - Integrated the GOES-R Fixed-Grid-Format projection into the community Java-netCDF package under the now accepted 'Geostationary' CF standard specification.
  - Image renderer problem for very large images (tiling problem now passed tests).
  - Reorganizing to make the fixed grid generation code easier to use for arbitrary sub-points.
  - Sandwich Product image generated in McIDAS-V featuring a double enhanced-V and overshooting tops.
    - Created with Suomi NPP Visible and IR Data.
    - Overshooting top detection derived from GOES-14 SRSOR 1-minute data was combined with the sandwich product during a period of convection on 2014-05-08.
    - The sandwich product is a combination of the visible channel fused with a semi-transparent IR channel layer. The sandwich product is an excellent tool for analyzing developing storm systems because it retains the visual texture while simultaneously displaying the IR temperature field which captures cold cloud tops and enhanced-v features indicative of severe convection.
  - McIDAS-V scripts generated for creating multiple images and image types.
- Imagery Validation
  - Data quality warnings for current GOES being developed.
    - Still researching statistical criteria that reveal bad data based on previous images.
  - Jython script using McIDAS-V libraries to pinpoint stray light affected images.
- Assisted DOST to validate the ABI data being generated for end-to-end system validation.
  - There were navigation issues diagnosed.
- Participation in the NWA 39TH Annual meeting in Salt Lake City Utah, October 18th-23rd, 2014.
  - CIMSS/SSEC had a booth and demonstrated products in AWIPS-II, including simulated ABI datasets, and GOES-R related materials to the National Weather Service personnel and other attendees.
- Participation in the AMS 2015 Annual Meeting (Phoenix, AZ)
  - "Preparing Users for the Advanced Baseline Imager (ABI) on GOES-R" by Timothy J. Schmit, M. Gunshor, K. Bah, J. Gerth, B. Pierce, and S.J. Goodman (oral)
- Investigating DOE-0 output files
  - Providing feedback on file content.
  - Comparing files to PUG and providing feedback on PUG.

- Glance statistical analysis of many of the files here: http://www.ssec.wisc.edu/grafiir/ABI_DOE/
- Generating Imagery in McIDAS-V, both interactively and via script.

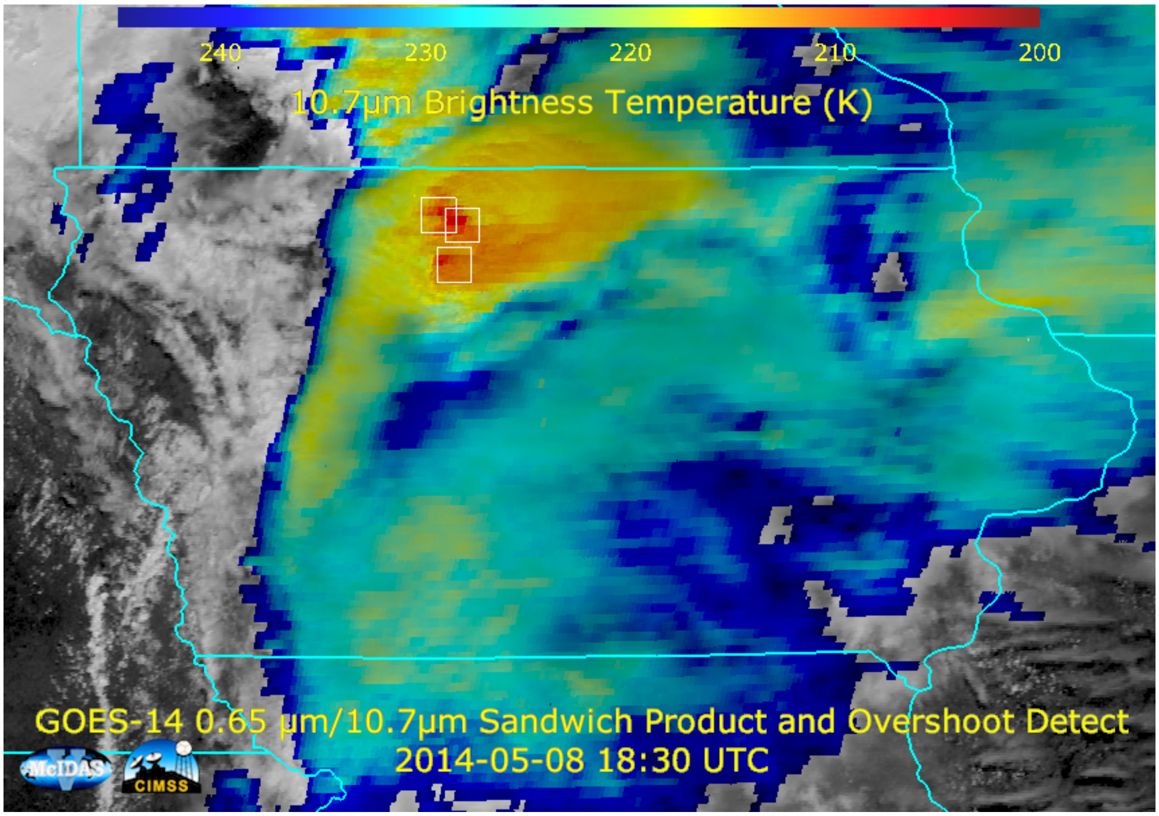


Figure 16. GOES-14 Sandwich Product with Overshooting Tops (OT) for 08 May 2014, 18:30 UTC. The 0.65 micrometer visible data are shown with the IR Window brightness temperatures overlain with transparency. This visualization allows the user to see the high spatial resolution visible data "through" the IR brightness temperatures, giving the IR data more texture so that high resolution features apparent at the tops of storms are visible with temperature data. This case features an enhanced-V signature that produced severe weather and OT detection boxes are shown as well.

Publications and Conference Reports

Participation in the AMS 2015 Annual Meeting (Phoenix, AZ, January 2015). "Preparing Users for the Advanced Baseline Imager (ABI) on GOES-R" by Timothy J. Schmit, M. Gunshor, K. Bah, J. Gerth, B. Pierce, and S.J. Goodman (oral).

Schmit, Timothy J.; Goodman, Steven J.; Lindsey, Daniel T.; Rabin, Robert M.; Bedka, Kristopher M.; Gunshor, Mathew M.; Cintineo, John L.; Velden, Christopher S.; Bachmeier, A. Scott; Lindstrom, Scott S. and Schmidt, Christopher C.. Geostationary Operational Environmental Satellite (GOES)-14 super rapid scan operations to prepare for GOES-R. Journal of Applied Remote Sensing, Volume: 7, Issue: 1, 2013, doi:10.1117/1.JRS.7.073462.

4.12 Estimation of Fractional Snow Cover with ABI

CIMSS Task Leaders: Xuanji Wang, Yinghui Liu
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.

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 was 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 project is for obtaining, evaluating, and implementing the fractional snow cover software, and expanding the validation activities.

Summary of Accomplishments and Findings

We have continued 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 Himawari-8 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.

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. Future work includes routine runs on more test data on MODIS, SEVERI, and possibly AVHRR and JMA's H-8/AHI data when available. A website will be created to present the results. 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.

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 2014

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
- Environmental Models and Data Assimilation

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).

Summary of Accomplishments and Findings

During the reporting period, we have continued development of the NOAA/CIMSS Volcanic Cloud Monitoring Website (http://volcano.ssec.wisc.edu). The Washington and Anchorage VAACs have begun to receive a limited set of automated volcanic alerts via email in near real-time. The email serves as a quick-look at the alert information, as well as a link to the website, allowing a user the ability to further interrogate alert details and imagery. The website alert subscription allows users to customize their alert subscriptions by alert type, geographical region, VAAC region, and by satellite sensor. Figure 17 shows a website screenshot of alert text and imagery used by the Anchorage VAAC during the eruption of the Pavlof volcano in Alaska during June 2014. Additionally, algorithm logic was developed to prevent multiple alerts being sent to users for the same volcanic cloud. The feedback gathered from operational partners has lead to continued improvements to the alert content and website layout.

The Co-Is at New Mexico Tech determined there was no significant relationship between lightning observed by ground-based lightning detection array during the 2010 Eyjafjallajokull eruption and cloud growth rate or other volcanic properties. We have continued to work with Co-Is in the HYSPLIT group in working toward incorporating VOLCAT results into automated HYSPLIT model initialization.

Lastly, Mike Pavolonis presented the status of this work to members of NOAA Senior Leadership and Congress at NOAA Science Days in Washington D.C. in June 2014.

Publications and Conference Reports

Pavolonis, M. J., J. Sieglaff, and J. Cintineo (2014), Spectrally Enhanced Cloud Objects (SECO): A Generalized Framework for Automated Detection of Volcanic Ash and Dust Clouds using Passive Satellite Measurements, Part I: Multi-spectral Analysis, *J. Geophys. Res.* (in revision).

Pavolonis, M. J., J. Sieglaff, and J. Cintineo (2014), 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. (in revision).

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.

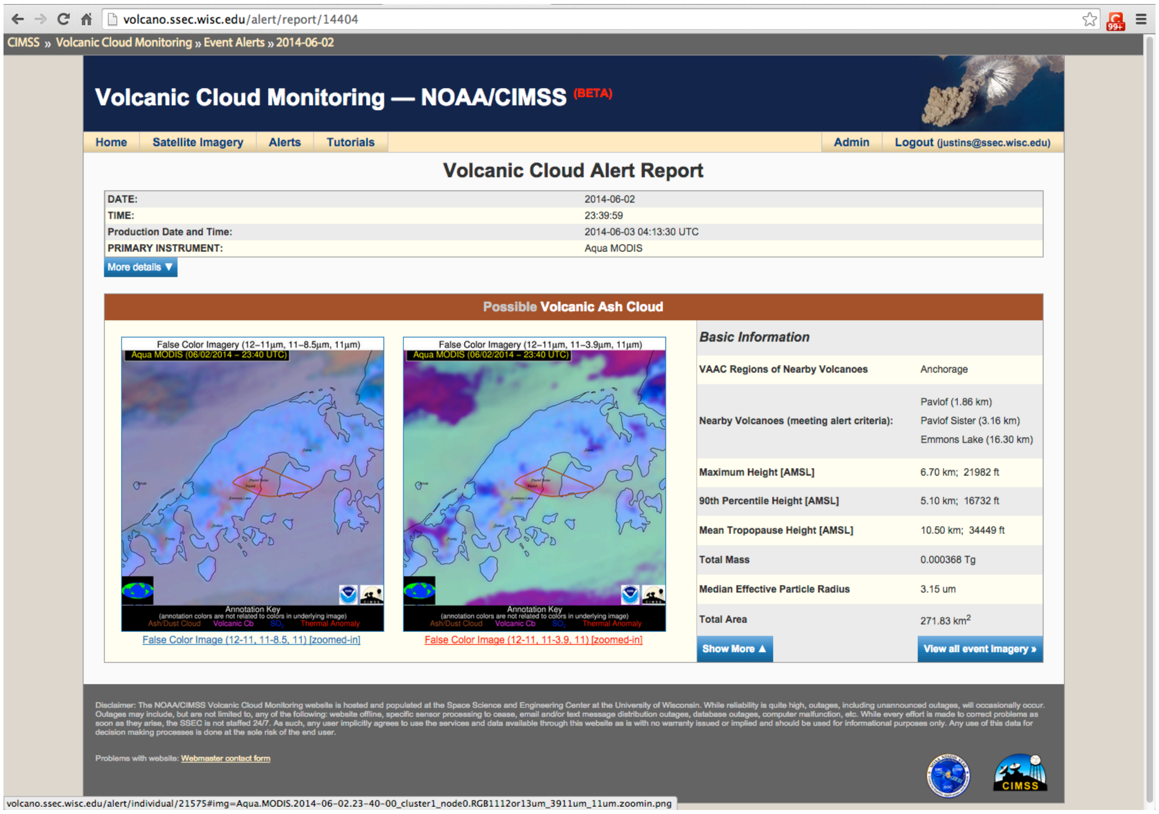


Figure 17. A website screen capture of a volcanic ash cloud alert for the June 2014 Pavlof eruption in Alaska. This alert was generated from observations taken from MODIS aboard the Aqua satellite. The Anchorage VAAC used the ash cloud spatial extent and ash cloud height information in real-time.

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.

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).

Summary of Accomplishments and Findings

The focus this year was on quantifying the hourly error characteristics of the various AMV types and running assimilation experiments. Results from these experiments show that the innovation errors (observation minus background) generally increased with longer forecast times even after all of the quality control procedures were used. This characteristic was true for all 4 AMV types. Generally, the three hour model forecast used for the three hours before synoptic time (T-3) innovations had the least error and increased through the assimilation window up through the eight hour model forecast, used for the 2 hours after synoptic time (T+2) innovations as shown in Figure 18. It was determined that this innovation error growth was due to the model forecast error growth and not due to a change of AMV quality within the assimilation window.

Assimilation experiments were then conducted to determine analysis and forecast impacts. The 2012 version of the NCEP GDAS/GFS was used for the assimilation system. All four of the GOES-R like AMVs types, derived each hour from SEVIRI, were assimilated during 1 November to 31 December 2013. All of the new GOES-R developed quality control procedures were used. The assimilation weights were modestly inflated to account for the increased number of AMVs.

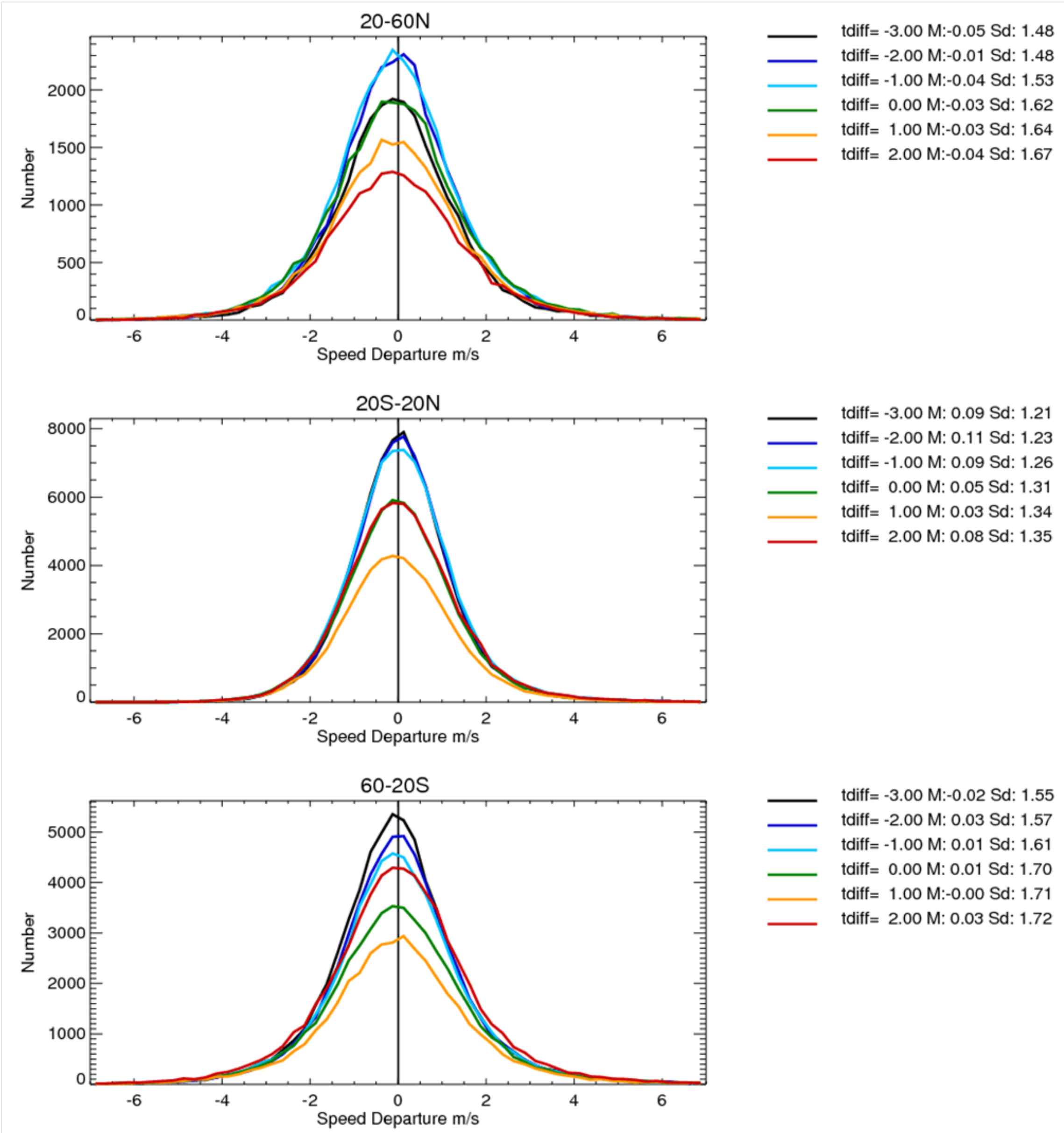


Figure 18. Speed innovations for the Northern Hemisphere (top), Tropics (middle), and Southern Hemisphere (bottom) for the 6 hour assimilation window derived from the Visible type AMVs. Mean (M) and standard deviation (Sd) are displayed on the right with respect to the difference from synoptic time (tdiff).

Assimilating the GOES-R like AMVs produced several interesting impacts on the model analysis/initialization wind fields. The seasonal Experiment minus Control differences for the U component (top) and V component (bottom) at 250 hPa are shown in Figure 19. The U component of wind was significantly increased in the tropics and Southern Hemisphere at upper levels of the troposphere. Large biases are also noted in the V component of wind in these same regions. These same biases are not found in the Northern Hemisphere suggesting the lack of rawinsonde and aircraft data in the Tropics and Southern Hemisphere may require more AMVs to correct the model forecast errors within these two regions.

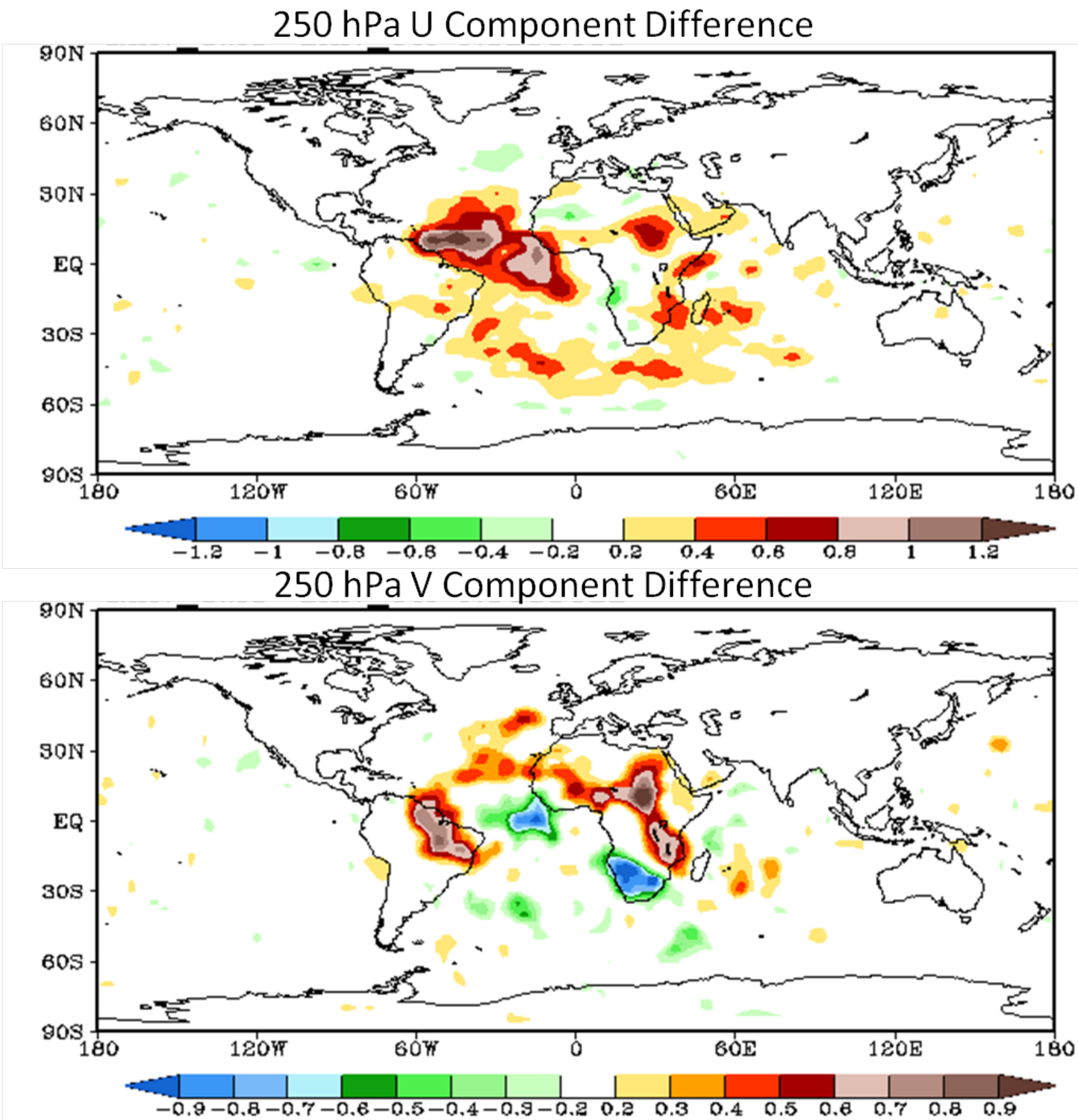


Figure 19. 1 October – 31 December 2013 average Experiment – Control analysis differences at 250 hPa for U-Component (top) and V-Component (bottom) of wind. Note: differences are mostly confined to the tropics and Southern Hemisphere within the Meteosat-10 footprint.

The visible, shortwave and low level infrared AMV types also produced an interesting feature in the low level jet centered along 60S (shown in the top panel of Figure 20). Adding these AMVs seems to have moved the Southern low level jet further north as illustrated by the increase/decrease couplet shown in the bottom panel of Figure 20 and suggests there is a model feature placement error. The similar low level jet in the Northern Hemisphere (60N) shows minimal differences. The lower levels in the Southern Hemisphere is a very data sparse region and there may not be enough observations in the current GDAS/GFS to adequately remove any model feature placement errors that exist.

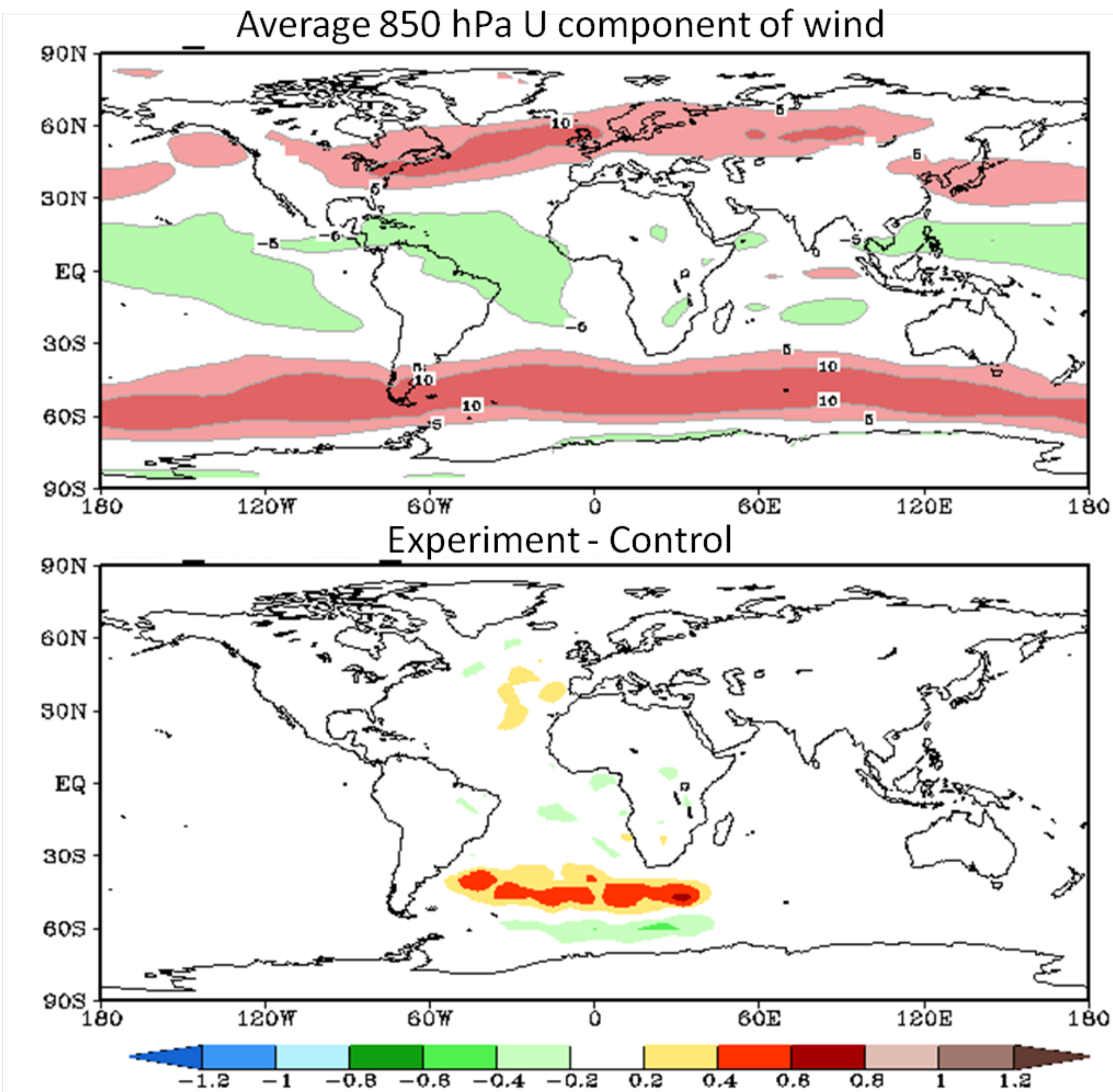


Figure 20. 1 October – 31 December 2013 average low level (850 hPa) U component of wind from the Control (top) and the difference between the Experiment and the Control (bottom). Adding the AMVs from SEVIRI shifted the Southern Hemisphere low level jet northward within the Meteosat-9 footprint but had little effect on the Northern Hemisphere low level jet.

Further investigation into the source of these model placement errors in the Tropics and Southern Hemisphere and how the various types of AMVs may improve the model initialization in these regions is needed.

Publications and Conference Reports

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. *Twelfth International Winds Workshop, Copenhagen, Denmark, 16-20, June 2014*.

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.

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.

Summary of Accomplishments and Findings

During 2014, 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 2014 NOAA HWT Spring Experiment. The accuracy of the synthetic brightness temperature datasets was evaluated through comparison with real GOES observations. The accuracy of the cloud microphysics schemes was also evaluated. In addition, a collaborative effort was initiated with scientists at the German Deutscher Wetterdienst to explore the impact of assimilating SEVIRI infrared brightness temperatures at convection-resolving resolutions using an ensemble Kalman filter (EnKF) data assimilation system.

Publications and Conference Reports

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.

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: Brad Pierce

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 have developed and focused on their own RGB products with future plans to coordinate 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 has focused 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) are 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.

Summary of Accomplishments and Findings

- Implemented CIMSS WRF-CHEM RGB Air Mass product within AWIPS II as grib2 files.
- Collaborated with NCEP to define and implement the new GOES-R grib2 parameter for discipline 3, category 192.
- Demonstrated contoured brightness temperatures overlay.
- Participated and presented our results at the joint CIMSS/CIRA/SPoRT VSP meeting at NOAA NCEP in College Park, MD (September 15-18, 2014).

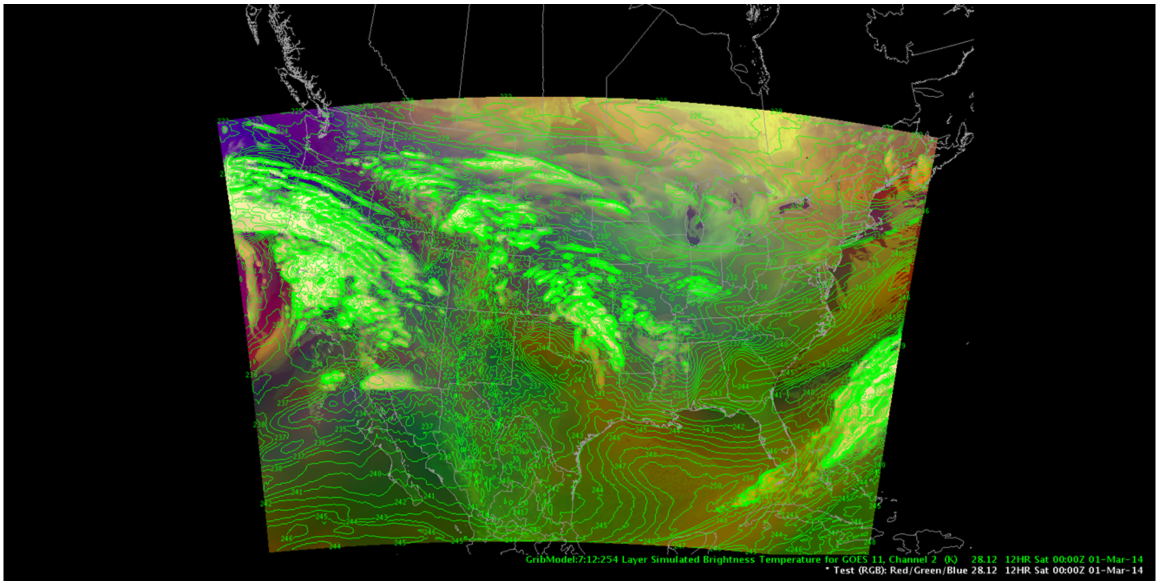


Figure 21. RGB Airmass product with brightness temperature contours overlay. Data are simulated GOES-R ABI.

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

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. 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 WFOs and other potential users so they can start working with the products, 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.

Summary of Accomplishments and Findings

Currently, the AWC, AAWU, and, at least, 27 NWS WFOs are utilizing the GOES-R FLS products in operations. We determined the best way to train a large amount of forecasters to properly interpret the GOES-R FLS products was to create a comprehensive training module. One important aspect of the training module was to use region-specific examples so forecasters working in different parts of the country would see how the products look on real cases pertinent to their geography. This was relevant because forecasters are more familiar looking at certain FLS events common to their specific forecast area and are therefore more comfortable seeing how new products can be useful when looking for and identifying areas impacted by those events. The training module was created as a PowerPoint presentation and also converted into a VISIT training module. The VISIT training module is available at:
http://rammb.cira.colostate.edu/training/visit/training_sessions/forecaster_training_for_the_goes-r_fog_low_stratus_products/
In the interest of keeping examples current, a running blog is also kept updated (usually several new entries per week) by Scott Lindstrom here at UW–Madison/CIMSS. This blog focuses on both common and uncommon FLS events from different geographic areas and shows in detail how the GOES-R FLS products can be used to identify hazardous areas of fog/low stratus in each. This blog can be found at: http://fusedfog.blogspot.com/.

Along with continuing the effort of training new users on using the FLS products we also started developing a method to up-scale the GOES spatial resolution using high-resolution Morphometric landform classifiers, such as "valleyness," and LEO satellites such as MODIS and VIIRS. The "valleyness" parameter is combined with the FLS products with the goal of utilizing high-resolution topography data to improve the ability of the GOES-R FLS products to resolve small-scale valley fog events. By combining GOES-R IFR probabilities with high-resolution topographic information, the low-resolution GOES-R FLS product can be up-scaled to the spatial resolution of the digital elevation model thereby greatly improving the spatial detail provided by the FLS products. In addition, data from LEO satellites are being used in concert with the morphometric landform metrics to further improve the Bayesian classifier via the *a priori* (See Figure 22 and
http://www.jpss.noaa.gov/science_seminars/Presentations/SSP24_JPSS_GOESR_FLS_Pavolonis_Dec12014_v2.pdf). The up-scaling procedure is still being developed, but shows great promise.

The up-scaled FLS probabilities will be used to develop a valley fog formation alerting capability.

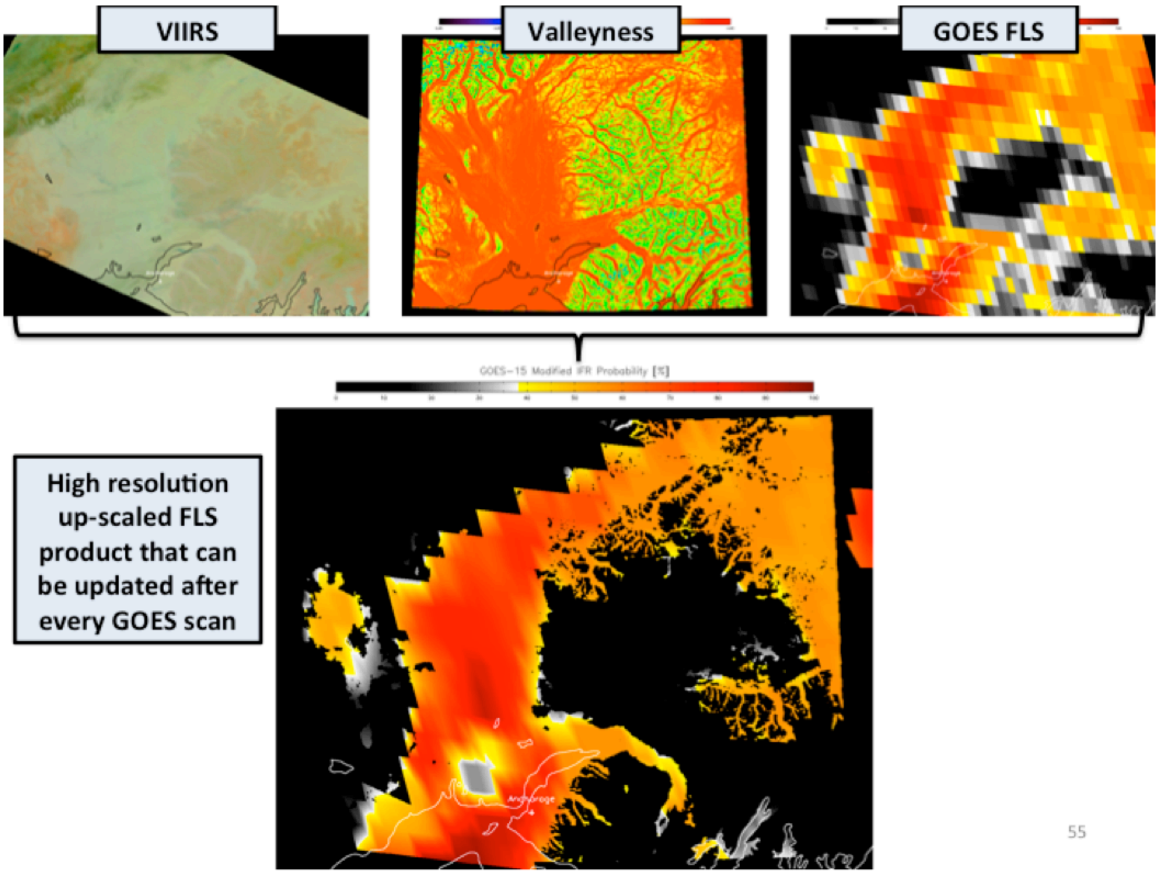


Figure 22. The end result of blending the GOES-West IFR probability product with VIIRS and the "valleyness" metric, which is derived from digital elevation model, is shown in the bottom figure for a scene near Anchorage, AK. The coarse resolution GOES-West IFR probability product is effectively up-scaled to the resolution of the VIIRS product. The information content of the VIIRS image is maintained for many GOES images through use of the digital elevation model and temporal consistency.

Publications and Conference Reports

Gultepe, I., B. Zhou, J. Millbrandt, A. Bott, Y. Li, A.J. Heymsfield, B. Ferrier, R. Ware, M. Pavolonis, T. Kuhn, J. Gurka, P. Liu, and J. Cermak, 2015: A review on ice fog: Measurements and modeling, *Atmospheric Research,* **151 (1)**, 2-19.

Gultepe, I., T. Kuhn, M.J. Pavolonis, C. Calvert, J. Gurka, A.J. Heymsfield, P.S.K Liu, B. Zhou, R. Ware, B. Ferrier, J. Milbrandt, B. Hansen, and B. Berstein, 2014: Ice fog in the Arctic during the FRAM-IF project: Aviation and nowcasting applications., *Bull. Amer. Meteor. Soc.*, doi: 10.1175/BAMS-D-11-00071.1

In addition, a journal article describing and evaluating the GOES-R FLS probability products is nearing completion and will be submitted shortly.

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. The TOT product has also participated in the Aviation Weather Center (AWC) Proving Ground, as the presence of overshoots is an indicator of potential aircraft turbulence (Bedka et al., 2010). Feedback from the Proving Grounds 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) field experiment for the past 3 Atlantic hurricane seasons. Feedback from the HS3 Operations Center was generally positive, with a request that the TOT heights (rather than temperatures) be estimated for better use with aircraft altitude data.

Summary of Accomplishments and Findings

Based on feedback from the NHC Proving Ground, adjustments were made to the TOT algorithm. One particular update was to reduce the identification of false "TOTs" in the striated cirrus bands around TCs. Another adjustment involved the detection of TOTs near the center of TCs where the presence of a cold, dense cirrus canopy or eyewall can make overshoot detection more difficult by reducing the brightness temperature difference between TOTs and their surrounding pixels. Both of these updates were implemented and applied to real-time TOT detection during the 2014 Atlantic hurricane season. An example of a modest increase in TOT detection near the center of Hurricane Gonzalo (2014) can be seen in Figure 23.

TOTs are currently expressed in temperature units, however feedback from HS3 and the AWC PG indicated that height units would be more practical for aviation applications. To address this, an equation to transform TOT and OT (hereafter referred to as overshoots) temperature to height was developed using numerical weather prediction (NWP) model output, collocated CloudSat Cloud Profiling Radar (CPR) cloud top heights, and overshoot IR brightness temperatures (BT):

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

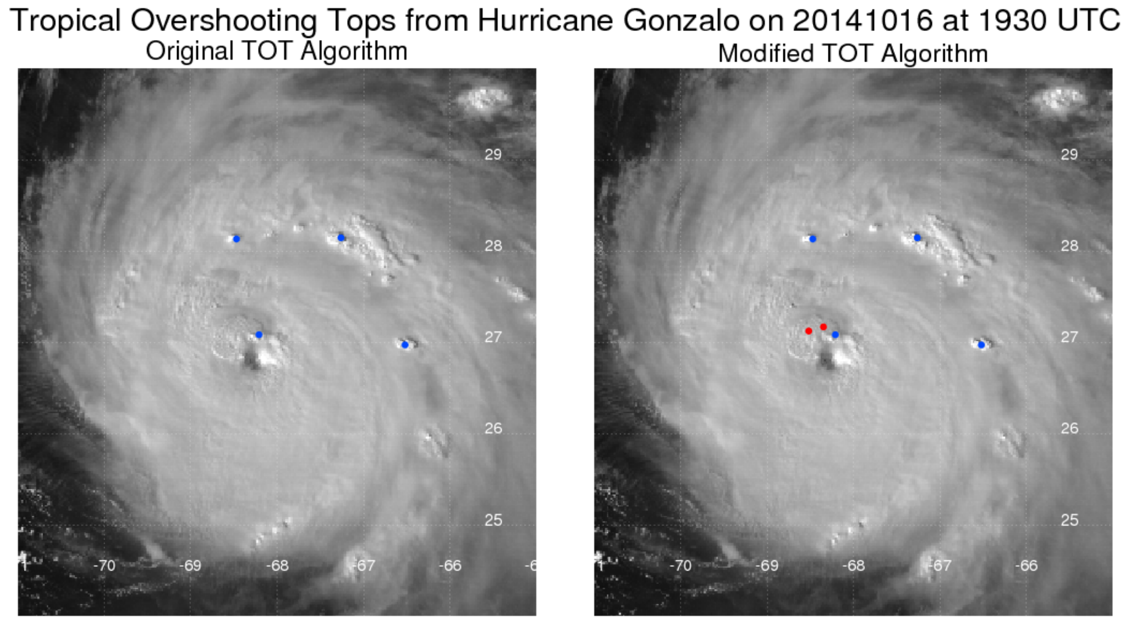


Figure 23. Detected TOTs (blue dots) from the original (left) and modified (right) TOT detection algorithm for Hurricane Gonzalo (2014). The two red TOTs on the right are only identified with the modified TOT algorithm, which is designed to increase identification of TOTs in the core of a tropical cyclone.

The overshoot anvil height is estimated by comparing the mean anvil BT to a collocated NWP model profile of temperature and height. The overshoot lapse rate is determined by the difference between the overshoot and mean anvil BT divided by the difference between collocated CPR overshoot height and overshoot anvil height. Using 107 TOTs derived from high-resolution MODIS IR imagery, we identified a median overshooting lapse rate of ~-7.3 K/km, which is employed in all subsequent comparisons below.

For validation, samples of TOT heights calculated using the equation above were compared with collocated CloudSat Cloud Profiling Radar (CPR) cloud top heights. A Monte Carlo approach revealed 50% (75%) of MODIS overshoot heights are within 250m below and 350 m above (400m below and 500 m above) the respective CPR heights. The heights of 83 Meteosat-SEVIRI and 61 GOES identified TOTs were also calculated and compared to collocated CPR heights. About 41.0% (70.0%) of SEVIRI-identified TOT heights are within 250m (500m) of the CPR heights and 36.1% (59.0%) of the calculated GOES overshoot heights are within 250m (500m) of the CPR heights (Figure 24).

Publications and Conference Reports

Griffin, S. M., K. M. Bedka, and C. S. Velden, 2015: Calculating the Height of Overshooting Tops. Manuscript in preparation.

References

Bedka, K., J. Brunner, R. Dworak, W. Feltz, J. Otkin, and T. Greenwald, 2010: Objective Satellite-Based Detection of Overshooting Tops Using Infrared Window Channel Brightness Temperature Gradients. *J. Appl. Meteor. Climatol.*, **49**, 181–202.

Monette, S. A., C. S. Velden, K. S. Griffin, and C. M. Rozoff, 2012: Examining Trends in Satellite-Detected Tropical Overshooting Tops as a Potential Predictor of Tropical Cyclone Rapid Intensification. *J. Appl. Meteor. and Climatol.*, **51**, 1917-1930.

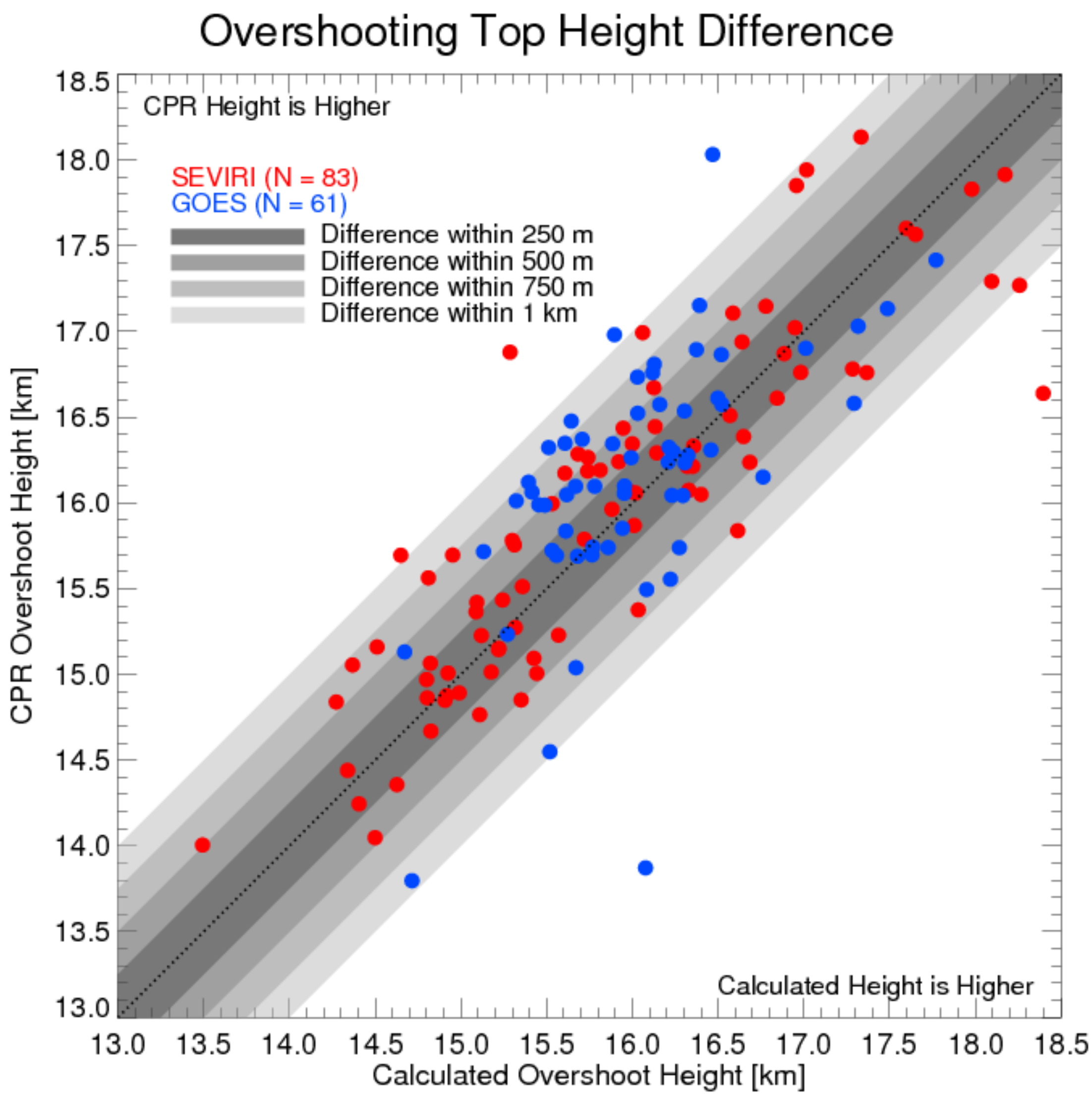


Figure 24. Differences between collocated CPR overshoot heights and calculated overshoot heights from Meteosat-SEVIRI and GOES. Of the 83 SEVIRI overshoots, 41.0% (70.0%) have a calculated overshoot height within 250m (500m) of the CPR height, and 36.1% (59.0%) of the 61 calculated GOES overshoot heights are within 250m (500m) of the CPR heights.

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).

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 25). 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.

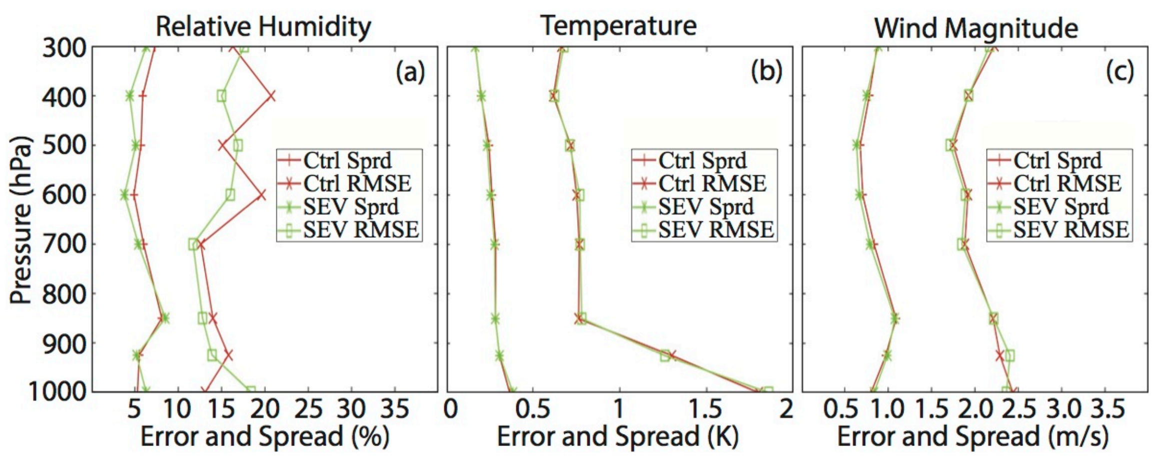


Figure 25. Vertical profiles of root mean square error and ensemble spread for (a) relative humidity (%), (b) temperature (K), and (c) wind magnitude (m s-1). The profiles were computed using data from the posterior ensemble mean at 00 UTC on 05 June 2011. Results are shown for the Control (red) and 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 (NCDC/CIMSS)

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 of further examination as it 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/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 NOAA/CIRA Project Lead, Dr. John Knaff, 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 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.

Summary of Accomplishments and Findings
A developmental dataset of brightness temperatures (T_b) from passive microwave sensors aboard various low-earth orbiting satellites was constructed for the Eastern Pacific and Atlantic Ocean basin TCs from 1995-2012. These data include horizontal and vertical polarizations of T_b at 19, 37, and 85 GHz and include the Special Sensor Imager (and Sounder) [SSMI(S)], Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) and the Advanced Microwave Scanning Radiometer-EOS (AMSR-E). Storm-centered data were created from swath data for swaths that fully intercepted a TC's estimated center location. After a few calibration steps, these data were interpolated to polar coordinates with respect to the storm center. The different sensors have varying spatial resolution from one another. Therefore, all data were interpolated to a

common polar grid with a radius of 600 km. Once this large historical dataset was established, an algorithm to relate microwave imagery (MI) to the TC wind field was developed.

Another two datasets were used to relate MI to the TC wind field. These datasets include a two-dimensional (2D) aircraft reconnaissance wind field analysis dataset from Knaff et al. (2015) and the National Hurricane Center's (NHC's) North Atlantic Hurricane Database (HURDAT; Jarvinen et al., 1984), the latter of which simply contains best estimates of the TC's position and intensity. A multiple linear regression model is designed to relate the azimuthal wavenumber 0-2 amplitudes and phases of the 2D wind fields to a variety of parameters, including the storm's current intensity, position, and motion, and also the principle components of the 2D empirical orthogonal functions (EOFs) describing the structures in the MI dataset. This model thereby estimates the wind structure of the inner core from MI imagery. The methodology is similar to the technique described in Knaff et al. (2015), which uses IR data to estimate the wind field. An example of the MI-based method is provided in the figure below and results are being written up in Rozoff et al. (2015).

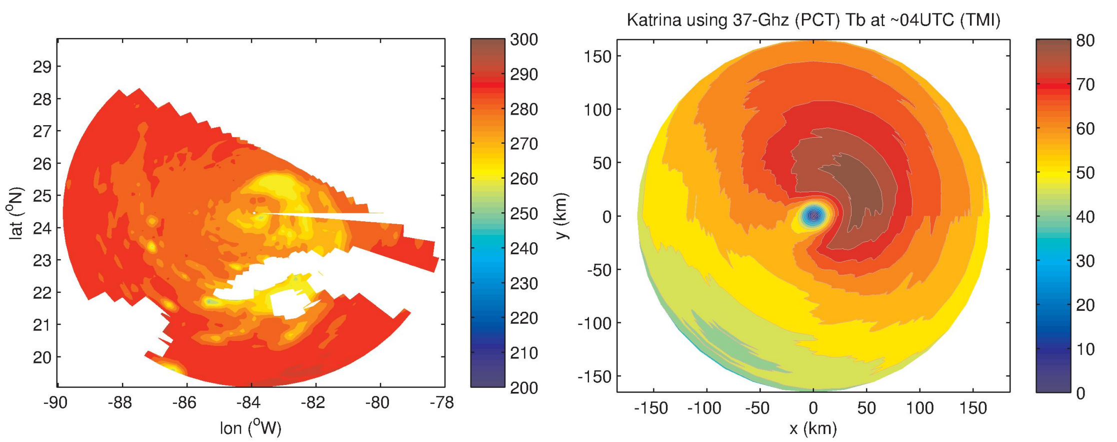


Figure 26. (left) TMI polarization corrected temperatures (K) (37 GHz) of Hurricane Katrina (2005) at 0400 UTC 27 August. Missing data are seen in this image where there is land and in the northeast due to the region falling outside of the satellite overpass. (right) Model diagnosed flight-level tangential wind (kt) diagnosed from the 37-GHz MI 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., J. A. Knaff, and M. Amin, 2015: Objective estimation of a tropical cyclone's wind field from passive microwave imagery. *J. Appl. Meteorol. and Climatol.*, in preparation.

References

Jarvinen, B. R., C. J. Neumann, 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.

6. CIMSS GOES-R Risk Reduction Program New Starts 2014

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 2014, although 2013 was a more active year, and undergraduate students were actively involved. 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 which 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.

Summary of Accomplishments and Findings

- Documented extreme pyroconvection events; collect pertinent data necessary for detailed case studies and post results on PyroCb blog (http://pyrocb.ssec.wisc.edu).
- Prepared 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.
- Undergraduate student (Britta Gjermo) presented a PyroCb poster at the AMS Annual Meeting in Jan 2015.
- Further documented selected PyroCb events per requests by Dr. Timothy Lang.

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 will be posted to a Twitter account initiated in 2014: @PyroCb_CIMSS.

A VISITview® training module (see Figure 27) 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.

As demonstrated in recent work by our collaborator Dr. Timothy Lang, there is some evidence that pyroCbs may be associated with clusters of lightning. This aspect of pyroCbs will be investigated with data from the Geostationary Lightning Mapper (GLM) once it becomes operational on the GOES-R satellite. Dr. Lang requested additional information on approximately a dozen PyroCb events captured on the blog, and we are expanding the original blog posts as requested. For example, the Hardluck Fire (26 July 2013) case was expanded to include more ancillary data and GOES satellite analyses using Dr. Andy Heidinger's ACHA (AWG Cloud Height Algorithm) software.

The pyroCb blog currently enlists three undergraduate atmospheric science students; the number fluctuates as students graduate and new students are brought in and trained. The students are trained to prepare geostationary image animations and organize ancillary data. This leaves the investigators with more time to spend on the more complex tasks. Our training program will continue to enlist and train students to provide analysis and discussion of pyroCb events as they occur. One such example is provided in Figure 28, where undergraduate student Ms. Britta Gjermo led the discussion. The rather spectacular shot is taken by an F-15 Eagle pilot from the 173rd Fighter Wing, Oregon Air National Guard. Since Ms. Gjermo is in ROTC, she was able to go through channels and establish a connection with the 173rd Fighter Wing group. We also sent Britta to the AMS Annual Meeting in January, 2015, where she presented a poster.

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

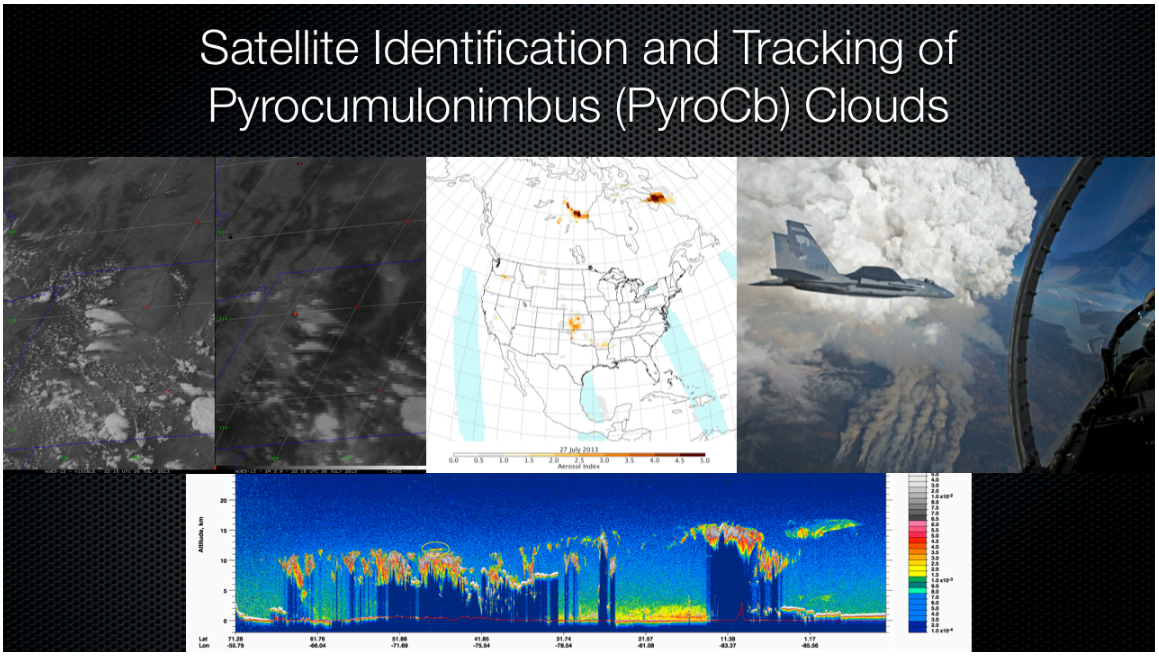


Figure 27. Screen-shot of the title slide of the recently-developed VISITview module.

Figure 28. Britta Gjermo, an undergraduate working with our team, obtained permission to use this image by contacting the pilot who took the photo. This shows an F-15 Eagle from the 173rd Fighter Wing, Oregon Air National Guard, in the foreground of a pyroCb produced from the Beaver Complex Fire on 1 August, 2014. (Photo Credit: Jim "Hazy" Haseltine, HIGH-G Productions.

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

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

Summary of Accomplishments and Findings

All gaps in NOAA's Comprehensive Large Array-data Stewardship System (CLASS) data archive for GOES-14 SRSOR data were filled by the SSEC Data Center. GOES-14 SRSOR data were supplied to CLASS for dates in June 2013 and May 2014.

Work continues to connect radar and satellite data visualizations, though some progress has been made in McIDAS-V (see Figure 29). CIMSS researchers are working closely now with NSSL meteorologists to improve on the visualization work.

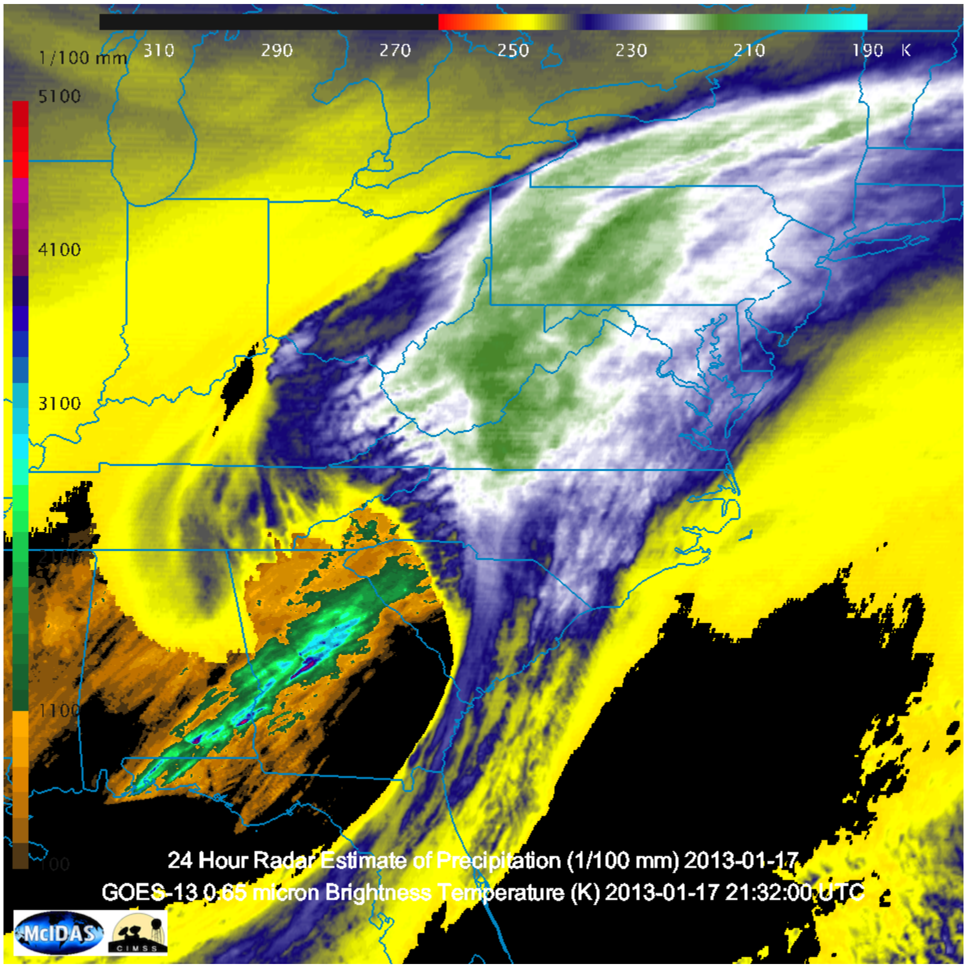


Figure 29. Example of radar estimated precipitation with GOES Imager visible data overlain from January 2013 (McIDAS-V). Visualization of multiple geo-located datasets is made easier in McIDAS-V.

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.

Summary of Accomplishments and Findings

Hurricane Sandy over the period October 25-31, 2012 was identified as our initial tropical cyclone test case. Not only was Sandy an event of historic proportions, but GOES-14 was in SRSO mode with continuous 1-min. sampling for 5 days before/during landfall. This high rate of image refresh allows us to test AMV derivation in a simulated way to what GOES-R will provide. A ‘Benchmark’ AMV dataset for Hurricane Sandy was produced using the traditional derivation practices and settings/tuning based on previous research. This dataset consists of hourly files containing AMVs derived from 3-min. VIS, and 5-min. IR/SWIR using the GOES-14 Super Rapid Scan imagery. All AMV types, including LWIR, Cloud-top Water Vapor, SWIR, and Visible were then reprocessed for Hurricane Sandy with the new GOES-R nested tracking algorithm (our ‘Experiment-1’ dataset). A significant amount of testing was performed to select an optimum configuration (i.e., size of the outer target selection box, image time interval to use, quality control thresholds to use) to use for generating AMVs in tropical cyclone environments with this new processing algorithm. The optimized configuration provides high quality AMV datasets with higher spatial and temporal coverage than the nominal configuration. Figure 30 below shows an example of the AMV product generated from the 1km visible imagery. Wind vectors that exceed hurricane force (> 75 mph) are colored in cyan. The AMVs were generated at STAR in College Park and then ftp’d to CIMSS where the AMV impact experiments involving NCEP’s Hurricane Weather Research and Forecasting (HWRF)/ Gridpoint Statistical Interpolation (GSI) system were run.

Both the Benchmark and Experiment-1 AMV datasets were assimilated into the HWRF/GSI on the Jet computer for the Hurricane Sandy case. The assimilation cycle was every 6 hours. A control run (CTL) used only radiosonde data and GFS analyses as background fields. The preliminary results of the forecast impact experiments assimilating the AMVs are encouraging: Both the Benchmark and Experiment-1 AMV forecast errors are lower than the CTL for both track and intensity at almost all forecast times, and the results are comparable to the full data assimilation operational run. These results are particularly impressive given the already relatively low forecast errors from the CTL and H214 for Sandy.

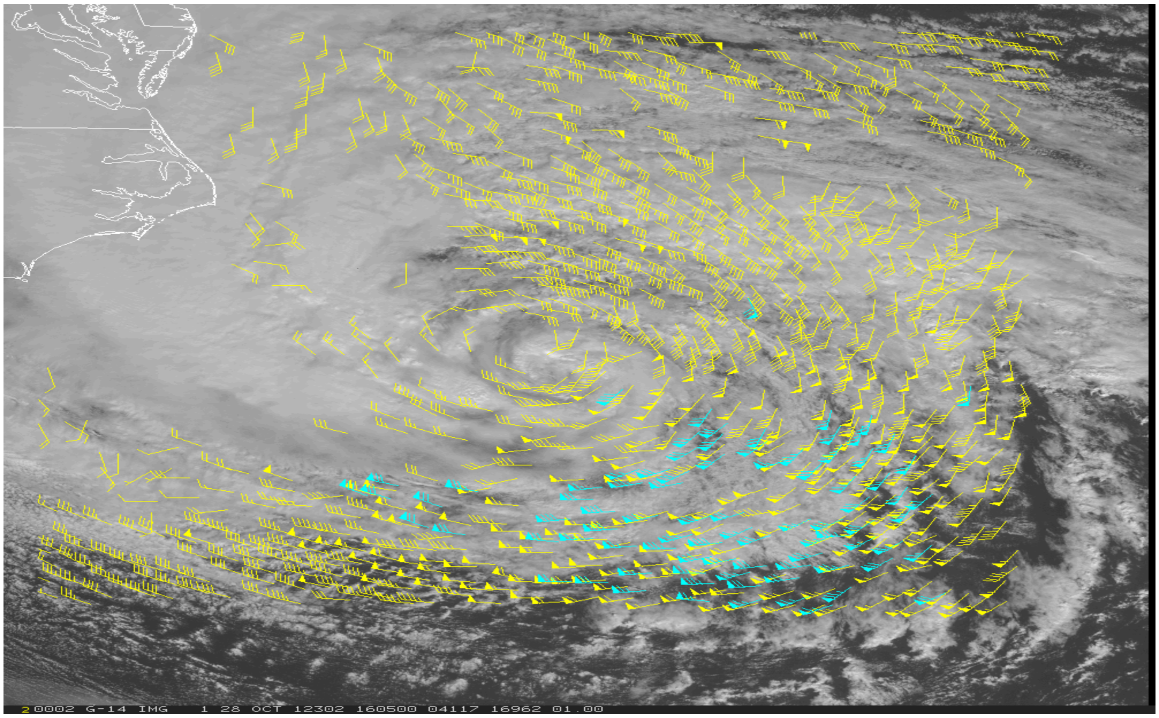


Figure 30. Example of the cloud-drift winds derived from GOES-14 Super Rapid Scan 1-minute imagery over Hurricane Sandy at 1605 UTC on 28 October 2012 using a modified configuration of the new GOES-R nested tracking winds algorithm. These winds are derived from tracking cloud features using the 1km 0.65um (VIS) imagery. AMVs that exceed hurricane force are colored in cyan.

Publications and Conference Reports

Velden, C., J. Daniels, W. Bresky, S. Wanzong and D. Stettner, 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 verification system for the HRRR model that will provide operational forecasters objective tools to quickly determine the accuracy of current and prior HRRR model forecasts. 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 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.

Summary of Accomplishments and Findings

During the past nine months, we developed the infrastructure to retrieve and compare observed and simulated GOES brightness temperature datasets and post the analysis results to a prototype project webpage. Real GOES observations are being obtained in real-time from the SSEC Data Center whereas the simulated GOES observations from the HRRR model will be obtained from the NOAA Earth System Research Laboratory starting in April. The simulated GOES brightness temperatures for the 6.7 μm water vapor band and the 10.8 μm window band will be computed for each HRRR forecast cycle using the CRTM implemented in the Unified Post Processor. Code has been written to compute standard statistical measure including root mean square error, mean absolute error, and bias for each infrared band and analysis time. The simulated and observed GOES observations are remapped to a common grid prior to computing the statistics over pre-defined subsets of the model domain. The code has a flexible structure so that it can be easily reconfigured to compute statistics for any region of interest. The statistics are computed each hour with the analysis results and simulated and observed satellite imagery posted to the project webpage (http://cimss.ssec.wisc.edu/hrrrval/) in near real-time. Users can select a sector and band to evaluate and then sort the verification results using different validation metrics. Links are also provided to view side-by-side animations of the simulated and observed satellite imagery. A representative screenshot of the project webpage is shown in Figure 31.

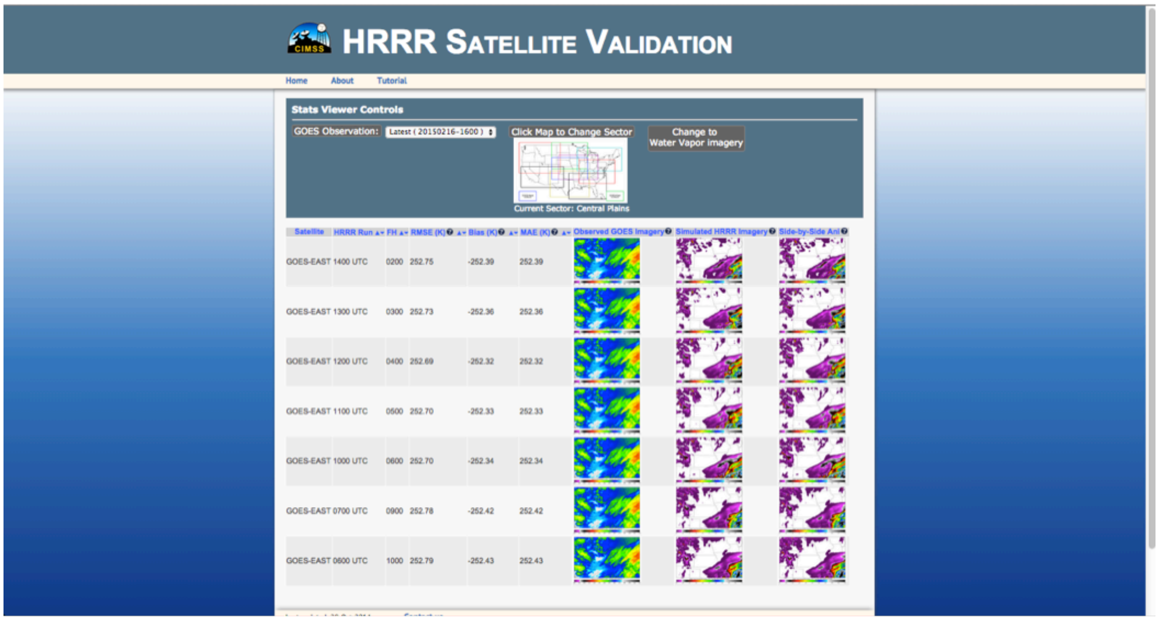


Figure 31. A screen capture showing the end-user's visualization of the simulated HRRR output on the prototype project webpage. After selecting a sector of interest, a user can choose the GOES observation time and band to analyse for a given model sector and then sort the table by various validation metrics. Side-by-side animations of the simulated and observed GOES brightness temperatures can also be examined.

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, Scott Bachmeier, and Jim Nelson
NOAA Collaborators: Jeff Craven (NOAA/NWS) and Timothy J. 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

Project Overview

Observations of moisture transportation in pre-convection environment and during storm development are very useful for forecasters. NOAA's next 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 layer 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 layer 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.

Summary of Accomplishments and Findings

- Implemented cloud detection and cloud phase detection for GOES Sounder;
- Cloudy RTM developed for GOES-R ABI and GOES Sounder IR bands, for cloudy profile retrieval purpose;
- Developed cloudy training dataset for GOES Sounder and GOES-R ABI TPW and LPW (layered PW) retrievals;
- Version 1.0 TPW/LPW algorithm developed under cloudy sky conditions for both ABI and GOES Sounder;
- All-sky TPW/LPW demonstrated with GOES Sounder typical cases, real time processing for GOES-15 and GOES-13 Sounder are ongoing for CIMSS satellite blog and the local forecast applications.

Data fusion in this project is the process of integration of NWP and GOES-R ABI IR radiances for producing a consistent, accurate, and useful representation of TPW/LPW field. In clear sky conditions, the 1DVAR based operational GOES-R legacy atmospheric profile (LAP) retrieval algorithm (Jin et al., 2008) uses NWP as background. While in the cloudy sky conditions, the statistical retrieval algorithm uses NWP as additional predictors (Li et al., 2008; 2009). The ABI pixels has been masked into clear and cloudy sky conditions with GOES-R AWG ABI cloud mask algorithm (daytime) in GEOCAT. This project will use GOES Sounder as proxy of ABI for all weather LPW/TPW algorithm development, and the focuses of this project are on (a) the algorithm development in cloudy skies, (b) validation of TPW/LPW in cloudy skies, (c) converting derived TPW/LPW into AREA format so that the data can be put into AWIPS-II, and (d) making all sky product available in real time for demonstration and applications.

During FY14 for this GOES-R Risk Reduction (GOES-R3) project, LAP algorithm for cloudy skies has been developed; first version is demonstrated with GOES-15 Sounder.

Algorithm description and technical approaches for LAP in cloudy skies

Unlike the physical retrieval algorithm for clear skies, the GOES-R ABI cloudy total precipitable water (TPW) and layer precipitable water (LPW) algorithm is based on Li et al. (2009) which uses a statistical linear regression technique. Some key elements of the algorithm are:

- Training dataset in cloudy situation. The training dataset should contain profiles of temperature, moisture and ozone, local zenith angle, surface skin temperature, surface pressure, surface emissivities, CTP, 0.55 µm cloud optical thickness (COT), and effective particle size, in such a way the cloudy IR radiances can be simulated accurately. Currently the SeeBor training database [Borbas et al., 2005; Smith et al., 2012] contains 19948 global cloudy profiles of temperature, moisture and ozone. In order to make cloudy training, the following information has been added to Seebor to make cloudy training:

- A physically based characterization of surface skin temperatures is also included in this database.
- Cloudy profile generation, In order to generate the cloudy profiles, clouds are added at one single selected level based on the relative humidity (RH) profile (Jin et al., 2006). An RH threshold profile, in which the threshold changed smoothly with altitude in the range between 65 and 95 %, was used to ensure an evenly distribution of the cloud top pressure. Among the all cloudy profiles, about 55 % profiles are found suitable where ice clouds can be added and the other 45 % for water clouds. The clouds are added with a random value of COT from [0.01, 0.1, 0.2, 0.5, 1.0, 1.5, 2.0, 3.0, 4.5, 6.5, and 10.0].
- The training set is classified into 10 different satellite view angles (note this is not local zenith angle) classes appropriate for the GOES Sounder [3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, and 8.0]. For each view angle x, random values between x - 0.25 º and x + 0.25 º are assigned. For ice clouds, the effective particle size in diameter (De) is obtained using (Heymsfield et al., 2003).
- Using RTM in cloudy skies. Since the Community Radiative Transfer Model (CRTM) in cloudy situation has large uncertainty, especially under ice cloudy situations according to our assessment, the cloudy radiances will be calculated by coupling the clear-sky optical thickness from CRTM with the associated COT at 0.55 μm. The COT is calculated with a fast radiative transfer cloud model developed by University of Wisconsin–Madison (UW–Madison) and Texas A&M University (Wei et al., 2004). The original model, designed for hyperspectral IR sounders, is adopted for the GOES-R ABI. In this model, the bulk single-scattering properties of ice crystals are calculated by assuming aggregates for large particles (>300 μm), hexagonal geometries for moderate particles (50–300 μm) and droxtals for small particles (0–50 μm); the water cloud droplet is assumed to be spherical and the classical Lorenz-Mie theory is used to calculate the single-scattering properties. The UW–Madison baseline fit emissivity database will be used for surface IR emissivities (Seemann et al., 2008).
- Constructing Forecast Error Profile. The forecast temperature and moisture profiles are used as predictors for the retrievals by providing extra profile information (Li et al., 2008) under cloudy skies. Since there are no forecast data in the SeeBor training database, the forecast error profiles have to be constructed to simulate the forecast data in training dataset. Forecast error will be constructed based in the schemes developed by Li et al. (2009). Except around 200 hPa, where the temperature is highly variable near the tropopause, the constructed forecast profiles have similar bias and root mean square (RMS) as the NWP ones (e.g., GFS). Besides, the vertical correlative errors are well represented in this scheme.
- Cloud Phase Determination. Two sets of Tb are calculated, one with ice and the other with water cloud regression coefficients. Cloud phase is determined based on the simulated Tb from the retrieval; the one closer to the observed Tb (smaller residuals) is chosen and cloud phase is assigned accordingly. When applying regression to real ABI data, the cloud phase will be determined from ABI cloud phase mask.
- TPW/LPW calculation and quality control. After the moisture profile is retrieved from combined NWP and ABI IR radiances, the TPW and LPW products will be generated for applications. Quality control will be developed based on the residual, CTP, and COT.

The above procedures have been developed based on SeeBor training dataset with cloud properties assigned and tested (for realistic), first version of prototype codes have been developed for retrieval algorithm in cloudy skies; regression coefficients have been generated for both

GOES-15 and GOES-13 Sounder. The whole process has been tested with case study using GOES-15 Sounder radiance measurements, initial results are reasonable.

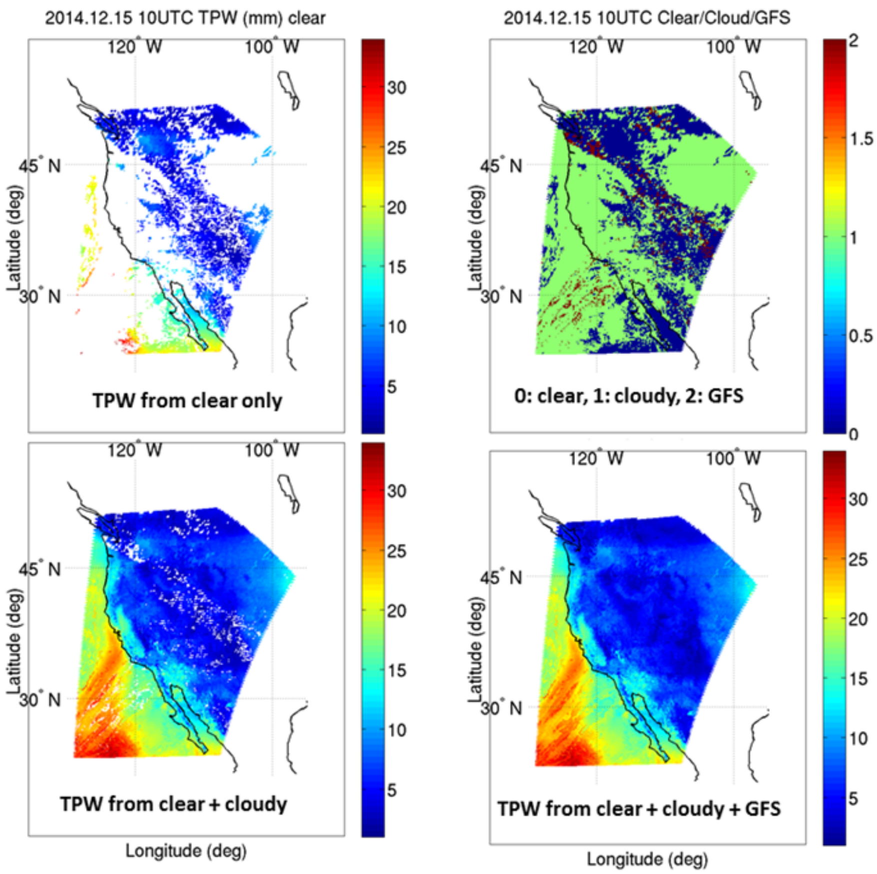


Figure 32. One example of GOES-15 TPW (mm) retrievals under clear skies only (upper left), under both clear and some cloudy skies (lower left), and all skies (lower right).

Figure 32 shows TPW from GOES-15 Sounder with GOES-R LAP algorithm in clear skies only (upper left), TPW from clear and cloudy skies (lower left), TPW from all-weather conditions (clear + cloudy + GFS) (upper right). The lower right panel of Figure 32 shows the coverage of TPW from clear, cloudy, and GFS, respectively. It can be seen that for this particular case, the clear sky only TPW has less coverage and deriving products in cloudy skies are very important for expanding the GOES-R LAP product coverage for better applications in weather forecasting.

Note that in the figure, the upper left panel represents the operational GOES-R LAP product coverage, while lower left panel shows the expanded GOES-R retrieval coverage under this GOES-R3 research. GOES-15 Sounder data are used as proxy in this study.

Real time processing of both GOES-13 and GOES-15 Sounder in GEOCAT should be available in April 2015 for demonstration, evaluation and applications.

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Li, Z., J. Li, W. P. Menzel, J. P. Nelson III, T. J. Schmit, Elisabeth Weisz, and S. A. Ackerman, 2009: Forecasting and nowcasting improvement in cloudy regions with high temporal GOES Sounder infrared radiance measurements, *Journal of Geophysical Research. - Atmospheres*, **114**, D09216, doi:10.1029/2008JD010596.

Wei, H., P. Yang, J. Li, B. A. Baum, H.-L. Huang, S. Platnick, Y. Hu, and L. Strow, 2004: Retrieval of semitransparent ice cloud optical thickness from Atmospheric Infrared Sounder (AIRS) measurements. *IEEE Trans. Geosci. Remote Sensing*. **42**, 2254 - 2267.

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.

Summary of Accomplishments and Findings

One major goal of this project is to incorporate additional datasets into the VOLCAT system to further increase skill and confidence of the detection of volcanic eruptions. Using several small explosions of Mount Cleveland (Alaska), an assessment of the robustness and timing of satellite derived fields was compared to eruption signals inferred from United States Geological Survey (USGS) infrasound and ground-coupled airwaves. The results indicate that the infrasound and ground-coupled airwave signals can be used to reduce uncertainty in the satellite based detection of eruptive clouds. In most cases the Cleveland explosions were detected by infrasound and ground-coupled airwaves prior to the appearance of an eruptive cloud in satellite imagery. If an explosion is detected using infrasound and/or ground-coupled airwaves, that information can be used to increase the satellite detection efficiency of hard to detect ash emissions such as the one shown in Figure 33. Additionally we have acquired software needed to co-locate hyperspectral sounder and imager measurements from same LEO spacecraft. This is the first step towards using the hyperspectral sounder data to correct for the influence of cirrus on ash detection. The VOLCAT system architecture has been modified for the addition of SO_2 alerting (in addition to volcanic ash cloud, thermal anomaly, and explosive eruptive cloud alerting).

The usefulness of VOLCAT derived ash effective radius retrievals is also being evaluated. The 2009 eruption of Redoubt volcano in Alaska was chosen for analysis due to numerous MODIS observations (many spectral channels similar to GOES-R ABI), USGS C-band radar observations of the ash plume, and ground-truth of particle size from various ash fallout deposit collections. Two particular explosions were identified for further study because of the significant difference in the ash grain size distributions inferred from fall deposits and c-band radar (one that produced very little fine-grained ash, one that produced more fine grained ash). The VOLCAT retrieval of effective particle radius does show a difference that is consistent with the fall deposits, which implies that the satellite-derived effective particle radius product might be useful assessing the atmospheric residence time of volcanic ash. More research is needed.

Publications and Conference Reports

Pavolonis, M., 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, Submitted to *Journal Geophysical Research* (in revision).

Pavolonis, M., 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, Submitted to *Journal Geophysical Research* (in revision).

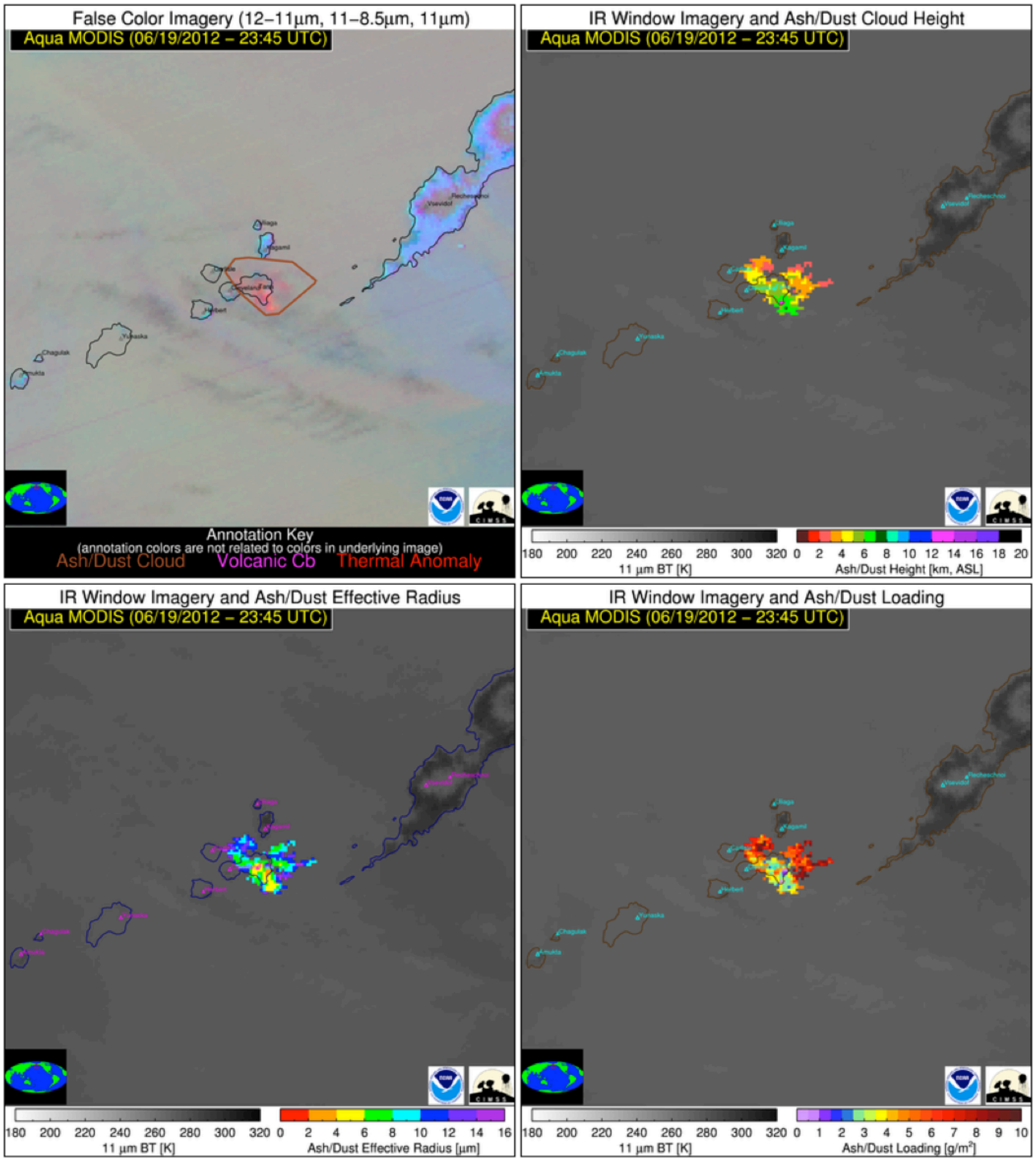

Figure 33. A small ash cloud, produced by an explosion of Mount Cleveland (Alaska) on June 19, 2012, is detected with greater confidence using the VOLCAT satellite algorithms with infrasound and ground-coupled airwaves. The explosion that produced this ash cloud was detected by infrasound and ground-coupled airways about 50 minutes prior to a weak ash cloud appearing in satellite imagery, which allows those measurements to be used to increase satellite-based detection and alerting confidence.

References

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

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

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.

Summary of Accomplishments and Findings

A control simulation has been completed, covering the time period 2014040100 – 2014053100. An experiment is currently underway to assimilate LEO/GEO observations in a manner similar to MODIS infrared AMVs, utilizing the same quality control. In addition, LEO/GEO AMVs are being monitored within the GSI, so that they are not (yet) assimilated, but the GSI ingests the winds and produces a 4-dimensional interpolation of the model background to pair to the observation. This way, we can begin compiling statistics on how various LEO/GEO AMVs compare to the model background. It is found, for example, that a LEO/GEO AMV computed with three satellites produces a larger deviation from background wind speed and background wind direction than a LEO/GEO AMV computed with two satellites (not shown); statistics like these can help produce a quality control method that is modulated by several different characteristics of LEO/GEO AMVs, for comparison to the first assimilation experiment.

Several single-cycle experiments have been performed to test the impact of assimilating LEO/GEO winds on historically poor (bust) forecasts in the Apr-May 2014 time period (as defined by the 500 hPa geopotential height anomaly scores for the operational GFS). Six analysis periods were chosen, representing three forecast busts for the northern hemisphere and three for the southern hemisphere, defined by poor performance of the forecast at day-3 and day-5 initialized from the same analysis. One such experiment takes place on 11 April 2014, which resulted in poor performance in the northern hemisphere. LEO/GEO AMVs were assimilated throughout the gap corridor between 60 and 70 degrees latitude in both hemispheres (Figure 34). Since this experiment is performed in single-cycle, it uses the same background as the control simulation when producing the analysis. The 500 hPa geopotential forecast is improved between beyond 96 hours (Figure 35, blue line), while some degradation is observed between 48-96 hours. It is important to recognize that these forecast impacts are achieved through a single-cycle experiment, and do not include the impact of preconditioning of the model background through previous assimilation of LEO/GEO AMVs. It is also helpful to note that early forecast “degradation” is likely an artifact of modifying the analysis from which the error is computed.

A fully cycled assimilation experiment is currently underway, and the experimental forecast for 0000 UTC 11 April 2014 is also available for examination (Figure 35, red line). The forecast using the fully cycled assimilation of LEO/GEO AMVs improves substantially more than the single-cycled experiment between 24-48 hours, and less degradation is observed at mid-range. However, there is also less improvement beyond 96 hours than is observed in the single-cycled experiment. An investigation is underway to determine the cause of these differences, and any possible relevance to the quality control and assimilation of LEO/GEO AMVs during cycling.

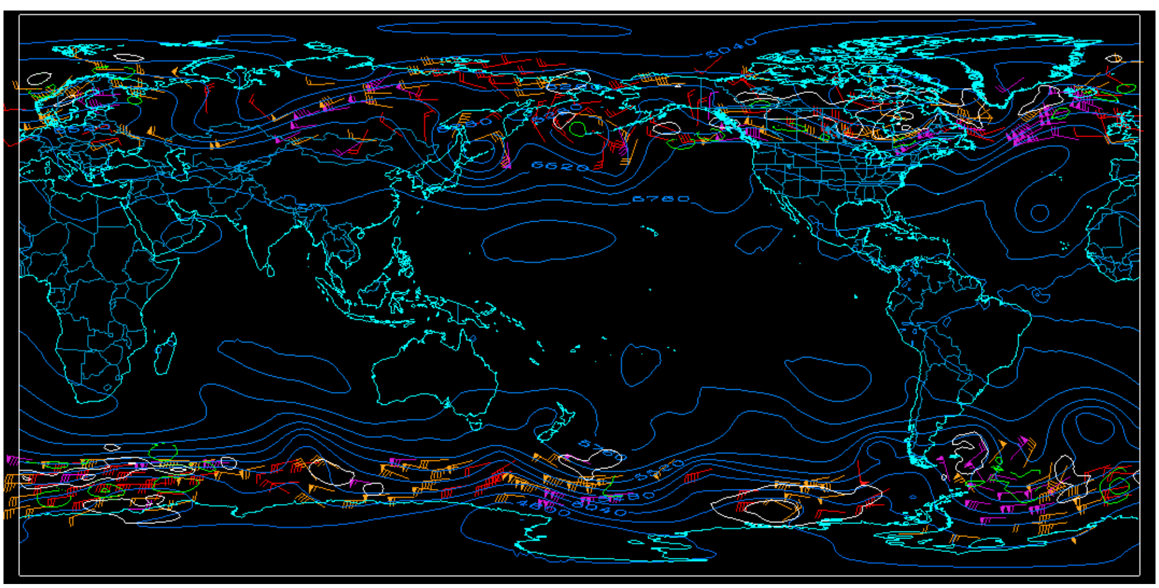

Figure 34. Assimilated LEO/GEO AMVs in a single-cycle experiment for 0000 UTC 11 April 2014. LEO/GEO AMVs plotted as barbs; AMVs at pressures greater than 600 hPa are in red, AMVs between 600-400 hPa are in orange, and AMVs at pressures less than 400 hPa are in purple. Geopotential height from the control analysis is provided in blue, with white (green) contours in regions where the heights are raised (lowered) when LEO/GEO winds are assimilated.

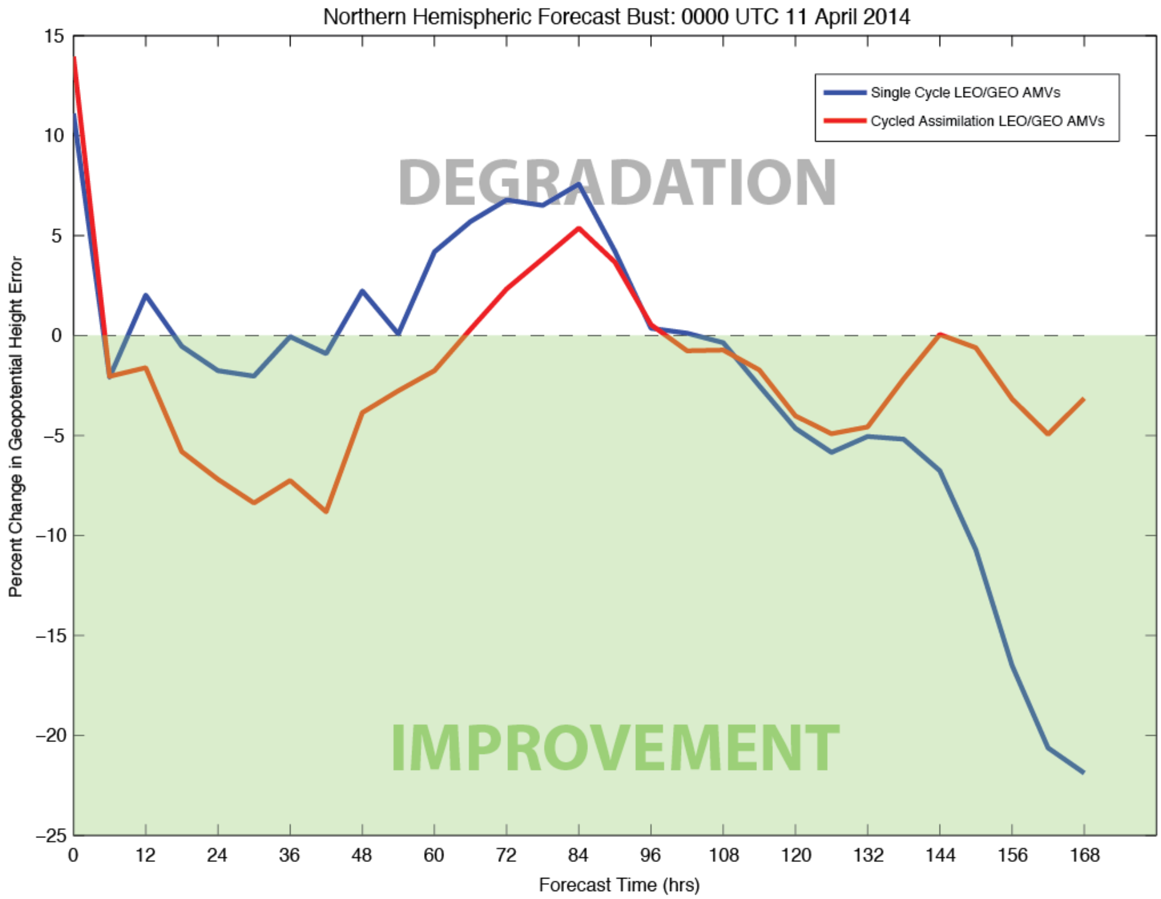

Figure 35. Forecast impact of single-cycle experiment (blue) and fully cycled assimilation experiment (red) for northern hemispheric forecast bust initialized 0000 UTC 11 April 2014. Plot represents the percent-change in 500 hPa geopotential height error in the northern hemisphere as a function of forecast time when LEO/GEO AMVs are assimilated, relative to a control simulation with no LEO/GEO AMVs. The difference between the forecast and a verifying analysis is computed and its absolute value is summed between 30N-80N, using a cosine-weighting for latitude.

Publications and Conference Reports

Results from these experiments will be presented at the 13th JCSDA Technical Review Meeting & Science Workshop on Satellite Data Assimilation, 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.

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, band14).

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.

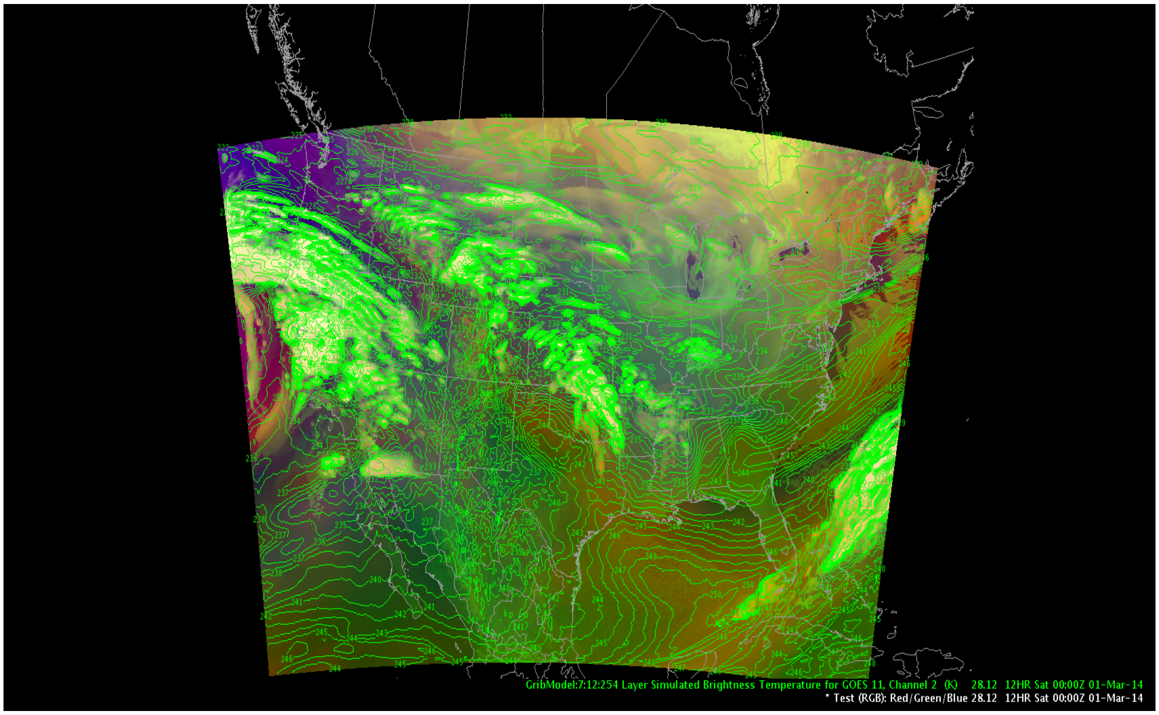

Figure 36. March 01, 2014 00z WRF-CHEM simulated ABI airmass RGB overlay with simulated ABI band 08 high density contours showing brightness temperatures greater than 240k (driest air) in AWIPS-II. This image was made leveraging predefined AWIPS-II GOES-11 grib2 placeholders for ABI bands. This approach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

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.

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.”

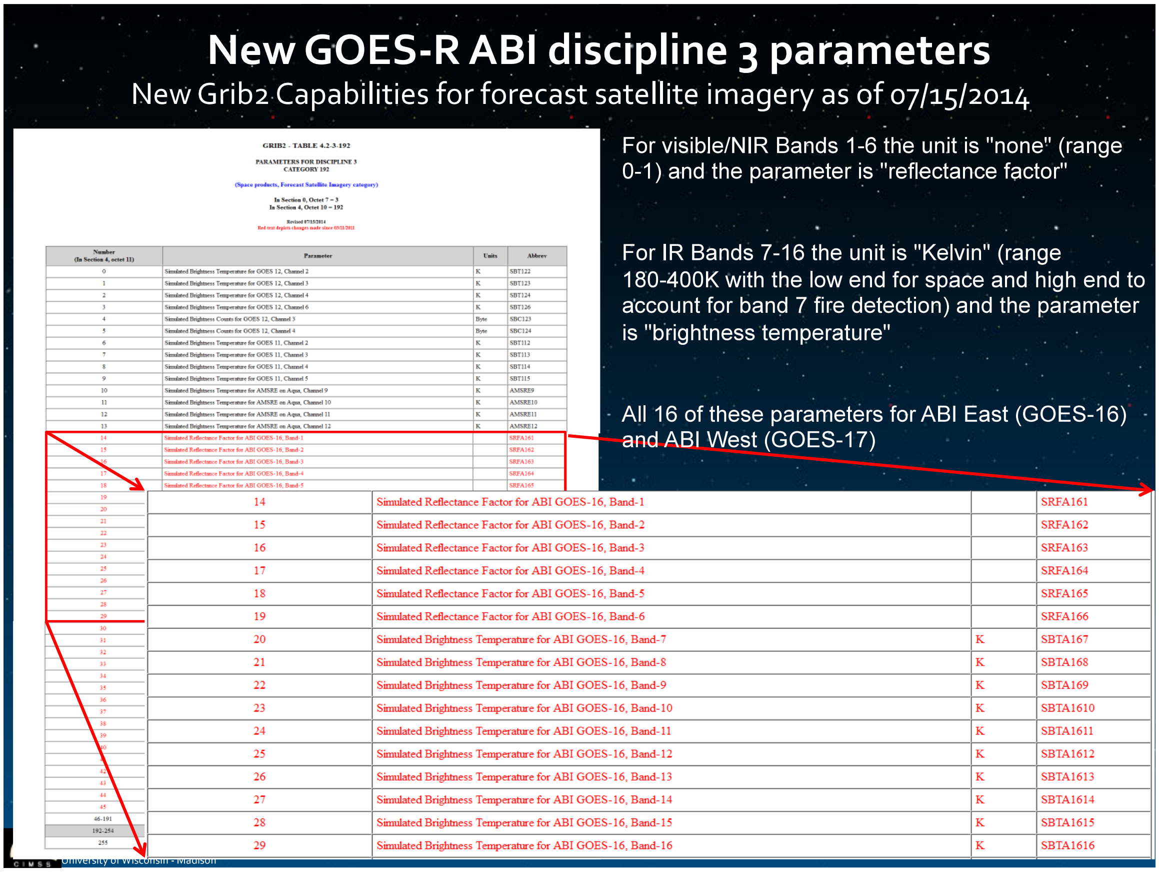

Figure 37. The newly NCEP defined GOES-R ABI discipline 3 parameters forecast satellite imagery as of 07/15/2014. Showing the grib2 parameter name, abbreviations, and units.

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 task is for continued support to the NOAA GOES-R Proving Ground to 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.

Summary of Accomplishments and Findings
In 2014-2015 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 hosted and participated in the March 2014 Virtual NOAA Satellite Science week 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 2014-2015 including the American Meteorological Society (AMS) Conference, the National Weather Association (NWA) Conference, and the 2014 EUMETSAT Annual conference in Geneva, Switzerland. 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 2014 – 30 March 2015 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 (5 May – 6 June, 2014). Participants included over 4 CIMSS researchers, 16 forecasters, and several visiting scientists.
2. National Hurricane Center (NHC) Tropical Cyclone Demonstration (1 August – 30 November 2014) Participants included forecasters from NHC
3. Aviation Weather Center (AWC) Summer Experiment (11 August – 15 August, 2014). 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.

UW–Madison/CIMSS scientists were engaged with the demonstrations listed above by providing the following GOES-R Baseline, Future Capability, or Risk Reduction decision support proxy data. Product assessment highlights for eight of the UW–Madison/CIMSS decision support products are listed below as reported in the GOES-R PG 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

UW–Madison/CIMSS Decision Support Product GOES-R Proving Ground Significant Outcomes and Product Assessment Highlights:

1. The Fog and Low Stratus products are currently scheduled to be operationalized on OSPO ESPC systems and will be delivered to NWS users via Satellite Broadcast Network (SBN), NCEP Central Region Operations (NCO) backbone, Direct Broadcast, and possibly AWIPS Data Distribution Service (DDS) as an alternative.
2. The GOES-R Probability of Severe Model output was made available for testing within HWT for the first time. Summary: **When asked if they would use the product during warning operations at their home WFO if available, 98% of respondents answered yes. Additionally, the broadcast meteorologists really appreciated that the product highlights the most threatening storms, as the busy broadcast environment often limits their ability to fully investigate the necessary meteorological data. It was apparent from this experiment that the ProbSevere model can have a positive impact on the forecast and warning decision-making of a variety of forecasters, and its continued development and improvement will certainly be appreciated.**
3. Simulated Satellite Forecasts are available in AWC and SPC operations (experimental).
4. The Cloud Top Cooling (CTC) product was transitioned into SPC and AWC operations (experimental) in Fall 2012 and the use of the product has continued to gradually increase,
   GOES-R CTC Proxy 2014 SPC Mesoscale Convective Discussions:
   http://www.spc.noaa.gov/products/md/2014/md1724.html
   http://www.spc.noaa.gov/products/md/2014/md1729.html
   http://www.spc.noaa.gov/products/md/2014/md0748.html
   http://www.spc.noaa.gov/products/md/2014/md0753.html
   http://www.spc.noaa.gov/products/md/md0555.html
   http://www.spc.noaa.gov/products/md/md0162.html

5. 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

6. 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

   SRSO 2014 SPC Mesoscale Convective Discussions:
   http://www.spc.noaa.gov/products/md/md0647.html

   Forecaster input:
   http://satelliteliaisonblog.wordpress.com/2014/05/22/goes-14-1-minute-imagery-use-in-spc-with-texas-severe-521/

   http://satelliteliaisonblog.wordpress.com/2014/06/13/goes-14-1-minute-imagery-use-in-spc-with-pany-severe-52214/

   http://satelliteliaisonblog.wordpress.com/2014/06/17/goes-14-1-minute-imagery-use-in-spc-with-south-carolina-severe-52314/

1a. 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.

One such example in which multiple forecasters used the synthetic imagery to evaluate the 00 UTC NSSL-WRF model forecast cycle occurred on May 22 in western Virginia (Figure 38). Forecasters noticed that the NSSL-WRF forecast had developed convection by 19 UTC that was not occurring in the actual imagery. They believed the discrepancy was due to the fact that the model had not produced the thick cirrus shield that was present in reality over the region which had likely prevented the heating necessary for convection to occur at that time. Convection developed in the area two hours later.

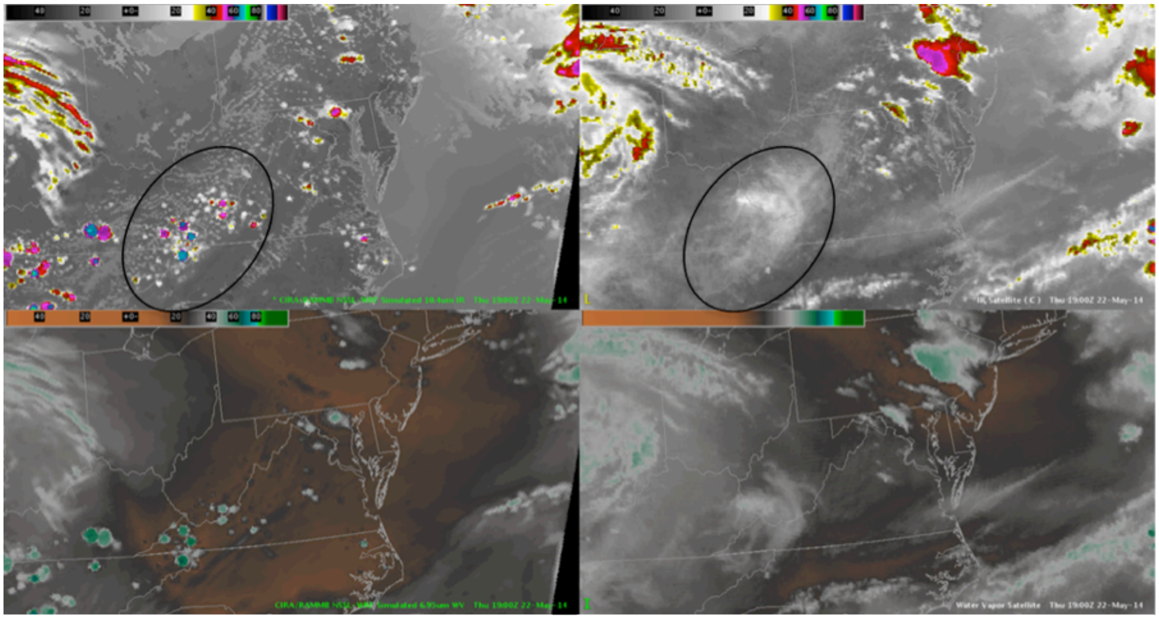

Figure 38. On left, May 22, 1014 00 UTC NSSL-WRF 19 hours forecast valid at 19 UTC for 10.35 um IR (top) and 6.95 um IR (bottom). On right, May 22, 2014 19 UTC observed GOES-East 11 um IR (top) and 6.7 um IR (bottom).

1b. GOES Imager Super Rapid Scan Operations Imagery (Baseline)

HWT input:
Similar to what has been experienced in previous demonstrations, forecasters quickly appreciated the benefit of 1-minute satellite imagery over current 5-30 minute imagery. After the initial excitement, participants consistently realized situations in which the 1-minute imagery itself has a positive impact on the forecaster decision-making process. When asked if 1-minute imagery provided additional value compared to 5- or 15- minute imagery, all respondents answered “Yes”. Some of the most commonly experienced improvements to forecaster situational awareness and nowcasting included: quicker and more confident identification of boundaries, improved lead time to confidence that convective initiation is occurring, more value in identifying overshooting tops and other cloud top features and their trends, and enhanced ability to differentiate between stronger and weaker updrafts.

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 has not 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

1c. 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 (Figure 11). 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.

1d. University of Wisconsin Convective Cloud Top Cooling rates (Future Capability)

***AWC Input*:**
While the GOES-R CI tends to lose its value at the CSIG desk once convection has begun, the Cloud Top Cooling remains a useful at-a-glance too1. Not only is it simple and easy to interpret, but it also provides forecasters with something to quickly key in on in the fast-paced nature of their operations. It can also be used in tandem with radar to provide further confidence in the issued CSIG area. This is especially important over busy terminals.
As previously mentioned, CCFP is a longer term forecast in its current state, but forecasters at this desk tend to have the CTC product at hand as a means of verification. Additionally, once the CCFP transitions to the AWS, the short-term (within 4 hours) will become the focus of the forecast, potentially making the CTC a very valuable situational awareness tool.

1e. 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

As an example, the NearCast instability forecasts provided to forecasters increased confidence about the development and evolution of convection across Maryland on May 22, 2014. At 1935 UTC, the forecaster mentioned in a blog post that, according to the NearCast forecast, "the unstable environment would start over western MD and move across the state into the Delmarva Peninsula. Behind it some more stable air will move in. It will be interesting to see if storms follow this track and move from NW to SE along the area and at the same time." The forecaster wrote a follow-up blog post at 2141 UTC, explaining that "storms initiated on the boundary and as they moved into the unstable air, they became stronger." Figure 39 shows this thunderstorm development along the gradients in the NearCast theta-e difference field. The forecaster went on to explain that storms further to the west "began to weaken as more stable air moved in."

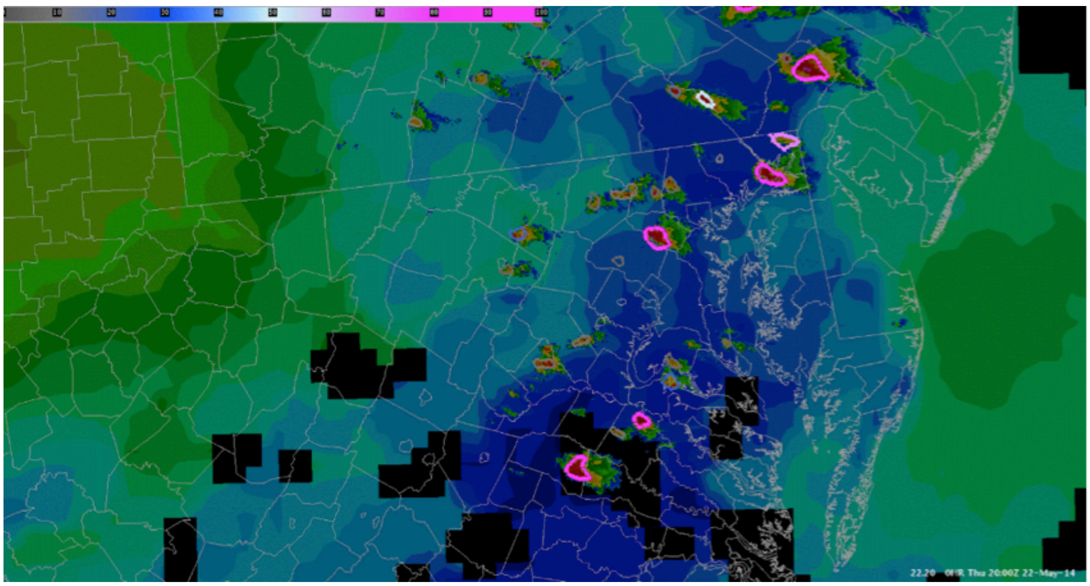

Figure 39. May 22, 2014 2000 UTC Nearcast model theta-e difference analysis with Multi-Radar Multi-Sensor (MRMS) composite reflectivity and ProbSevere model contours overlaid. From blog post "NearCast verifies with Radar".

1f. Probability of Severe Model

HWT input:

In summary, participants really enjoyed evaluating the ProbSevere model, offering many suggestions for algorithm improvement and display enhancement. The product increased confidence and sometimes lead-time to warning issuance, and also identified which storms should be monitored or interrogated further. When asked if they would use the product during warning operations at their home WFO if available, 98% of respondents answered yes. Additionally, the broadcast meteorologists really appreciated that the product highlights the most threatening storms, as the busy broadcast environment often limits their ability to fully investigate the necessary meteorological data. It was apparent from this experiment that the ProbSevere model can have a positive impact on the forecast and warning decision-making of a variety of forecasters, and its continued development and improvement will certainly be appreciated.

One example of the ProbSevere model providing increased lead time before the first occurrence of severe weather came in southeast South Dakota during the afternoon of May 8 (Figure 40). In an environment characterized by ~1500 J/kg MUCAPE and ~50 kts EBShear, a cell had experienced strong satellite growth rates. The model first generated probabilities over 50% at 2006 UTC, when the storm reached 60%. Forecasters were advised to pay attention to the 50% threshold as cells that go beyond that value are more likely than not to become severe according to the model. The local WFO issued a severe thunderstorm warning at 2025 UTC when the ProbSevere value was 91%. One inch hail was reported with this storm at 2038 UTC, 32 minutes after the ProbSevere probability first exceeded 50%.

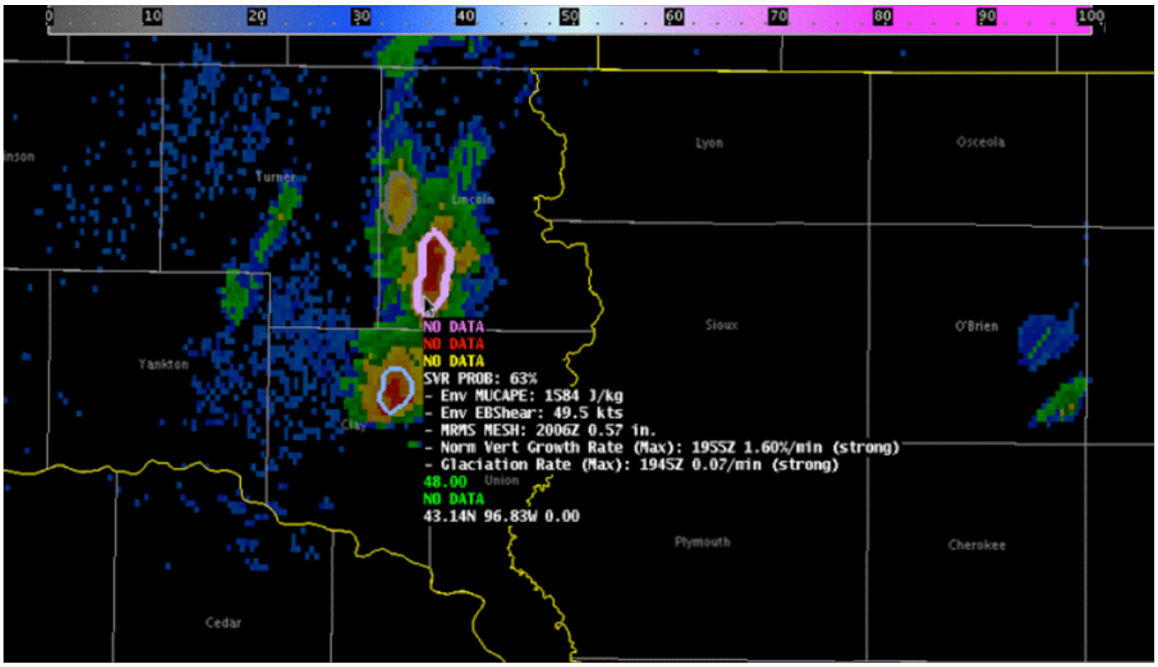

Figure 40. May 8, 2014 2006 UTC MRMS composite reflectivity and NOAA/CIMSS ProbSevere model probability contour and readout. From blog post "Storms develop further southwest along dryline".

1g. 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 2013 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.

2. Development of New GOES-R Weather Event Simulations and AWIPS-II Transition Support

CIMSS remains committed to assuring a smooth transition of all CIMSS research to operations products from the existing AWIPS software to the upcoming AWIPS-II. Preliminary work has been done finding a new product implementation approach for AWIPS-II. AWIPS-II activities are rapidly accelerating on the national scale to transition local applications between the two software environments. An AWIPS archive capable of archiving 60 days worth of AWIPS formatted files has been acquired through SSEC funding to support easier generation of WES cases AWIPS-II will soon be accessible for use at CIMSS, with training modules employing the new AWIPS software included as part of the VISIT/COMET training programs for operational satellite meteorology professional development. UW–Madison/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
CIMSS Support Scientists: Jinlong Li, Kevin Baggett, Feng Zhu
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
- Environmental Models and Data Assimilation

Project Overview

The primary goal of CIMSS high impact weather (HIW) project is to study the applications of high spatial and temporal resolution water vapor information from GOES-R series on improving severe storm warning and short-range forecasts. To take advantage of high vertical resolution information, the advanced infrared sounder measurements from polar-orbiting satellites are used together with GOES-R series water vapor information for HIW warning and forecasting. Focuses are on: (1) how to better use of high temporal and spatial resolution GOES-R series water vapor information in pre-convection environment for severe storm warning, and (2) how to improve severe storm over CONUS and tropical cyclones (TCs) such as Sandy (2012) with high temporal and spatial resolution GOES-R series water vapor information in regional and storm scale numerical weather prediction (NWP) models.

Summary of Accomplishments and Findings

High spatial and temporal resolution GOES-R moisture proxy information tested in regional NWP models

One of the key information GOES-R ABI will provide is the high temporal and spatial resolution moisture. While there will be no hyperspectral IR sounder on GOES-R to provide more accurate vertical temperature and moisture information, and important benefit to regional numerical weather prediction (NWP) model applications, ABI's high spatiotemporal resolutions make it possible for severe storm nowcasting and short-range forecasting. The spatial resolution of 2 km (IR channels) is not seen by any other satellite measurements, making it ideal for pre-convection moisture observations. The temporal resolutions of 30 seconds (mesoscale)/5 minutes (contiguous United States; CONUS)/15 minutes (full disk) also provide unprecedented measurements that could capture the rapid evolution of convections which is useful for short-term severe storm forecasts. The IR window channels provide information about boundary and water vapor channels provide information about middle and upper troposphere.

In order to test the GOES-R moisture information in regional NWP, the MODIS and current GOES Sounder are used as proxy; the GOES-R legacy atmospheric profile (LAP) algorithm has been transferred to process MODIS and GOES Sounder, the following data assimilation experiments are conducted in regional NWP models through collaboration with NCAR and ESRL:

(1) MODIS layer precipitable water (LPW) and total precipitable water (TWP) have been generated for tropical cyclone cases (Typhoon Sinlaku) with GOES-R LAP algorithm, the data are provided to NCAR and assimilated into WRF/DART, DART is ensemble-based data assimilation system developed by NCAR, high spatial MODIS TPW product (5 km) provided positive impact on typhoon track and intensity forecasts, although still lack of temporal information from MODIS. The mean intensity forecast errors from assimilating Terra MODIS TPW and Aqua MODIS TPW, respectively, for Typhoon Sinlaku (2008) indicate that the MODIS TPW provides the smallest intensity error compared with control run which assimilates RAOBs, Ship data, aircraft observations and AMVs, while Aqua MODIS provides similar result of control run, the reason might be that Aqua overpass time is close to that of RAOBs. GOES-R can provide moisture information at times when RAOBs are not available.

(2) GOES Sounder LPW have been generated with GOES-R LAP algorithm for storm forecasts over CONUS, two assimilation/forecasting systems are used:

(a) SDAT at CIMSS: based on GSI for assimilation, forward operator for TPW/LPW has been developed by CIMSS HIW team within GSI. Impact studies indicate positive impact on precipitation forecasts; Figure 41 shows the hourly precipitation forecasts of 2012 CONUS derecho case, two experiments are conducted, one with conventional (GTS), the other with conventional and GOES Sounder three layered LPW (SFC-900 hPa, 900 – 700 hPa, and 700 – 300 hPa). The model resolution is 4 km in this case. It can be seen that GOES Sounder LPW helped the intensity of hourly precipitation forecasts although the position of precipitation is a little off the observations. More experiments with GOES Sounder TPW/LPW on storm forecasting over CONUS are ongoing. Comparisons between TPW/LPW assimilation and radiance assimilation with GSI will also be conducted.

(b) LAPS at ESRL: the LPW data have been provided to ERSL for assimilation experiments, forward operator has also been developed in LAPS, impact study are ongoing, CIMSS HIW team will collaborate with LAPS team (Yuanfu Xie) on the comparison between GOES Sounder radiance assimilation and LPW derived product assimilation with LAPS. GOES Sounder cloud detection with GOES-R AWG team algorithm will also be provided to ESRL for assimilation experiments.

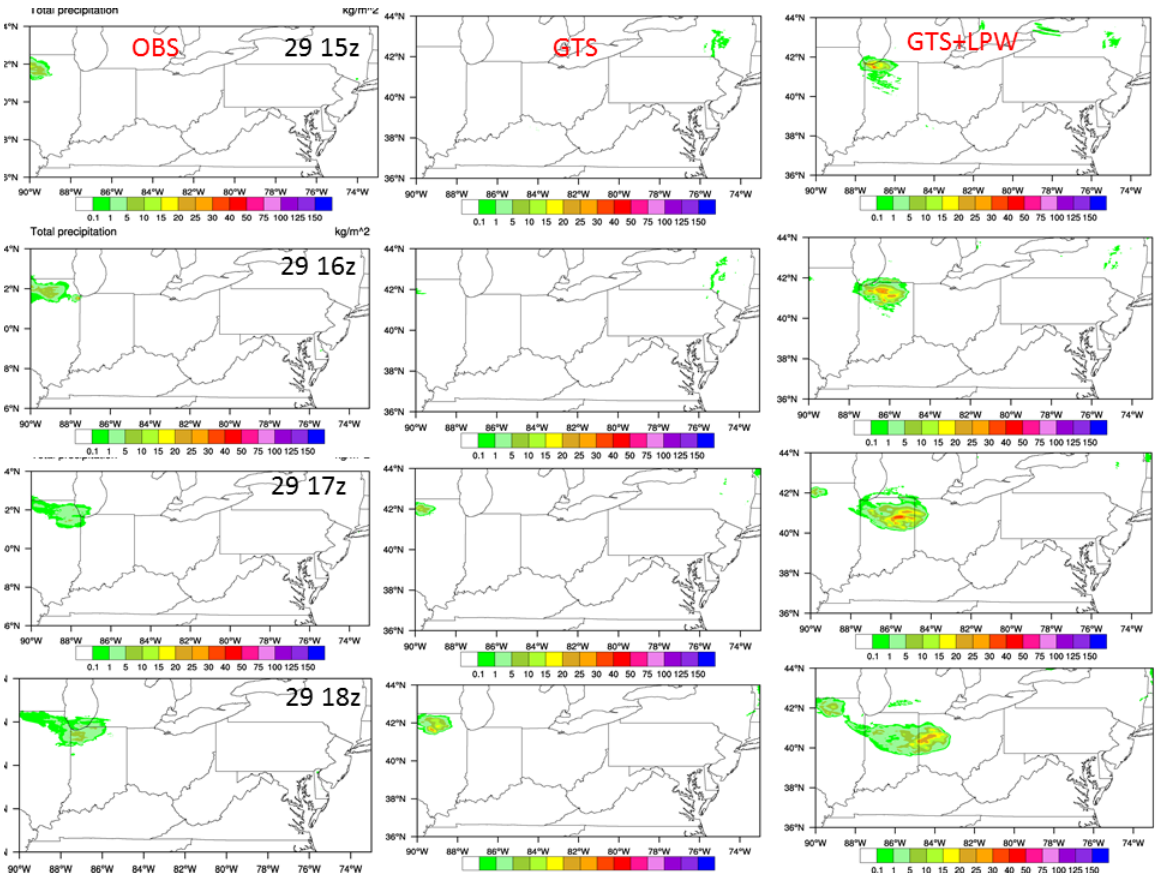

Figure 41. The hourly precipitation forecasts of 2012 CONUS derecho case, two experiments are conducted, one with conventional (GTS) (middle panels), the other with conventional data and GOES Sounder LPW (right panels). The left panels are observations.

GOES-R Rapid scan proxy AMVs impact on high impact weather forecasts

The derived products such as atmospheric motion vectors (AMVs), one of the important products of GOES-R, are very useful for improving HIW forecasts. CIMSS scientists (Chris Velden's group) have developed the advanced AMV research products such as rapid scan AMVs which are valuable for tropical cyclone (TC) forecasts. CIMSS HIW team is collaborating with Chris Velden's group on assimilating the real time research AMV product from GOES/GOES-R into SDAT (CIMSS satellite data assimilation for tropical storm forecasts, http://cimss.ssec.wisc.edu/sdat). Recently, Chris' group have reprocessed the rapid scan AMVs for hurricane Sandy (2012) case with more time steps, we have done assimilation experiments with those re-processed AMVs in SDAT, we assimilated it along with conventional data (GTS) and four AMSU-A (Aqua, NOAA-15, NOAA-18, and Metop-A) data followed by 72-hour forecasts. The experiments include assimilation of IR winds, VIS winds and both IR/VIS winds. Instead of assimilating data every 6 hours, the AMVs are assimilated every 3 hours to reflect the high temporal resolution of GOES/GOES-R measurements. Assimilation times are from 18 UTC 25 Oct to 18 UTC 27 Oct 2012; forecast times are from 18 UTC 25 Oct to 18 UTC 30 Oct, 2012. Total 9 groups of forecasts are included in the comparisons with the best track reference, Figure

42 shows the RMSE of minimum sea level pressure (SLP) (lower right panel) forecasts (6 – 72 hours) for Hurricane Sandy (2012). The numbers of distribution as a function of atmospheric pressure level for IR and VIS AMVs are shown in the middle right panels, one example of coverage for IR and VIS AMVs assimilated into WRF are shown in the upper right two panels. This is the 3-hourly assimilation results for Hurricane Sandy (2012) with assimilation of AMV data. The assimilation of AMV (IR) shows positive impact on the long time track forecasts, assimilation of AMVs has also positive impact on hurricane intensity (SLP), especially the assimilation of AMV (all) and AMV (IR). 3-hourly assimilation of AMV data shows better results in general than 6-hourly assimilation which is the current operational approach. The next step is to add AIRS in the ctrl run (GTS+AMSUA+AIRS), and then assimilate GTS+AMSUA+AIRS+AMV as the experiments. Also, we want to test different QC of AMV data, and also to do bias correction for AMV before assimilation.

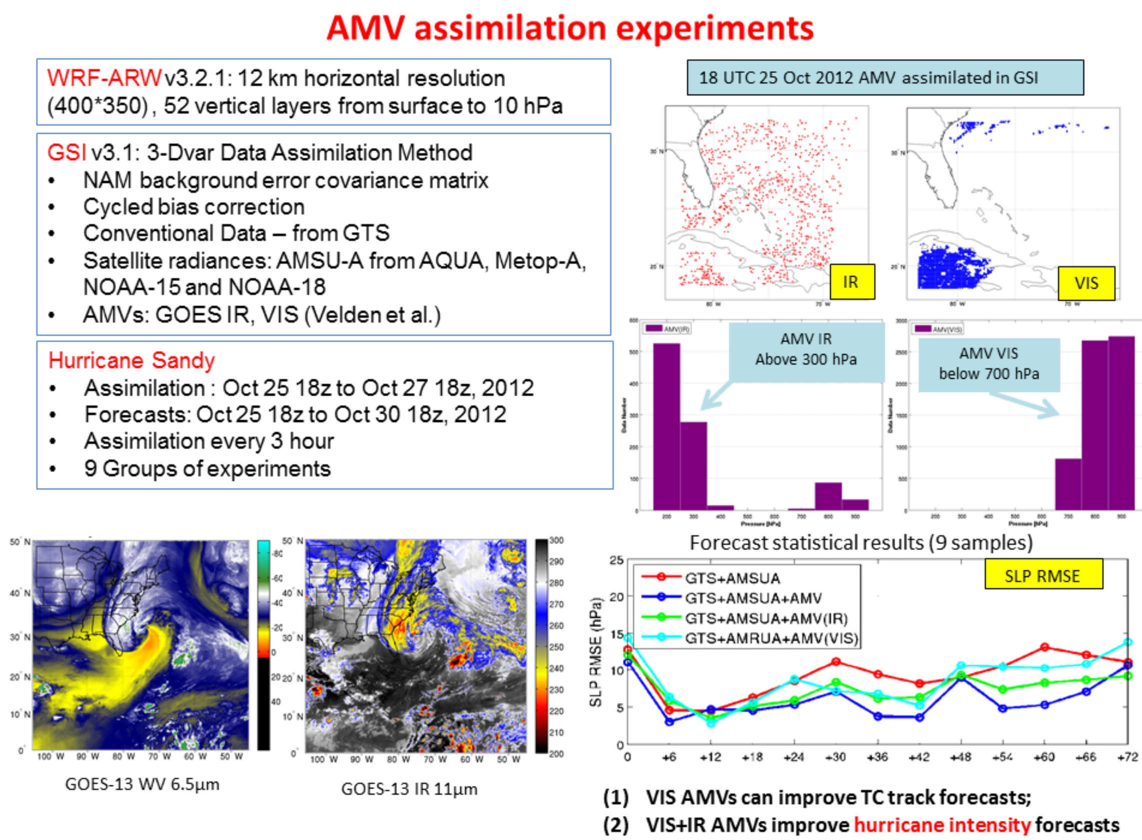

Figure 42. The RMSE of minimum SLP (lower right panel) forecasts (6 - 72 hours) for Hurricane Sandy (2012) (lower right panel). The numbers of distribution as function of atmospheric pressure level for IR and VIS AMVs are in the middle right panels, one example of coverage for IR and VIS AMVs assimilated into WRF are in the upper right two panels.

Deep convective cloud identifications from both broadband and hyperspectral IR measurements

Deep convective clouds (DCCs) are associated with severe storms, which usually cause dangerous turbulences and transport ice and supercooled large droplets into high-level atmosphere to form icing condition. Those are the reasons for it becoming a threat to aviation safety. However, there is not a universal DCC identification method for satellite measurements. In the past, the most two popular methods are:

(1) Thresholds based on the absolute value of an atmospheric IR window channel;

(2) Thresholds based on the brightness temperature difference (BTD) between an atmospheric IR window or a weak water vapor absorption channel, and a channel centered on a strong water vapor absorption line.

Hyperspectral IR sounders, such as AIRS, CrIS and IASI, allow the application of BTD method for better DCC detection but only from low earth orbit (LEO) platforms, the broadband spectral imagers, such as imagers from Japanese MTSAT series, U.S. GOES series, and European MSG series, etc., remain the primary measurements in observation of DCC development from GEO platforms. Our study is focused on the following questions:
(1) What pressure level (geopotential height) can the convective clouds reach once they are identified as DCC?
(2) What threshold is appropriate for DCC from an atmospheric IR window channel?
(3) What are the advantages of hyperspectral IR measurements on DCC identification over the broadband images?

Methodologies have been developed for detecting DCC from both broadband and hyperspectral IR measurements accounting for atmospheric profile and local zenith angle. Figure 43 shows the satellite BT images from a broadband GOES-12 Imager (upper left) and hyperspectral AIRS (lower left) for a case of Air France (AF) 447 (red circle area), and the BT distribution (frequency) with different DCC detection methods (BTD<0, BT<224.7 K and BT<232.4 K), the blue lines indicates the calculated relationship between IR window BT and the cloud-top pressure (CTP) (right y-axis), the radiosonde (green diamond) located in the left panels is used in the calculations, the upper right panel is for GOES-12 Imager and the lower right panel is for AIRS.

Publications and Conference Reports

Li, Jinlong, Jun Li, Pei Wang, 2014: A Near Real-Time Regional Satellite Data Assimilation System for High Impact Weather Research and Forecasts, JCSDA Newsletter, No. 46, March 2014 (http://www.jcsda.noaa.gov/documents/newsletters/201403JCSDAQuarterly.pdf).

Zheng, J., Jun LI, Timothy J. SCHMIT, Jinlong LI, and Zhiquan LIU, 2015, The Impact of AIRS Atmospheric Temperature and Moisture Profiles on Hurricane Forecasts: Ike (2008) and Irene (2011), Advances in Atmospheric Sciences, 32, 1 – 17.

Li, Jinlong et al., A near real time regional satellite data assimilation system for high impact weather research and application, 5th Asian Oceania Satellite Users' Conference, 19 – 21 November 2014, Shanghai, China.

Li, Jun, Pei Wang, Jinlong, and Tim Schmit, 2014: Handling clouds in assimilating high spectral resolution infrared radiances, The 94th AMS Annual Meeting, 2 – 6 February 2014, Georgia World Congress Center, Atlanta, Georgia.

Li Jun, Timothy J. Schmit, Jinlong Li, Pei Wang, and Zhenglong Li, 2014: A near real time regional GOES-R/JPSS data assimilation system for high impact weather applications, Warn-on-Forecast and High Impact Weather Workshop, 29 March – 01 April, 2014, Norman, OK.

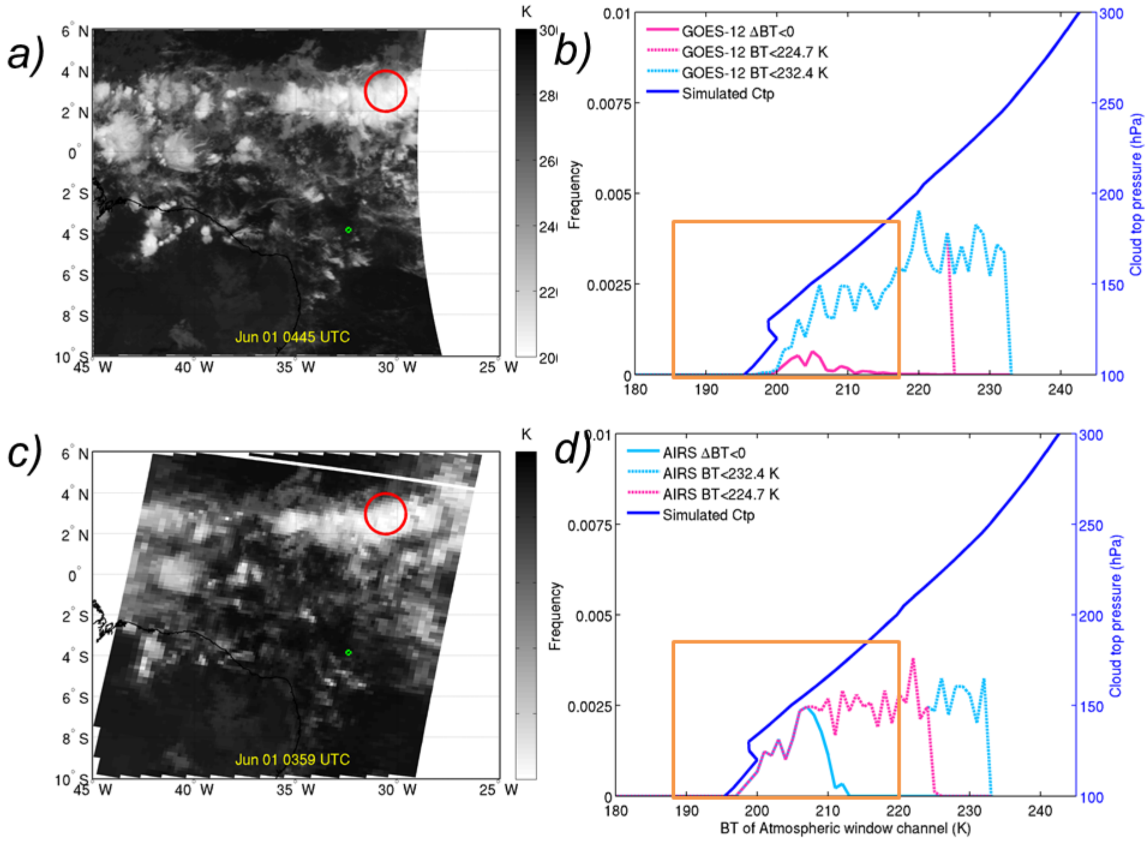

Figure 43. The satellite BT images from GOES-12 Imager and AIRS (left panels), and the BT distribution with different DCC detection methods, along with the calculated relationship between BT and CTP. The results are for AF 447 case.

9. Investigations in Support of the GOES-R Program

9.1 Ongoing Support
CIMSS Task Leader: W. Paul Menzel
NOAA Collaborator: 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

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

Project Overview

Dr. Menzel, Senior Scientist at the University of Wisconsin–Madison, NOAA Cooperative Institute for Meteorological Satellite Studies (CIMSS), will participate in research on environmental remote sensing systems that helps to guide NOAA in evolving the GOES-R and JPSS satellite holdings. This will include (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.

Summary of Accomplishments and Findings in Past Year

Participation in Next Generation GOES Science Team

In June-July 2014 I participated in discussions of the Next Generation GOES Science Team. We drafted a position paper noting three broad goals: evolving the capability of the sensors on the GOES-R series, restoring the removed sensors that were previously approved for GOES-R operations, and considering new capabilities/instruments/spectral regions.

Regarding restoration of the sounding function on GOES, we noted that high spectral resolution IR measurements will enable improved delineation of critical moisture distributions, especially in the boundary layer. This includes depiction of both changes over time as well as changes in the vertical column; small scale features of moisture will be identified vertically (1 km) and horizontally (<10 km) in the atmosphere. It is expected that the beginning designs should build upon the trade-space from the IR part of the HES (Hyperspectral Environmental Suite) as it was presented at the end of the GOES-R formulation stage. The spatial resolution is finer than 10 km, extended CONUS coverage is possible every 30 minute, and the spectral resolution is at least 0.6 cm-1. While the key measurement will be vertical and horizontal distribution of moisture, other variables can be derived include trace gases, cloud properties, dust, etc. Restoring the HES IR would restore the operationally required and research desired products that have been missing since HES was cancelled. These include: (1) Hourly Advanced Atmospheric vertical moisture and temperature profile (required in NWS Operational Requirements Document for the Evolution of Future NOAA Operational Geostationary Satellites, 1999); (2) Capping inversion information (height & strength); (3) Moisture flux; (4) Surface emissivity; (5) Cloud Base altitude; and (6) Carbon monoxide concentration.

Collaborations with EUMETSAT

Upon invitation from EUMETSAT, I agreed to co-chair (with Dr Dieter Klaes) a session at the EUMETSAT 2014 Meteorological Satellite Conference on satellite data in global and regional modeling. We reviewed roughly 40 papers and selected a subset for oral presentation. I attended the conference held in Geneva Switzerland, chaired the session, and gave a talk on "Recalibrating HIRS Sensors to Produce a 30 year Record of Radiance Measurements."

In December Dr. Schmetz and I finished an article for publication titled "A Look at the Evolution of Meteorological Satellites - Evolving Capabilities and Meeting User Requirements" and submitted it to Weather, Climate, and Society.

Coordinating with Indian Scientists on INSAT-3D Utilization

SSEC is writing software to stage the INSAT 3D sounding data for local processing. We will compare soundings produced at SSEC with those prepared at ISRO SAC and pursue further retrieval testing. Ultimately INSAT-3D soundings will be assimilated in a regional model evolved from the CIMSS Regional Assimilation System (CRAS) to study forecast impact.

Evolving the HYDRA Toolkit

Working with Tom Rink at SSEC, we have improved the HYDRA data visualization toolkit used in the training boot camps. The software supporting Suomi NPP has been added to the CSPP (Community Satellite Processing Package) and user feedback has been positive. In addition software has been added for beta testing to support AVHRR from the Metop series via EUMETSAT's EPS HDF5 format as well as HIRS and MHS also available in HDF5. The new version of HYDRA thus enables quantitative interaction with data from the following instruments: AIRS, AMSU, ATMS, AVHRR, HIRS, IASI, MODIS, MHS, and VIIRS.

Participation in IAC during NOAA Science Week

In February 2015, I participated in the Independent Advisory Committee discussions and helped to draft the final recommendations to the JPSS and GOES-R programs. Some of the recommendations that may be of interest are:

- Plans for scientists to remain close to their algorithms during operational implementation need further specification. A C++ facilitator must be sustained for scientists /algorithm providers to adjust / update / correct their original code (incorporating the 5-7 years of progress that has been accomplished under the AWG) and preparing for rapid post-launch adaptation to actual data. Anticipating the usual necessary post-launch adjustments, a briefing to the IAC on the algorithm change process should be arranged for all instruments including space weather.
- A briefing from the AWG to the IAC should be scheduled after 6 months of experience with AHI data; lessons learned from the processing and L2 product quality should be addressed. Destriping and rectification studies should also be presented where possible.
- Changing from 15 to 10 minute full disk imaging with ABI must be made a high priority. Japan (will demonstrate this capability with the AHI), Europe, and China are preparing their geo satellites for 10 minute imaging. Global synergy and improved products should dictate implementation in the US also.
- Cal/Val must remain a sustained effort during the lifetime of the mission. Prospective field experiments need to be posted and coordinated with possible partners and scientific goals need to be focused on highest priority needs. Routine GSICS intercalibration for ABI to VIIRS/CrIS must become a cornerstone that is supported by the GOES-R program.
- To pursue the missing continuous hyperspectral viewing necessary for completely capturing the rapidly changing conditions that go with severe weather, the move to a GEO high spectral resolution IR sounder should receive strong consideration. Updates on the Geo hyperspectral IR OSSE need to be briefed to the IAC. In addition, opportunities for accessing MTG IRS data and FY4 data need to be explored. The various options for providing hyperspectral data from geostationary orbit again need to be considered.
- In relation to the future CrIS and VIIRS for J3 in around 2026, improved spatial and spectral coverage should be pursued. The need for addition of the water vapor channel on VIIRS to accomplish polar winds for NWP has been documented. VIIRS DNB spectral expansion should be explored. Spectral gaps on CrIS should be filled where possible. Improvement of the CrIS FOV to 10 km should be considered. The IAC recommends keeping all scan lines in the VIIRS SDR for future JPSS-1,… Currently several lines are removed in the bow-tie areas toward the end of scan.

9.2 McIDAS-V Support for GOES-R Risk Reduction Projects
CIMSS Task Leader: Tom Rink
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
The goal of our project was to develop McIDAS-V computation and visualization of 2D/3D wind parcel trajectories from a time varying, Eulerian set of gridded wind fields. Applications relevant to GOES-R include: display 3D trajectories through time combining ABI retrieved Aerosol Optical Depth (AOD) and numerical model wind forecasts; visualization of forward trajectories of wind parcels combined with ash/SO2 ABI retrievals in the vicinity of a volcanic eruption. McIDAS-V is well suited to GOES-R data product integration into an interactive, 4D display environment since it has the ability to 'understand' CF-compliant datasets, and GOES-R products are mandated to adhere to this community standard to facilitate data sharing.

Summary of Accomplishments and Findings
Computation and visualization of wind parcel trajectories from a Eulerian gridded wind field has been implemented and demonstrated on a representative set of datasets including NCEP forecast and reanalysis products for 2D flow fields. Users can interactively control trajectory duration, start locations and other parameters, as well as, color the trajectory rendering to represent an arbitrary scalar value, for example a conservative property like equivalent potential temperature. Figure 44 shows progress to date in developing the necessary software infrastructure to compute and visualize wind parcel trajectories from a time series of gridded wind fields. Parcel trajectory paths can be animated through time – not shown. Enhancements for 3D domain are currently being developed and tested.

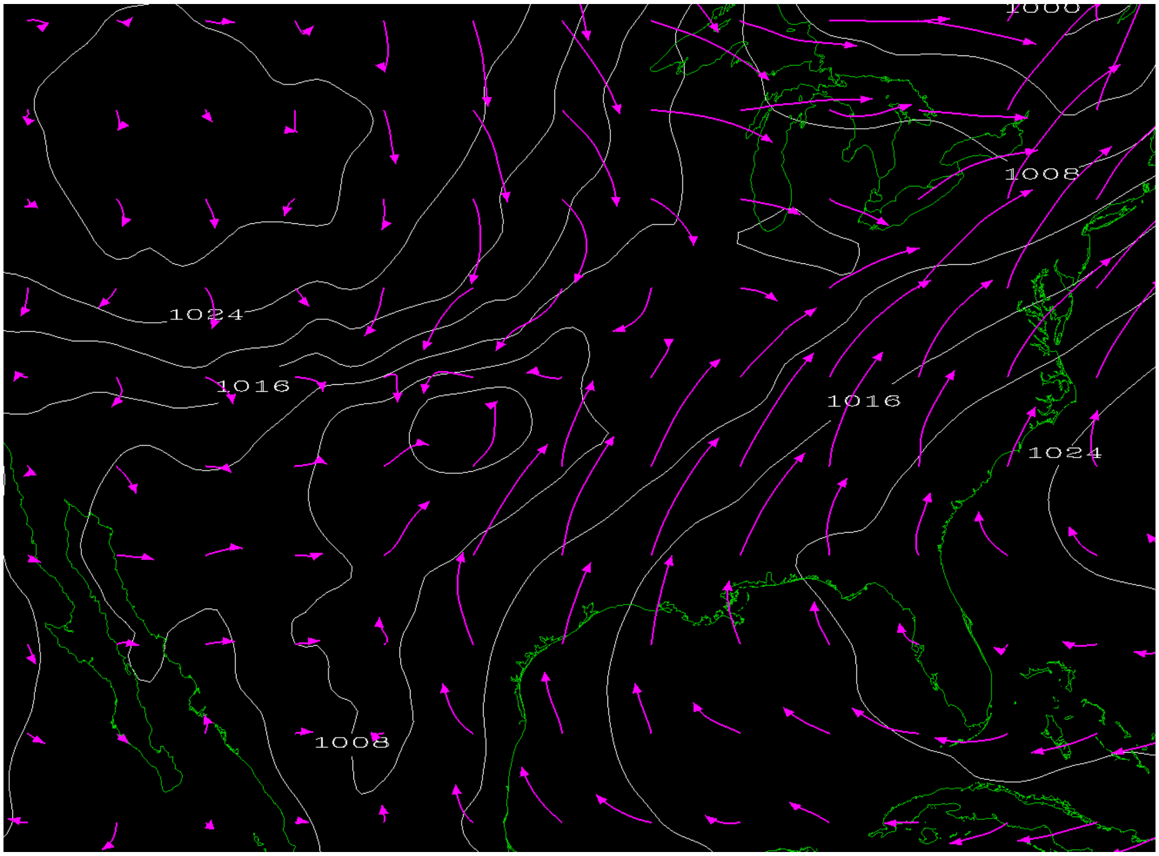

Figure 44. Wind parcel trajectories (purple) computed from RAP (Rapid Refresh) with MSL (white) at 900 mb.

Publications and Conference Reports
AMS Annual Meeting (IIPS): 2005-2013
AMS Satellite Meteorology Conference: 2007, 2009, 2010, 2012, 2013, 2014
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), 2009-2015
International TOVS Working Group Meeting: 2007, 2008, 2010 (workshop), 2012, 2013
McIDAS Users Group: 2006-2013 (workshops 2008-2014)

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
- 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.

Summary of Accomplishments and Findings

Alaska is in the extreme northeast portion of AHI full-disk coverage (Figure 45), 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 (Figure 46).

A number of Himawari-8 AHI images that are suitable for high-latitude work have been acquired. Cases are from February March 2015. The algorithms listed above are currently being modified for use on the AHI data. Results with the test cases are expected to be available by May 2015.

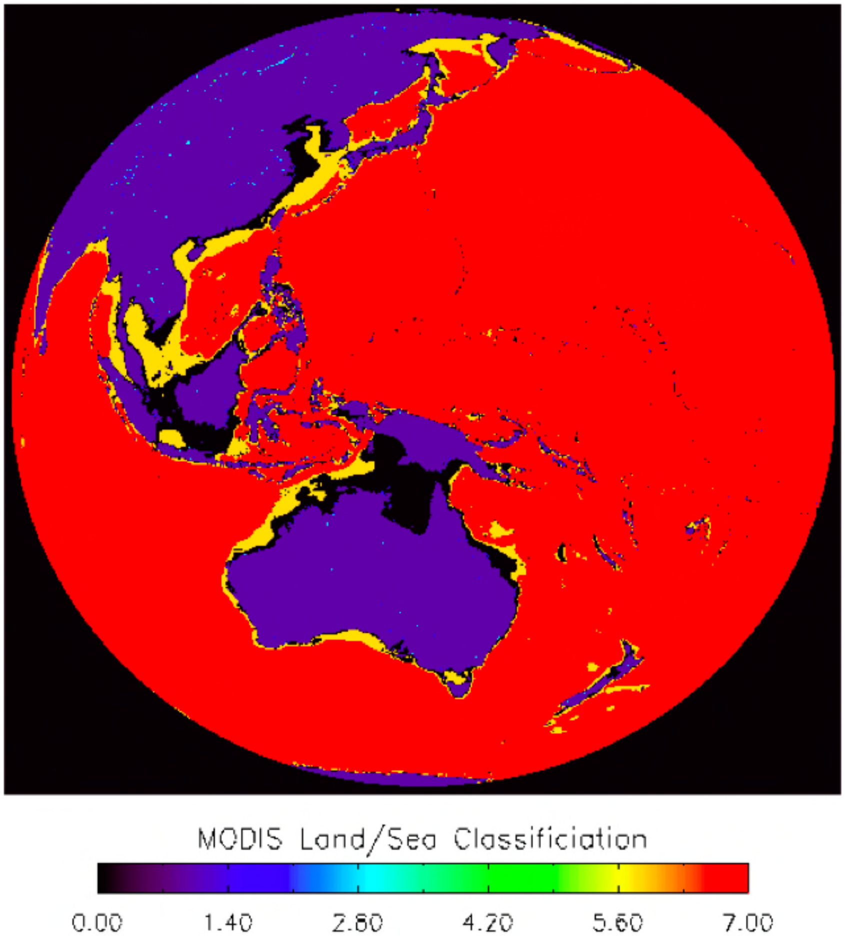

Figure 45. MODIS land/sea classification projected on the Himawari-8 AHI disk. Western Alaska is in the upper right.

Figure 46. False color AHI image on a projection that better illustrates coverage of the northern latitudes. Alaska is in the upper right.

11. Assimilation of All-Sky Microwave and Infrared Satellite Radiances: from Research to Operations

CIMSS Task Leader: Jason Otkin
CIMSS Support Scientist: Sharon Nebuda

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 are an essential component of the atmosphere as they occupy a central role in the earth system water cycle and radiative budget. Hence a proper depiction of the cloud microphysical parameters is crucial for climate modeling and numerical weather prediction. However, clouds are still poorly represented in the initial conditions used by numerical weather prediction models. This results in major limitations for short-term weather prediction, particularly for extreme events that can be very sensitive to moist dynamical processes in cloudy regions. Satellite observations provide valuable information about the cloud field, however, observations affected by clouds and precipitation are typically discarded in operational data assimilation systems, which means that potentially valuable information is lost. The assimilation of such data requires overcoming difficult challenges such as the accuracy of the radiative transfer model in cloudy conditions, the correction for biases, the estimation of background and observation errors, the ability to handle strong nonlinearities, and the adaptation for non-Gaussian error distributions.

For this project, research will be conducted to improve the assimilation of all-sky (i.e., clear and cloudy) satellite radiances for microwave and infrared sensors in the hybrid Global Forecasting System (GFS) Gridpoint Statistical Interpolation (GSI) Ensemble Kalman filter data assimilation system. New satellite observation quality control and bias correction procedures will be developed along with methods to handle nonlinearities in the models. The data assimilation analysis control variable and background error covariance matrix will also be expanded to include cloud hydrometeors during the assimilation step. These developments will be implemented in the latest trunk version of the GSI and the impact of all-sky radiances on forecast skill will be evaluated. The CIMSS contribution to this project, which is being led by researchers at the National Center for Atmospheric Research, is to evaluate the accuracy of the Community Radiative Transfer Model (CRTM) for cloud and precipitation-affected satellite observations.

Summary of Accomplishments and Findings

To examine the accuracy of the CRTM in all-sky conditions, collocated observed and model equivalent brightness temperatures were obtained for a two month period from April-May 2014 using version 2.1.3 of the CRTM and the current operational version of the hybrid GFS data assimilation system run at T670 resolution benchmarked on the S4 supercomputer. Our analysis has focused on examining relationships in the departures between observed and model equivalent brightness temperatures for several infrared and microwave sensors. Dependencies on sky conditions depicted by the satellite sensor and GFS model have been found for the brightness temperature departures. Figure 47 shows the root mean square errors computed over the two-month time period for ocean grid points for six channels on the AMSU-A microwave sensor for both ascending and descending orbits and all satellite zenith angles. These errors are plotted as a function of the AMSU-A estimated cloud liquid water content along the x-axis. The image on the left shows the errors before the variational bias correction scheme is applied, whereas the image on the right shows the errors after the bias correction scheme has been used. Overall, large errors are present in the 23.8, 31.4, and 50.3 GHz water vapor sensitive channels before bias correction has been applied with the errors steadily increasing as the amount of cloud liquid water increases. The errors are much smaller after the bias correction scheme is applied, however, there is still a notable increase in the errors as the cloud liquid water content increases, which indicates that there is still a cloud-dependent component to these errors.

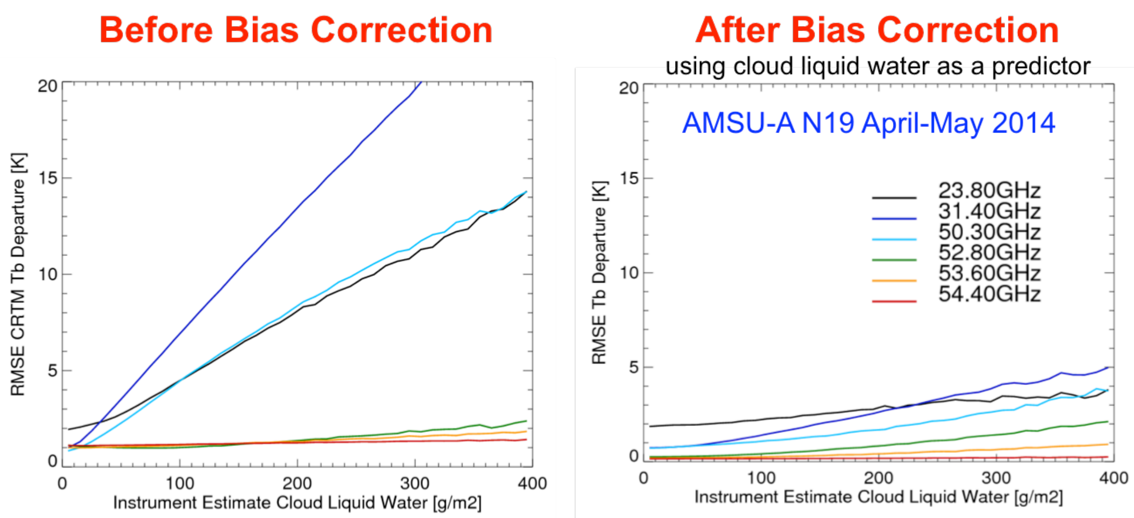

Figure 47. Root mean square errors computed using data from ocean grid points during the two month evaluation period for six channels on the AMSU-A microwave sensor before the existing variational bias correction scheme is applied (left panel) and after the correction scheme has been used (right panel).

Efforts are currently being directed toward determining optimal ways to estimate sky conditions in the observations and model background as a means to segregate the data into groups in which the observed and model cloud fields have similar characteristics. The goal is to identify biases in the simulated brightness temperatures due to deficiencies in the representation of the cloud characteristics in the CRTM and GFS rather than to a mismatch of the large-scale circulation of the model first guess with the observed state. Consideration is also being given to the uniformity of the cloud features to reduce the influence of disparities of scale between the model grid boxes and sensor footprints.

12. GOES-R Capable Antenna Upgrade - EOY

CIMSS Task Leader: Steve Ackerman
NOAA Collaborators: Jeff Key, Tim Schmit

NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation
- Society is prepared for and responds to weather-related events

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

Project Overview

It is important that CIMSS/SSEC has an antenna on site that is capable of receiving GOES-R Rebroadcast (GRB) data, and that the antenna is in place when the GRB data stream is turned on. This will allow us to test our software on the live data stream before we release new versions, and to address any software issues reported by users as they arise.

We propose to split the costs of the GOES-R reception system. The GEO Community Satellite Processing Package (CSPP) project will provide a 7.3 meter antenna and all infrastructure necessary to receive GRB data from one satellite located anywhere between 75 degrees West and 137 degrees West. The cost for the antenna electronics (RF Kit, DVB2 receiver, cable kit and other acquisition hardware) is estimated to be $84,000. CIMSS/SSEC proposes this cost to be split between GOES-R GEO CSPP and NOAA NESDIS with each contributing $42,000.

Summary of Accomplishments and Findings

The majority of the funds were used to purchase the antenna components (feed, cabling, DVB-S2 demodulator), with some funds devoted to system redundancy and longevity (the compressed air for the feed allows for longer life and reliability.) The costs for existing antenna and infrastructure are not specified. The cost for installation will be known after installation is completed.

The request for bids was published on January 20, 2015. The wining bid to upgrade an existing 7.3 m antenna totaled $100,500 USD. The winning bidder was Quorum Communications Inc. A requisition was submitted for the winning bid on March 9, 2015. The upgrade installation is scheduled for late summer 2015.

This task provided $42,000 toward the purchase. An additional $42,000 was contributed by the CSPP-GEO project. The 7.3 meter antenna was provided by the University of Wisconsin SSEC. The remaining $16,500 balance was paid for from other non-NOAA sources.

Component	Unit Cost	Qty	Total
Antenna electronics (Feed, DVB-S2 demodulator)	$51,500	1	$51,500
Compressor for pressurized feed	$2,500	1	$2,500
Redundant "hot spare feed" and redundant demodulator	$46,500	1	$46,500
7.3 meter Antenna	Unknown	1	Unknown
Total*			$100,500

*Total does include value of antenna or installation costs provided by UW–Madison SSEC.

13. GOES-R Future Capability: SO_2 Detection

CIMSS Task Leader: Justin Sieglaff
CIMSS Support Scientist: John Cintineo
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 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%). An example of the GOES-R AWG SO_2 detection product is shown in Figure 48.

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.

Summary of Accomplishments and Findings

Similar to volcanic ash, a cloud object based approach is utilized to detect SO_2. The approach also utilizes a combination of radiative transfer theory, a statistical model, and image processing techniques to identify SO_2 in satellite imagery with skill comparable to that of a human expert (e.g., Pavolonis et al., 2014a; Pavolonis et al., 2014b). An extensive training dataset has been developed using MODIS spectral data from several explosive eruptions in the recent past (e.g., Kasatochi 2008, Sarychev 2009, Redoubt 2009, and others) containing large amounts of SO_2, as well as very recent events of non-explosive SO_2-producing volcanoes (Bardabunga 2014 – see Figure 49, Fogo 2014). This dataset has been manually analyzed to isolate areas of SO_2. Certain spectral properties unique to SO_2 detection will then be extracted from within the spatial bounds of these identified regions and used to train the statistical model of the algorithm. The SO_2 detection algorithm, as developed within VOLCAT, will be tested and validated using existing satellite imagers with the required spectral measurements (e.g., SEVIRI, MODIS, and Himawari-8). Upon implementation of the SO_2 detection algorithm within VOLCAT, the SO_2 detection and alerting will be processed in near-realtime at UW–Madison/CIMSS and distributed to operational partners for evaluation.

References

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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*.

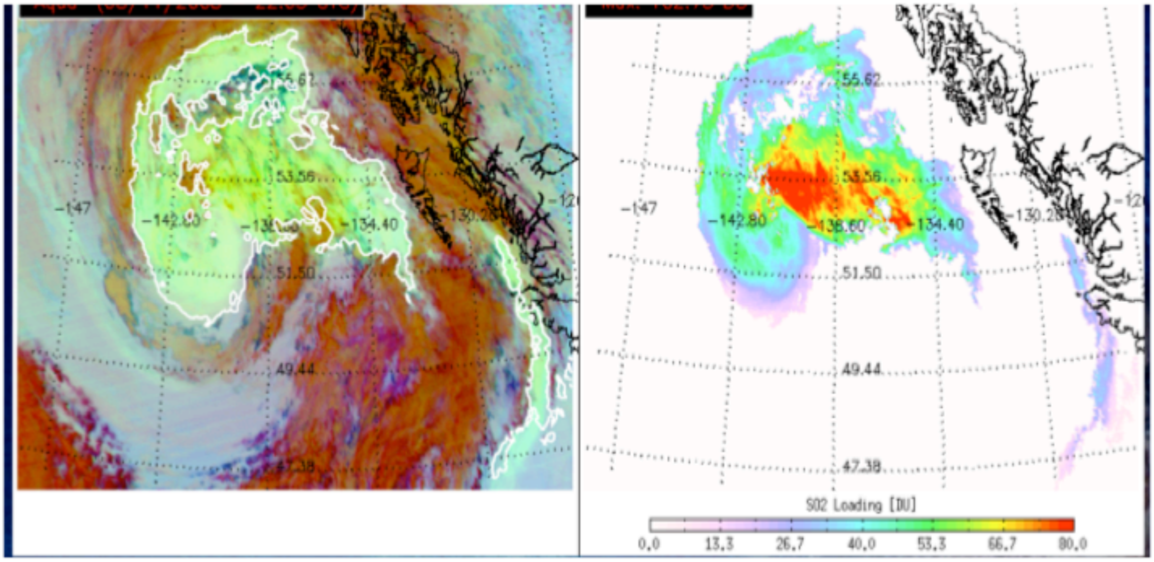

Figure 48. An example of GOES-R AWG SO_2 detection for the Kasatochi Volcano eruption on August 11, 2008 viewed by Aqua-MODIS. The left panel is a false color image with the region of SO_2 detected by the GOES-R AWG algorithm outlined in white and the right panel is SO2 loading (DU) for the SO_2 detected pixels.

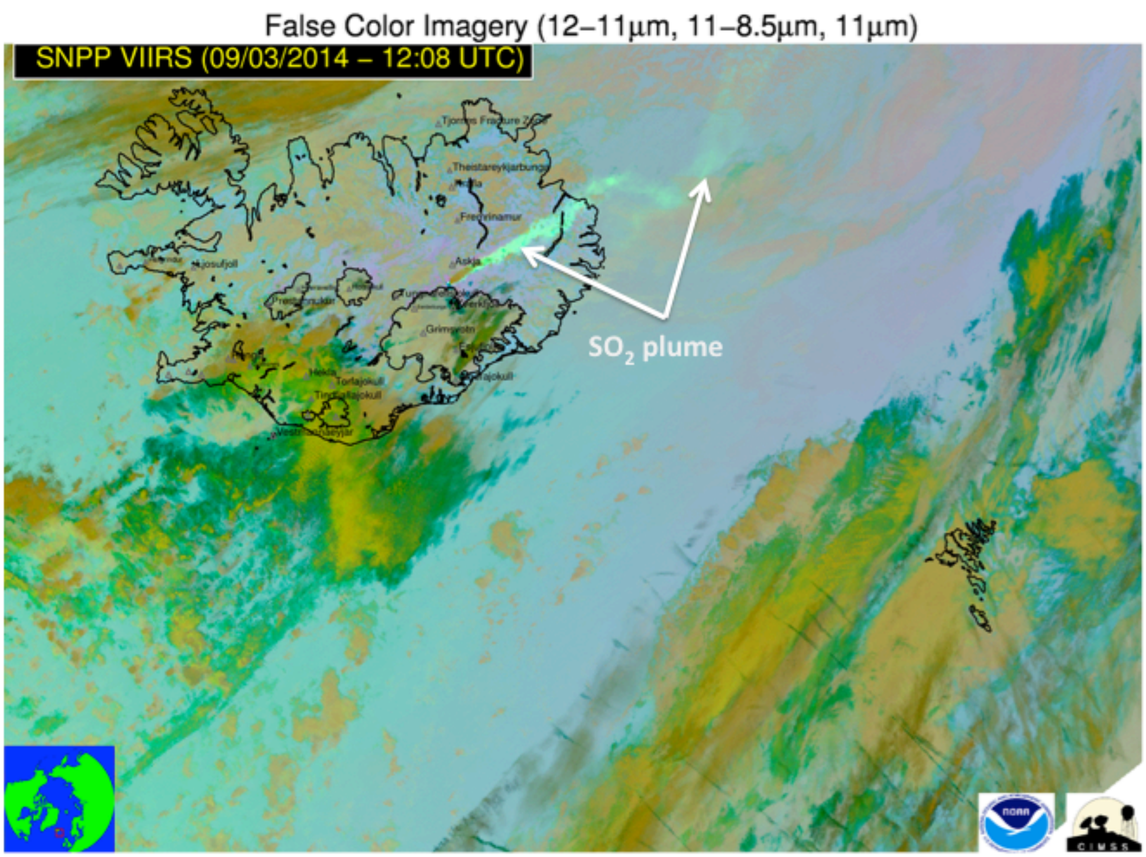

Figure 49. False color imagery from Suomi NPP VIIRS, highlighting an SO_2 plume from the fissure northeast of the Bardabunga volcano in Iceland. The high spatial resolution from LEO satellites may help inform spectral signatures observed in data from high temporal GOES-R ABI.

14. Identification of GOES-R Storm Top Features
CIMSS Task Leader: Pao K. Wang

NOAA's 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
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 investigate special features exhibited in visible and infrared storm images (for example, the cold-U, V, above anvil plumes, and jumping cirrus) and study their characteristics. We utilize a physics-based cloud resolving model to simulate thunderstorm processes so as to see if the simulated storm exhibits the same visible and IR features as observed. If the simulating is successful, then we use the model physics to explain the physical processes responsible for producing these features. The characteristics of the features so identified and physically interpreted can used to form quantitative relations between them and physical variables of the storm (e.g., winds, updraft, humidity, turbulence, etc.). Such relations will serve as the basis for quantitative retrieval of storm properties. We propose to continue examining existing and identifying new storm top features and studying the physics and dynamics responsible for producing them.

Summary of Accomplishments and Findings
We have identified several features in the past and have performed model simulations of them. We are analyzing the model results to understand the physics behind these features. Among such features, we are currently working on two of them: the ship wave signature and the radial cirrus feature. Figure 50 shows a ship wave feature that we believe is due to the obstacle effect of storm updraft to the ambient flow.

We have performed a series of model sensitivity studies to test the theory that this feature is generated by the obstacle effect of the storm updraft. The preliminary results show that the theory is probably correct, as indicated by the presence of the counter-rotating eddies in the core region in the simulated results (Figure 51). We will investigate this phenomenon further. Since the formation of ship waves is related to the ambient winds, the elucidation of it may lead to a quantitative method of retrieving storm top winds.

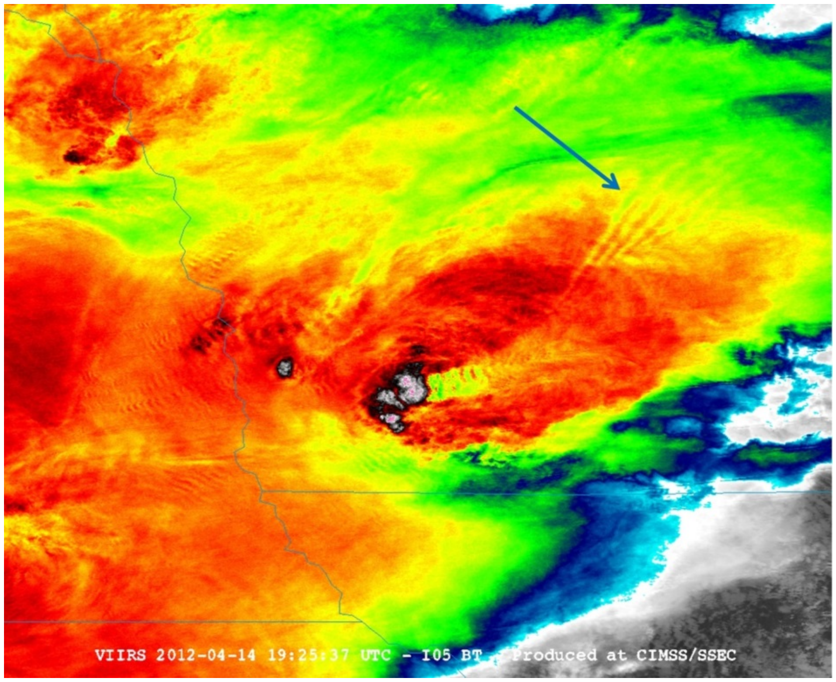

Figure 50. An example of storm top ship wave (indicated by blue arrow) in Suomi NPP VIIRS image (courtesy of Kris Bedka).

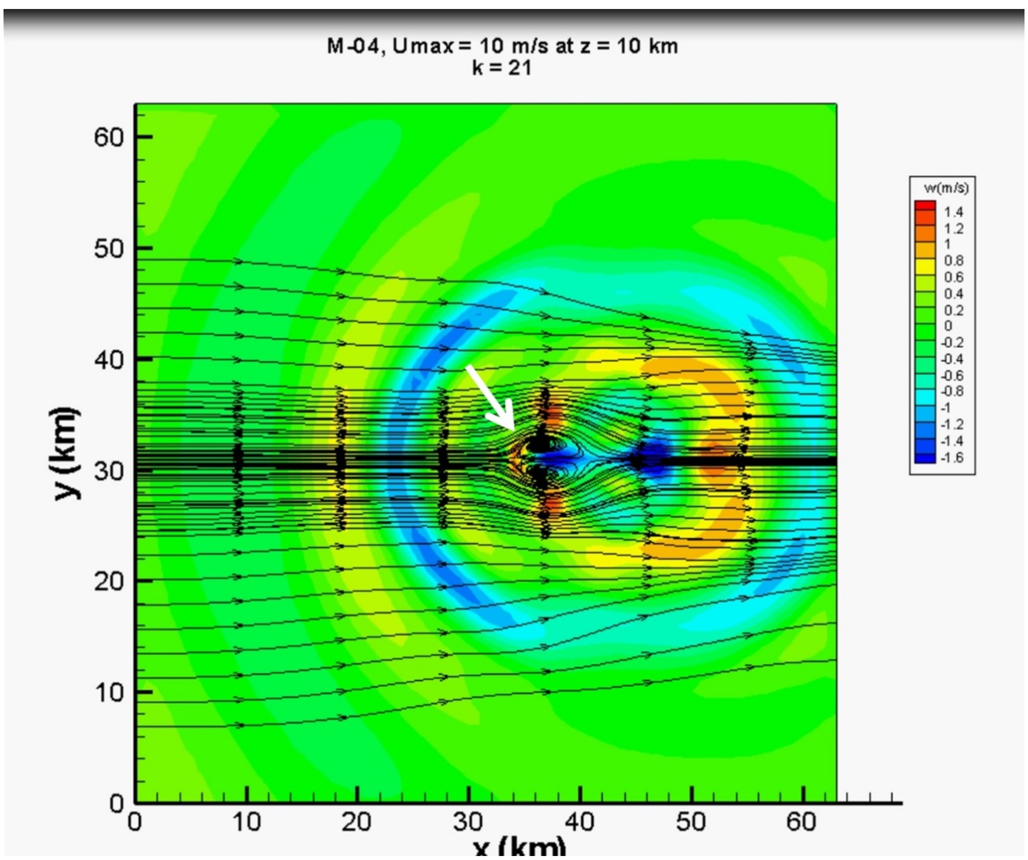

Figure 51. The distribution of updraft (w, color) and streamlines (black contours) on the horizontal cross-section z = 10km of a simulated idealized storm showing the presence of a pair of counter-rotating eddies (indicated by a white arrow) in the updraft core region of the storm.

Another phenomenon that we have been studying is the "storm top radial cirrus" (Figure 52). Currently we theorize that this feature is due to the interference of upward propagating internal gravity waves. We are performing simulations to investigate the physics of this feature.

We have also discovered a "gullwing" feature in the CALIPSO image of a storm system (Figure 53). 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). We have submitted a paper to *J. Geophys. Res.* This paper is currently under revision.

We had also participated in the webinar sponsored by NOAA. The title is listed below.

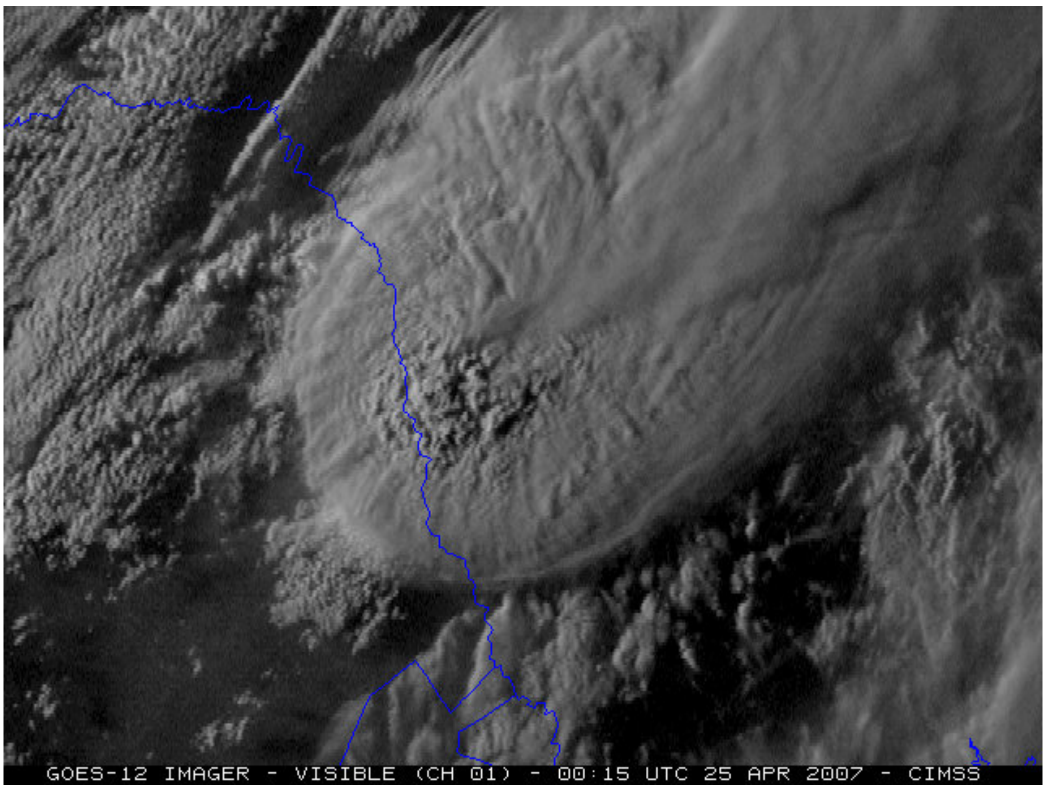

Figure 52. An example of storm top radial cirrus in a channel 1+2 satellite storm image (Courtesy of CIMSS).

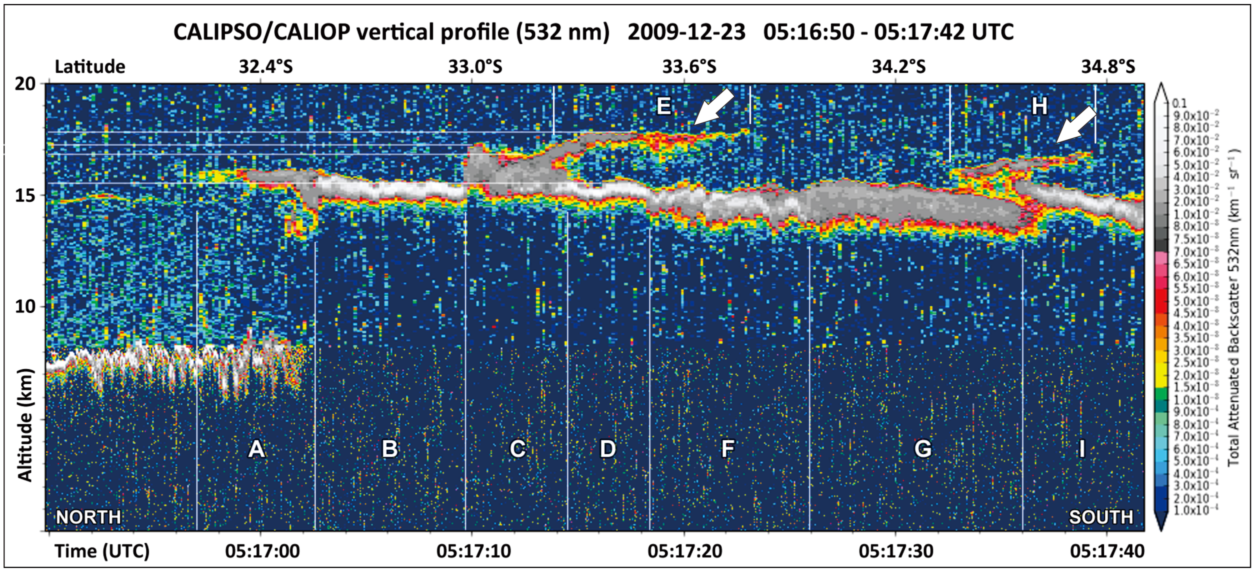

Figure 53. The gullwing feature (indicated by white arrows) of two storm systems in a CALIPSO image (courtesy of M. Setvak).

Publications and Conference Reports

Wang, P. K., K. Y. Cheng, M. Setvak, and C. K. Wang, 2015: The origin of the gullwing-shaped cirrus above an Argentinian thunderstorm as seen in CALIPSO images. J. Geophys. Res. (submitted, under revision)

Wang, P. K., T. Hashino, K.-Y. Cheng, M. Putsay, M. Setvak: Gravity wave interference signatures atop thunderstorms as observed by satellites. EUMETSAT Conference 2014, 26 Sept 2014, Geneva.

Wang, P. K., 2014: Interpretation of storm top features as observed by satellites. Webinar presented at GOES-R Seminar, 30 Oct 2014, Madison, WI.

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

CIMSS Task Leader: Liam Gumley (PI), Graeme Martin (PM)
CIMSS Support Scientist: Scott Mindock, Jess Braun, Nick Bearson, Tommy Jasmin, Geoff Cureton, Kathy Strabala, Ray Garcia
NOAA Collaborator: Steve Goodman, Satya Kalluri

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.

CIMSS/SSEC is creating software for decoding the GOES-R sensor data from data received via the GRB downlink. To this end, SSEC will review the GOES-R Product Users' Guide (PUG) for the definitions of the GOES-R Level 1B products (Level 2 for GLM) and create requirements, a design specification, and software for decoding, extracting, and reassembling the Level 1 products in netCDF format from the CCSDS packets included in the GRB downlink.

CIMSS/SSEC is adding support for geostationary satellites in the Community Satellite Processing Package (CSPP), starting with the current generation of GOES, and in future extending support to GOES-R, Meteosat, MTSAT, and Himawari. The initial effort is focused on releasing a subset of the GOES-R Algorithm Working Group (AWG) cloud algorithms integrated in the Geostationary Cloud Algorithm Testbed (GEOCAT) framework to support processing of GVAR data from the current generation GOES Imager. GEOCAT will allow users who receive direct readout GVAR data from GOES 12-15 to create Level 1B (calibrated and geolocated sensor observation) and Level 2 (geophysical retrieval) products using the GOES-R AWG algorithms. The CSPP GEO product generation software will initially be released to a small group of testers in the GOES Direct Readout community to help test the software, verify the products, and provide feedback. Following a successful test phase, the CSPP GEO software will be released to the US and international direct readout community at large.

As a primary goal, the CSPP GEO software will be capable of processing GOES Rebroadcast (GRB) data received from the next-generation GOES-R satellite, scheduled for launch in early 2016. Level 2 Advanced Baseline Imager (ABI) products will be generated by state-of-the-art science algorithms developed under the GOES-R Algorithm Working Group project. These algorithms are currently being adapted for DB use in collaboration with the original science teams. To help prepare users for the launch of the GOES-R satellite, the project will also develop and release software to process current GOES Imager and Himawari AHI data received by DB users, including Level 2 product generation using the algorithms developed for GOES-R. This will give users an early look at the GOES-R products and also provide products that are useful for forecasting and modeling.

The CSPP GEO Software is freely available and is distributed as self-contained binary packages built for 64-bit Linux systems. Recommended hardware configurations vary by package, however in general users can expect that the minimum hardware baseline for GRB data processing will be higher than CSPP packages for LEO, due to the higher bitrate.

Based on our experience in developing similar software for Polar Orbiter Instruments, we expect that the benefits of this project to NOAA and to the direct readout community will include:

- Promoting the use of the GOES-R data products and science software.
- Encouraging early use of GOES-R data among users.
- Encouraging vendors to provide early support for GOES-R data.
- Encouraging DB users to be ready to process GOES-R data on day one.
- Allowing DB users to stay updated on versions of the operational product algorithms.
- Allowing DB users to develop new products, or tailor products to local conditions.

- Providing a catalyst for involving the direct readout community in GOES-R calibration and validation.

Summary of Accomplishments and Findings

The CSPP GEO team at CIMSS SSEC worked on several tasks during the reporting period, including:

1. Packaging prototype L1 and L2 software for creating cloud products from GOES GVAR data;
2. Working with the GRB Simulator to obtain GRB test data;
3. Developing GVAR L1 decoding software to enable L2 products to be created from current GOES GVAR data;
4. Developing GRB decoder software to reconstruct L1 data from GOES-R (L2 for GLM).

Prototype L1 and L2 Software for creating cloud products from GVAR

The CSPP GEO team prepared and released a prototype software package to demonstrate Level 1 and Level 2 processing of GOES imager data using the GEOCAT application. This software package was intended as a proof of concept to show how calibrated/navigated earth observations and geophysical products can be created from GEO data obtained by direct broadcast. In this package this capability was demonstrated using daytime GOES-15 Imager GVAR data obtained from a SSEC Data Ingestor (SDI). The software package was released to a limited set of testers on May 20, 2014. The intent of this version is to demonstrate basic processing capability by running on a supplied test dataset. Support for continuous processing will be added in a later version, including automated download of dynamic ancillary data. The package contained binaries and scripts capable of processing GVAR- formatted GOES-West imager data from an SDI ingestor to produce AREA files, and to further process the AREA files through to level 2 cloud and fog products. The Level 2 products were generated by research implementations of the GOES-R product algorithms, running in a testbed application called GEOCAT, which was developed at the Cooperative Institute for Meteorological Satellite Studies.

Working with GRB Simulator to obtain GRB test data

CIMSS/SSEC obtained a GRB simulator for testing during the reporting period, and used it to better understand the structure of contents of the GRB data to be retransmitted from GOES-R. Copies of test data were retrieved from the simulator, and the simulator was also run in real time mode to send packetized GRB data over the network to an instance of the CSPP GEO GRB decoder software. The CSPP GEO team demonstrated that with the appropriate hardware configuration and network settings, it was possible to decode GRB data fast enough to keep up with the expected 31 Mbit/sec data rate from the GRB transmissions. The CSPP GEO team identified several errors or omissions in the GRB simulator data formats and documentation and fed these back to Harris Corporation. The CSPP GEO team also held several telecons with the Harris team and Quorum Communications to discuss details of the GRB format and demodulation.

CSPP GEO GVAR Software

CIMSS/SSEC announced the release of the CSPP Geo GVAR Version 1.0 software package on April 10, 2015. This is the initial release of software that allows Direct Broadcast users to process GOES Imager data received via the GVAR data stream. The software is publicly available and free to use. The main functionality included in this release is to read raw GVAR files containing GOES-13 or GOES-15 Imager data, and create AREA files remapped to a common projection. The output is intended primarily for use in GEOCAT, a future CSPP Geo software package that will produce Level 2 products using algorithms developed for GOES-R, but it can also be used with McIDAS and other software that is capable of reading AREA files. Additional features include quicklook image generation, and remapping existing AREA files from other sources to a common projection, making them suitable for use in GEOCAT processing.

The system requirements are:

- Intel or AMD CPU with 64-bit instruction support,
- 4GB RAM (minimum),
- CentOS 6 64-bit Linux (or other compatible 64-bit Linux distribution),
- 100 GB disk space (minimum).

The software, documentation and a test case can be downloaded from the CSPP Geo website: http://cimss.ssec.wisc.edu/csppgeo/gvar_v1.0.html

Current operational GOES data (GOES-13 or GOES-15) in GVAR or AREA format are required as input to the CSPP Geo GVAR software. The input GVAR files must have byte- aligned block headers. GVAR files and Index files from the NOAA CLASS archive may be used with this software. The main processing script is $CSPP_GEO_GVAR_HOME/l0/gvar_l0.sh, which operates by default in the current directory. It creates intermediate files, as well as the final AREA output files. The CSPP Geo GVAR software requires a GVAR Image Index file (INDX) in order to process the GVAR files and convert them into AREA files. To execute the GVAR L0 script the path of the index file and the desired region to be processed must be provided. There are four regions that can be selected: Full Disk (FD), Northern Hemisphere (NH), Contiguous US (CONUS), and South Hemisphere (SH). Only one region can be selected at a time. The software creates quicklook images from GVAR data as shown in Figure 54. The software can ingest and reproject AREA files from other sources, and it can also generate index files for GVAR data in the SSEC SDI format.

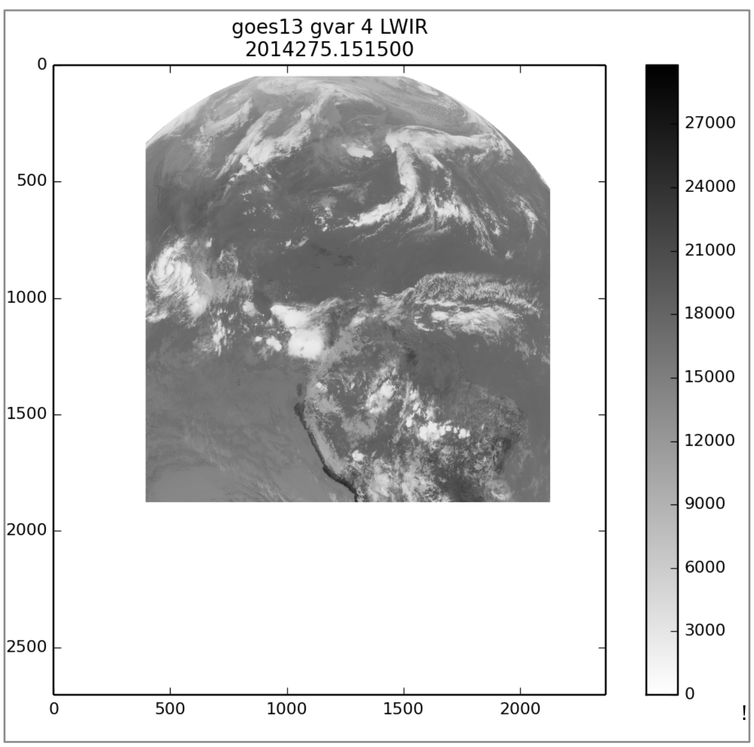

Figure 54. GOES-13 band 4 quicklook image from CSPP GEO GVAR test data (2014, day 275, 15:15 UTC).

CSPP GEO GRB Software

CIMSS/SSEC announced the release of the CSPP Geo GRB software on March 11, 2015. This software will Direct Broadcast users to decode and process GOES Rebroadcast (GRB) data received on their antennas from the GOES-R satellite, after it is launched in 2016. The main functionality included in this release is to ingest a simulated GRB data stream, recover Advanced Baseline Imager (ABI) Level 1 and Geostationary Lightning Mapper (GLM) Level 2 data payloads, reconstruct the datasets, and write the output to mission-standard NetCDF files. Optionally, quicklook images can be generated from the ABI radiances. Later releases will add support for recovering data from the remaining GOES-R instruments: SUVI, EXIS, MAG and SEISS. The software is supported on 64-bit Centos6-compatible Linux platforms.

This package contains a mix of original software developed at the University of Wisconsin–Madison, third-party software libraries, and a modified version of RT-STPS, which is developed and maintained by the NASA Direct Readout Laboratory. The CSPP Geo GRB Prototype package is distributed through the CSPP Geo website at http://cimss.ssec.wisc.edu/csppgeo/. Software, test data, and documentation may be downloaded from this website.

The system requirements for the CSPP GRB software are as follows:

- 12 core, 2.4 GHz CPU with 64-bit instruction support,
- 32GB RAM,
- CentOS 6 64-bit Linux (or other compatible 64-bit Linux distribution),
- 100 GB disk space.

Test datasets were created and provided with the software for the purpose of testing the CSPP Geo GRB software (they are not intended to be used for product evaluation or verification). The ABI test dataset was derived from output from an early GOES-R Ground System Data Operations Exercise (DOE-0). The contents are the ABI Triplet dataset, which was produced by the GOES-R Proxy Team. The GLM test dataset was created by running a simple test pattern through the Harris GRB simulator. The data is only useful for exercising the CSPP Geo software, and to provide an example of the L2 GLM data format. Because the data is entirely artificial, users should not expect it to be suitable for any other purpose, such as creating higher level products.

The GRB software can be run in either of two processing modes, "streaming mode" or "command-line mode." In both modes, output is written to NetCDF files in the format described in the GOES-R Product Definition and User's Guide (PUG), Rev C-1. The PUG is available from the GOES-R project website, although Rev C-1 has not yet been posted at the time of this release. For more information on the software interface, refer to the "CSPP Geo GRB Software Version 1 Interface Control Document, Draft 20141114" (ICD), available on the CSPP Geo website. However, note the differences between the draft ICD and the interface implemented by this software version, as described in the following sections.

In streaming mode, the GRB software runs as a daemon, reading a GRB data stream over a single socket and writing output to NetCDF. For this software version, input must be in the form of UDP datagrams containing Consultative Committee for Space Data Systems (CCSDS) packets wrapped with IPDU headers. Note that the streaming mode interface is slightly different from the planned operational interface, which is described in the draft ICD. For this release the streaming data format was simplified due to the lack of test data in the CADU-based format that is described in the ICD. In addition, a future release will add support for reading data from two sockets to simultaneously process right-hand and left-hand polarization streams, as described in the ICD. The main control script for extracting CCSDS packets from the GRB data stream is cspp-rt-grb.sh. This script uses the Java Service Wrapper to start a GRB ingestor. The service wrapper will monitor the ingestor and restart in the event of any failure. The GRB ingestor will watch for UDP traffic on port 50002. It extracts CCSDS packets, and bundles them in intermediate output files by packet count or elapsed time according to the site configuration with a default bundling of one file written every 15 seconds. After each packet bundle is written, the GRB Reconstruction software is automatically executed to process the GRB space packets, assembling the data payloads into NetCDF output files.

In command-line mode, the GRB software is called at the command line, and processes files containing CCSDS packets. Input files must contain only unsegmented packets (with APID 0b11) or complete sequences of packets. A complete sequence of packets has the following characteristics:

- a single, identical APID,
- begins with a packet containing primary header sequence flag 0b01,
- ends with a packet containing primary header sequence flag 0b10,
- incrementing sequence count (mod 16384),
- no missing sequence counts.

The CSPP GEO GRB software also allows quicklook images to be created from the reconstructed Level 1 netCDF files. An example is shown in Figure 55.

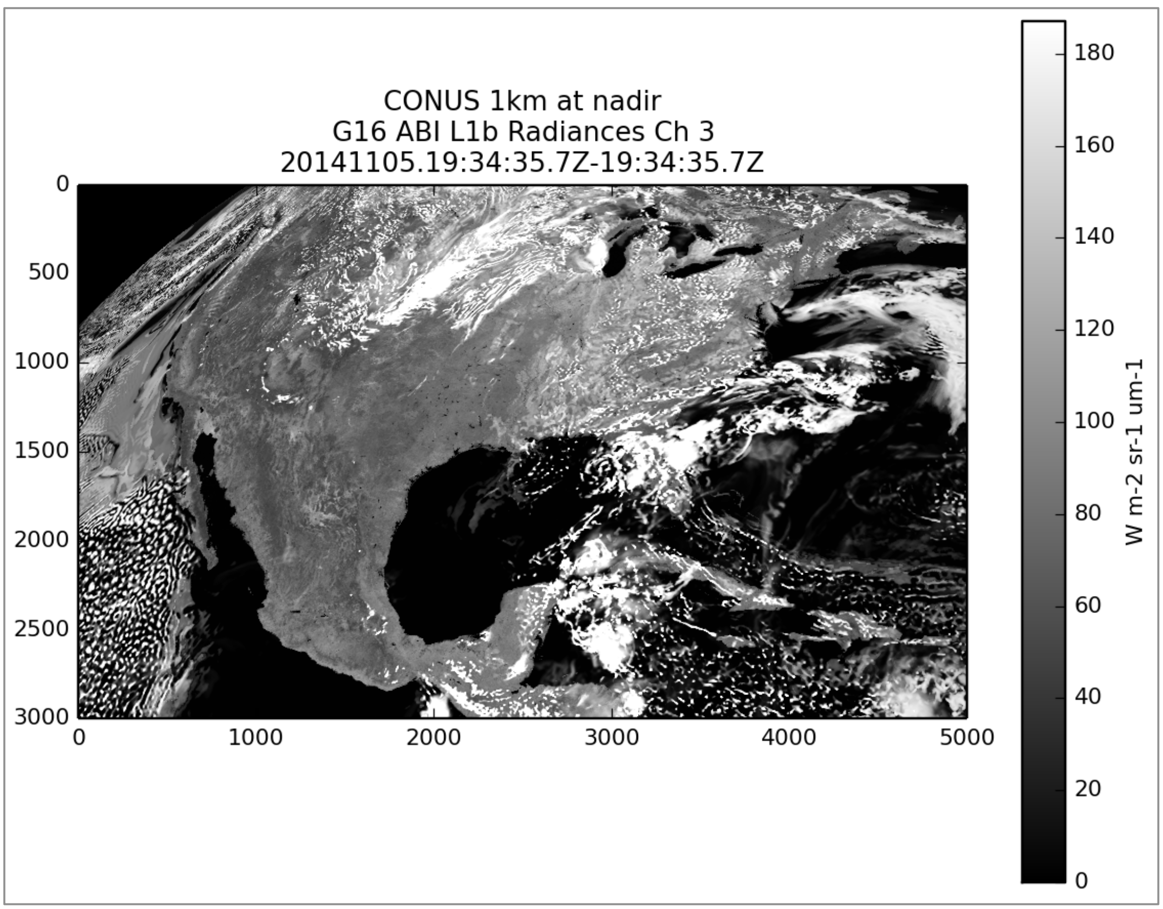

Figure 55. ABI channel 3 radiances reconstructed from GRB test data for 2014/11/05 at 19:34 UTC.

16. GOES-R Readiness Hardware

16.1 Create GOES-R Image Specification for McIDAS AREA and MD files

CIMSS Task Leader: David Santek
CIMSS Support Scientists: Russell Dengel, Rick Kohrs
NOAA Collaborators: Satya Kalluri, Ananth Rao at GOES-R Ground Segment

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 will create a specification for GOES-R imagery products in McIDAS AREA and MD files, similar to existing specifications for legacy GOES imagery products. These file format specifications will be provided for use in the development of data conversion software in the Product Distribution and Access (PDA) system. Also, the McIDAS-X and McIDAS-V software packages will be updated to include a new GOES-R server and associated calibration and navigation modules. This update will be available pre-launch and will ensure seamless access to GOES-R data, when first available, by the McIDAS software.

Summary of Accomplishments and Findings

A first draft of McIDAS AREA image specification for the ABI imager bands was delivered to our NOAA collaborators. This 16-page document details each word in the McIDAS AREA directory, calibration block, navigation block, and data block in a series of tables containing the AREA word number, netCDF variable name, and comments as necessary.

A similar document will be created for the Level 2 and 2+ products when the netCDF documentation is finalized and example product files are available from NOAA.

In preparation for GOES-R ABI, a McIDAS ADDE server was developed for Himawari-8 AHI data. Many issues with navigation and calibration were resolved, that will be applicable to the ABI ADDE server. An example image from the AHI server, displayed in McIDAS-X, is in Figure 56.

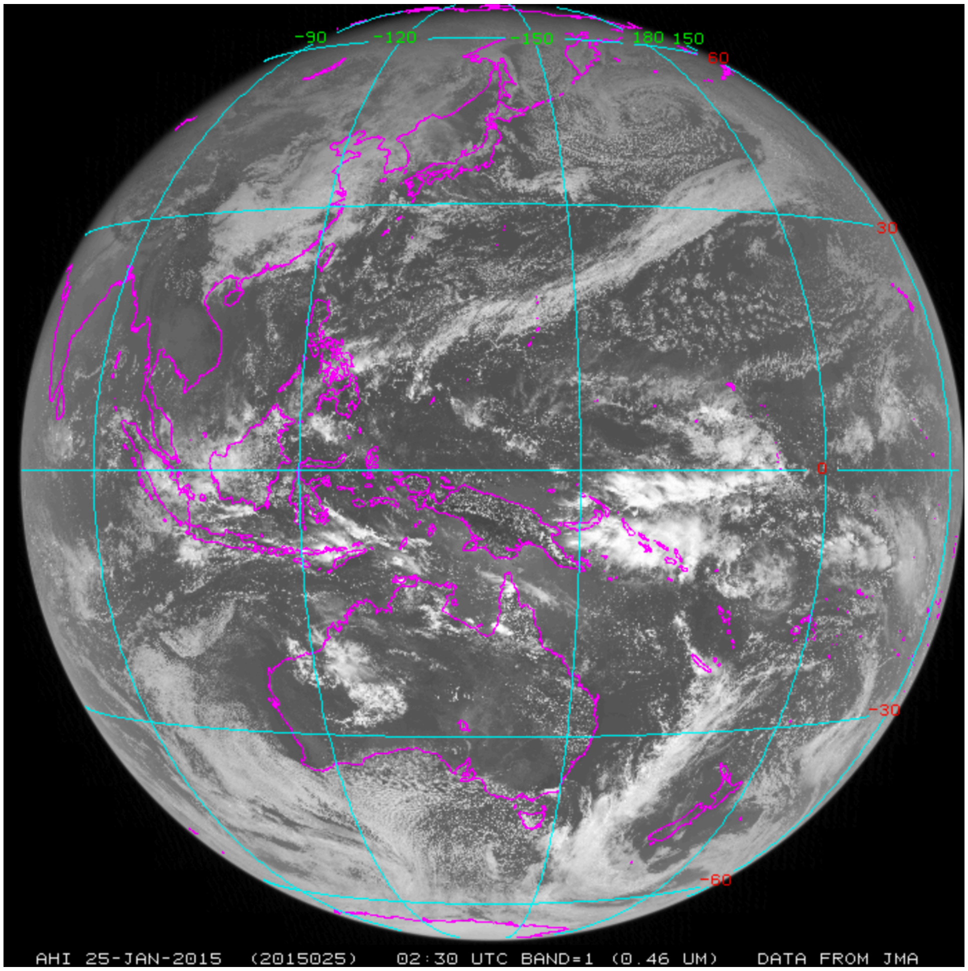

Figure 56. Himawari AHI band 1 (0.46 micron) image from 25 January 2015 at 0230 UTC.

16.2. SSEC/CIMSS GOES-R Capable Antenna Upgrade
CIMSS Task Leader: Jerrold Robaidek
NOAA Collaborator: Tim Schmit

NOAA Long Term Goals:
- Climate Adaptation and Mitigation
- Weather-Ready Nation
- Society is prepared for and responds to weather-related events

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

It is important that CIMSS/SSEC has an antenna on site that is capable of receiving GOES-R Rebroadcast (GRB) data, and that the antenna is in place when the GRB data stream is turned on. This will allow us to test our software on the live data stream before we release new versions, and to address any software issues reported by users as they arise.

We propose to split the costs of the GOES-R reception system. The GEO Community Satellite Processing Package (CSPP) project will provide a 7.3 meter antenna and all infrastructure necessary to receive GRB data from one satellite located anywhere between 75 degrees West and 137 degrees West. The cost for the antenna electronics (RF Kit, DVB2 receiver, cable kit and other acquisition hardware) is estimated to be $84,000. CIMSS/SSEC proposes this cost to be split between GOES-R GEO CSPP and NOAA NESDIS with each contributing $42,000.

Summary of Accomplishments and Findings

The majority of the funds were used to purchase the antenna components (feed, cabling, DVB-S2 demodulator), with some funds devoted to system redundancy and longevity (the compressed air for the feed allows for longer life and reliability.) The costs for existing antenna and infrastructure are not specified. The cost for installation will be known after installation is completed.

The request for bids was published on January 20, 2015. The wining bid to upgrade an existing 7.3 m antenna totaled $100,500 USD. The winning bidder was Quorum Communications Inc. A requisition was submitted for the winning bid on March 9, 2015. The upgrade installation is scheduled for late summer 2015.

This task provided $42,000 toward the purchase. An additional $42,000 was contributed by the SSEC/CIMSS Research Tasks GOES-R Capable Antenna Upgrade - EOY funding. The 7.3 meter antenna was provided by the University of Wisconsin SSEC. The remaining $16,500 balance was paid for from other non-NOAA sources.

Component	Unit Cost	Qty	Total
Antenna electronics (Feed, DVB-S2 demodulator)	$51,500	1	$51,500
Compressor for pressurized feed	$2,500	1	$2,500
Redundant “hot spare feed” and redundant demodulator	$46,500	1	$46,500
7.3 meter Antenna	Unknown	1	Unknown
Total*			$100,500

*Total does include value of antenna or installation costs provided by UW–Madison SSEC.

16.3. Level 0 Data Archive at CIMSS/SSEC
CIMSS Task Leader: Jerrold Robaidek
NOAA Collaborator: Tim Schmit

NOAA Long Term Goals:
- Climate Adaptation and Mitigation
- Weather-Ready Nation
- Society is prepared for and responds to weather-related events

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
There will be no official long-term storage of the Level 0 data from the GOES-R instruments. To help mitigate this, we propose to acquire and transfer ABI Level 0 data to the SSEC Data Center, where it will be archived. The data will be available for download for five days after it is received.

This will allow for monitoring the affect of the remapping process, where the detector information is projected to the fixed grid format in pixel space. This could help understand the process on high spatial resolution products such as hotspots.

Summary of Accomplishments and Findings
Preliminary work for purchasing and locating storage resources has begun. To minimize storage costs, level 0 storage space is expected to be purchased late summer of 2015 to coincide with other large UW–Madison/SSEC storage purchases.

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

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

We intend to 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). This project will also aim to discover bugs and potential fixes in the VIIRS Cloud Mask (VCM). At this moment VCM reached Validation stage 2.

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

Summary of Accomplishments and Findings
A combined (VCM and VIIRS Cloud Properties) Long-Term Monitoring webpage (http://cimss.ssec.wisc.edu/patmosx/ltm/monitor.html) is developed by using tools to plot data from NOAA-19/AVHRR, Aqua/MODIS and S-NPP/VIIRS over North Pacific Ocean region (Figure 57). This webpage is updated approximately once per week. It helps to control the number of valid VCM pixels, and validate it with the other cloud mask algorithm products (NOAA PATMOS-x), analyze the quality of the clear radiances, and compare the performance of the VCM over mentioned above region. It is planned to increase number of validated regions. We use these tools to identify errors and differences between the VIIRS, AVHRR and MODIS cloud masks. The tools allow making a statistical comparison with the other cloud mask products.

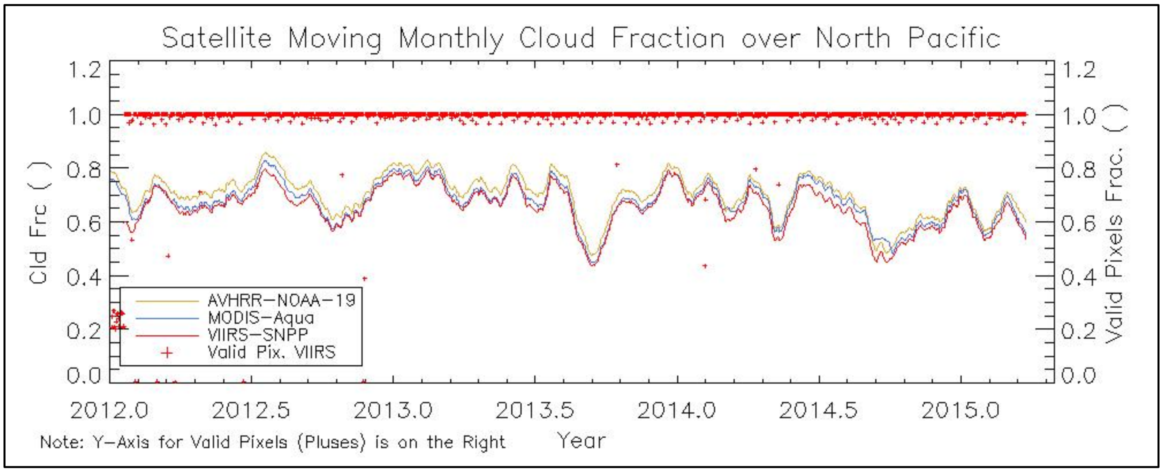

Figure 57. VCM performance for the whole VIIRS record, ascending node (day time) over the North Pacific Ocean (longitude from 120W to 140W, latitude from 15N to 35N).

The CALIPSO – VIIRS match-ups collocation tools are used to generate many days of results and to also track changes in performance as the VCM is tuned (Figure 58). These tools are capable of processing large amounts of data. We operate these tools periodically to track the performance changes of the VCM as it is tuned and refined.

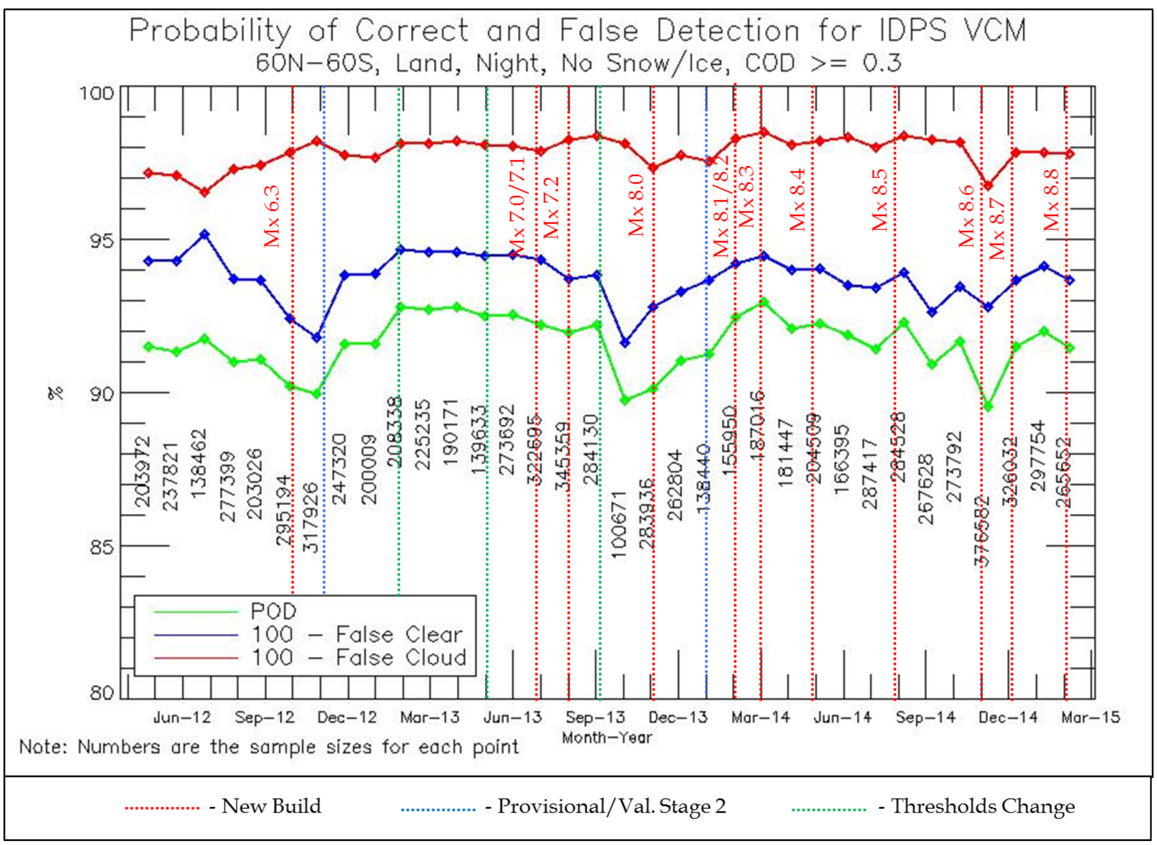

Figure 58. VCM – CALIPSO performance time series over 60N-60S, Land, Night, No Snow/Ice.

Publications, Reports, Presentations

Kopp, T. J., W. Thomas, A. K. Heidinger, D. Botambekov, R. A. Frey, K. D. Hutchison, B. D. Iisager, K. Brueske, and B. Reed (2014), The VIIRS Cloud Mask: Progress in the first year of S-NPP toward a common cloud detection scheme, J. Geophys. Res. Atmos., 119, 2441–2456, doi: 10.1002/2013JD020458.

17.2 Cloud Optical Properties
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 the Cloud Optical Properties (COP) products of the JPSS VIIRS team. The work was proposed to be done in cooperation with NGAS colleagues, who developed the algorithm. The evaluation work shall be used for improvements at further developments of the retrievals.

Summary of Accomplishments and Findings
After focusing on the evaluation of **quality flag** and **physical properties** in the first part of the project, the here reported period focused on finalization and reporting of the overall outcome of the evaluation.

We provided a discrepancy report and also presented the results during several meetings.

It could be shown that the overall performance of IDPS COP retrieval for optical properties are very low and critical for success of IDPS. The results for COD and REF don't meet the requirements on local and global scale. Very obvoius was espeacelly a strong angular dependency for both parameters, Cloud optical thickness and effective radius.

As a result of our efforts, we could give several suggestions for better performance of the retrieval. As an example, some of the issues could be rersolved by reshaping the look-up-tables design.

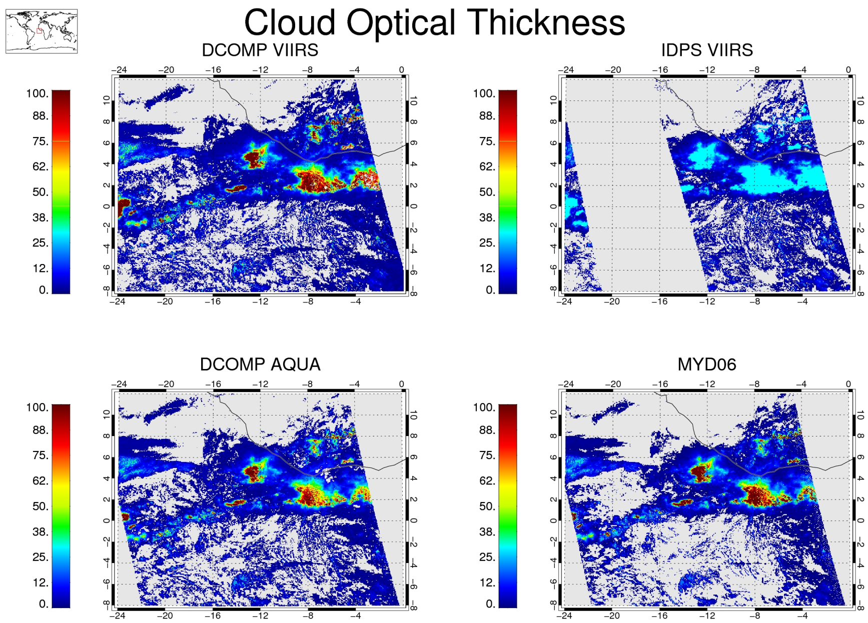

Figure 59. Cloud Optical Thickness comparison between DCOMP on VIIRS, IDPS on VIIRS, and DCOMP on MODIS and MODIS science team on MODIS.

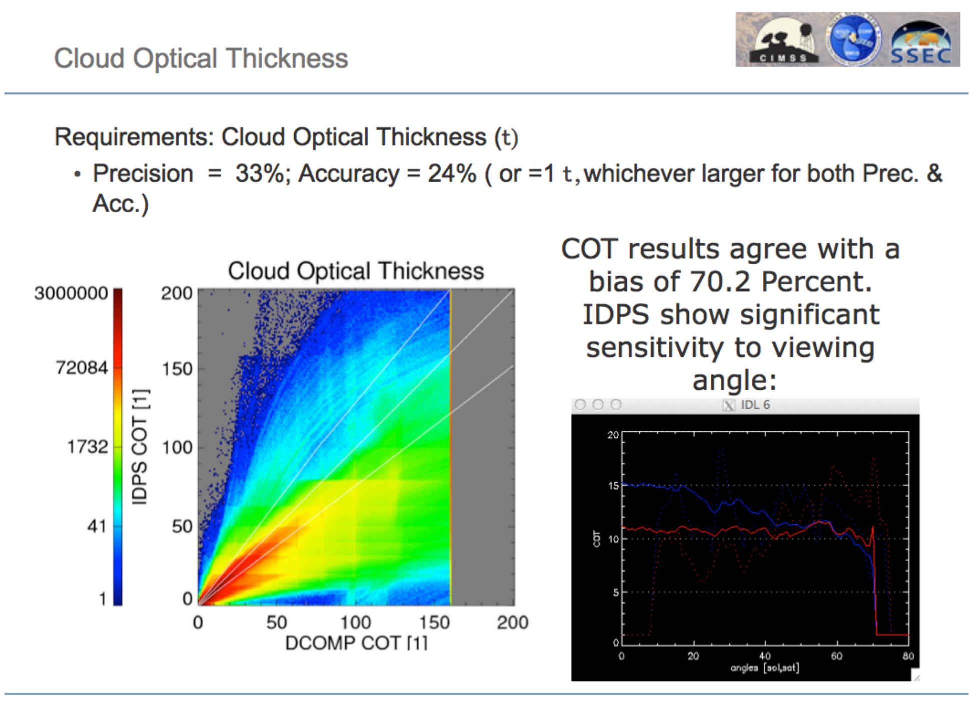

Figure 60. Slide of provisional presentation in 2014 showing angular dependency on COD performance.

Publications and Conference Reports

Walther, Andi: Discrepance report for COP retrieval, 2014

17.3 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 supports the development of the JPSS VIIRS Cloud Top Properties (CTP) algorithm. The goal of this effort is to evaluate and improve the CTP algorithm by comparing against different passive and active sensor retrievals and by introducing new scientific techniques. The IDPS CTP algorithm developed at NGAS was replaced by the NOAA CLAVR-x ABI Cloud Height Algorithm (ACHA) applied to VIIRS. At this moment VIIRS CTP products reached Validation stage 1.

Summary of Accomplishments and Findings

Validation of VIIRS ACHA products are conducted by comparing retrievals from different algorithms using the same VIIRS data. Collocation tools are also used to compare VIIRS CTP with other satellite sensor retrievals, for instance CALIPSO and MODIS. In Figure 61, we evaluated cloud top height retrievals from different products using the same VIIRS granules. The results from extensive comparisons show that VIIRS CTP can provide a reliable dataset for both scientific use and long-term monitoring of global clouds.

Efforts have also been made to ensure that ACHA are implemented into the AIT FRAMEWORK correctly (Figure 62). Data used here are nearly 1000 granules selected across seasons in 2013 and tools are used to generate collocated CALIPSO-VIIRS data. The performances meet the expectations and the differences can be primarily attributed to the following reasons in the two processing systems:
- Different radiative transfer models;
- Different numerical weather prediction (NWP) data and smoothing technique;

References

Andrew K. Heidinger and Michael J. Pavolonis, 2009: Gazing at Cirrus Clouds for 25 Years through a Split Window. Part I: Methodology. *J. Appl. Meteor. Climatol.*, **48**, 1100–1116. doi: http://dx.doi.org/10.1175/2008JAMC1882.1

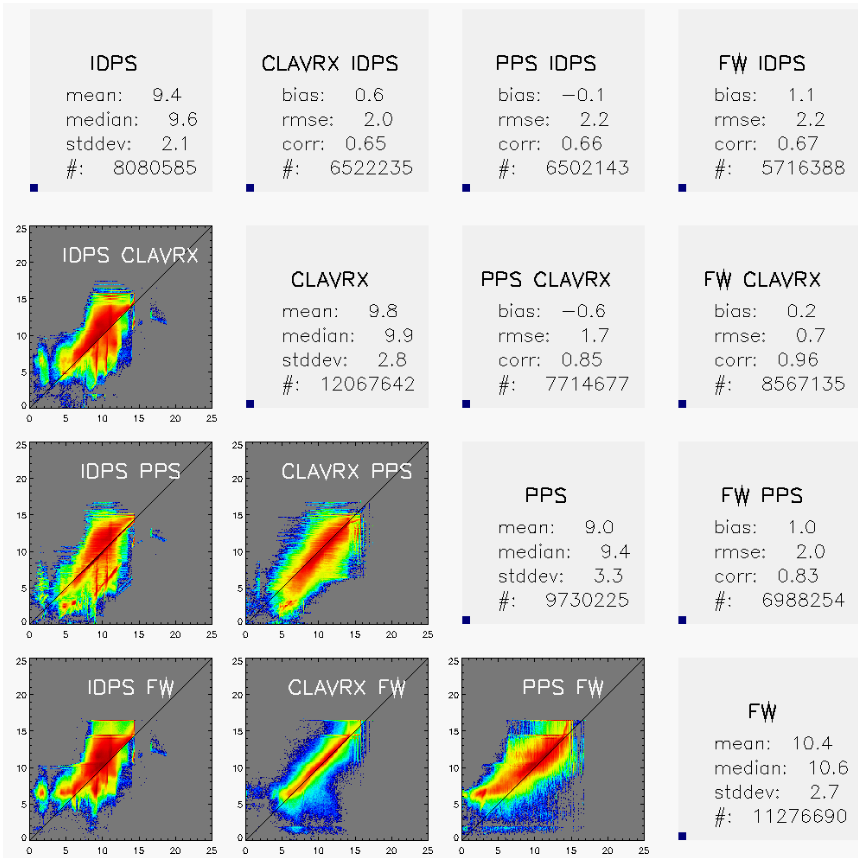

Figure 61. Intercomparisons of ice phase cloud top height based on 22 VIIRS granules on 09/26/2013. Units are in km. Here PPS stands for the EUMETSAT's VIIRS product and FW refers to ACHA implemented in the AIT FRAMEWORK.

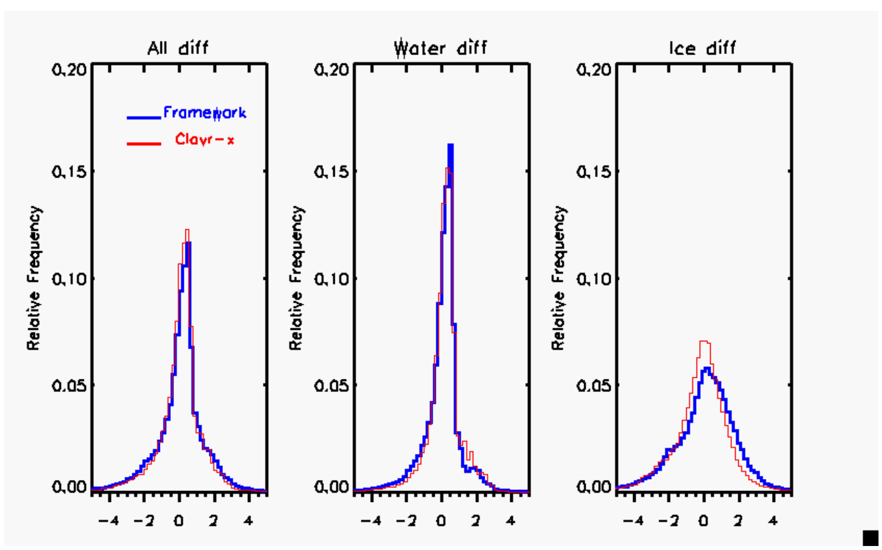

Figure 62. Histogram showing differences between VIIRS ACHA cloud top height generated by two processing systems (FRAMEWORK and CLAVR-x) and CALIPSO for nearly 1000 granules in 2013.

17.4. CSPP Support
CIMSS Project 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

Since the first release of the CSPP CLAVR-x in 2013 the number of users, who have an opportunity to receive satellite data, and process it in the near real time to the level 2, is increasing every year. This requires us to work closely with users from the whole world. Often they have questions about our product, which help us to receive a feedback and improve the code. This work is coordinated with other research group members at CIMSS (Liam Gumley, Kathy Strabala, and Nick Bearson).

Task List

- *CSPP CLAVR-x Users Support*
  In timely manner and as clearly as possible answer all CSPP CLAVR-x users' questions. Outreach other possible users.

- *CSPP CLAVR-x Algorithms Improvement*
  Based on the users' feedback improve code (bug fixing, new algorithms developing, existing algorithms improvement). Prepare new releases of CSPP CLAVR-x.

Summary of Accomplishments and Findings

For the last year we were in close contact with Siberian Regional Center of "Hydro-Meteorology from Space, Science-Research Center – PLANETA" (Novosibirsk, Russian Federation). 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. They implemented CSPP CLAVR-x system for handling AVHRR, VIIRS and MODIS data. Several months ago they started to publish the results of cloud mask, cloud top temperature (CTT) and cloud top height (CTH, Figure 63) algorithms on their webpage in the experimental mode.

http://www.rcpod.ru/cgi-bin/prod.pl?Srcs=1920!1200&r=0.19694161637742558
http://www.rcpod.ru/cgi-bin/read_news.pl?ID=530

At this moment a new release of CSPP CLAVR-x is in the testing stage. It includes improvements to the previous release algorithms, new added algorithms (for example Nighttime Lunar Cloud Optical and Microphysical Properties – NLCOMP), increase of the code structure effectiveness and processing stability.

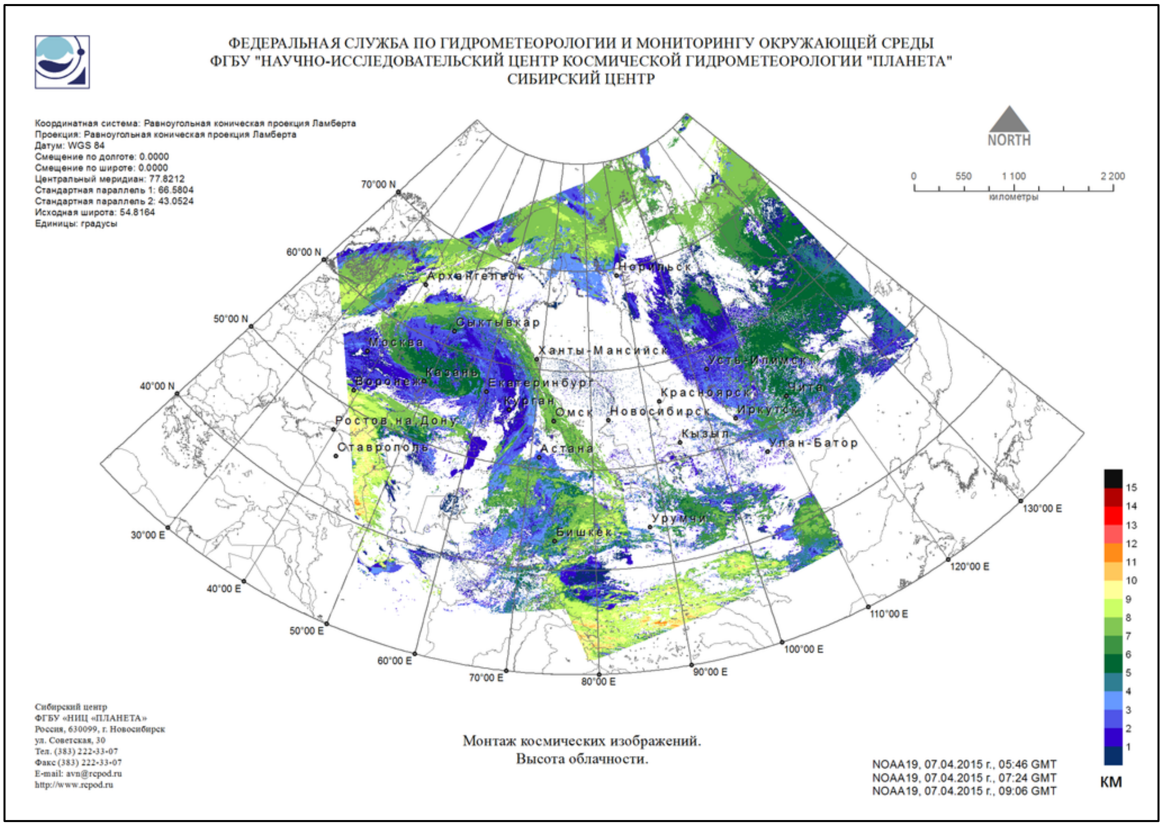

Figure 63. Cloud Top Height - CTH, CSPP CLAVR-x, NOAA19, April 07, 2015.

Publications, Reports, Presentations

Planning to participate at the next CSPP/IMAPP User's Group Meeting in Darmstadt, Germany, April 14-16, 2015.

17.5 McIDAS Support for VIIRS Imagery and Data Analysis

CIMSS Task Leaders: Tom Rink, David Santek
CIMSS Support Scientist: Tommy Jasmin
NOAA Collaborator: Don Hillger (NESDIS/STAR Imagery Applications Team Lead)

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 previous year's accomplishments relating to VIIRS and other Suomi NPP imagery and data analysis capabilities in McIDAS-V include options to display and interrogate all bit-level fields contained in each data granule. This provides access to all Quality Flags, as well as valuable intermediate product information such as the VIIRS Cloud Mask detection, confidence, and related data. The user can interactively interrogate displayed data for all bit-level fields. Another major accomplishment in the previous year is the ability to save and restore the state of the application when working with Suomi NPP data – a capability known as McIDAS-V "bundles." This allows users to save the exact state of a data analysis session, to return to at a later date, or share with a colleague.

The NESDIS/StAR Imagery Team expressed a strong desire to be able to work with VIIRS data from the Jython scripting environment in McIDAS-V. This capability allows a user to create scripts to access and process VIIRS data in an unattended background mode.

Also, updates will be made for generalizations and extensions to the Suomi NPP data processing to stay compatible with system changes to provide better overall data interoperability, including data source time matching when multiple datasets are loaded at varying time-steps.

Summary of Accomplishments and Findings

Several specific improvements have been made to McIDAS-V for better utilization of the data from the instruments on Suomi NPP:

- Scripting hooks have been added which allow users to do automated background processing of VIIRS data using McIDAS-V. For example, scripts can fetch data, create RGB composites, and write out image data for compositing or other use.
- A time dimension was added to Suomi NPP data in McIDAS-V. This allows users to leverage the Time Matching capability in McIDAS-V, to create loops of various datasets which may have differing temporal frequencies.
- Users can now add multiple bands of Suomi NPP data simultaneously, with a graceful error if the time-steps do not match. This greatly simplifies common tasks such as generating color composites from bands M5, M4, and M3.
- Users can now customize the Layer Labels for Suomi NPP data with macros such as granule count, timestamp, and data source name.
- McIDAS-V now assigns correct units for all Suomi NPP data, including geolocation.
- The stability of processing ATMS and CrIS data has been improved.

SSEC continues to participate in the monthly VIIRS Imagery Team Meetings, coordinated by Don Hillger (StAR JPSS Imagery Team Lead) and Thomas Kopp (Aerospace Corp. Validation Lead). These meetings provide SSEC timely awareness of any new JPSS data problems, or system changes, and a venue to assess and prioritize appropriate changes to the McIDAS-V codebase. Figure 64 is an example of displaying aggregated VIIRS DNB granules in McIDAS-V.

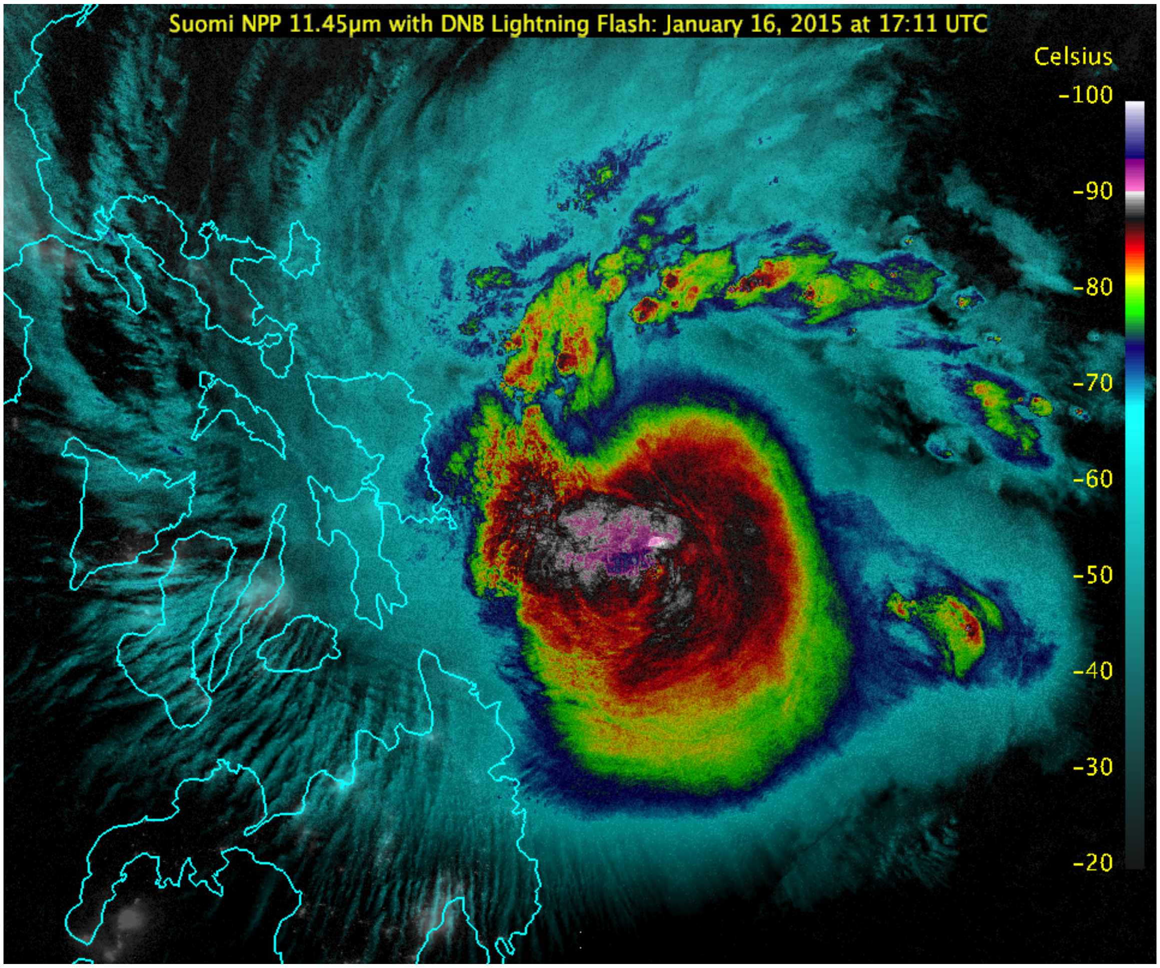

Figure 64. Typhoon Mekkhala was captured by the Suomi NPP VIIRS instrument as the storm was intensifying at 17:11 UTC on January 16, 2015. The VIIRS 11.45 µm Infrared (IR) channel was layered with the 0.7 µm Day/Night Band (DNB). A bright lightning flash near the storm center and storm-top gravity waves were observed in the DNB band, while peripheral transverse banding and extremely cold cloud-top temperatures (~100 C) were observed in the 11.45 µm IR channel.

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

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

CIMSS Task Leaders: Dave Tobin, Hank Revercomb

CIMSS Support Scientists: Joe Taylor, Robert Knuteson, Lori Borg, Dan DeSlover, Graeme Martin, Aronne Merrelli, Tom Greenwald

NOAA Collaborator: 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

Project Overview

For the past period of performance, efforts of this project have focused on the four 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.

Summary of Accomplishments and Findings

The CrIS SDRs have reached a high level of maturity and we are working on making the SDRs the highest quality possible for weather and climate applications. For CrIS on Suomi NPP, this included various studies to support the transition to full spectral resolution mode which occurred in December 2014, continuing studies of the "spectral ringing" artifacts and investigations into correction modules and improved calibration equation methods to remove this artifact, and continuing calibration/validation efforts using intercomparisons with various other data sources to monitor and assess the Suomi NPP CrIS spectral radiance product. For JPSS-1 CrIS, the sensor completed thermal vacuum testing and has been delivered to the spacecraft vendor for integration. We were integrally involved in the testing and some of the investigations are summarized below.

Imaginary Radiance and Phase Residual Analysis

We performed a detailed analysis of imaginary radiance and phase residuals observed during the TVAC testing of the S-NPP and JPSS-1 CrIS sensors. In both cases, small non-zero imaginary radiances and phase residuals are observed, with the size of these artifacts being FOV dependent and largely correlated with the magnitude of the second order radiometric nonlinearity associated with the particular FOVs. Our investigations initially focused on the imperfect nonlinearity corrections and/or higher order nonlinearity contributions to explain the artifacts, but this hypothesis was not successful in explaining the observations. Ultimately, we found that the application of very small detector time delays, which are proportional to the detector nonlinearity and signal on the detector, can be used to eliminate the observed phase differences. This finding would suggest that detectors with higher nonlinearity also have slightly different time constants, and we are pursuing this hypothesis. Also, a major implication of this explanation is that the effect has negligible impact on the real part of the calibrated radiances. Looking forward, it is also hopeful that component level testing of future CrIS detectors (e.g., JPSS-2) could use this time-delay/nonlinearity correlation to screen for more linear detectors.

Nonlinearity Analyses Using Diagnostic Mode Data Collections

Diagnostic Mode (DM) data (by-passing the FIR filter, and retaining the out-of-band signals) is collected for JPSS-1 bench testing and for each plateau of TVAC testing. From the low-wavenumber out-of-band region, we derive quadratic nonlinearity coefficients, a_2, from the DM data as a preliminary estimate of the nonlinearity magnitude. These values agree very well with similar analyses performed by Exelis, with the exception of small differences for some of the very linear MW FOVs and the very linear SW FOVs; these differences are under investigation. For example, we observe MW FOV2 to have very small but consistently positive values. These DM a_2 values are particularly useful in trending of the nonlinearity behavior, as the detector nonlinearity has the potential to change with warm-up/cool-down which occurs between bench testing, TVAC testing, spacecraft level testing, and on-orbit.

Nonlinearity Analysis using stepped ECT view data

A primary goal of the TVAC testing is to determine the nonlinearity behavior and correction coefficients from "stepped ECT view data." This is ECT view data collected over a range of ECT temperatures which can be used to measure nonlinearity. Our preliminary analysis of the Mission Nominal TVAC ECT view data was presented at the 05 November SDR telecom. ECT view residuals (calibrated ECT view spectra minus predicted ECT view spectra) are minimized by tuning of the quadratic nonlinearity coefficients using the Mission Nominal data. ECT view data at 310K, 299K and 260K is used in this analysis but ECT residuals are investigated for all temperatures. The lower temperature ECT view data is not currently used in the analysis due to large uncertainties in the predicted ECT views and in the Space Target views due to reflections. Overall, the ECT residuals are very small and very well behaved, providing evidence that the nonlinearity for J1 is very well characterized. The ECT view analysis and nonlinearity determinations are on-going. Currently, the a2 values included in the engineering packet are from the UW–Madison analysis:

lw: [0.0141 0.0145 0.0152 0.0159 0.0355 0.0110 0.0095 0.0157 0.0085]
mw: [0 0 0 0 0 0 0 0 0.0507]
sw: [0 0 0 0 0 0 0 0 0]

These values are derived using linear CrIS FOVs to determine the FOV dependent ECT view temperatures which are used to predict the ECT view spectra, and using Vinst and modulation efficiency values derived by Exelis. Similar analyses have been performed using the R1 and R2 temperature sensors on the back plate of the ECT, along with various candidate correction terms, to predict the ECT view spectra, which provide slightly different a2 values. These analyses will continue and will also take into account NIST measurements of the ECT which were collected in February.

Gas Cell Spectral Interfov Analysis

To compliment TVAC spectral calibration analyses, we have performed a "spectral inter-FOV" analysis of the J1 TVAC gas cell data. This analysis method is similar to other approaches but instead of using a calculated transmission spectrum as the reference, it uses the center FOV 5 as the reference for the other off-axis FOVs. Since the center FOV5 is relatively insensitive to FOV diameter and position, it provides a robust reference for the other FOVs which require large spectral corrections. And, opposed to calculated spectra, the use of FOV5 as reference avoids all issues associated with the calculation of the gas transmission. Also in our analyses, we use the ICT and ST view spectra along with the gas cell view data to calibrate the data with nonlinearity and FIR convolution corrections included to produce observed transmission spectra. Results of this type of analysis presented within the SDR team and at several conferences. These analyses provide information on 1) the quality of the TVAC gas cell data, 2) the spectral characteristics of J1 CrIS, 3) the performance of the self-apodization corrections, and 4) estimate the J1 off-axis FOV angles. The observed spectral inter-FOV residuals are, in general, very well behaved. Recently this analysis has been extended to include all of the J1 TVAC gas cell data, including all four gases (CO_2, NH_3, CH_4, CO), three temperature plateaus (Mission Nominal, Protoflight High, Protoflight Low), instrument electronic sides (1 and 2), and interferometer sweep directions (forward and reverse). These results were presented to the team at the 25 February Wednesday telecom. We also presented detailed comparisons of our results to candidate J1 ILS parameters provided by Exelis in December. In general, we find very good agreement with the Exelis parameters, but recommend to not average results over the three temperature plateaus but to instead just use the Mission Nominal values, since we see small differences in off-axis angles among the three plateaus.

Publications and Conference Reports

SDR Telecon presentation: CrIS Ringing Artifacts, 24 September 2014.

SDR Telecon presentation: Preliminary analysis of J1 CrIS MN TVAC Radiometric Calibration data, 5 November 2014.

SDR Telecon presentation: CrIS Ringing Artifacts: Progress on Implementing a Correction, 19 November 2014.

SDR Telecon presentation: Spectral Inter-FOV analysis of J1 CrIS MN TVAC Gas Cell Data, 19 November 2014.

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, David, Hank Revercomb, Fred Best, Robert Knuteson, Joe Taylor, Dan DeSlover, Lori Borg, Graeme Martin, Infrared Hyperspectral Calibration and Intercalibration: Recent experience with Satellite and Aircraft Sensors, EUMETSAT Meteorological Satellite Conference, Geneva, Switzerland, 22-26 September 2014.

Merrelli, Aronne; Tobin, David; Knuteson, Robert; Greenwald, Thomas; Revercomb, Hank; (2014), Comparing Cross-track Infrared Sounder Observations with Forward Model Calculations, Abstract IN13C-3656 Presented at 2014 Fall Meeting, AGU, San Francisco, Calif., 15-19 Dec.

DeSlover, D. H., R. Knuteson, D. C. Tobin and H. E. Revercomb (2015): Monitoring climate signatures with high spectral resolution infrared satellite measurements. *Proceedings from the 95th American Meteorological Society Annual Meeting, 27th Conference on Climate Variability and Change*, Phoenix, AZ, January 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.

18.2 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 supports expert participation in VIIRS pre- and post-launch performance evaluation:

1. SNPP VIIRS SDR Performance
    - Continue data collection under implemented Cal/Val task network assignments (RAD-01, RAD-04, RAD-12A,B, RAD-21), including beneficial modifications to strategy that may become evident going forward in the SNPP post-launch era.
    - Performance analyses and reports on UW–Madison Cal/Val tasks. These include tasks on radiometric, spectral and HAM performance.
    - On-going review of VIIRS performance through VIIRS data inspection using McIDAS to identify, isolate and characterize anomalous performance in all VIIRS bands.
    - Remain vigilant on SNPP VIIRS spectral performance, including RTA mirror degradation anomaly impact on VIIRS RSR and OOB contribution to TOA radiance. Further updates to SNPP VIIRS RSR are not anticipated but will be addressed if needed.
    - Continue investigating strategies for mitigating systematic performance anomalies as revealed in post-launch era of SNPP, e.g., scene dependent biases in TEB.
    - Support LUT updates as needed in coordination with the VIIRS instrument lead.
    - Direct interaction with EDR teams (land, ocean, cloud/atmosphere) to communicate VIIRS SDR performance anomalies, identify VIIRS SDR performance anomalies in the context of EDR performance, and plan effective mitigation strategies when needed.
    - Continue to manage VIIRS RSR characterization in coordination with STAR to support science community use of VIIRS RSR.
    - Participate in aircraft-based assessments of VIIRS performance, including support of data collection, production, and analysis to enable VIIRS performance analyses using aircraft based data sets.
    - Continue effort in coordination with STAR and NIST exploring the use of high altitude aircraft based measurements to characterize lunar irradiance. This effort also supports preparation for JPSS-1 VIIRS on-orbit assessment.
    - Participation in review of performance analyses and reports for non-UW–Madison Cal/Val tasks.
2. JPSS-1 VIIRS Pre-Launch Test Program Performance Characterization
    - Participation in reviews of ground support equipment (GSE) for the JPSS-1 VIIRS pre-launch test program.
    - TVAC environment testing in late summer 2014 with performance evaluations and reviews ongoing during and after the completion of the TVAC phase

  - Spatial, spectral, and radiometric performance reviews with particular interest in the spectral characterization where UW–Madison played a leadership role in the SNPP VIIRS pre-launch effort

3. Support STAR and SDR Team Meetings and Activities
   - participation on the VIIRS SDR Team, providing analyses on VIIRS SDR performance and participating in the review of all VIIRS performance issues.

Summary of Accomplishments and Findings

This reporting period includes and extends beyond the 3rd year of on-orbit performance by SNPP VIIRS as well as completion of the sensor level pre-launch test program for JPSS-1 VIIRS.

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 SNPP VIIRS-CrIS spectral radiance comparisons over 3+ years on-orbit continue to reveal excellent calibration performance for bands M13, M15, M16, and I5 with globally averaged differences < 0.1 K for typical scenes. Existing scene temperature dependence remains within specification at all scene temperatures for these bands. Reconciliation of small but systematic biases at cold scene temperatures is being sought through SNAP2015 aircraft validation flights (see item below).
- SNPP VIIRS – CrIS comparisons reveal some mirror side and detector striping. Band M15 shows 40-50 mK mirror side striping at cold scenes, and <10 mK effect at warm scene temperatures. Even-odd detector striping of about 10-20 mK also exists in M15. M13 shows even-odd detector dependence of about 150 mK for warm scenes, and a similar amplitude, but of opposite sign, in cold scenes. No mirror side striping is evident in M13. Mirror side and even-odd detector striping appear to be <10 mK for warm scene temperatures in M16 and perhaps 10-20 mK for cold scenes.
- Recent SNPP VIIRS-CrIS comparisons continue to indicate that the HAM RVS is well characterized for bands M13, M15, M16, and I5 with scan angle dependence < 0.1 K.
- VIIRS-IASI SNO comparisons with Metop-A and Metop-B have been updated through Spring 2015, increasing the data record to about 3 years. Biases in MWIR bands (M12, M13, I4) continue to be elevated at very cold scene temperatures, exceeding 1 K for these bands for scene temperatures below 220K. LWIR bands continue to perform very steadily with minor (~0.1 K) bias dependence in the 200 – 275 K scene temperature range of the SNOs.
- Time series data suggest trends in VIIRS-IASI biases remain very small (<10 mK/yr) in LWIR bands (Figure 65). MWIR band trends are also very small with a minor exception for band I4 which appears to be about 20-30 mK/yr. MWIR band trends also contain larger seasonal variation, likely due to the larger cold scene biases in these bands.
- During the SNAP2015 campaign, the NASA ER-2 aircraft flew 7 science missions over Greenland, 6 of which included direct underflights of SNPP to assess VIIRS (and CrIS) cold scene (<250 K) calibration performance. The calibration assessment will be based upon co-incident comparisons with the SHIS instrument (NIST traceable calibration source). Observed scene temperatures over Greenland range from 230 – 250 K.
- Wisconsin has worked with Aerospace Corp to reconcile radiance/reflectance and radiance/brightness temperature inconsistencies in the VIIRS SDR product. Final updates (based upon phenomenological studies) to RadMax thresholds are anticipated to eliminate these occurrences.

- SNPP VIIRS day mode data collection during nighttime overpass occurred on June 12, 2014, providing an opportunity to review RSB performance in absence of solar reflection. A review of the imagery using McIDAS showed a random noise pattern in VisNIR bands but revealed a faint pattern in SWIR bands that is correlated with VIIRS MWIR bands, suggesting a possible minor cross talk from MWIR to SWIR. The contamination is very small, e.g., about 1% of typical radiance in M11 which is well within the M11 SNR requirement. This does not appear to impose any meaningful influence on the radiometry of SWIR bands.

JPSS-1 VIIRS Pre-launch Performance Characterization

The JPSS-1 VIIRS sensor level pre-launch test program was completed this year, including Pre-TVAC, TVAC and post-TVAC phases. Wisconsin has focused on the spectral characterization of JPSS-1 VIIRS from the test program. During the Pre-TVAC and TVAC phases, spectral characterization data was collected for each VIIRS band using the dual-monochromator SpMA GSE. Under separate funding, Wisconsin provided on-site monitoring of the test data collection and worked with Raytheon analysts during the development of the Raytheon Relative Spectral Response (RSR) product. This commitment yielded invaluable detailed insight into the test data quality and nuances, which is supporting review and re-analysis of the test data collection under this funding. During the Post-TVAC phase, RSR was measured for VisNIR bands by the NIST unpolarized T-SIRCUS GSE using flood illumination (as opposed to slit illumination) of the VisNIR focal plane. This measurement integrates in-band, out-of-band and crosstalk influences into a single “flight-like” measurement. Wisconsin participated on-site in that effort and is supporting the government effort to analyze and incorporate these VisNIR RSR into the final VIIRS RSR characterization. Key elements of the JPSS-1 VIIRS spectral characterization are:

- The Raytheon RSR product was reviewed at Wisconsin and recommendations were implemented leading to the release of a V0 (beta level) RSR product to the VIIRS community. The RSR are provided for each detector of each band. A README and chart package containing plots of all bands is also available with the RSR files.
- An RTE model-based water vapor correction was generated at Wisconsin for the removal of water vapor influence on the M9 RSR measurement. The effort also retrieves a spectral offset for each detector, removing the spectral smile influence of the SpMA GSE. The water vapor corrected M9 RSR has been incorporated into the V0 release.
- Sensor level test program spectral measurements are currently under analysis by government elements. Departures from the Raytheon analysis are being taken to improve the RSR characterization. This analysis will become a V1 RSR product release.
- Analysis of the Post-TVAC spectral measurements using T-SIRCUS is underway. Early findings indicate some differences from the SpMA based spectral characterization. The T-SIRCUS based RSR for VisNIR bands will be combined with the V1 RSR product into a V2 RSR product that is intended to represent the at-launch RSR for JPSS-1 VIIRS.
- Wisconsin is working with STAR elements towards the generation of a JPSS-1 VIIRS SDR RSR LUT to support SDR algorithm testing.
- Wisconsin has collaborated with VCST to ensure a high quality water vapor correction of M9 RVS characterization.

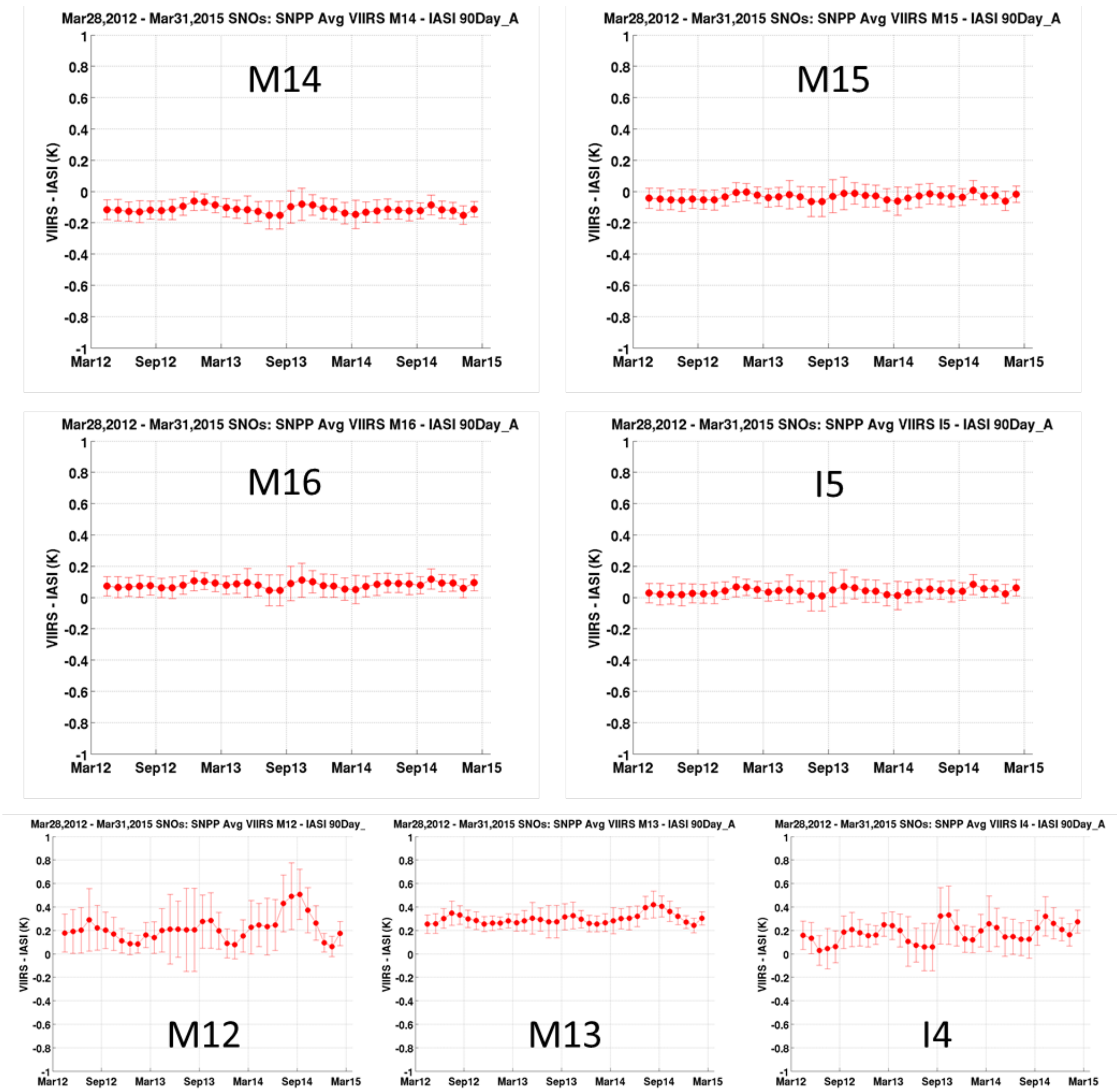

Figure 65. SNPP VIIRS - Metop-A IASI SNO comparisons using 90 day moving window average. These profiles suggest that trends in all bands are minor (<10mK/yr) over the 3 year data record with possible exception of band I4 (20-30mK/yr).

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". Accepted for presentation at IGARSS 2015, July 26-31, 2015, Milan, Italy.

C. Moeller, T. Schwarting, J. McIntire, and D. Moyer, "JPSS-1 VIIRS Pre-launch Spectral Characterization and Performance", Accepted for presentation at the Earth Observing System XX Conference, SPIE, Aug 9 -13, 2015, San Diego, CA.

18.3 CrIMSS EDR Cal/Val: ARM Site
CIMSS Task Leader: Dave Tobin
CIMSS Support Scientist: Lori Borg

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 SNPP 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 of the atmospheric state and surface properties at the satellite overpass times were produced via a similar collaborative effort between NASA and ARM. This work was a fundamental, integral, and cost-effective part of the EOS validation effort and provided critical accuracy assessments of the AIRS temperature and water vapor soundings. 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 SNPP mission.

Summary of Accomplishments and Findings

This effort has been divided into 3 phases, primarily due to funding and contract periods, see Table 1 for a summary. The initial phase (phase1), began in July 2012 after the initial checkout of the ATMS and CrIS SDRs. Phase1 involved launching Vaisala RS-92 radiosondes from three of the ARM field sites, including the Southern Great Plains (SGP), North Slope of Alaska (NSA) and Tropical Western Pacific (TWP) Manus island sites. Two launches per overpass were performed at the NSA and SGP sites, and one launch per overpass at TWP, with the goal of collecting data for a total of 90 overpasses. This phase ended in December 2012 at NSA and SGP with the completion of 90 and 89 sonde pairs respectively. Launch and contract issues stopped sonde launches at TWP in January 2013. They did not resume until March 2013, but completed in June 2013 with 94 single sonde launches. Phase2 of this effort began immediately after phase1 completed at TWP in June 2013. Along with reduced funding during this phase, a change in launch strategy occurred. The time between target overpasses was extended to every few days and every other dual sonde launch was reduced to a single sonde launch at NSA and SGP. The ARM program was able to supplement this effort with additional sondes, extending the effort through September 2014 at NSA and SGP, and May 2014 at TWP when the island site was closed. Phase2 produced data for a total of 124 overpasses at NSA, 129 overpasses at SGP, and 79 overpasses at TWP. Phase3 of this effort was delayed due to contract issues between ARM and NOAA, but recently restarted in February 2015 including the Eastern North Atlantic (ENA) ARM site, an island site in the Azores, replacing the TWP site. With a further reduction in funding, the total number of sondes allocated for phase3 is limited. The overall goal is to obtain data for 37 overpasses at ENA, 46 at NSA, and 49 at SGP through July 31st 2015.

Combined with other ARM data, an assessment of the sonde quality was performed, and post-processing corrections were applied, resulting in an ARM site best estimate product. Comparisons of the resulting best estimate profiles and the satellite retrievals were made to begin to assess the accuracy of the CrIMSS satellite data products. These results included data from phase1 and part of phase2 and were presented at the EUMESAT conference in Vienna in September 2013 (Borg et al., 2013), at the ARM conference in Atlanta, GA in February 2014 (Borg et al., 2014), and contributed to the journal publication by Nalli et al., 2013. It is anticipated that the remainder of the phase2 and phase3 data will be processed upon completion of phase3 and presented at the September 2015 EUMETSAT conference in Toulose with a journal publication to follow.

Our current and future efforts include 1) on-going coordination of the sonde launch schedule and logistics with the ARM personnel, 2) refinement of the best estimate products using more frequent information on the time change of the atmospheric state to interpolate between the two dedicated radiosondes and inclusion of cloud and surface characterization data, and 3) evaluation of the CrIMSS EDRs (and related CrIS sounding products such as from NUCAPS or other algorithms/groups) via comparisons with the ARM best estimate products.

Sonde Launch Efforts									
	Phase1			Phase2			Phase3		
	NSA	SGP	TWP	NSA	SGP	TWP	ENA	NSA	SGP
Overpasses targeted	90	89	94	124	129	79	12	13	12
nSingle	--	--	94	68	31	79	12	6	6
nDual	90	89	--	56	98	--	--	7	6
Start	Jul12	Jul12	Jul12	Jun13	Jun13	Jun13	Feb15	Feb15	Feb15
Stop	Dec12	Jan13	Jun13	Sep14	Sep14	May14	ongoing	ongoing	ongoing

Table 1. CrIMSS EDR Sonde Launch Efforts: Phase1-3, July 2012 through March 2015

Publications and Conference Reports

Borg, L., Tobin, D., Knuteson, R., DeSlover, D., Taylor, J., Revercomb, H., Barnet, C., Nalli, N., Holdridge, D., Mather, J. Suomi-NPP CrIMSS retrievals of temperature and water vapor: A comparison with ARM radiosondes (Poster presentation). Joint 2013 EUMETSAT & 19th AMS Meteorological Satellite Conference; 16-20 September 2013; Vienna Austria.

Borg, L., Tobin, D., Knuteson, R., Revercomb, H., Reale, A., Nalli, N., Holdridge, D., Mather, J. Validation of Suomi-NPP CRIMSS retrievals of temperature and water vapor using ARM site best estimates of atmospheric state (Poster presentation). Tenth Annual Symposium on New Generation Operational Environmental Satellite Systems, AMS 94th Annual Meeting; 2-6 February 2014; Atlanta, GA.

Nalli, Nicholas, Barnet, C., Reale, A., Tobin, D., Gambacorta, A., Maddy, E., Joseph, E., Sun, B., Borg, L., Mollner, A., Morris, V. R., Liu, X., Divakarla, M., Minnett, P., Knuteson, R., King, T. S., and Wolf, W. (2013), Validation of satellite sounder environmental data records: Application to the Cross-track Infrared Microwave Sounder Suite, J. Geophys. Res. Atmos., 118, doi:10.1002/2013JD020436.

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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, 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.

19. CIMSS Participation in the JPSS Algorithm Continuity Risk Reduction Program for 2014

19.1 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 Imaging Radiometer Suite (VIIRS). These and other state-of-the-art products have been developed for the ABI instrument but, due to budgetary considerations, will not initially be generated for GOES-R.

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

Summary of Accomplishments and Findings

GOES-R algorithms 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 algorithms. The latest algorithms have been delivered to the Algorithm Integration Team (AIT) with test cases.

We continued to make improvements to the One-dimensional Thermodynamic Ice Model (OTIM) for better and more accurate sea ice thickness and age products. Based on the year-long SHEBA in-situ measurements (1997-98), many OTIM built-in parameterization schemes have been improved and implemented for better estimations of snow-ice surface albedo, snow-ice interfacial temperature, snow depth, snow-ice surface downwelling/upwelling solar and thermal radiative fluxes. Below are some examples of the improved OTIM built-in parameterization schemes. Figure 66 shows the comparison of snow-ice interfacial temperature between OTIM built-in parameterization scheme and SHEBA measurements. Figure 67 gives a comparison of snow depth between OTIM built-in parameterization scheme and SHEBA. Figure 68 shows the comparison of surface downwelling longwave radiative flux between OTIM built-in parameterization scheme and SHEBA.

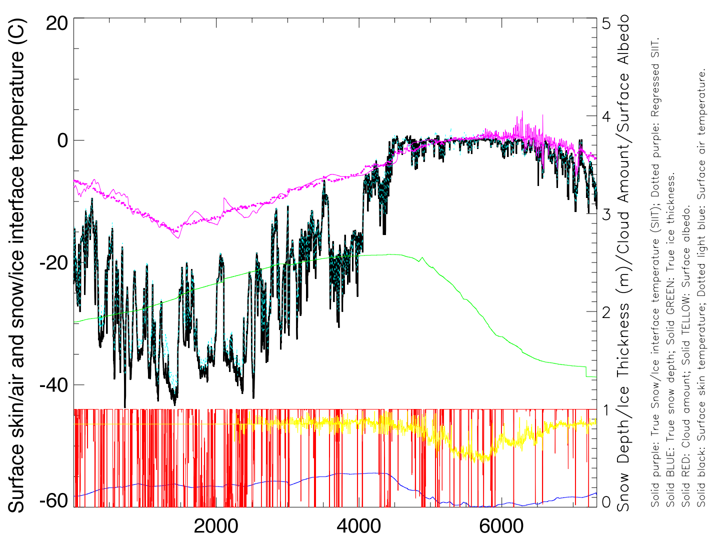


Figure 66. Comparison of snow-ice interfacial temperature between OTIM built-in parameterization scheme and SHEBA measurements. Solid purple line is SHEBA snow-ice interfacial temperature, and dotted purple line is OTIM built-in parameterization estimated snow-ice interfacial temperature. Other SHEBA measured variables included here are surface skin temperature (black line), surface air temperature (dotted light blue line), snow depth (blue line), cloud fraction (red line), sea ice thickness (green line), and surface albedo (yellow line).

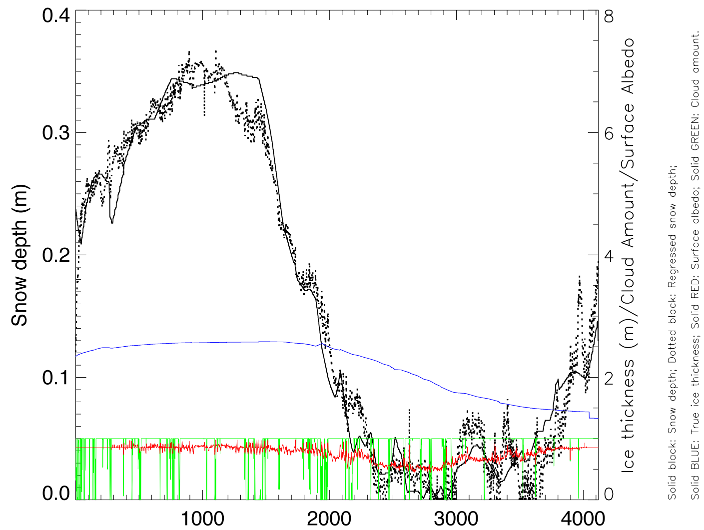


Figure 67. Comparison of snow depth between OTIM built-in parameterization scheme and SHEBA measurements. Solid black line is SHEBA measured snow depth, and dotted black line is OTIM built-in parameterization estimated snow depth. Other SHEBA measured variables included here are surface albedo (red line), cloud fraction (green line), and sea ice thickness (blue line).

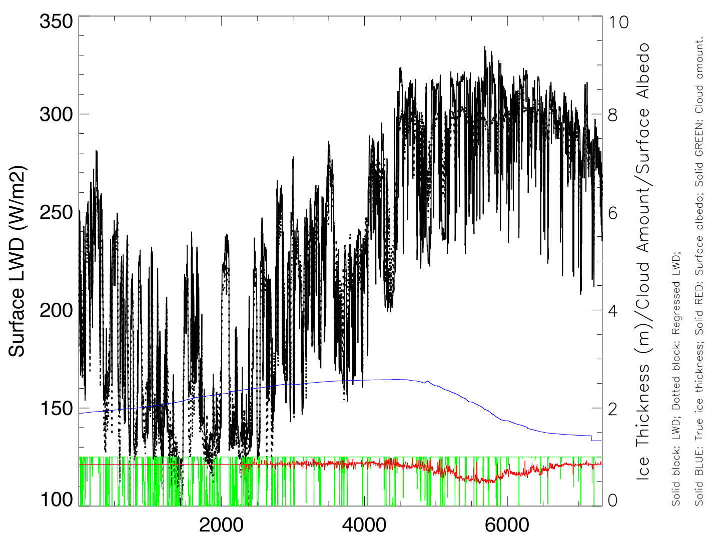


Figure 68. Comparison of snow-ice surface downwelling longwave radiative flux between OTIM built-in parameterization scheme and SHEBA measurements. Solid black line is SHEBA measured flux, and dotted black line is OTIM built-in parameterization estimated flux. Other SHEBA measured variables included here are surface albedo (red line), cloud fraction (green line), and sea ice thickness (blue line).

Ice Surface Temperature (IST) retrieval algorithm coefficients 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 studies using the operational VIIRS IST EDR and the CIMSS algorithm have been updated with IceBridge KT-19 for 2013 over the Arctic. Both algorithms show similarly good performance as shown below in Figure 69. However, the VIIRS IST EDR showed relatively poor performance when the IST is close to melting point (273 K). The CIMSS algorithm is expected to perform well under those conditions due to a more sophisticated design.

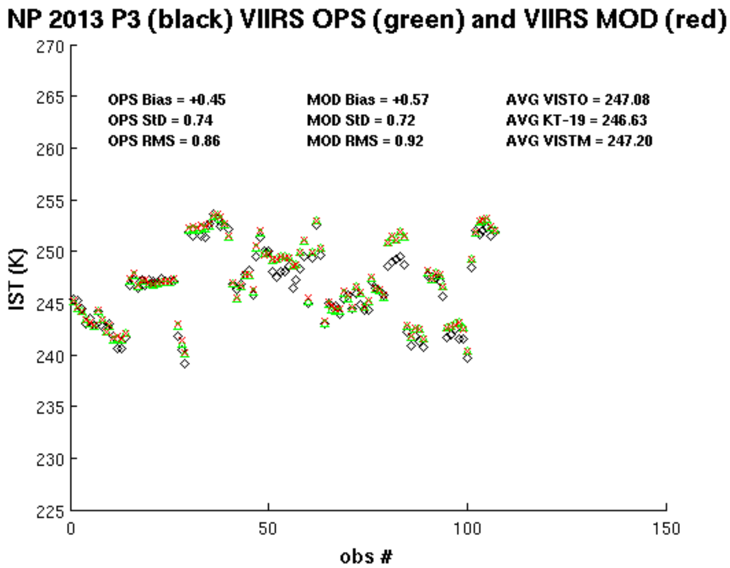


Figure 69. Ice surface temperatures from the IceBridge KT-19 instrument ("NP 2013 P3"), the operational VIIRS IST EDR ("VIIRS OPS"), and the CIMSS algorithm ("VIIRS MOD").

19.2 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 involves the implementation of the CIMSS GOES-R AWG Cloud Algorithms to the data from the Suomi NPP Visible Infrared Imaging Radiometer Suite (VIIRS). Specifically, this project covers the implementation of the ABI cloud mask (ACM), the ABI Cloud Height Algorithm (ACHA) and the Daytime Cloud Optical and Microphysical Properties (DCOMP) Algorithm. Implementation support is also provided for the Nighttime Cloud Optical and Microphysical Properties (NCOMP) Algorithm. In all, this project covers the generation on VIIRS of the following cloud products: clear-sky mask, top height, temperature and pressure, optical depth, particle size, water/ice path and base height. The motivation for this project is the demonstration of efficient processing of VIIRS data with NOAA and the generation of a set of products from VIIRS that is physically consistent with those from GOES-R.

ACM

The function of GOES-R ABI Cloud Mask (ACM) 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). This 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 ACM uses 9 spectral bands. Its cloud detection is based on spectral, spatial and temporal signatures. Most thresholds were derived from analysis of space-borne Lidar and current geostationary imager data. The ABI cloud tests were chosen to provide each algorithm a wide range of cloud detection options. The ABI mask is designed to allow algorithms and users to ignore certain tests and to efficiently re-compute the cloud mask. In addition, the ACM 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 a 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 on VIIRS are critical since they are used other products including the DCOMP and NCOMP cloud algorithms and the Atmospheric Motion Vectors (AMV) algorithms.

DCOMP

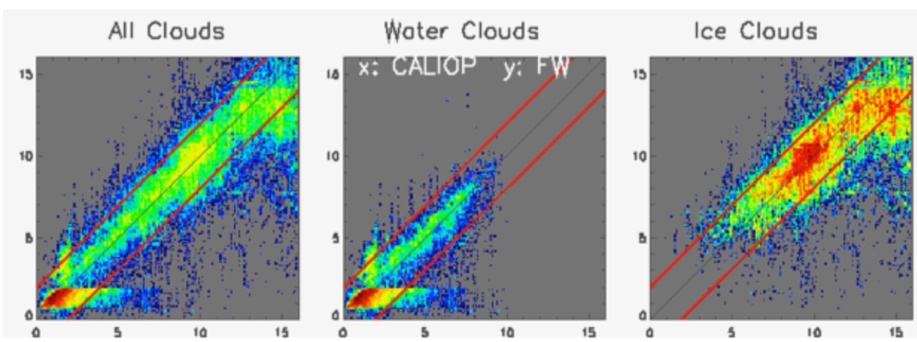
One other crucial component is the daytime cloud optical and microphysical properties (DCOMP) algorithm, which generates estimates of cloud optical thickness, cloud effective radius and ice/water path during daylight conditions [Walther and Heidinger, 2012]. DCOMP was developed with support from the 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 technical basis document (ATBD; Walther et al., 2011). 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.

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 on multiple modes, those 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.

Summary of Accomplishments and Findings

In this period we worked on the integration of the of the GOES-ABI cloud algorithms on VIIRS in to the NESDIS Operational Framework System (NOFS). This was successfully accomplished, resulting in a successful Test Readiness Review in early 2015. In addition, the NOFS running on the cloud algorithms was performed at CIMSS, resulting in the ability to run and evaluate the output from the NOFS. A demonstration of the performance of the performance of the AWG Cloud Height Algorithm (ACHA) implemented in AIT Framework, the equivalence of one day's worth of data (~1000 granules) that are collocated with CALIPSO over all seasons is shown Figure 70. Doing this validation demonstrates the compliance of the CTH output with the requirements for this project. . The stripe parallel to x-axis is primarily due to low level temperature inversions. Due to the limitation of passive sensor sensitivity to high thin ice clouds, in particular when low level clouds are present, the within spec percentages are lower for ice phase clouds as expected. This evaluation of the NOFS output will be performed on all of the cloud algorithms and is necessary to complete the Algorithm Readiness Review, which is the last step before the NOFS is delivered for operations.



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

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

CIMSS Task Leader: Corey Calvert
CIMSS Support Scientist: Justin Sieglaff
NOAA Collaborator: 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
- Environmental Models and Data Assimilation

Project Overview

The GOES-R AWG and RRR projects have resulted in development of new cloud phase and volcanic ash algorithms in recent years. These algorithms were designed with the GOES-R ABI spectral coverage (16 bands). We propose to modify the GOES-R Cloud Phase and Volcanic Ash algorithms to the VIIRS spectral channel availability and delivery these algorithms to NESDIS operations.

Summary of Accomplishments and Findings

The GOES-R Volcanic Ash detection and physical retrieval (height, mass loading, and effective radius) have been modified to account for reduced spectral information compared to GOES-R ABI (e.g., lack of 13.3 µm channel for physical retrievals). However, like GOES-R ABI, VIIRS contains an 8.5 µm channel, which is critical for volcanic ash detection. The increased spatial resolution (VIIRS: 750 m IR resolution versus ABI: 2,000 m IR resolution) results in the ability to detect and retrieve physical properties of smaller volcanic ash clouds. We have worked with the AIT teams (AIT-Midwest and AIT-East) to integrate the modified GOES-R AWG Volcanic Ash algorithm (modified to account for VIIRS spectral channels) into the AIT framework. This process is nearing completion. A number of test cases were run to compare the results between the AIT algorithm implementation and the CIMSS implementation. The comparisons indicate a few technical issues still need to be resolved in the AIT implementation and progress will continue to ensure the AIT algorithm implementation sufficiently replicates the CIMSS implementation.

Like the volcanic ash algorithm, the cloud type algorithm was also modified from the one created for the GOES-R ABI. The thresholds for the cloud type algorithm were theoretically developed for VIIRS pre-launch based on the modeling of single layer water and ice clouds (Pavolonis et al., 2005). Now that VIIRS is in orbit and data is flowing, initial evaluation indicated that some modifications were needed in order to improve the performance of the algorithm. These modifications include fine tuning threshold functions and values that are used to differentiate between the cloud phase and different cloud types. We have developed a tool that evaluates the VIIRS cloud type algorithm using collocated Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) data. The high-resolution lidar data is very sensitive to the cloud phase and is therefore a good data set to use for validating the cloud type algorithm. An example of a necessary modification is shown in Figure 71. The left image shows the cloud type algorithm applied to VIIRS over the South Pacific at 0033 UTC 11 July 2013. Notice the vertical discontinuities, circled in red, where the cloud type abruptly changes. This was caused by a threshold function that relied on preset satellite viewing angle bins. In order to fix the issue a linear interpolation with respect to satellite viewing angle was applied to the threshold function. The image on the right in Figure 71 shows the cloud type algorithm after the interpolation was applied. Note that the discontinuities are no longer present. Although further evaluation and threshold tuning may be needed, the first round of modifications has shown relatively significant improvement in the accuracy of differentiating between liquid water, mixed phase, opaque ice, cirrus and overlapping clouds. The VIIRS cloud phase algorithm has been delievered to the AIT and will be the first algorithm (before the volcanic ash algorithms) to start the transition into operations.

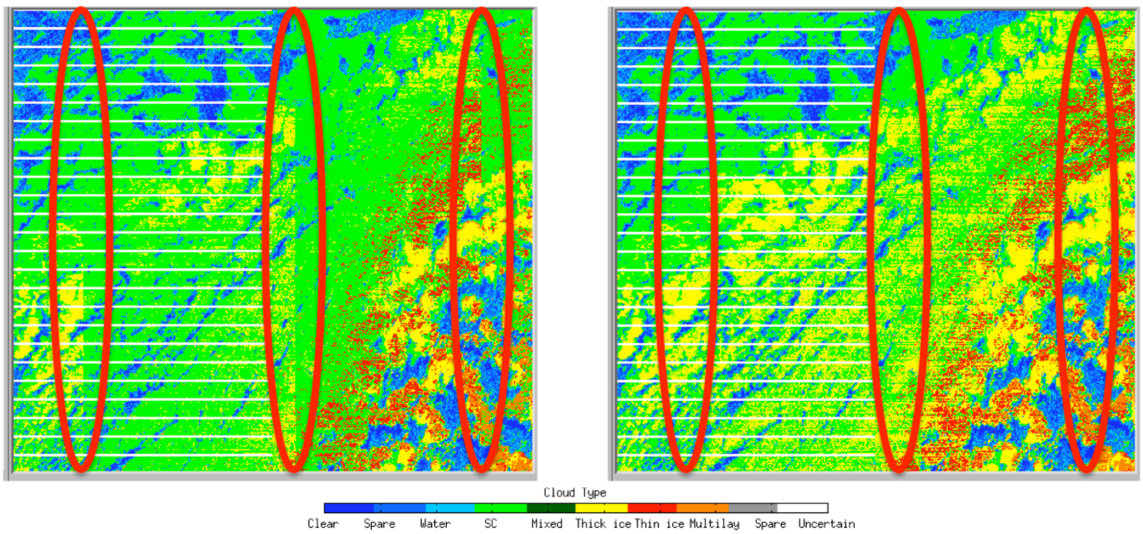


Figure 71. An example of the modified GOES-R cloud type algorithm applied to VIIRS over the South Pacific at 0033 UTC 11 July 2013. The left panel shows vertical discontinuities in the cloud type that were initially discovered at higher satellite viewing angles. The right panel shows the cloud type after a correction was applied that interpolates a necessary threshold function with respect to satellite viewing angle.

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.

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.

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.

19.4 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 included:
- 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.

Summary of Accomplishments and Findings
- Continued integration and verification of CIMSS algorithms to NESDIS Operational Framework System (NOFS) as needed for JPSS risk reduction
- Worked with AIT-E to establish “pluggable” science algorithms, allowing science to move between development systems and SAPF
- Collaborated with CIMSS scientists and AIT-E to integrate, deliver, and verify updated cloud, fog, volcanic ash algorithms for use with JPSS instrumentation
- Successfully compiled and ran NOFS locally at CIMSS for use by JPSS-RR algorithm developers.
- Participated in algorithm reviews as needed.

20. CIMSS Participation in the JPSS Risk Reduction Program for 2014

20.1 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, 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 objective is to use the JPSS (S-NPP, JPSS1, JPSS2) sounder measurements for improving the prediction of tropical cyclone (TC) genesis and evolution. 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.

Summary of Accomplishments and Findings

Real time Satellite Data Assimilation for Tropical storm forecasts (SDAT) for applications

Scientists from CIMSS have developed a near real time (NRT) regional Satellite Data Assimilation system for Tropical storm forecasts (SDAT) at NOAA/NESDIS-funded Supercomputer for Satellite Simulations and Data Assimilation Studies (S4), with the main purpose to use it as a research testbed and an application demonstration on the utilization of JPSS sounder observations for improving the tropical cyclone (TC) track and intensity forecasts. The core of SDAT system is the community Gridpoint Statistical Interpolation (GSI) assimilation system and the advanced Weather Research Forecast (WRF) model. Real time NOAA NCEP global forecast system (GFS) outputs are used as SDAT background and initial/boundary input. The system runs a 6-hour cycling assimilation followed by a 72-hour forecast. In addition to regular conventional and satellite radiances obtained from NCEP BUFR files which contain GOES Sounder, AMSUA, AMSUB, HIRS, MHS, ATMS, AIRS and IASI radiances, the system is also capable of assimilating satellite derived products such as atmospheric motion vector (AMV) products, total precipitable water (TPW) and layer precipitable water (LPW). So both satellite observed and derived data (radiances/products) can be assimilated in the system, which makes SDAT flexible for assimilating JPSS sounder radiances, NUCAPS soundings and cloud-cleared radiances (CCRs).

Since August 2013, SDAT system has been running at STAR (Center for SaTellite Applications and Research) supercomputer S4 in NRT over a domain covering CONUS and North Atlantic Ocean. In the last two years (2013 and 2014), Karen was the only hurricane landed onto CONUS. It is found that SDAT forecasts are closer to the observations than other dynamic models, and are very close to the official guidance (Figure 72). Through collaboration with CIRA (Kate Musgrave), CIMSS has been delivering SDAT forecast products in NRT to Automated Tropical Cyclone Forecast (ATCF) system that NHC (National Hurricane Center) uses since September

2014. The ATCF products can be accessed from:
ftp://rammftp.cira.colostate.edu/musgravek/SDAT/

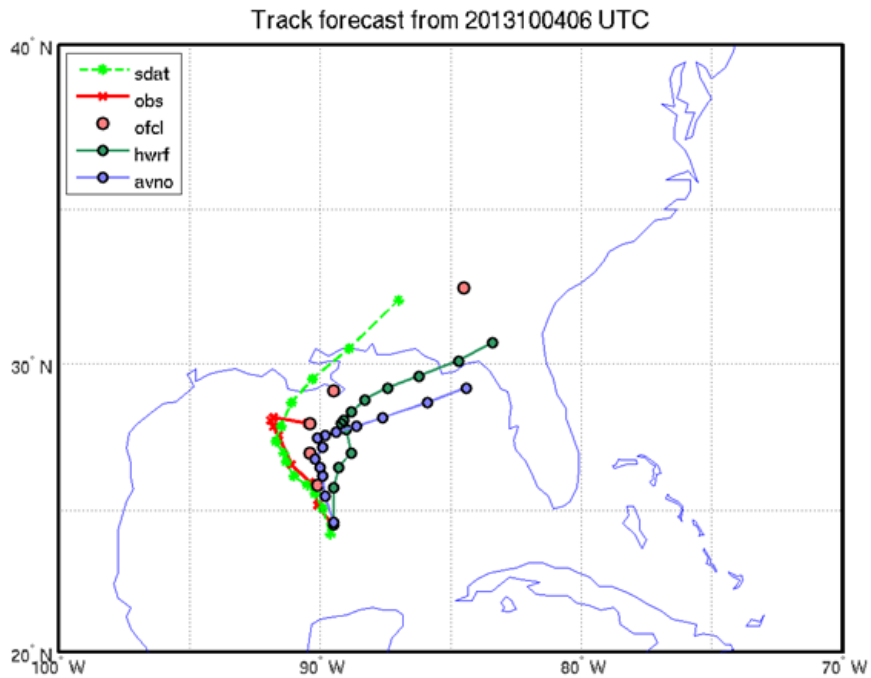


Figure 72. The track forecasts of storm Karen from SDAT (light green), NHC official guidance (pink), HWRF (dark green) and GFS (purple) along with the best track data (red). The forecasts started at 06 UTC 04 October and are valid until 06 UTC 07 October 2013. The observations (best track estimate) are only available until 06 UTC 06 October 2013.

Research conducted with SDAT on improving the utilization of advanced sounder measurements

Using SDAT as a testbed, studies have been conducted on improving the utilization of satellite data in regional NWP models. One of the studies is how to better detect clouds for hyperspectral IR sounder radiance assimilation. Improved cloud detection could reduce cloud contamination of clear fields-of-view (FOVs) and hence improve the assimilation of IR radiances. Synergistic use of high spatial resolution imager (e.g., MODIS) and high spectral resolution sounder (e.g., AIRS) data (Li et al., 2004) for improving the assimilation of sounder radiance in NWP model has been conducted with SDAT. Forecast experiments for hurricane Sandy in 2012 indicated that both hurricane track and intensity are substantially improved when the collocated high spatial resolution MODIS cloud mask is used for AIRS sub-pixel cloud detection for assimilating AIRS radiances, compared with those from current operational schemes on IR sounder cloud detection. The results are published in Geophysical Research Letter (Wang et al., 2014). Other researches such as the comparison between radiance assimilation and retrieval assimilation (Migliorini, 2012), radiance assimilation in cloud region (Wang et al., 2015) through imager/sounder cloud-clearing (Li et al., 2005), etc, have also been conducted with SDAT.

For example, in order to expand the radiance assimilation into cloudy region, research has been conducted on assimilating the cloud-cleared radiances (CCRs) into SDAT, the goal is to assimilate real time derived cloud-cleared product from community satellite processing package (CSPP) into SDAT. The motivation of assimilating cloud-cleared advanced infrared (IR) sounder radiances is that:

- Currently most operational NWP centers only use clear radiances (either clear field-of-view radiances or radiances of the channels not affected by clouds), expanding radiance assimilation into cloudy region is very important to maximizing the utilization of NPP advanced sounder data;
- Researches have been ongoing at many operational centers and research organizations on using cloudy radiances directly, but big challenges exist. The main challenges are that: (a) both NWP and RTM have relatively large uncertainties in cloudy situations, (b) there is temperature Jacobian jump at cloud level, which makes assimilation of temperature information in cloudy situation very difficult, and (c) there is inconsistency between NWP forecasts and satellite observations on cloudiness, for example, NWP is clear while satellite observed the clouds, and vice versa.

One of the objectives of this JPSS PGRR project is to conduct research offline with SDAT and finally make online use of cloud-cleared radiances (CCR), and potentially transfer the CCR assimilation to the operational NWP models such as HWRF and RAP. Two research topics are ongoing at CIMSS: use AIRS CCRs and prepare for CrIS CCRs. An optimal imager/sounder cloud-clearing technique has been developed at CIMSS for deriving IR sounder/imager CCRs. This technique can be used to retrieve clear column radiances through combining collocated multi-band imager IR clear radiances and the sounder cloudy radiances; no background information is needed in this method. The imager/sounder cloud-clearing technique is similar to that of microwave/IR cloud-clearing (Susskind et al., 2003) in the derivation of the clear-sky equivalent radiances. However, it retains the original IR sounder resolution, which is critical for regional NWP applications. In this study, we have investigated the assimilation of cloud-cleared IR sounder radiances using AIRS/MODIS for two hurricanes, Sandy (2012) and Irene (2011) in SDAT. Results show that assimilating additional cloud-cleared AIRS radiances reduces the 48- and 72-hour temperature forecast root mean square error (RMSE) by 0.1 - 0.3 K between 300 and 850 hPa when compared with assimilating AIRS clear radiances only, while the track forecasts can be substantial improved by 10 km to 50 km. This technique can also be applied to CrIS/VIIRS (Cross-track Infrared Sounder, Visible Infrared Imaging Radiometer) and IASI/AVHRR (Infrared Atmospheric Sounding Interferometer.

The assimilation experiments contain the following information:
- GSI V3.1, WRF-ARW V3.2.1
- Horizontal resolution: 12 km
- Vertical levels: 35 levels
- Model top: 10hPa
- Assimilation from 25 18z to 27 00z, Oct 2012
- Assimilation is every 6hr after 25 18z, so there are 6 groups of experiments
- After each assimilation, there is a 72 hr forecast for the hurricane track and intensity
- Data used includes:
- GTS: conventional data based on WMO standard
- AMSUA: amsua_aqua, amdus_metop-a, amsua_n15, amsua_n18 radiance data
- AIRS (GSI clr): airs_aqua clear radiance data with GSI cloud detection
- AIRS (MOD clr): airs clear radiance data with MODIS cloud mask for cloud detection
- AIRS (MOD cldclr): airs clear radiances with MODIS for cloud detection + AIRS cloud-clearing radiances (over ocean only)

Without changing the assimilation technique, the impact of the observations is heavily affected by the number and quality of observations assimilated. More quality observations assimilated usually leads to better analysis/forecast. On the other hand, poor quality observations, even a small percentage, may pose significant negative impacts on the analysis and forecast. The coverage of AIRS radiances assimilated in GSI at 1800 UTC 25 October 2012 is shown in Figure 73 using AIRS channel 210 (709.5659 cm^{-1}). The weighting function of this channel peaks around 500 hPa. The following three experiments are conducted:

- EXP1: GTS+AMSUA+AIRS (GSI clr), conventional data, four AMSU-A sounder data, AIRS radiances with GSI cloud-detection
- EXP2: GTS+AMSUA+AIRS (MOD clr), same as EXP1 but the AIRS radiances use MODIS for cloud detection
- EXP3: GTS+AMSUA+AIRS (MOD cldclr), same as EXP2 but adding AIRS/MODIS cloud-cleared radiances

Hurricane forecast are validated against the actual storm track and intensity with time (the best track and observations data were obtained from NOAA's NHC). Intensity is a measure of extreme meteorological conditions, either the maximum sustained (low-level) wind (MSW) or the minimum sea level pressure (MSLP) is used [Merrill, 1988]. Figure 73 shows the RMSE of the hurricane track (upper) and maximum wind speed (lower) of the 72-hour forecasts for Hurricane Sandy. The RMSE of the hurricane track from AIRS (MOD cld-clr) is the smallest among the three experiments for the whole process, especially after the 18-hour forecasts. The RMSE of the hurricane track from AIRS (MOD clr) is 10 to 25 km smaller than that from AIRS (MOD clr), and is 10 to 50 km smaller than that from AIRS (GSI clr). For the maximum wind speed, the three experiments have comparable results, making it difficult to determine which is better. For the maximum wind speed prediction (Figure 74 lower), it is neutral for the three experiments.

CrIS/ATMS CCR assimilation experiments

ATMS/CrIS cloud-cleared radiances (CCRs) have been successfully converted to BUFR format that GSI uses; ATMS/CrIS CCR assimilation tested with SDAT for Hurricane Sandy (2012) case, CCR test data are provided by Chris Barnet; Initial results are promising on using CCRs in assimilation; We are moving to test CSPP NUCAPS real time CrIS CCRs in SDAT.

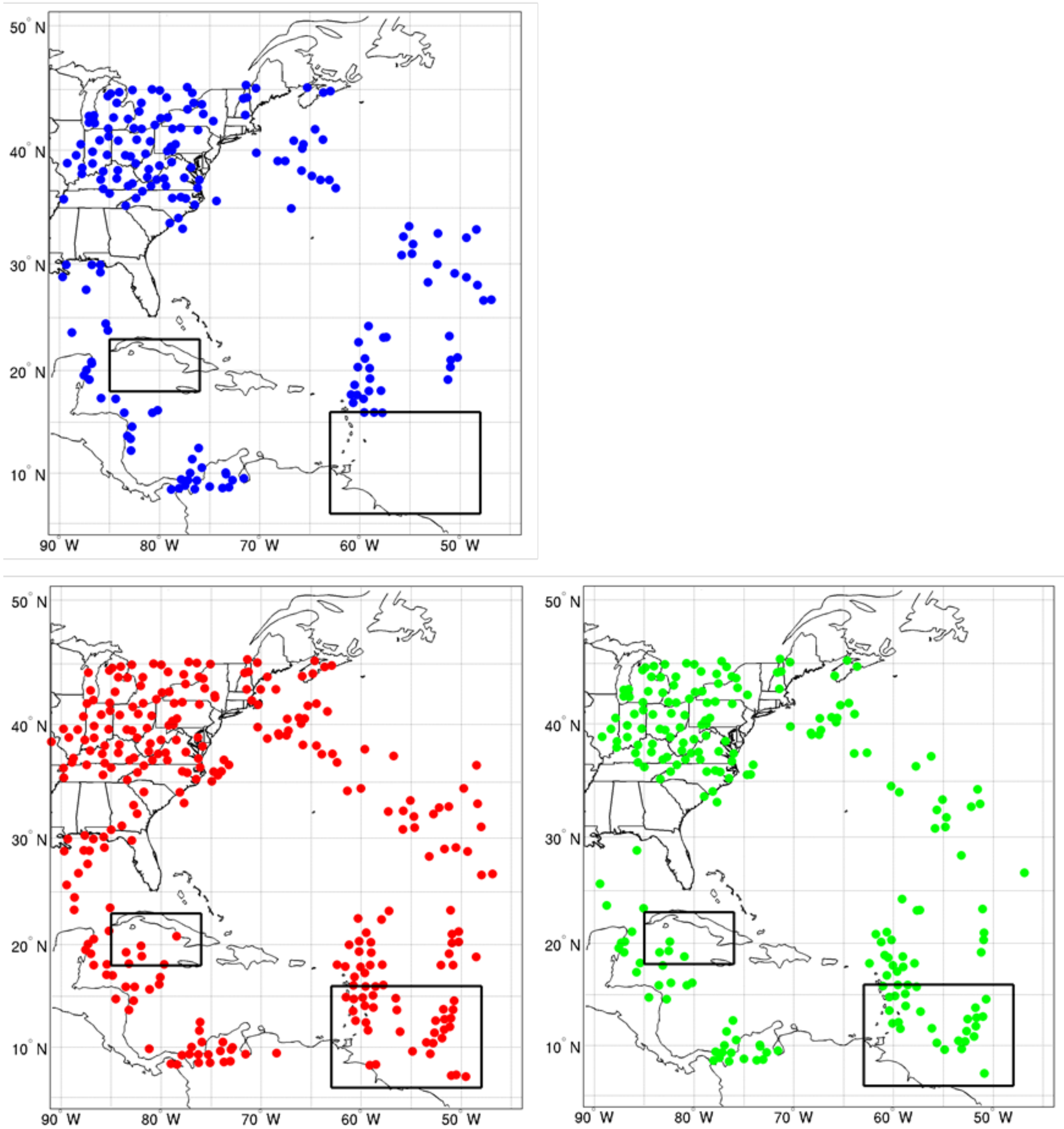


Figure 73. The locations at 1800 UTC 25 October 2012 where AIRS channel 210 (709.5659 cm^{-1}) is assimilated in GSI for AIRS (GSI clr) (lower left red), AIRS (MOD clr) (upper blue) and AIRS (MOD cld-clr) (lower right green).

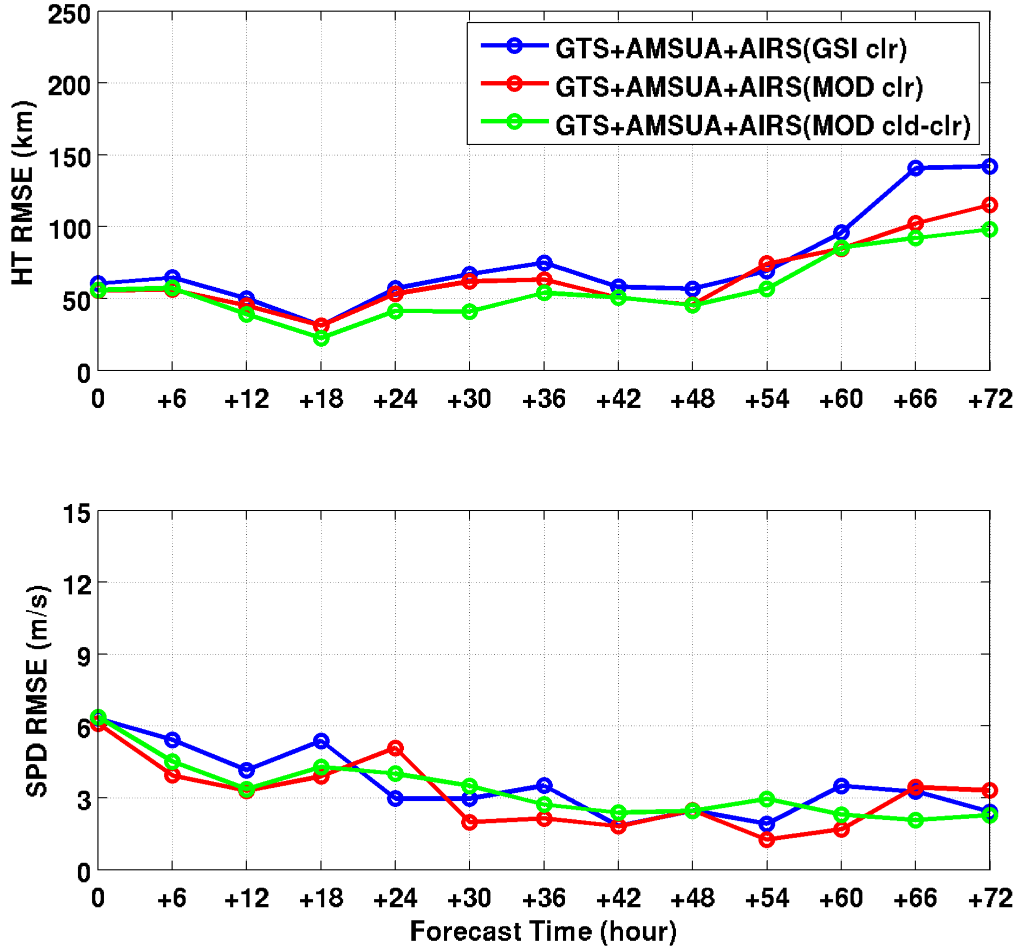


Figure 74. The track (top) and maximum wind speed (bottom) forecast RMSE with AIRS (GSI clr) (blue), AIRS (MOD clr) (red) and AIRS (MOD cld-clr) (green). Data are assimilated every 6 hours from 18 UTC on 25 October to 00 UTC on 27 October 2012, followed by 72 hour forecasts for Hurricane Sandy (2012).

Publications and Conference Reports

Wang, Pei, Jun Li, Jinlong Li, Zhenglong Li, Timothy J. Schmit, and Wenguang Bai, 2014: Advanced infrared sounder subpixel cloud detection with imagers and its impact on radiance assimilation in NWP, Geophysical Research Letters, 41,1773- 1780, doi:10.1002/2013GL059067.

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 (conditionally accepted).

Li, Jinlong, Jun Li, Pei Wang, and Tim Schmit, 2014: Near real time regional satellite data assimilation system and initial evaluation, The 19th International TOVS Conference (ITSC-19), 26 March – 01 April 2014, Jeju Island, South Korea.

Li, Jinlong, Jun Li, Pei Wang, Steven Goodman, Mitch Goldberg, and Timothy J. Schmit, 2014: Development of a near realtime regional satellite data assimilation system for high impact weather forecast, The 94th AMS Annual Meeting, 2 – 6 February 2014, Georgia World Congress Center, Atlanta, Georgia.

Li, Jun, Pei Wang, Timothy J. Schmit, Jinlong Li, Chian-Yi Liu, and Zhenglong Li, 2014: Handling Clouds for Hyperspectral Infrared Radiance Assimilation, The 19th International TOVS Conference (ITSC-19), 26 March – 01 April 2014, Jeju Island, South Korea.

Wang, Pei, Jun Li, Tim Schmit, Jinlong Li , Yong-Keun Lee, Zhiquan Liu and Zhenglong Li, 2014: Assimilation of Thermodynamic Variables from Satellite Measurements in Regional NWP for tropical Cyclone Forecast Improvement, The 94th AMS Annual Meeting, 2 – 6 February 2014, Georgia World Congress Center, Atlanta, Georgia.

20.2 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*
***CIMSS Collaborators**
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
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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 hyperspectral retrieval data access is currently limited. Efforts to expand data coverage and access are ongoing.

Summary of Accomplishments and Findings:

This project is designed to assist the NWS AR establish a technical framework and develop a more efficient and scientifically sound forecast process for using of satellite observations in Impact Decision Support Services (IDSS) in Alaska. Given the limited number of traditional observation systems in the Arctic (e.g., ASOS, upper air, buoys, etc.), AR relies heavily on satellite in the forecast process and is unique within the NWS in its reliance on LEO observations, including JPSS. At these latitudes, LEO systems provide sufficient temporal and spatial coverage to provide frequently updated observations. Thus many science and/or technological advances need to integrate LEO satellite information within their solutions. The high repeat cycle also allows adaption of applications similar to those developed for GOES sounder data over the CONUS.

Several forecast challenges have been identified that can benefit from improved short-range forecast tools that mitigate the aforementioned observational limitations in AR. They include:

- Convective location, timing and sustainment, including convection over lower terrain, Wildfire initiation and smoke, mesoscale heavy snow events
- Evolution of Turnagain Arm wind events that impact air traffic operations and depend on understating factors that control mountain wave forcing and responses (e.g., Stability, wind, moisture content, etc.)
- Improving short-range forecasts of the location and timing of Warm Season rain events by integrating satellite-detected moisture plums with larger scale vertical motion fields, including complex terrain.

The long-term goal of this effort focuses on improving very-short-range moisture, stability and precipitation forecasts by identifying the ‘best’ combination of LEO products and procedures to use in improving forecast guidance for the AR. As a first step in this effort, we are assessing of the accuracy of JPSS moisture data over land at high latitudes based on existing GPS Total Precipitable Water (TPW) observations. Results using data from 2013 (Figure 75) show a dry bias in clear-air IR-only hyperspectral observations, possibly because the retrievals were only sampling drier environments away from clouds while GPS was taking a time-average, including cloud effects. The approach includes retrievals generated using CIMSS, NESDIS and EUMETSAT retrieval approaches.

The second step builds upon investments already made by the GOES-R program by expanding forecaster utility of satellite soundings using predictive tools. Although the time between successive LEO soundings over AR is greater than that for GOES data over the CONUS, the quality of the LEO products available over AR will allow forecasters to expand the use of these products and help fill the 1-12 hour information-gap which exists between Nowcasts (based primarily on extrapolation of limited AR radar data) and longer-range NWP guidance. By adapting the data-driven CIMSS “NearCasting” system previously developed under the GOES-R program to use LEO observations, forecasters will be able to identify, track and anticipate extreme horizontal and vertical variations in the atmosphere (especially moisture fields) in analysis and forecast refreshes that become available immediately after every satellite product update. The systems has been shown to be useful over the CONUS in expanding the utility of current and future GOES DPI products in NWS offices, expanding their use from only offering observations of past conditions to providing predictions of pre-storm conditions in the near future.

The LEO-based NearCasting system has been tested over both AR and Europe, the latter location allowing additional inter-comparison with NearCasts using SEVIRI (a surrogate for GOES-R ABI). Figure 76 shows a sample comparison between NearCasts made using CIMSS (UW) and 2 versions of the EUMETSAT retrieval system. The former seems to present stronger gradients (especially at lower levels) while the latter provides greater areal coverage (due to the inclusion of microwave data). Based on results like these, data collection methods are being explored which could allow the merger of the benefits of both products over AR. The NearCast system is running

24/7 at CIMSS, with NearCasts being generated immediately after data from any available overpass has been collected, with output generated at 15-minute intervals.

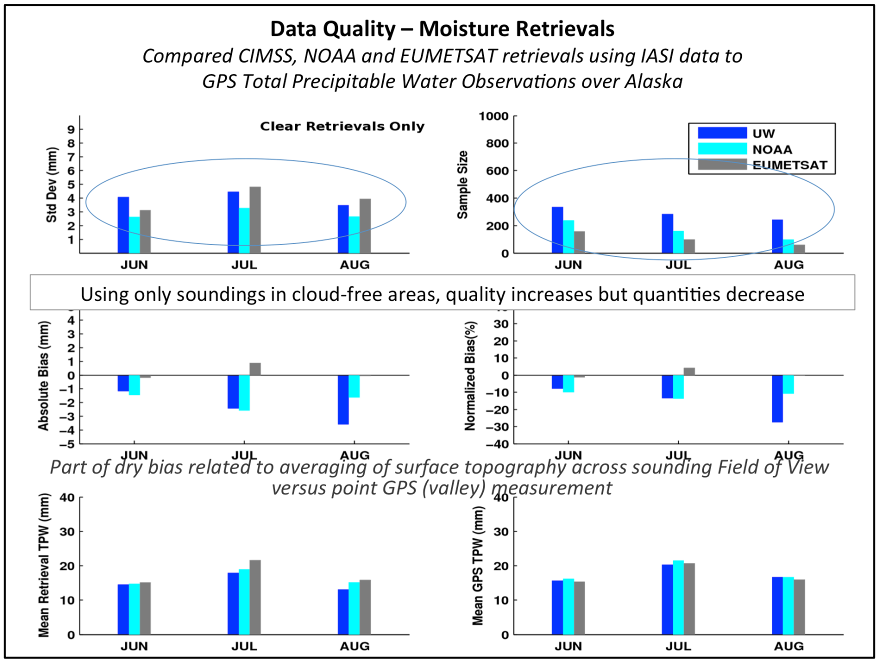

Figure 75. Comparison of TPW obtained between CIMSS (UW), NESDIS and EUMETSAT hyperspectral retrievals with surface-based GSP TPM observations for summer of 2013. For clear sky conditions, the EUMETSAT products have the smallest biases, but also the fewest number of retrievals available. CIMSS retrievals have the greatest areal coverage (based on sample size) but a large dry bias. NESDIS products at the time had a smaller random error, but still relatively large biases.

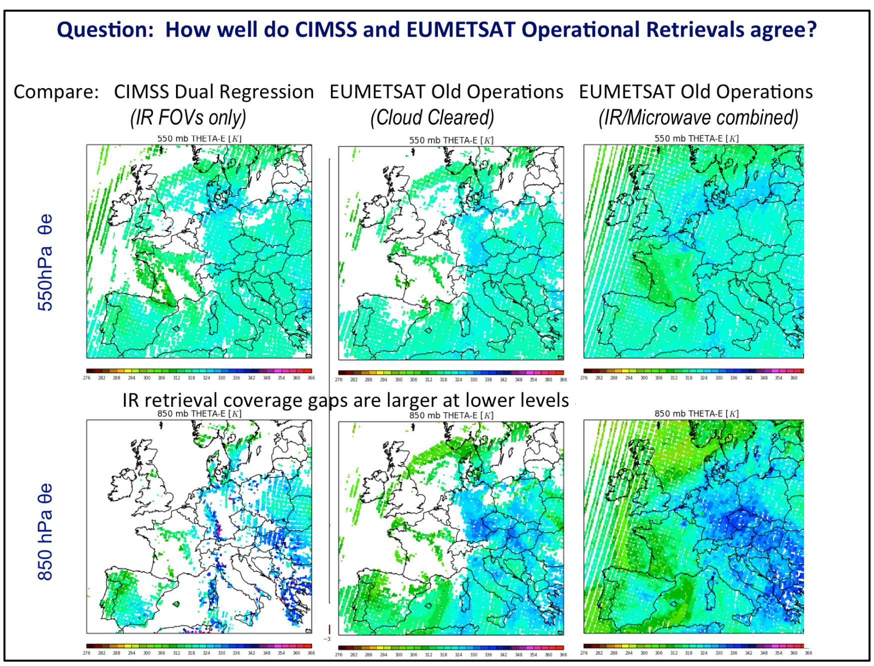

Figure 76. Comparison of NearCast analyses of 850 and 550 hPa Equivalent Potential Temperature using CIMSS, previously EUMETSAT and currently operational EUMETSAT retrievals. CIMSS products (using only IR observations) seem to have stronger gradients but inclusion of microwave data in new EUMETSAT products provides more extensive spatial coverage.

Publications and Conference Reports
Petersen et al. at EUMETSAT Users Conference and Conf. Report (Sept. 2014).

Petersen et al. at EUMETSAT Convection Working Group Workshop (April. 2014).

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

20.3 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.

Summary of Accomplishments and Findings

As part of the process of developing a blended visible/IR and passive microwave sea ice concentration product, validation of VIIRS and passive microwave-derived sea ice concentration is now being done by using high-resolution Landsat data. All Landsat 8 scenes in the year 2013 and 2014 that contain Arctic sea ice and are 90% or more clear sky were ordered from the U.S. Geological Survey (USGS) data sever. There are a total of 181 Landsat scenes. In each scene, each pixel has visible and thermal channel observation at 30 m spatial resolution from the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) onboard the Landsat 8. Each pixel at the original spatial resolution is identified as either snow/ice or water under clear conditions based on the visible channel reflectance and the derived Normalized-Difference Snow Index (NDSI). Sea ice concentration (SIC) at lower spatial resolutions of 1 km, 6.25 km, and 25 km are calculated as the ratio of the number of snow/ice pixels to the number of all pixels inside a grid cell. For each of the Landsat scenes a corresponding granule of the Suomi NPP VIIRS Sea Ice Concentration intermediate product (IP) with a spatial resolution of 375 m is located with a time difference of less than 1 hour. A daily mean sea ice concentration product is also obtained from the Advanced Microwave Scanning Radiometer 2 (AMSR2) at 6.25 km, and from the Special Sensor Microwave Imager/Sounder (SSMIS) on board the Defense Meteorological Satellite Program (DMSP) F17 satellite at 25 km using NASA algorithm.

These four SICs are remapped to 6.25 km EASE-Grid (though not for SSMIS SIC) using map projection tool MODIS Swath-to-Grid Toolbox (MS2GT) and compared. Bias and Root Mean Squared Error (RMSE) of SICs from the Suomi NPP VIIRS and AMSR2 are calculated with regard to SIC from Landsat.

Figure 77 shows the comparison between VIIRS and Landsat ice concentrations for different ice concentration bins. It also shows the bias and root-mean-square difference as a function of the VIIRS ice concentration. Biases and uncertainties (precision) are relatively small for all bins. Figure 78 gives the comparison between AMSR2 and Landsat concentrations. Unlike the VIIRS-Landsat comparison, AMSR2 has large biases and uncertainties for all but the highest concentration bin.

In the pursuit of the best sea ice product to deliver to the National Ice Center (NIC), VIIRS ice age and OTIM retrieved ice age products have been continuously compared. Figure 79 gives examples showing the VIIRS IST (upper-left), VIIRS M7 reflectivity (upper-right), VIIRS ice age (lower-left), and OTIM ice age (lower-right) on March 21, 2013 at 21:19 UTC. In terms of VIIRS ice age classification, ice age is defined by a threshold value (30 cm) of sea ice thickness for new/young ice and all other ices. VIIRS IST shows high thermal contrast leads and large warm lead where VIIRS M7 reflectivity shows high reflective contrast leads and large dark lead, correspondingly. OTIM ice thickness and age correlate well with VIIRS IST and M7 Reflectivity even for leads with thickness greater than 30 cm.

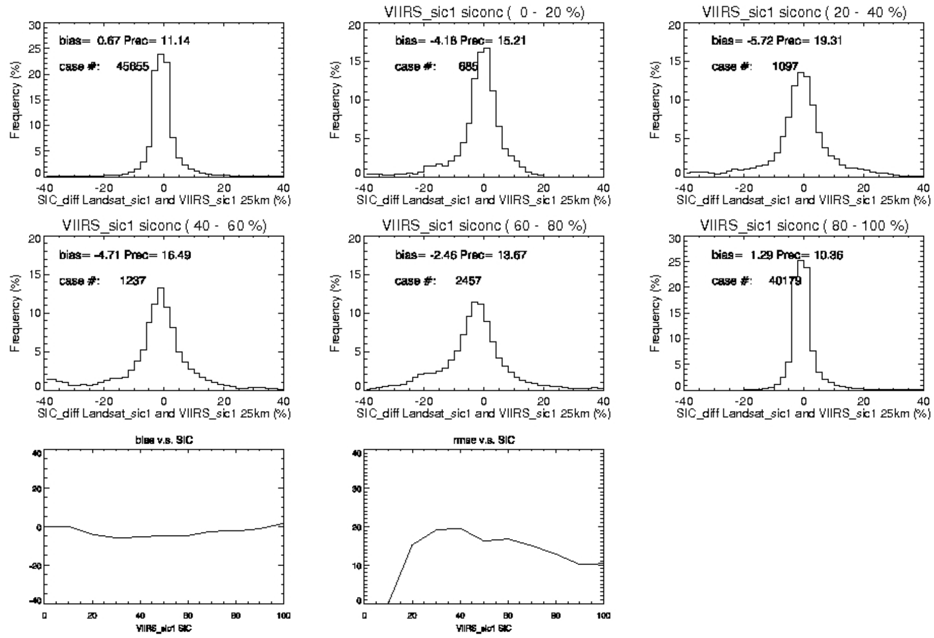

Figure 77. Comparison of VIIRS and Landsat ice concentrations for different concentration ranges/bins. Also shown are the differences overall (upper left) and the bias and root-mean-square (RMS) difference as a function of VIIRS ice concentration (bottom row).

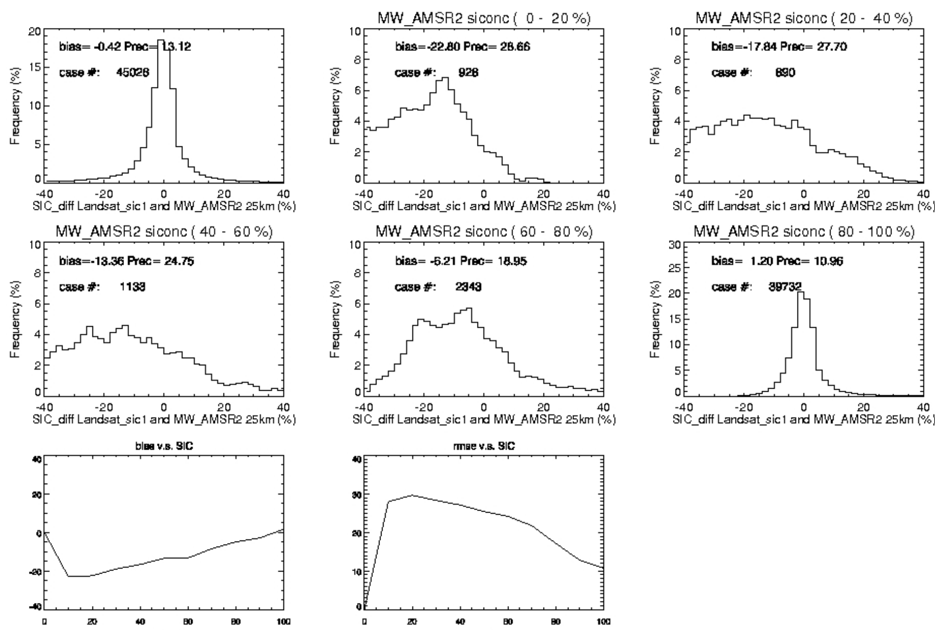

Figure 78. Comparison of AMSR2 and Landsat ice concentrations for different concentration ranges/bins. Also shown are the differences overall (upper left) and the bias and root-mean-square (RMS) difference as a function of AMSR2 ice concentration (bottom row).

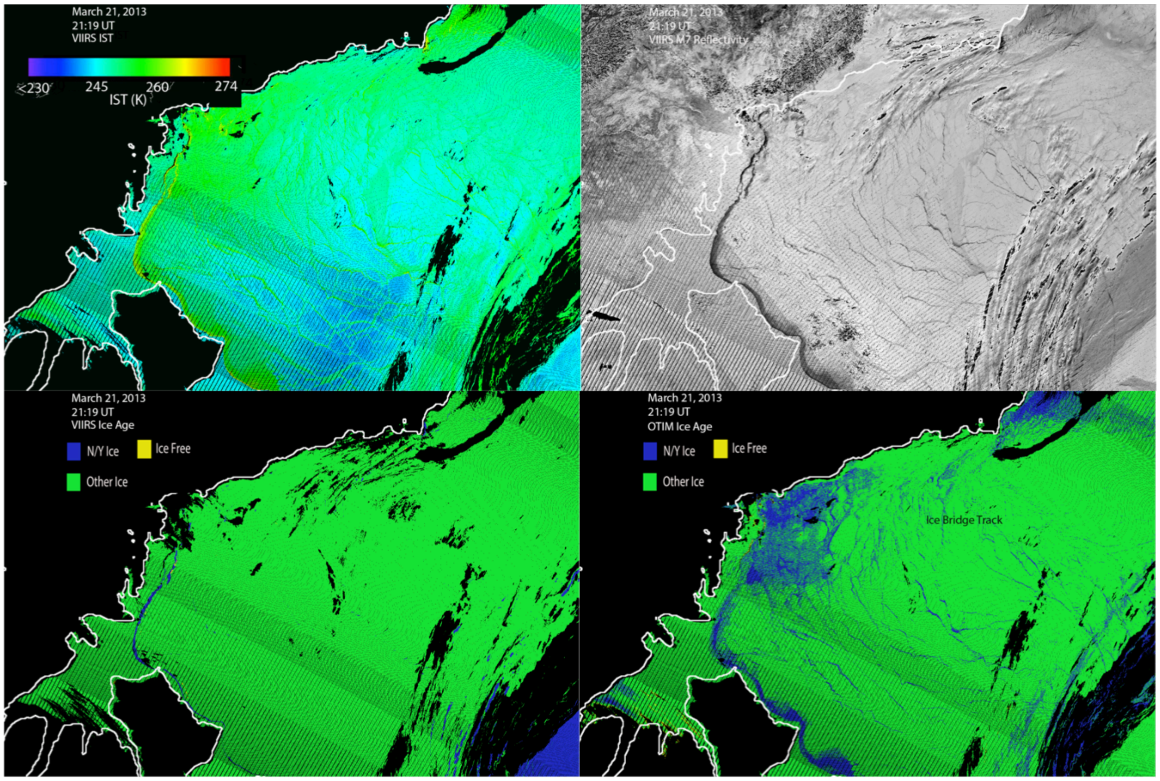

Figure 79. Comparisons between VIIRS sea age and OTIM ice age products for the date of March 21, 2013 at 21:19 UTC.

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20.4 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

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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 greatly enhance regional weather prediction capabilities. To encourage the operational use of hyperspectral retrieval data in NWS (National Weather Service) forecasting offices the value that hyperspectral infrared sounder retrievals add to forecasting applications is demonstrated by means of case studies in the Alaskan Region (AR) as well the CONUS area. Furthermore, selected retrieval products are prepared for near real-time viewing and analysis through the Advanced Weather Interactive Processing System (AWIPS). This will add new meteorological data to forecasting activities by NWS users.

Summary of Accomplishments and Findings

The study and analysis of AR and CONUS weather systems indicate the capability of hyperspectral sounder retrievals to provide quantitative information (e.g., from CrIS) for interpreting satellite imagery (e.g., from VIIRS) and to detect mesoscale variation in atmospheric temperature and moisture, as well as stability changes. A software package to convert selected dual-regression retrieval (Smith et al., 2012 Weisz et al., 2013) parameters (cloud top pressure, cloud optical depth, temperature and humidity at 500 hPa, Lifted Index) to gridded NetCDF-3 files apt for display and analysis in AWIPS has been delivered to GINA (Geographic Information Network of Alaska)/UAF (University of Alaska Fairbanks) in April 2014. Continued discussion with GINA scientists and AR NWS forecasters about the implementation of high-spectral resolution sounder retrievals into AR weather forecasting operations led to the identification of need for accurately detecting cold air layers aloft over the Arctic in real-time. 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 these cold air layers. We were able to demonstrate that hyperspectral sounders are capable of detecting these cold air pockets as shown in Figure 80. Another case is shown in Figure 81, where radiances from consecutive orbits of Metop-A, Metop-B, S-NPP and Aqua have been utilized. NOAA has since prioritized this novel application and supports a newly established working group, which is specifically dedicated to make this product available for operational usage.

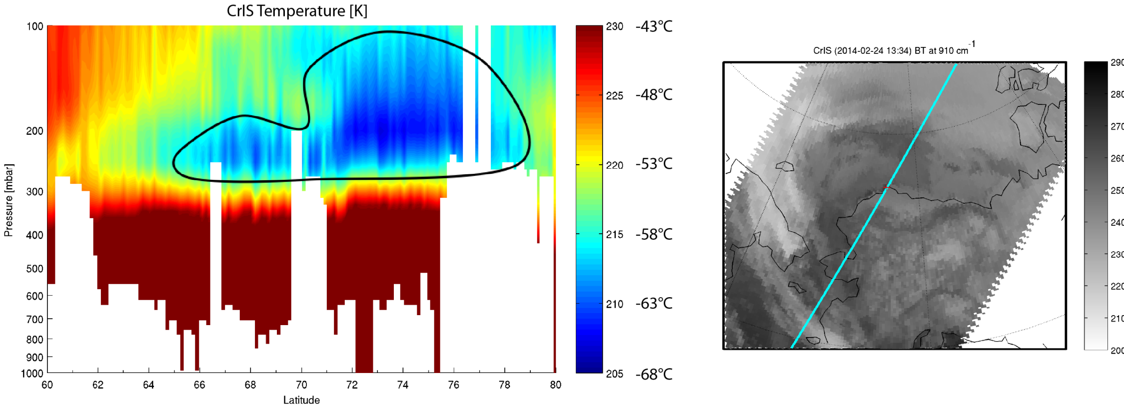


Figure 80. CrIS temperature cross-section (left) along the line shown in right image (CrIS brightness temperatures at 910 cm^{-1}) on February 24, 2014.

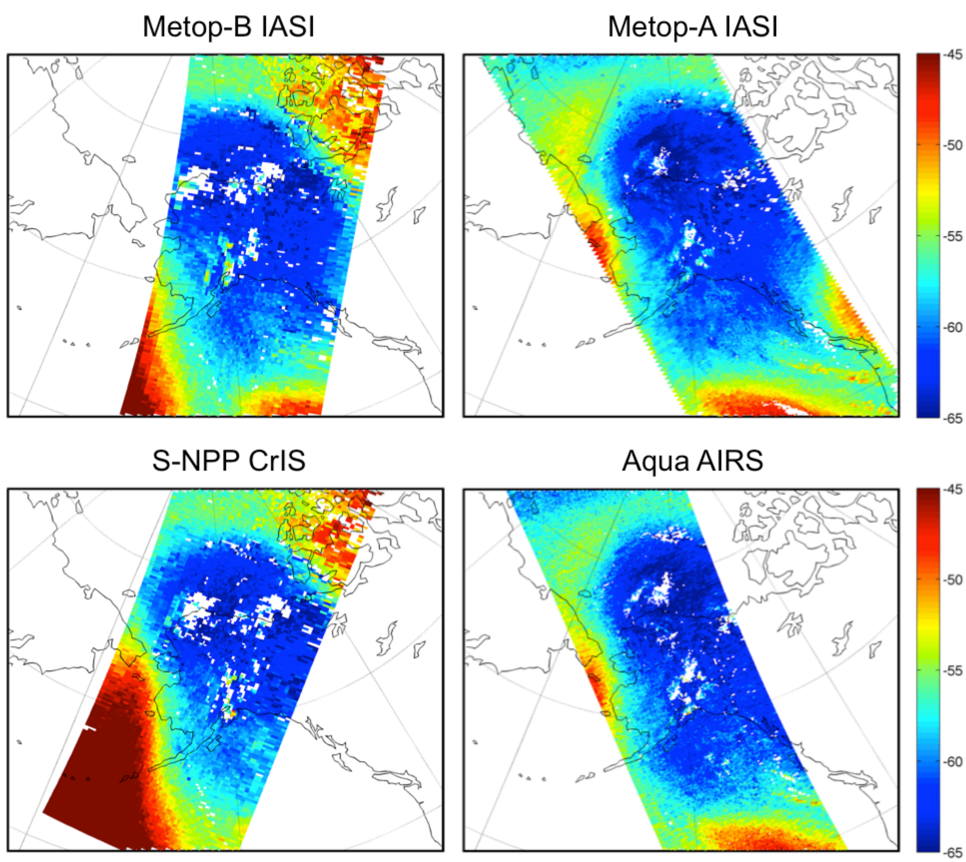


Figure 81. Temperature [°C] at 200 hPa retrieved from Metop-B IASI, Metop-A IASI, S-NPP CrIS and Aqua AIRS measurements in consecutive orbits on November 12, 2014 (~20:00 to 22:40 UTC).

Publications and Conference Reports

Smith Sr., W. L., A. Larar, H. Revercomb, M. Yesalusky, E. Weisz, M. Goldberg, "Validation of CrIS Dual Regression Sounding Products during the Airborne Suomi-NPP Cal/Val Campaign", Presentation at the 2014 STAR JPSS Teams Annual Meeting (May 12-16, 2014), NOAA Center for Weather and Climate Prediction, College Park MD.

Smith Sr., W. L., A. Larar, M. Goldberg, X. Liu, H. Revercomb, E. Weisz, M. Yesalusky, and D. Zhou, "May 2013 SNPP Cal/Val Campaign – Validation of Satellite Soundings", Asia Pacific Remote Sensing Symposium conference on Multispectral, Hyperspectral, and Ultra-spectral Remote Sensing Technology, Techniques and Applications held 14-16 October 2014 in Beijing China.

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*.

20.5 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 time scale of tropical cyclone (TC) track and intensity changes is on the order of 12 hours, which makes JPSS instruments well suited for the analysis of these parameters. An application of JPSS data is being developed that uses thermal channels and radiance data from ATMS in the storm environment to estimate TC intensity. Once the ATMS algorithm is mature, the products will be made available through the JPSS Proving Ground to the National Hurricane Center (NHC) and Joint Typhoon Warning Center (JTWC) for evaluation and feedback. If the evaluation is positive, the products will be positioned for transition to NHC and JTWC operations.

Summary of Accomplishments and Findings

Work this period has focused on tuning and optimizing the ATMS MSLP intensity algorithm, and adding a MSW (maximum sustained wind) estimation component. A scan angle correction has been developed to account for the bias induced by larger FOVs as scan angles approach the limb of the overpass swath. The original algorithm was updated with this correction and regressions re-derived. Navigation code for matching S-NPP overpasses with real-time TC positions has been completed, and 181 ATMS passes over TCs covering all TC basins have been collected and reprocessed for the period 2012-2014. TC intensity estimates from the ATMS algorithm for these passes are compared to Best Track (BT) estimates and ground-truth reports for validation (aircraft reconnaissance in the Atlantic (40 cases) along with a few surface observations). The results are presented in Table 2 and Table 3 below. As can be seen, the mean performance statistics of the ATMS intensity estimates for MSW are on par with existing operational Dvorak-based estimates. These encouraging results, based on a dependent sample, will be put to the test in a real-time demonstration for the upcoming 2015 TC season.

Pending the acceptance of a submitted follow-on proposal to the JPSS program, we plan to conduct the real-time demo in accordance with the JPSS Proving Ground. Near real-time ATMS intensity estimates will be provided via ATMS and a web site for viewing by operational partners participating in the proving ground. We also hope to study and implement the ATMS intensity estimates into the satellite-based consensus approach (SATCON), also being developed at CIMSS.

Table 2. CIMSS ATMS-derived TC intensity estimates: Dependent results from 181 TC cases in 2012-2014 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=181	ATMS MSLP (hPa)	ATMS MSW (kts)	DVK MSW (kts)
Bias	0.0	0.4	-3.1
Abs Error	5.5	8.3	8.6
RMSE	6.9	10.4	11.0

Table 3. As in Table 2, except only for cases where ground truth (aircraft data, buoys and/or land observations and radar velocities) are available for validation.

N=103	ATMS MSLP (hPa)	ATM MSW (kts)	DVK MSW (kts)
Bias	0.2	-0.4	-2.9
Abs Error	5.1	7.5	8.0
RMSE	6.2	9.7	10.2

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.

Herndon, D. and C. Velden, 2014: An update on tropical cyclone intensity estimation from satellite microwave sounders. *31st AMS Hurricanes and Tropical Meteorology Conference,* San Diego, CA, March 31-April 4.

20.6 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

Extending the HIRS cloud data set to include CrIS will be researched. This involves reducing the high spectral resolution CrIS data to resemble the HIRS broad band spectral coverage and estimating the cloud top pressures and effective emissivities. Co-located HIRS and IASI data are being used initially to provide proof of concept. In addition the high spectral resolution data will be investigated for opportunities to characterize the uncertainties in the broad band cloud products

Summary of Accomplishments and Findings

A combination of the CO2 slicing and IRW techniques for deriving cloud top pressures (CTPs) was applied to high spectral resolution IASI measurements (adapting an approach suggested in Holz et al., 2006). 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 to CALIOP determinations. There is good agreement for low level clouds (difference in transect b along the edge of low and mid-level clouds can be understood by realizing IASI field of view sees mid and low clouds, while CALIOP sees only low clouds). For higher clouds in transect B, it appears that the water cloud solution (IRW) is used in preference to the ice cloud solution (CO2), perhaps indicating some difficulty with the cloud phase determination (this will be investigated next quarter).

Results from this work to date support the conclusion that HIRS CTPs can be continued by using CrIS measurements convolved to HIRS spectral response functions. Comparisons with CALIOP are helping to characterize the strengths and weaknesses of HIRS CTP determinations compared to IASI CTPs.

Remaining work includes further data collection and CTP comparison. CTPs (IASI-DR, HIRS-DR, HIRS-CO2-IRW, IASI-CO2-IRW) must be sorted by cloud effective emissivity for individual CTPs. Uncertainties for differing cloud conditions need to be charted. A CrIS CTP algorithm that continues the HIRS cloud record then can be finalized and resulting s/w transferred to National Centers for Environmental Information.

Publications and Conference Reports

A poster was presented at the Boston AMS Cloud Conference in July 2014.

References

Holz, R. E., S. Ackerman, P. Antonelli, F. Nagle, R. O. Knuteson, M. McGill, D. L. Hlavka, and W. D. Hart, 2006: An improvement to the high-spectral-resolution CO2-slicing cloud-top altitude retrieval. J. Atmos. Oceanic Tech., 23, 653–670.

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.

Weisz, E., W. L. Smith, N. Smith, 2013: Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements. J. Geophys. Res.-Atmospheres, 118, 6433-6443.

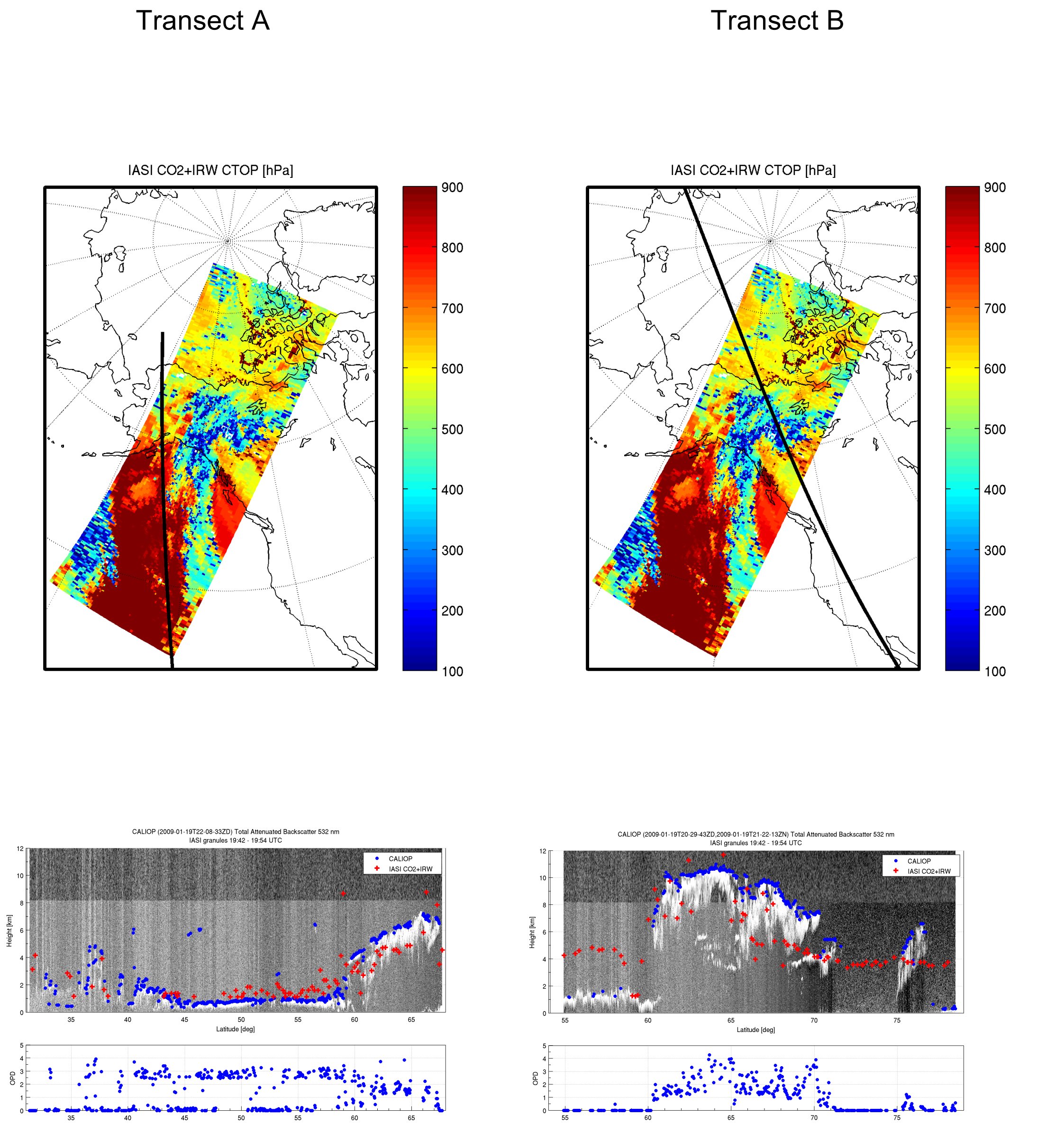


Figure 82. Comparisons results for 19 January 2009 around 1950 UTC. (top) IASI CTP (in hPa) using CO2 slicing for ice and IRW for water clouds with CALIOP transects superimposed. (bottom) Associated comparisons with CALIOP (blue) and IASI (red) determinations of cloud top height (in km) and CALIOP cloud optical depths along the respective transects.

21. The Development of the High Performance JPSS Analysis Facility for Instrument Impacts on Requirements (JAFIIR)

CIMSS Task Leaders: Allen Huang, Mathew Gunshor

CIMSS Support Scientists: Hong Zhang, Agnes Lim, Eva Schiffer

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

CIMSS has designed, implemented, and operated a high performance end-to-end system analysis facility in support of JPSS. The two tasks associated with this project includes support of the JPSS program in the area of future sensor design (Task 1) and improvement as well as in the area of current and future instrument waiver analysis (Task 2). The JPSS Analysis Facility for Instrument Impacts on Requirements (JAFIIR) project was first designed to conduct sensor modeling, measurement simulation, EDR algorithm adaptation, and VIIRS instrument impact assessment on current and future system requirements (Task 2). This proposed work follows the successful GOES-R Analysis Facility for Instrument Impacts on Requirements project (GOES-R AWG GRAFIIR), which has so far supported 12 ABI waiver analyses. Additionally, JAFIIR's capability has been extended to analyze the impact on NWP forecasts from reduction of the FOV size for the next generation CrIS, as both global and regional operational weather forecasts are aggressively moving toward smaller grid sizes (Task 1).

Summary of Accomplishments and Findings

Task 1: OSSE study - IFOV size impact on NWP forecasts

The Global Modeling and Assimilation Office (GMAO) at NASA Goddard Space Flight Center has released a 2-year non-hydrostatic 7-km global mesoscale simulation produced with the Goddard Earth Observing System (GEOS-5) atmospheric general circulation model. The simulation was produced as a Nature Run suitable for conducting observing system simulation experiments (OSSEs). Generation of the 7-km GEOS-5 Nature Run (7km-G5NR) was motivated in part by the desire of the OSSE community for an improved high-resolution sequel to an existing Nature Run produced by the ECMWF, which has served the community for several years. For this project, the 7km-G5NR in this proposal is used for generating simulated observations to evaluate proposed observing system designs regarding new configuration for the next generation of CrIS instrument. The 7km-G5NR includes standard meteorological components, a suite of aerosol types and several trace gas concentrations, with emissions downscaled to 10 km using ancillary information such as power plant location, population density and night-light information. The 7km-G5NR has produced nearly 4 petabytes of data at 30-minute intervals throughout the 2-year simulation (http://gmao.gsfc.nasa.gov/global_mesoscale/G5NR/).

Beyond the global data, the CIMSS proxy team has been running and providing CONUS area simulated atmosphere for GOES-R Algorithm Working Group (AWG). Expertise in simulating satellite observations from microwave, visible, near infrared and infrared sensors uniquely qualify CIMSS to provide the independent OSSE study optimized to meet JPSS timely and evolving needs. Furthermore, software has been developed to simulate synthetic satellite observations in collaboration with Joint OSSE and NOAA/AOML. The software is capable of simulating observations both clear and cloudy radiances using different radiative transfer models, including

CRTM, RTTOV and SARTA (for hyperspectral IR sounder only) using various NRs (such as ECMWF T511 and T1279, the AOML regional NR, the G5NR, and etc).

Figure 83 shows the progress that has been achieved in the past 7 months setting up the OSSE framework. The simulation of current observing data types has been split into a few components: simulation of conventional data (rawinsodes, aircraft and surface observations), simulation of satellite observations, and simulation of GPSRO observations. Conventional data simulation for the required time period (4 months) has been completed. In our OSSE framework, we choose to "fly" satellites in the NR instead of retrieving the position from the NCEP archived BUFR file. To do so, an orbit simulator for the instruments on the different 5 platforms to be assimilated has been developed. It has been verified that the simulator generates data coverage very similar to that of real observations (Figure 84). The orbit simulator is then used to generate satellite geometry information to be input into radiative transfer model to compute simulated brightness temperature for the instruments needed. Figure 85 shows samples of simulated brightness temperatures for CrIS. GPSRO simulator framework has been completed and is in the testing stage. Utility packages to add noise to ideal observations (observational noise simulator) and an encoder to write satellite observations into the BUFR format that is accepted by GSI are in progress. For calibration, statistics are compared between real world and simulated world. Real world OSEs needed have been run and planned statistics to be used in the calibration process have also been derived.

Task 2: VIIRS instrument impacts and waiver analysis

The Band-to-band registration (BBR) issue on JPSS-1 VIIRS was addressed primarily by the JAFIIR team, with help from the Active Fire and Cloud Teams. The algorithms looked at were active fires, VIIRS cloud mask, and CLAVR-x products (cloud mask, cloud phase, cloud top height, etc.). A special look at the possibility of creating false fog reports was also generated. An example of a Glance output report for the CLAVR-x products can be found here: http://www.ssec.wisc.edu/grafiir/JAFIIR/CLAVRx_VIIRS_BBR/ Since the BBR effect was largest in the I-Bands, that is what was simulated and I-bands are generally not used quantitatively in the products. The BBR error in the M-Bands was considered negligible. The effect in the I-Bands was more apparent for certain fire scenes. A report was generated and presented to the JPSS Waiver Working Group.

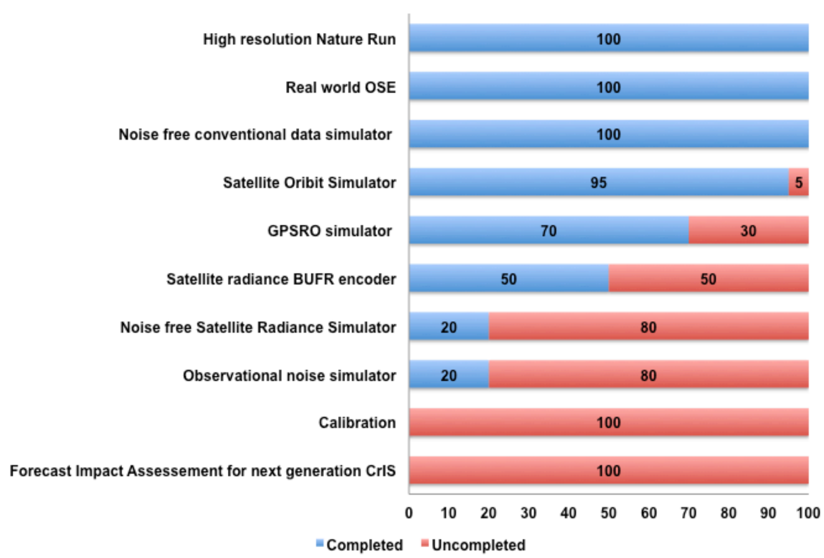


Figure 83. Progress of various components of the OSSE.

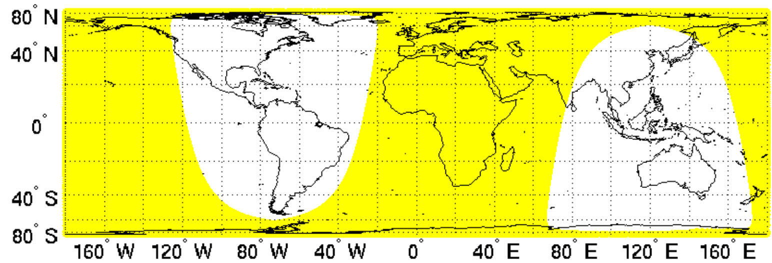


Figure 84. Sample results from orbit simulator orbital coverage of S-NPP over a 6 hour period.

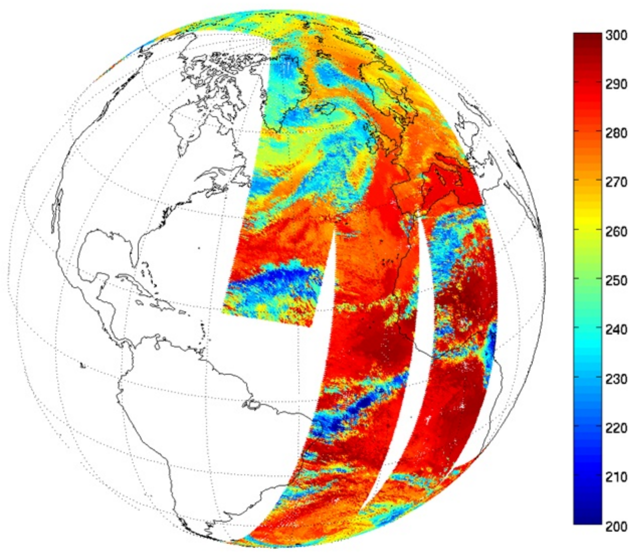


Figure 85. Simulated brightness temperatures using the orbit simulator to generate satellite geometry information for S-NPP CrIS channel 482 (CO_2).

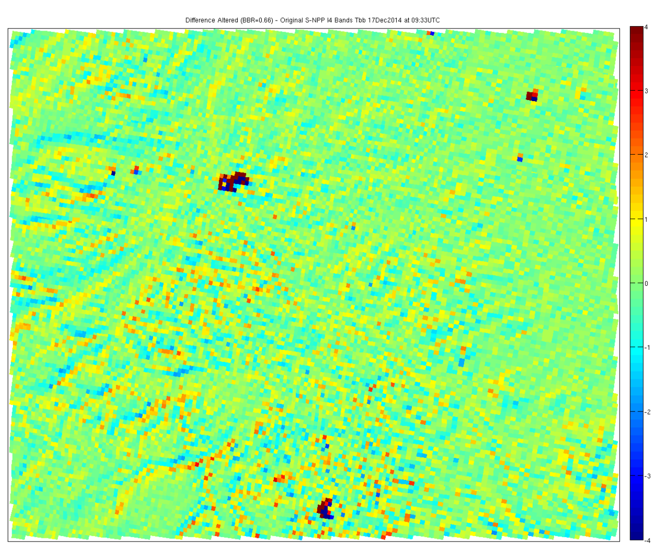


Figure 86. Altered minus Original I4 (3.7 µm) band image difference showing brightness temperature differences on 17 Dec 2014 at 09:33 UTC. The two clusters of blue and red, one just northwest of the center of the image and one near the bottom-middle of the image, are fires showing relatively large (-11K to +30K) differences after the co-registration error was simulated.

Publications and Conference Reports

Posters presented at the AMS 95th Annual Meeting (4-8 January, 2015, Phoenix, AZ).

- "Impact Analysis of LEO Hyperspectral Sensor IFOV size on the next generation NWP model forecast performance" by Agnes Lim, Jim Jung, Allen Huang, Zhenglong Li, Jason Otkin, and Mitch Goldberg.
- "GRAFIIR and JAFIIR – Efficient End-to-End Semi Automated GEO and LEO Sensor Performance Analysis and Verification Systems" by Mathew Gunshor, Hong Zhang, Eva Schiffer, and Allen Huang.

22. 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, Elisabeth Weisz, Nadia Smith, Nick Bearson, Jim Davies

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 is optimized for real-time processing and regional applications. The CSPP Suomi NPP/JPSS software has the following capabilities:

- Ingest CCSDS packet files from VIIRS, CrIS, ATMS and NPP spacecraft diary;
- Create SDR and EDR products for VIIRS, CrIS, and ATMS using the current operational versions of the IDPS PRO algorithms and lookup tables;
- Produce all 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;
- 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.

Summary of Accomplishments and Findings

As of April 2015, 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.

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 supports the distribution of a number of third-party software packages developed by 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.

April 9, 2015 (CSPP Advanced Clear-Sky Processor for Oceans (ACSPO) Software Version 1.0)
First release of the of the NOAA/NESDIS/STAR ACSPO software that retrieves sea surface temperatures from input S-NPP VIIRS, NOAA-15, 16, 17, 18 and 19 and Metop-A and B AVHRR, and Aqua and Terra MODIS imagers.

April 3, 2015 (CSPP International ATOVS Processing Package (IAPP) Software Version 1.0)
First release of the of the IAPP software that retrieves vertical profiles of temperature, moisture and other parameters from input NOAA-15, 16, 18 and 19 and Metop-A and B HIRS, AMSU-A and MHS Infrared and Microwave Sounders.

February 24, 2015 (CSPP NUCAPS CrIS/ATMS EDR Retrieval Software Version 1.0)
First 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.

February 2, 2015 (CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software Version 2.1)
New version of the calibration and geolocation Sensor Data Record (SDR) software for the Visible Infrared Imaging Radiometer Suite (VIIRS), Advanced Technology Microwave Sounder (ATMS), and the Cross-track Infrared Sounder (CrIS) instruments that includes an update to the ADL 4.2.6 (IDPS Mx8.6) code base.

October 20, 2014 (CSPP Suomi NPP Patch for SDR Version 2.0)
CSPP SDR Patch for CSPP V2.0 SDR software which allows processing of CrIS and VIIRS SDRs after the JPSS downlink of CrIS Full Spectral Resolution (FSR) begins. The increased direct broadcast data volume required to include CrIS FSR, results in VIIRS M-Band 7 and CrIS Field of View (FOV) 4 being excluded from the downlink. The Patch, labeled CSPP SDR V2.0.1, is required in order to process VIIRS SDRs and CrIS SDRs once this direct broadcast switch has been made.

September 3, 2014 (CSPP VIIRS SDR GeoTIFF and AWIPS Reprojection Software Version 1.2)
Update to the software that creates reprojected GeoTIFFS and/or AWIPS NetCDF-3 files from Visible Infrared Imaging Radiometer Suite (VIIRS) Sensor Data Record (SDR) HDF5 files. This update includes a simplified one step VIIRS corrected reflectance to true color imagery implementation.

August 4, 2014 (CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software Version 2.0)
New version of the calibration and geolocation Sensor Data Record (SDR) software for the Visible Infrared Imaging Radiometer Suite (VIIRS), Advanced Technology Microwave Sounder (ATMS), and the Cross-track Infrared Sounder (CrIS) instruments that includes an update to the IDPS Mx8.4 code base, a new dynamic ancillary data and Look-Up-Table distribution site, and the addition of Terrain Corrected arrays within the VIIRS Day/Night Band geolocation files (GDNBO*.h5). This software is designed to work with the CSPP VIIRS EDR version 2.0 release.

August 4, 2014 (CSPP Suomi NPP VIIRS EDR Software Version 2.0)
Update to the VIIRS Environmental Data Record (EDR) software suite that includes an update to the IDPS Mx8.4 code base, and new products including the Land Surface Temperature. This software is designed to work with the CSPP VIIRS SDR V2.0 release.

August 4, 2014 (CSPP Suomi NPP Imagery EDR Software Version 2.0)
Update to the software package that supports the creation of Visible Infrared Imaging Radiometer Suite (VIIRS) instrument Imagery Environmental Data Record (EDR) HDF5 products in Ground Track Mercator (GTM) Projection that includes an upgrade to the IDPS Mx8.4 code base. This software is designed to work with the CSPP VIIRS SDR V2.0 release.

May 16, 2014 (CSPP CLAVRx VIIRS, MODIS and AVHRR Cloud Retrieval Software Version 1.0)
First release of the NOAA Clouds from AVHRR Extended (CLAVR-x) Retrieval Software Package in support of Suomi NPP VIIRS, Aqua and Terra MODIS and NOAA-18, NOAA-19, Metop-A and Metop-B AVHRR imagers. CLAVRx retrieval software produces a suite of cloud products at single field-of-view resolution; it is NOAA's operational cloud processing system for the AVHRR, and it's cloud algorithms are scheduled to migrate to the operational processing system for NOAA JPSS.

April 29, 2014 (CSPP CrIS, AIRS and IASI Dual Regression Retrieval Software Version 1.3)
New version of the multi-instrument hyperspectral retrieval software package that uses Suomi NPP CrIS, Aqua AIRS or Metop IASI radiances as inputs and produces vertical profiles of temperature, moisture, ozone as well as cloud and surface properties at single field-of-view resolution. This software package update includes improvements in distinguishing clear sky from low cloud.

The new CSPP software releases during the reporting period included several of the JPSS official algorithms for SNPP, including CLAVR-x, NUCAPS, and ACSPO. These algorithms and the resulting products are intended to replace the corresponding products created by IDPS. Examples of these new products are shown in Figure 87, Figure 88, Figure 89, Figure 90. The NOAA Level 2 product algorithms now included in CSPP also have the advantage of being capable of processing data from multiple sensors on different satellites, i.e.,:

- CLAVR-x: VIIRS, AVHRR, MODIS
- ACSPS: VIIRS, AVHRR, MODIS
- NUCAPS: CrIS/ATMS (current), IASI/AMSU (future), AIRS/AMSU (future).

The MIRS microwave retrieval algorithm released in 2013 as part of CSPP is also multi-sensor capable, supporting ATMS on Suomi NPP and AMSU/MHS on the Metop and NOAA satellites.

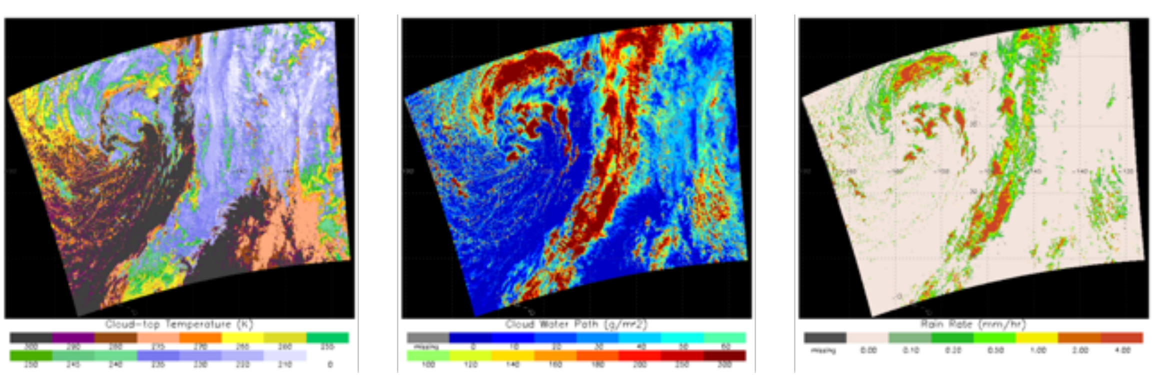


Figure 87. CSPP CLAVR-x cloud products from SNPP 2013/03/10 23:00 UTC.

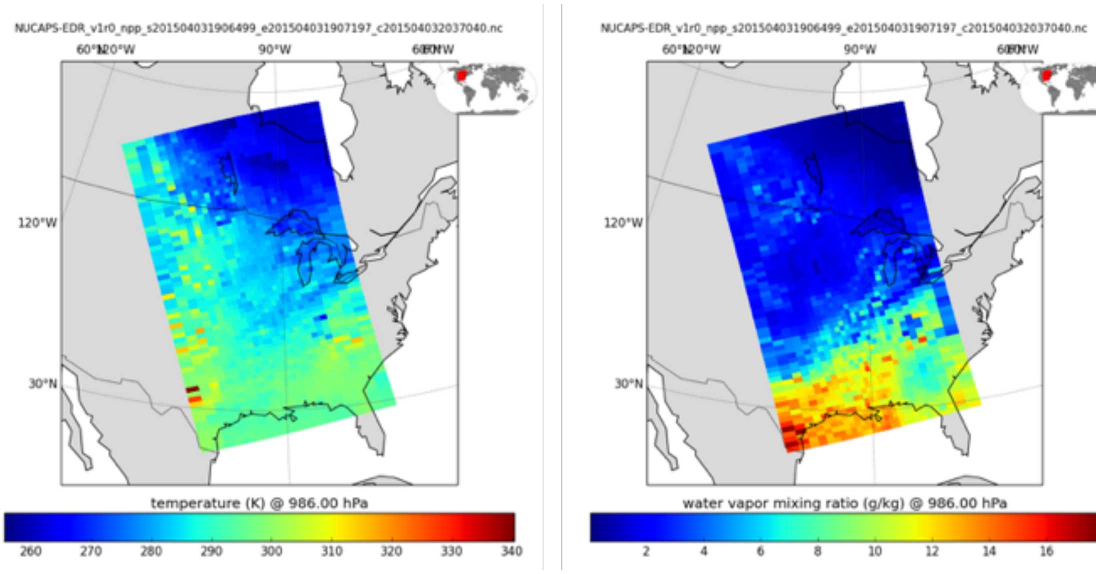


Figure 88. NUCAPS temperature and moisture products from CrIS/ATMS on 2015/04/03.

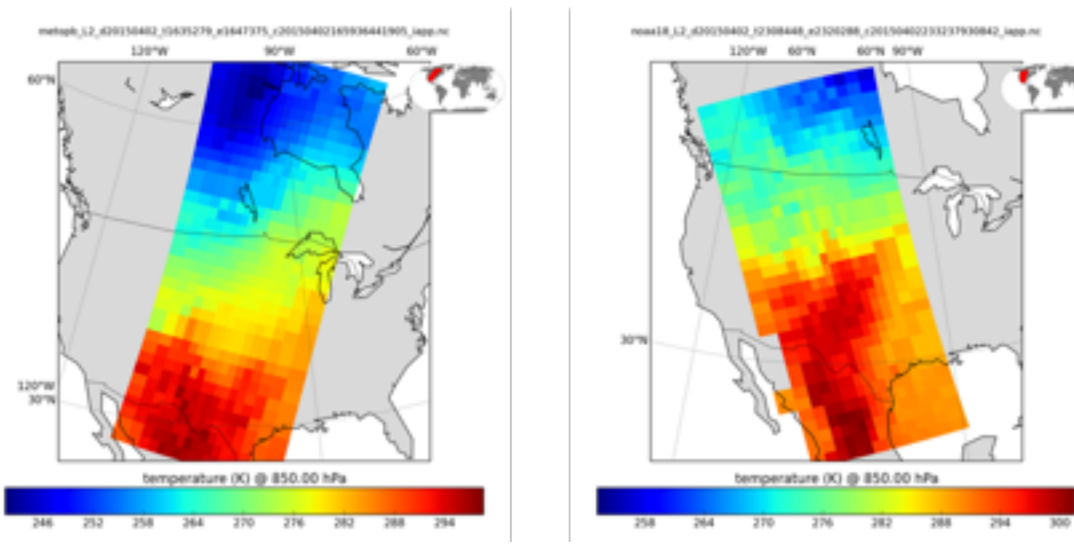


Figure 89. IAPP temperature retrievals from Metop and NOAA-18 ATOVS on 2015/04/02.

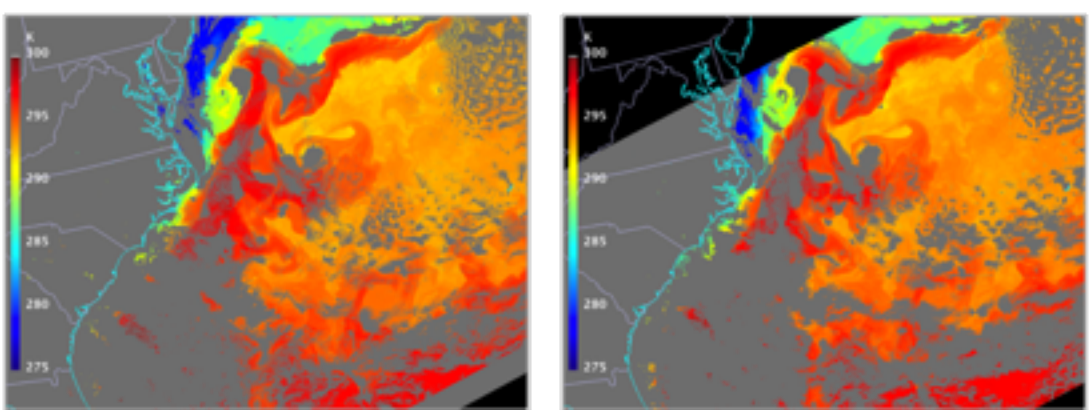


Figure 90. ACSPO sea surface temperature retrievals from VIIRS (left) and AVHRR (right) on 2015/04/02.

The CSPP software ecosystem now supports 7 different satellites, including Suomi NPP, Metop-A and B, NOAA-18 and 19, Aqua, and Terra. Some relevant statistics for CSPP are shown below:

- Satellites supported: 7
- Software packages: 10
- Sensors supported: 25
- Releases and updates: 29
- Registered users: 913
- Individual downloads: > 5000

The following table shows the sensors supported by the current suite of CSPP software packages.

CSPP Software	Suomi NPP	Metop-A/B	NOAA-18/19	Terra	Aqua
1. SDR	VIIRS, CrIS, ATMS	Provided by AAPP	Provided by AAPP	Provided by SeaDAS	Provided by SeaDAS
2. VIIRS EDR	VIIRS	N/A	N/A	N/A	N/A
3. HSRTV	CrIS	IASI	N/A	N/A	AIRS
4. Polar2Grid	VIIRS, CrIS, IASI	Future version	Future version	MODIS	MODIS, AIRS
5. Hydra	VIIRS, CrIS, ATMS	AVHRR, IASI	AVHRR	MODIS	MODIS, AIRS
6. MIRS	ATMS	AMSU, MHS	AMSU, MHS	N/A	N/A
7. CLAVR-x	VIIRS	AVHRR	AVHRR	MODIS	MODIS
8. NUCAPS	CrIS, ATMS	Future version	N/A	N/A	Future version
9. IAPP	N/A	HIRS, AMSU, MHS	HIRS, AMSU, MHS	N/A	N/A
10. ACSPO	VIIRS	AVHRR	AVHRR	MODIS	MODIS

The CSPP team supported the transition of SNPP CrIS to full spectral resolution (FSR) in December 2014 by ensuring the CSPP SDR software continued to function normally without any interruption. A patch was supplied to CSPP users in advance of the FSR transition to accommodate the loss of VIIRS M7 and CrIS FOV 4 in the HRD downlink. The CSPP SDR software automatically reconstructs VIIRS M7 from the I2 data during daytime; and CrIS FOV 4 is set to missing values.

The CSPP team tested the prototype software for calibration at full spectral resolution that was developed at NOAA/NESDIS/STAR by the CrIS SDR team. The software has been running operationally at CIMSS/SSEC on DB data since January 2015. The CSPP team has created an alpha release package for DB users who support NWP centers so that they can test the FSR processing and data formats. Release of the CSPP version of CrIS full spectral SDR is expected by end of 2015, and the current version will still be available to users (reduced resolution SDR product).

23. 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 continues to support the JPSS project as a member of the Algorithm Development Library (ADL) Team. SSEC will support the ADL project by:

- Acting as the release point for ADL to the JPSS user community;
- Maintaining the ADL Website and User Forum;
- Providing user support for installing and operating ADL;
- Providing training material and courses for end users of ADL;
- Developing and enhancing the Virtual Appliance distribution of ADL;
- Developing an ingest and pre-processing capability for dynamic ancillary data in ADL;
- Verify compatibility with RDRs from Direct Broadcast sources.
- Check compatibility of Direct Broadcast produced SDRs with the corresponding IDPS SDRs
- Verify robustness of ADL distributions before public release.

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

Summary of Accomplishments and Findings

ADL Support

SSEC provided support to the JPSS community for ADL 4.2 during 2014. The JPSS MX builds associated with this release included 5.8.03 (Mar 2014), 5.8.04 (Jul 2014), and 5.8.05 (Sep 2014). Each of these MX releases initiated several activities at SSEC. These activities included:

- Staging of ADL release DVD contents, including generation of checksums,
- 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.

The current ADL virtual appliance is based on ADL 4.2 and MX 5.8.05. The ADL VA allows end users who may not have access to a configurable Linux system (e.g., users in the NOAA security zone) a way to get started with ADL using a Windows host computer. The ADL Virtual Appliance functions identically to a native Linux install of ADL, and provides all the functionality of the ADL build and run environment. The ADL VA is used both as a reference and development platform by the community. Each release of ADL is followed by a release of the VA.

The SSEC team developed a simplified website for ADL distribution and end-user support in 2014, which may be found at https://jpss.ssec.wisc.edu/ (Figure 91). 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 92). 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 support and develop 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
- LUTs needed for SDR processing

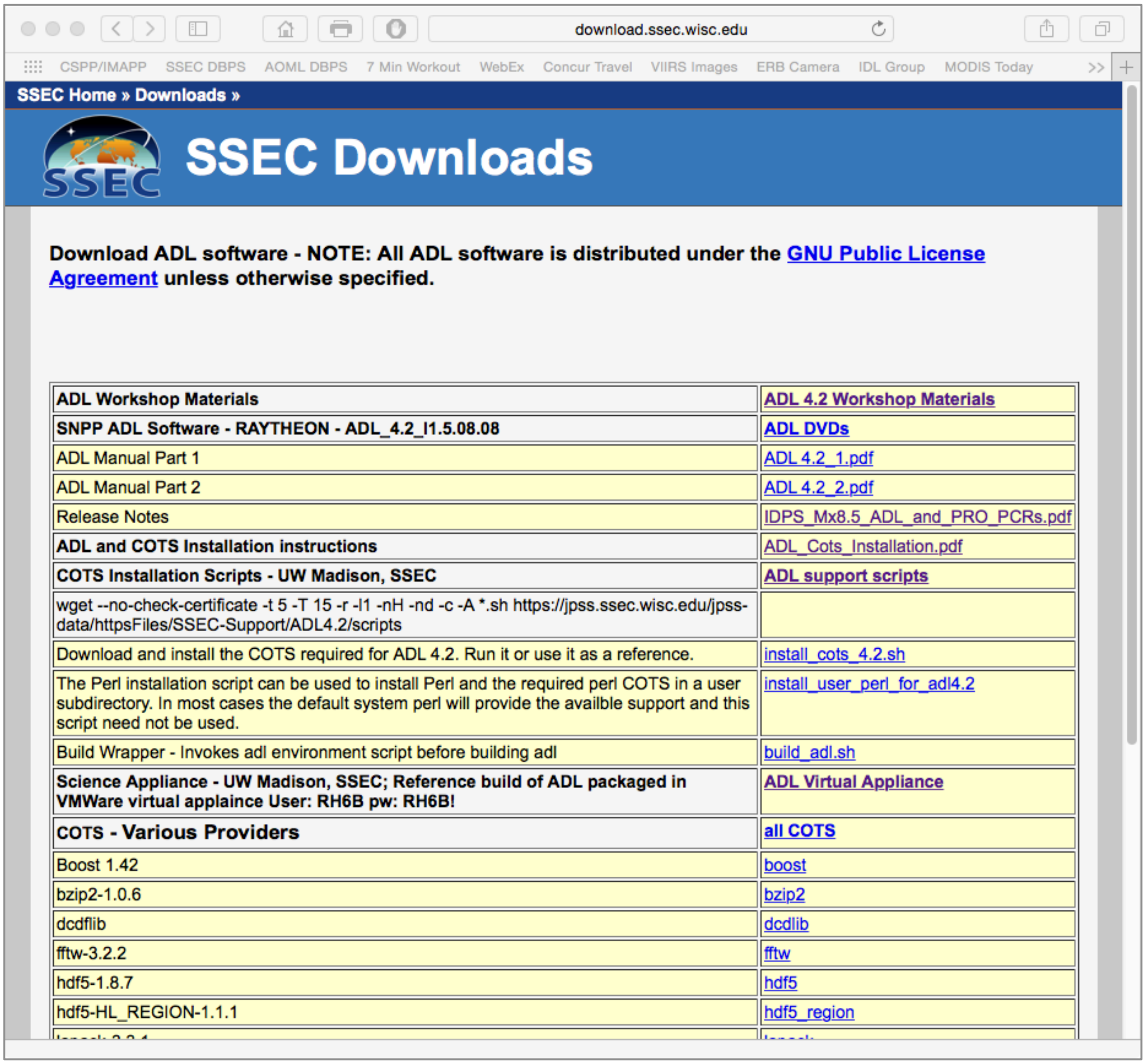
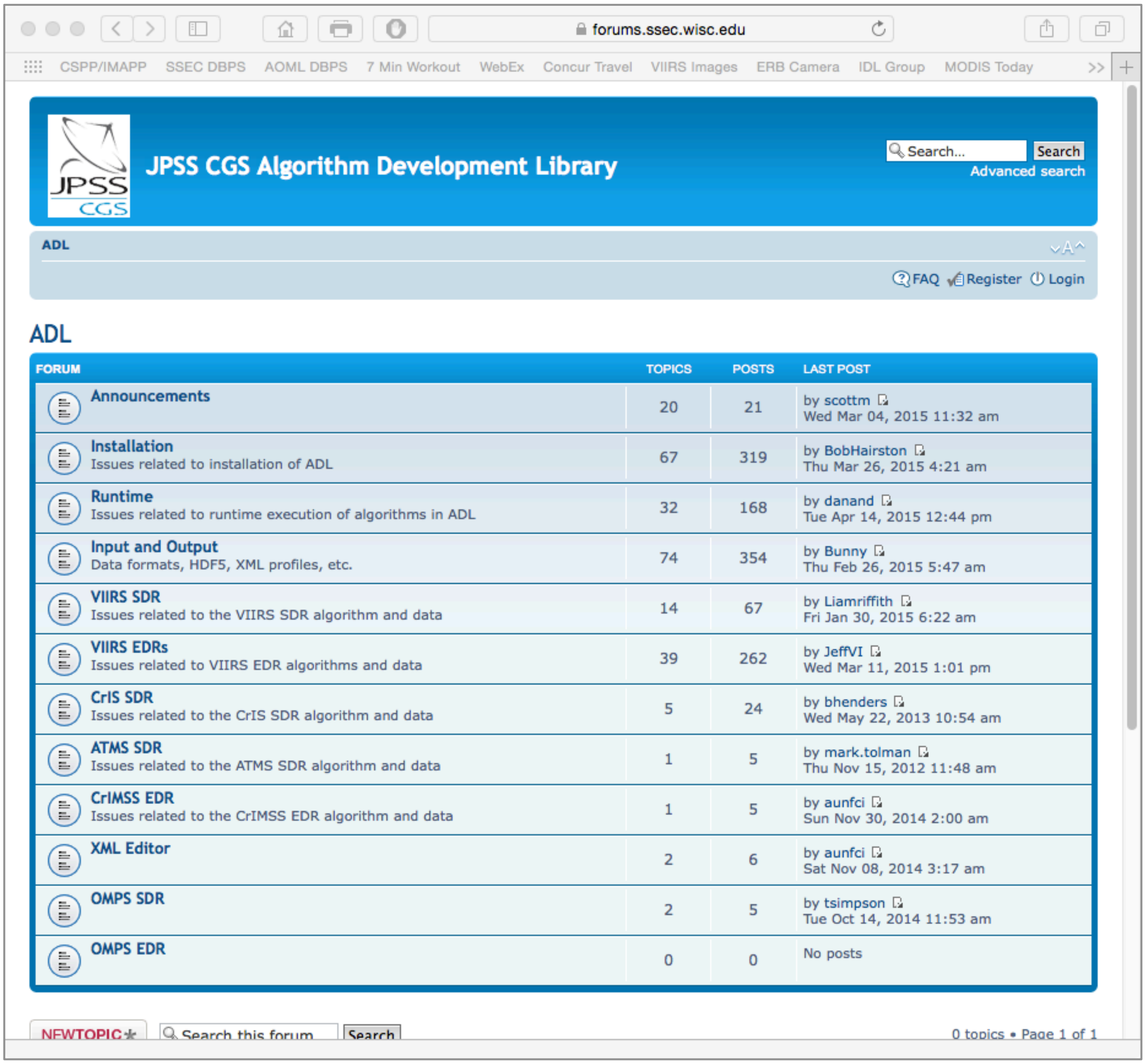


Figure 91. SSEC ADL Website showing ADL installation instructions.



FORUM	TOPICS	POSTS	LAST POST
Announcements	20	21	by scottm Wed Mar 04, 2015 11:32 am
Installation Issues related to installation of ADL	67	319	by BobHairston Thu Mar 26, 2015 4:21 am
Runtime Issues related to runtime execution of algorithms in ADL	32	168	by danand Tue Apr 14, 2015 12:44 pm
Input and Output Data formats, HDF5, XML profiles, etc.	74	354	by Bunny Thu Feb 26, 2015 5:47 am
VIIRS SDR Issues related to the VIIRS SDR algorithm and data	14	67	by Liamriffith Fri Jan 30, 2015 6:22 am
VIIRS EDRs Issues related to VIIRS EDR algorithms and data	39	262	by JeffVI Wed Mar 11, 2015 1:01 pm
CrIS SDR Issues related to the CrIS SDR algorithm and data	5	24	by bhenders Wed May 22, 2013 10:54 am
ATMS SDR Issues related to the ATMS SDR algorithm and data	1	5	by mark.tolman Thu Nov 15, 2012 11:48 am
CrIMSS EDR Issues related to the CrIMSS EDR algorithm and data	1	5	by aunfci Sun Nov 30, 2014 2:00 am
XML Editor	2	6	by aunfci Sat Nov 08, 2014 3:17 am
OMPS SDR	2	5	by tsimpson Tue Oct 14, 2014 11:53 am
OMPS EDR	0	0	No posts

Figure 92. SSEC Forum Website for ADL.

24. Science and Management Support for NPP VIIRS Snow and Ice EDRs

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).

Summary of Accomplishments and Findings

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.

The relationship between the error in VIIRS Ice Surface Temperature (IST) EDR and both satellite and solar zenith angles was investigated through comparisons to surface temperatures measured by the KT-19 instrument on NASA IceBridge flights over the Arctic and Antarctic in 2012-2013. Figure 93 illustrates that the dependence of the difference between VIIRS and KT-19 IST on satellite zenith angle is weak, except for two groups of outliers (under investigation) at satellite angles of about 40 and 55 degrees. The root-mean-square difference between the VIIRS and KT-19 ISTs is 0.86K for satellite zenith angles less than 40 degrees, and somewhat larger for satellite angles greater than 40 degrees. The uncertainty requirement is 1.0K. The figure also demonstrates that there is no obvious dependence on solar zenith angle, except for the two groups of outliers. This is not surprising because the algorithm uses thermal channels only.

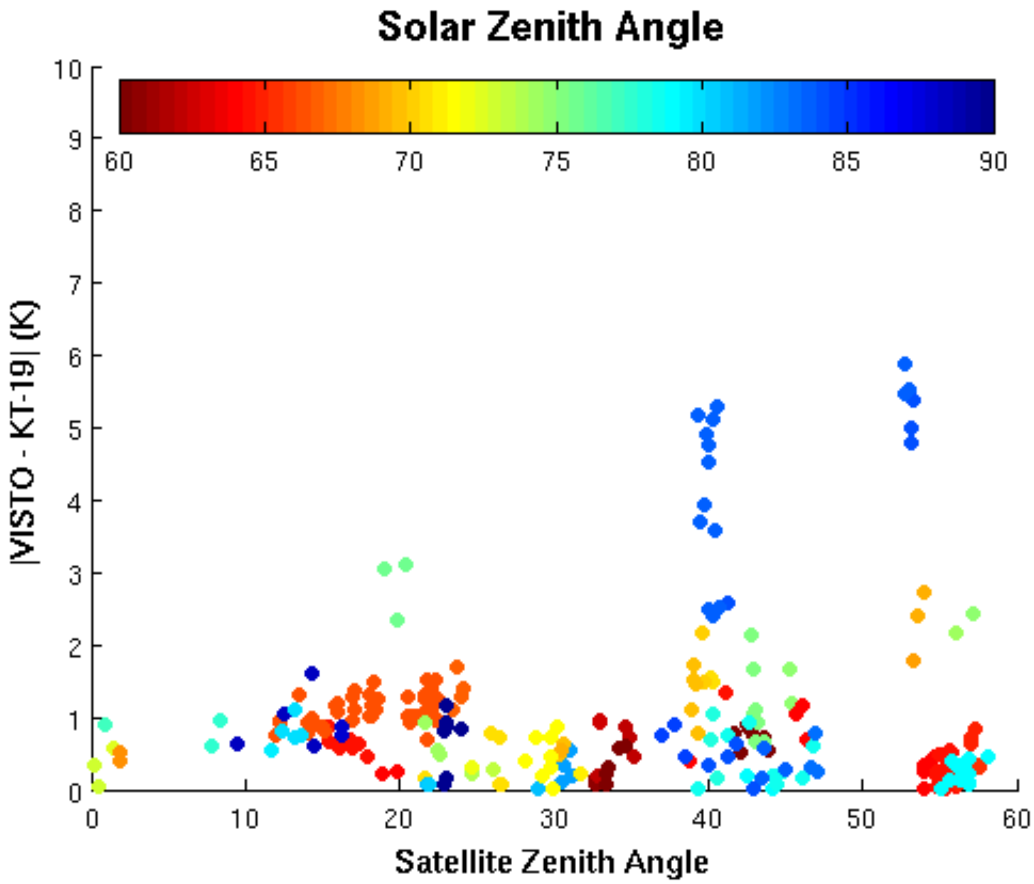


Figure 93. The difference between VIIRS Ice Surface Temperature and the KT-19 IceBridge surface temperature as a function of satellite and solar zenith angles. Data are from IceBridge flights over the Arctic and Antarctic in 2012-2013.

Validation of VIIRS and passive microwave-derived sea ice concentration is now being done by using high-resolution Landsat data. Figure 94 shows the comparison between VIIRS and Landsat ice concentrations in 1km spatial resolution for different ice concentration bins. It also shows the bias and root-mean-square difference as a function of the VIIRS ice concentration. Biases and uncertainties (precision) are relatively small for all bins. The overall bias is 0.74% with precision 12.2%.

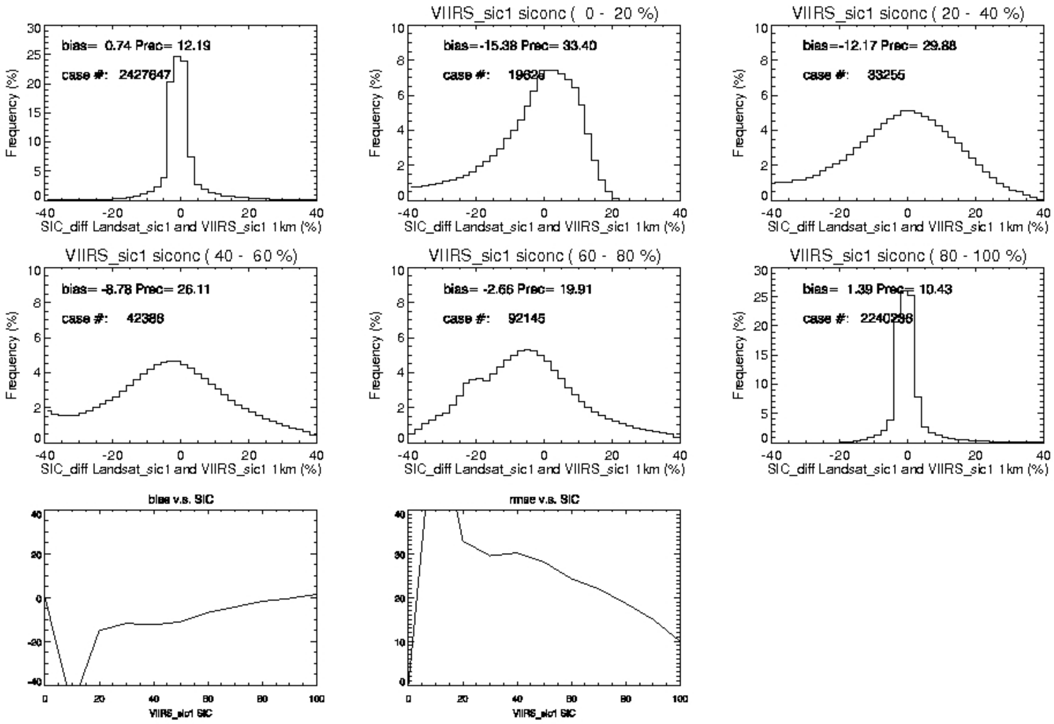


Figure 94. Comparison of VIIRS and Landsat ice concentrations in 1km resolution for different concentration ranges/bins. Also shown are the differences overall (upper left) and the bias and root-mean-square (RMS) difference as a function of VIIRS ice concentration (bottom row).

In collaboration with our colleagues at the University of Colorado-Boulder, an examination of multi-granule composites of the Sea Ice Characterization EDR were created in order to examine the evolution of ice "age" (new/young versus other ice) through freeze-up into mid-winter. Figure 95 shows the SIC composites for October 27, November 18, December 19, 2013, and January 10, 2014. The progression is reasonable, with much less ice in October than in January three months later, and the evolution of thinner ice ("new/young") to thicker ("other") ice as winter progresses. However, the appearance of additional new/young ice in January is likely a problem with the algorithm. It is under investigation.

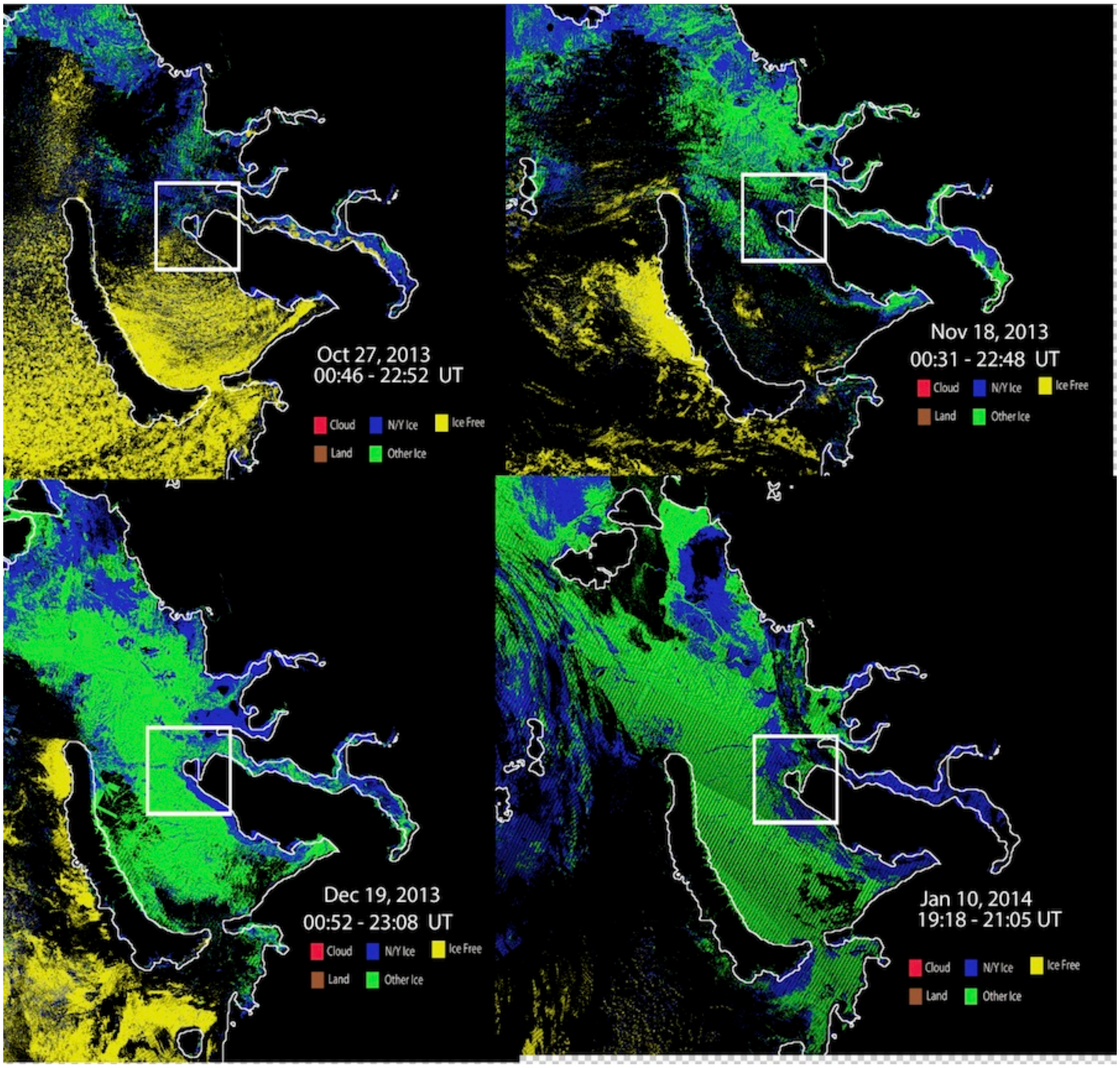


Figure 95. Sea Ice Characterization EDR multi-granule composites for December 19, 2013, and January 10, 2014.

25. CIMSS Visiting Scientist on Tropical Cyclone Monitoring and Predicting with Satellite Sounder 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

- 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 primary goal of CIMSS tropical cyclone (TC) monitoring and prediction project is to improve microwave (MW) satellite data assimilation for TC forecast by taking advantages of collocated high spatial resolution imager cloud products. The AMSU-A/Aqua measurements are collocated with 1-km resolution cloud products from MODIS/Aqua to enhance the accuracy of cloud detection, and the cloud-screened AMSU-A radiances are assimilated into WRF/GSI system for Hurricane Sandy (2012) forecast. Experiments are carried out to determine the thresholds of MODIS cloud fraction (CF) and cloud top height (CTH) for distinguishing the cloud affected and unaffected AMSU-A radiance measurements. The methodology used in this study can be applicable to the advanced MW sounders and high spatial resolution imagers such as ATMS/VIIRS onboard NPP in JPSS series, for the improved TC track and intensity forecasts.

Summary of Accomplishments and Findings

AMSU-A radiances are assimilated into a forecast model through the GSI assimilation system, a unified variational data assimilation system which was initially developed at NCEP as a next generation analysis system. In this study, the thinning box for AMSU-A is 60 km. The thinning box, background error covariance matrix and observation error table are followed by North American Mesoscale Forecast System (NAM), the NCEP operational regional system. The initial bias coefficients are from NCEP GFS. With the cycling run, the bias correction coefficient is updated based on the previous results. WRF version 3.2.1 was employed as the NWP model to provide TC track and intensity forecasts. A forecast domain was set up with 400 x 350 horizontal points at 12 km grid distance and 35 vertical levels from surface to 10 hPa pressure height. The horizontal domain covers an area of 5ºN – 50ºN and 40ºW – 100ºW on the Lambert Conformal Conic projection. An assimilation system was designed to be run at 6-hour cycles with 90 minutes of time window followed by 72 hr forecast. The model is performed with 8 assimilation cycles from 0600 UTC Oct 25, 2012 to 0000 UTC Oct 27, 2012, and the forecast period is from 0600 UTC Oct 25, 2012 to 0000 UTC Oct 30, 2012. In addition to the AMSU-A radiances, data from WMO GTS is assimilated into the system which includes all the conventional data. The initial condition of the first forecast and boundary conditions come from the NCEP Final Operational Global Analysis data.

The collocation between AMSU-A and MODIS CF and CTH is constructed using the viewing geometry of AIRS. The MODIS pixels are collocated with AIRS FOV using the methodology developed by Nagle (1998), and then we can collocate an AMSU-A radiance with the MODIS cloud products by simply matching an AMSU-A FOV with the MODIS pixels mapped inside the corresponding 9 AIRS FOVs. Using the collocated AMSU-A radiance observations and MODIS cloud products, experiments are carried out with various MODIS CF and CTH thresholds in addition to the default cloud screening algorithm in current GSI system, and optimal CF and CTH thresholds were determined by considering RMSEs of the hurricane track and minimum sea level pressure (SLP) errors. The reference HT and SLP are obtained from NHC best track dataset.

Based on the RMSE analysis for various CF thresholds, an optimal threshold, CF < 70% (MOD_CF70), was determined. The track and SLP errors of the MOD_CF70 are compared with those of the AMSU-A stand-alone cloud detection (AMSU-A_GSI) in Figure 96. For the hurricane track, it is evident that the RMSE is reduced for most of the forecast times when the cloud-contaminated radiances are rejected with the collocated MODIS CM. The SLP errors of MOD_CF70 are smaller than those of AMSU-A_GSI as well, although a slight degradation occurs at forecast time of 18 hr. For a validation of the generated forecasts, mean bias and RMSE of the temperature and relative humidity (RH) profiles are calculated against radiosondes, and the statistics at 72-hr forecast time are given in Figure 97. For the temperature analysis, differences between the MOD_CF70 and AMSU-A_GSI are less than 0.1 K for both of the mean bias and RMSE, which are almost negligible. However, the water vapor RMSE of the MOD_CF70 is smaller than that of the AMSU-A_GSI for the pressure levels from 500 to 900 hPa indicating the improvement in forecast RH fields of the middle and lower troposphere.

Going through the same process finding the CF threshold, a CTH threshold of 4 km is chosen for the AMSU-A/MODIS cloud detection, and an experiment using the CHT threshold (MOD_CTH4) is carried out. The forecast track and SLP RMSEs against to the best track are plotted in Figure 96. On the whole, the track error of MOD_CTH4 is obviously smaller than that of the AMSU-A_GSI showing an overall reduction in track forecast error, and comparable to the MOD_CF70 RMSE. For the SLP, RMSE of MOD_CTH4 is slightly reduced than that of the AMSU-A_GSI or comparable on average, however, it is larger than the RMSE of the MOD_CF70 after 24 hr of forecast time. The temperature and RH profiles of forecast fields are compared with the radiosonde data in Figure 97. The RH bias and RMSE of the MOD_CTH4 bear resemblance to those of the MOD_CF70. Comparing with the AMSU-A_GSI, RH RMSE is reduced from 450 to 900 hPa as in the case of the MOD_CF70. For the temperature statistics, mean bias and RMSE of the MOD_CTH4 becomes slightly smaller than the AMSU-A_GSI between 200 and 350 hPa.

The overall reduction of the track and SLP errors due to the use of the collocated MODIS cloud products indicates that the sub-pixel cloud detection with high resolution instruments have a capability to improve the TC track and intensity forecast. This method can be applied to process ATMS/VIIRS onboard NOAA JPSS, AMSU-A/AVHRR onboard EUMETSAT Metop-A/-B and MWTS/MERSI onboard CMA FY-3, especially for near real time assimilation of MW sounder radiances from direct broad (DB) sites.

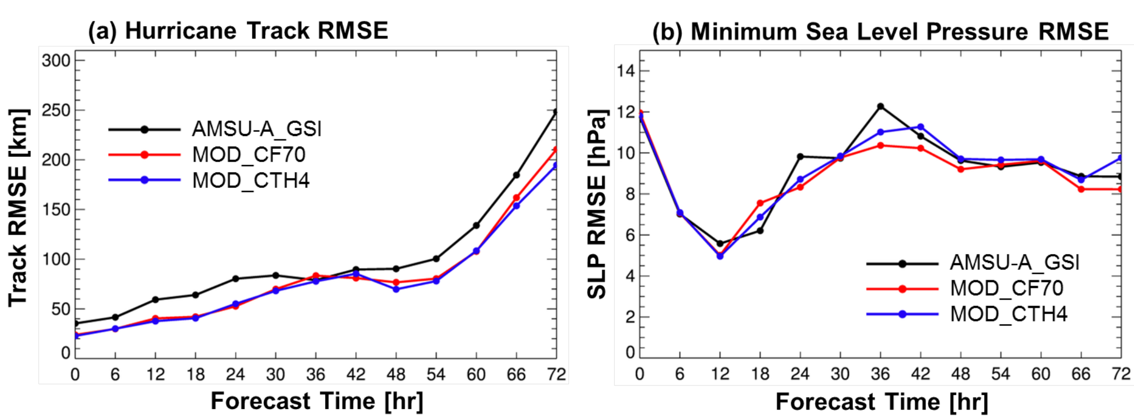


Figure 96. (a) The hurricane track and (b) minimum sea level pressure RMSE for AMSU-A_GSI (black line), MOD_CF70 (red line), and MOD_CTH4 (blue line).

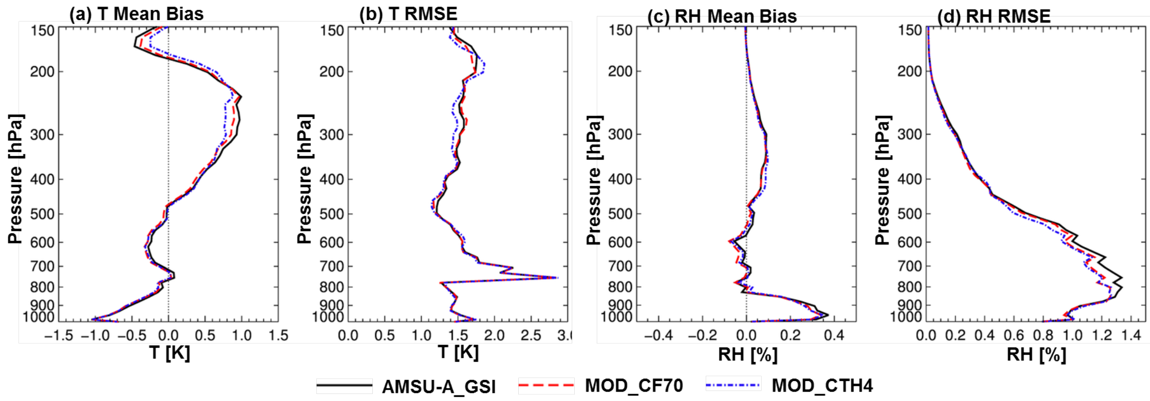


Figure 97. Biases (a and c) and RMSE (b and d) of temperature (a and b) and RH (c and d) profiles for 72-hr forecasts. The statistics are calculated against the radiosondes for AMSU-A_GSI (black solid line), MOD_CF70 (red dashed line), and MOD_CTH4 (blue dashed and dotted line).

Publications and Conference Reports

Han, Hyojin, J. Li, M. Goldberg, P. Wang, J. Li, and Z. Li, 2014: Improving assimilation of microwave radiances in cloudy situations with collocated high resolution imager cloud mask, 2014 AGU Fall Meeting, 15-19 December 2014, San Francisco, CA, USA.

Han, Hyojin, J. Li, M. Goldberg, P. Wang, J. Li, and Z. Li, 2015: Improving assimilation of AMSU radiances in cloudy situations with collocated MODIS cloud mask, 2015 Annual Meeting, 4-8 January 2015, Phoenix, AZ, USA.

26. 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 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.

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. They are being modified, as necessary, to adapt them to AMSR2 and to improve their accuracy. The snow cover detection algorithm is based on a brightness temperature-based decision tree approach (Grody, 1991; Grody and Basist, 1996) with additional climatology tests as enhancements. The snow depth algorithm is based on a dynamic empirical approach (Kelly, 2009) blended with a routine for dry/wet snow differentiation.

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 98 shows the accuracy of the snow detection algorithm applied to AMSR-E and AMSR2 data when compared to the Interactive Multisensor Snow and Ice Mapping System (IMS) as the reference. The overall accuracy for dry snow is generally above 80%. Based on this result, the product will meet the system requirements. Figure 99 gives a qualitative comparison of snow depth with the Kelly (2009) algorithm and the corresponding snow water equivalent. These two variables 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 two products are similar.

During the next project year we will further refine the snow detection, snow depth methodologies and snow water equivalent algorithm.

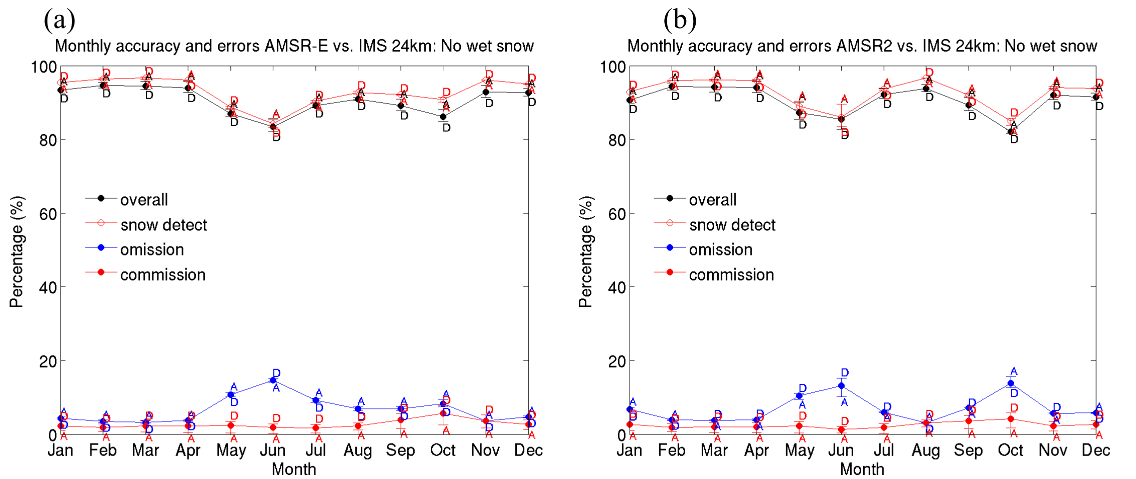


Figure 98. Snow detection/false alarm rate of (a) AMSR-E and (b) AMSR2 with Grody's algorithm for dry snow compared to IMS snowcover for every 5 day (13-17) of each month between June 2002 and September 2011 for AMSR-E and between August 2012 and July 2013 for AMSR2. The bars above and below each point indicate descending ("D") and ascending ("A") orbits.

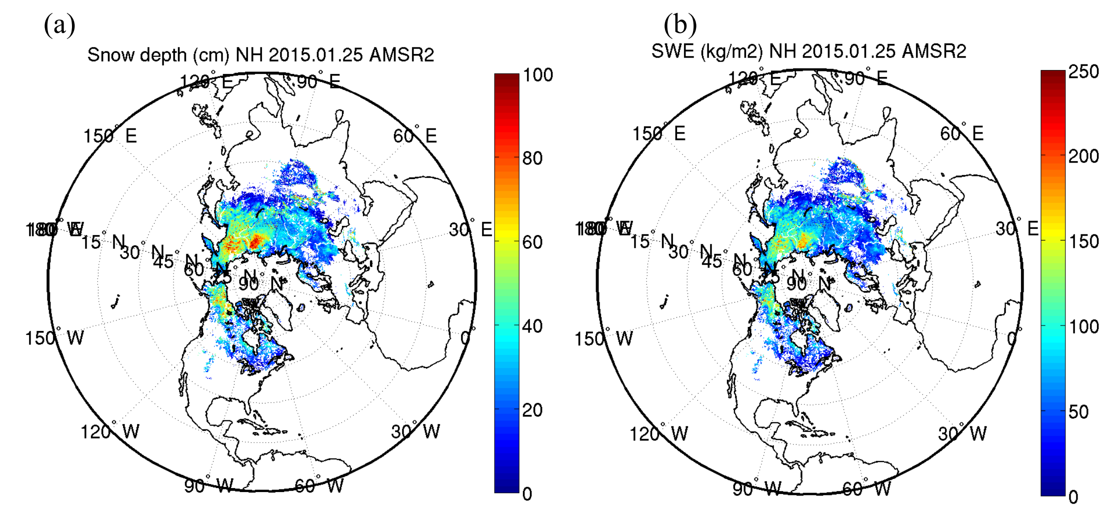


Figure 99. (a) Snow depth from AMSR2 (Kelly's algorithm) and (b) snow water equivalent product on 25 January 2015. The two products show similar spatial patterns and variability.

Publications and Conference Reports

Lee, Y.-K., C. Kongoli, and J. R. Key, 2014, "Snow cover detection and snow depth algorithms for the Global Change Observation Mission (GCOM) AMSR2 measurement", 2014 Fall meeting, AGU, 15-19, Dec. San Francisco, CA.

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.

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27. CIMSS Participation in VIIRS Cloud Products Using DNB the JPSS Risk Reduction Program for 2014

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 use moonlight visible reflectance measured by the VIIRS Day/Night band channel to improve cloud property and cloud mask retrievals during nighttime. The new algorithms will be developed as a part of an existing cloud retrieval system (CLAVR-x).

Drawing from the OLS lineage is the VIIRS "Day/Night Band" (DNB), a sensor capable of measuring extremely low levels visible-band light down to the levels of moonlight reflectance (e.g., on the order of $mW\ m^{-2}\ sr^{-1} \mu m^{-1}$, several orders of magnitude fainter than conventional daytime visible light measurements) with notable improvements to its predecessor in terms of calibration, radiometric and spatial resolution.

One component of the current AWG cloud retrieval scheme at CIMSS is the daytime cloud optical and microphysical properties (DCOMP) algorithm, which generates estimates of cloud optical thickness, cloud effective radius and ice/water path during daylight conditions [Walther and Heidinger, 2012]. 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 technical basis document (ATBD; Walther et al., 2011). 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.

This project involves a feasibility study if DCOMP is extendable to nighttime products by moonlight reflectance measurements. We will add a nighttime component to DCOMP by help of a lunar spectral irradiance model developed by Miller and Turner (2009).

Summary of Accomplishments and Findings

Efforts in this reported period mainly focused on further development work of the new cloud optical properties retrieval for nighttime observations by use of lunar reflection (NLCOMP) and derived atmospheric products, such as rain rate.

We defined a new NLCOMP software release 1.1 and implemented it in CLAVR-x. We have been working on further improvements in the code. For this purpose we incorporated a city light map in CLAVR-x, which flags pixels with a extreme high radiance over land.

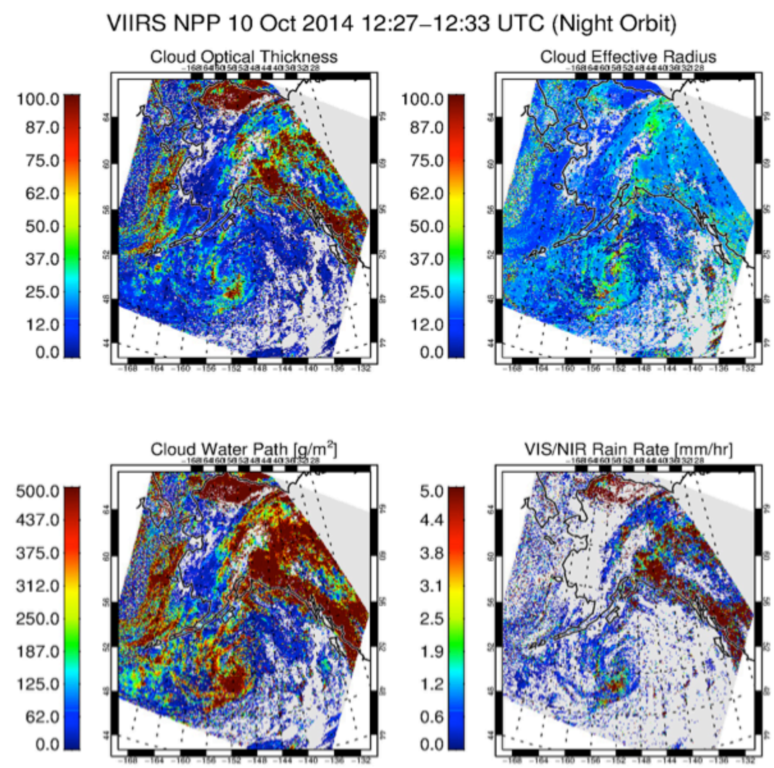

Figure 100. Filling the Arctic winter gap of observations: Left panel shows NLCOMP results from COD to rain rate, which is based on cloud water path and effective radius. Right panel shows corresponding microwave-based rain rate, which is more physically-based, but have a much lower spatial resolution (750m vs. 35 km).

Publications and Conference Reports

Walther, A.: Presentation at AMS Phoenix, AZ, January 2015: "Nighttime Cloud Microphysical Products from DNB/VIIRS"

28. Support CIMSS JPSS and AWIPS II OCONUS Satellite Liaison

CIMSS Task Leader: Jordan Gerth

NOAA Collaborator: Bill Ward and Eric Lau, National Weather Service Pacific Region Headquarters, 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
- Education and Outreach

Project Overview

The scientist funded under this project focuses on:

- conducting scientific investigations and serving as the coordinator for demonstrating JPSS-related science products in National Weather Service (NWS) Pacific Region and Alaska Region operations,
- integrating GOES-R and JPSS imagery and science products into the Advanced Weather Interactive Processing System (AWIPS) II, and
- acting as a technical coordinator and AWIPS II developer for Geostationary Operational Environmental Satellite R-Series (GOES-R) and Joint Polar Satellite System (JPSS) proving ground partners.

Summary of Accomplishments and Findings

The OCONUS satellite scientist serves three primary functions beyond his capacity as a satellite meteorologist and remote sensing scientist for NWS forecast offices in the states of Alaska and Hawaii, and the territories of Guam, American Samoa, and Puerto Rico. First, the scientist is a software developer and technical consultant, focusing on AWIPS, and the NWS technical infrastructure, including networking, data flow, and antenna systems, to assure satellite imagery and products are making it to the field and meeting the needs of operational meteorologists. Second, the scientist is a coordinator of satellite proving ground and related activities, including the visiting scientist program in NWS Pacific Region, which introduces new capabilities to the field. Third, the scientist is a liaison for meteorologists and office management to assist in the development and delivery of training and addressing specific questions about the capabilities of current and future meteorological satellites, particularly GOES-R and JPSS.

Major accomplishments between 1 April 2014 and 31 March 2015 are summarized here. During this period, the scientist:

- established a visiting scientist program and a process for new products to be introduced in Honolulu forecast office operations, with Bill Ward and Eric Lau,
- shadowed forecasters at the Honolulu forecast office to better understand their operations, and value of satellite imagery and products to their forecast process,
- assisted Carl Dierking and Eric Stevens in Alaska with proving ground activities at NWS forecast offices in Anchorage and Fairbanks,

- delivered several enhancements to the AWIPS II baseline code, including:
  - additional true color capabilities for satellite and gridded data,
  - code to add satellite source and configurability to satellite legends,
  - code to capture frames with date and time in the filename,
  - code to make warning polygon outline settable in bundle file, and
  - code to ingest Lambert Conformal projections with two standard parallels using the "regionalsat" decoder,
- added new National Polar-orbiting Partnership (NPP) imagery and products to AWIPS II in NWS Pacific Region, including:
  - Visible Infrared Imaging Radiometer Suite (VIIRS) Environmental Data Records (EDRs), such as
    - I1, I2, I3, I4, I5, M1, M4, M9, M14, M15, M16, and Day Night Band (DNB),
  - Microwave Integrated Retrieval System (MIRS) rain rate, and
  - Advanced Technology Microwave Sounder (ATMS) 90 GHz band,
- envisioned the concept of operations-focused fact sheets for individual bands of the Advanced Baseline Imager (ABI), with Bill Ward,
- developed content for the ABI band fact sheets, with Tim Schmit; the plan is to produce approximately one band fact sheet per month,
- organized and executed the OCONUS satellite meeting in Honolulu, Hawaii, in July 2015; the meeting was hosted at the Inouye Regional Center on Ford Island; time was also spent at the NWS Honolulu forecast office,
- drafted the JPSS proving ground initiative for AWIPS and OCONUS,
- provided support to the Honolulu forecast office during the approach of Hurricane Iselle, and conducted several live television interviews,
- helped to reestablish the GOES-West rapid scan operations sectors for Hawaii and Alaska; the Hawaii sector was implemented immediately before the approach of Hurricane Ana in October 2014; a new sector will be established for American Samoa,
- conducted research into frontal passages impacting Hawaii using VIIRS imagery, with Eric Lau; a poster was presented at the National Weather Association (NWA) annual meeting in Salt Lake City in October 2014,
- assisted with planning for L/X-band antennas in Puerto Rico and Guam,
- maintained the L/X-band antenna at Honolulu Community College and assured that imagery and products from the antenna system were available to the NWS Pacific Region and Honolulu forecast office,
- developed top-level guidance for the NWS Operational Advisory Team (NOAT) on scan mode selection for GOES-R,
- developed a new vision with Bill Ward and Carven Scott for how to improve the GOES-R cloud layers and heights products based on operational requirements,
- facilitated the correction of a wintertime GOES-15 navigation issue that impacted the quality of imagery over Hawaii, with staff from the National Environmental Satellite, Data, and Information Service (NESDIS),
- completed the Distance Learning Operations Course (DLOC), including one week of residency in Norman, Oklahoma, in January 2015, and
- supported the JPSS river ice and flooding initiative, with Dave Santek, increasing the use of VIIRS imagery and products in certain the NWS River Forecast Centers (RFCs).

The scientist attended the following meetings during the award period:

- Satellite User Readiness Meeting (Kansas City, Missouri)
- GOES-R/JPSS OCONUS R2O Interchange Meeting (Honolulu, Hawaii)

- National Weather Association Annual Meeting (Salt Lake City, Utah)
- American Meteorological Society Severe Local Storms Meeting (Madison, Wisconsin)
- American Meteorological Society Annual Meeting (Phoenix, Arizona)
- NOAA Satellite Science Week (Boulder, Colorado)

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

Publications and Conference Reports

Future Geostationary Weather Satellites
Talk, National Weather Association Annual Meeting—General Session B3 (Salt Lake City, Utah)
October 21, 2014

Subtropical and Tropical Frontal Passages: A Hawaii Perspective *with Eric Lau*
Poster, National Weather Association Annual Meeting (Salt Lake City, Utah)

Preparing for GOES-R with Himawari-8 *with Bill Ward*
Talk, American Meteorological Society Annual Meeting—11th Annual Symposium on New Generation Operational Environmental Satellite Systems (Phoenix, Arizona)https://ams.confex.com/ams/95Annual/webprogram/Paper259337.html
January 7, 2015

R2-Whoa: Challenges and solutions for executing best practices in transferring NOAA's research to NWS operations
Poster, American Meteorological Society Annual Meeting (Phoenix, Arizona)
Poster, NOAA Satellite Science Week (Boulder, Colorado)

29. JPSS Ground Project Field Terminal Node Support 2014

CIMSS Task Leader: Liam Gumley
CIMSS Support Scientists: Scott Mindock, Ray Garcia, Graeme Martin
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 proposes to support 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.

Summary of Accomplishments and Findings

Task 1: Algorithm and software package development

CIMSS/SSEC provided ADL-based software to the DB community for creating the following products from SNPP:

1. VIIRS, CrIS, and ATMS Sensor Data Records (SDRs),
2. VIIRS Imagery EDR at 0.64µm (I1), 3.74µm (I4), 11.45µm (I5), 8.55 µm (M14), 10.763 µm (M15), and 12.03 µm (M16) for latitudes greater than 60N.

CSPP SDR

The VIIRS, CrIS, and ATMS SDR software was released as part of CSPP on 4 August 2014, with updates following on October 20, 2014, and February 2, 2015. This software package supports the calibration and geolocation of the Visible Infrared Imaging Radiometer Suite (VIIRS), Advanced Technology Microwave Sounder (ATMS), and the Cross-track Infrared Sounder (CrIS) instruments. 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 NPP SDR products is HDF5, and descriptions of the NPP file formats are available here (see the Common Data Format Control Books). The August 2014 release included the following new features:

- SDR software has been updated to NOAA Operational IDPS version Mx8.4 (ADL 4.2.4),
- New dynamic ancillary and Look-Up-Table distribution websites are used,
- VIIRS Day/Night Band geolocation files (GDNBO*.h5) now include Terrain Corrected datasets (i.e., Height_TC, Latitude_TC, Longitude_TC),
- Added trim option to instrument SDR scripts that allows users to remove N number of leading or trailing granules of a pass,
- A set of release notes with more detailed information on general and specific instrument updates and changes is provided in the SDR_2_0/RELEASE_NOTES.txt document.

The CSPP SDR software patch released on October 20, 2014 included support for the transition to CrIS full spectral resolution. As a result of the increased downlink data rate, VIIRS M-Band 7 and CrIS Field-of-View (FOV) number 4 are no longer be included in the direct broadcast. The CSPP SDR V2.0.1 software patch for CSPP SDR V2.0 is prepared to handle these changes, using the following approach:

CrIS SDR: The CrIS version 2.0.1 SDR software includes a truncation algorithm to handle the FSR data that will be included in the Suomi NPP downlink. When the switch to FSR data occurs, the software will ingest the full resolution data and truncate it, thus creating output files of the same size and format as the current SDRs. The only exception to this is that there will be no observations for FOV 4, which will contain fill values. The truncation will continue until the full spectrum CrIS SDR software is available and has been validated.

VIIRS SDR: When S-NPP begins downlink of CrIS FSR data, the extra required bandwidth will come at the expense of the downlink of M-Band 7 (.865 micron). If the CSPP v2.0.1 software detects that the SVM07*.h5 data set contains all fill values, and the SVI02*.h5 data contains valid reflectances, the SVM07 radiance and reflectance values will be reconstructed using those I-Band 2 (SVI02) .865 micron observations. The reconstructed file will contain data values that are close but not identical to what the downlinked values would be. The algorithm used by CSPP SDR 2.0.1 for duplication is very simple; it adds together the appropriate higher spatial resolution SVI02 data pixels and then divides by 4 to create the SVM07 replacement pixel. If any of the 4 SVI02 data values that go into producing one SVM07 pixels is missing, the value is stored in the SVM07 file as missing. Since the M-Band 7 is a dual gain channel, differences in the reconstructed array may be most noticeable in dark (small radiance/reflectance) scenes. Downstream products which include the use of M-Band 7 reflectances will be affected by this as well, including the VIIRS cloud mask product.

The CSPP SDR software was updated on February 2, 2015. This version of the software updates the science algorithms to ADL 4.2.6 (IDPS Mx8.6). In VIIRS SDR products created by previous versions of the CSPP SDR software, dual-gain bands (SVM01, SVM02, SVM03, SVM04, SVM05, SVM07, SVM13) would sometimes contain non-physical values in regions where data was missed during a DB pass. This caused problems such as the VIIRS Active Fire algorithm to detect spurious fire locations. In this version of the VIIRS SDR software, the missing values and quality flags for these regions are set correctly, and the VIIRS Active Fire algorithm should not detect spurious fires. The software also included the following features:

- Added logic for reconstructed M-Band 7 quality flags using input from I-Band 2
- Added parallelization option for aggregation. Using the -p (num_procs) option with the -a option will now result in parallelization of SDR software execution and file aggregation,
- Quick look naming conventions have been standardized.
- A bug was corrected in the get_anc_jpss_polarwander.bash affecting some archived data processing.
- A bug was corrected that caused the SDR software to fail when using directories that included an "_c" in a path name.

VIIRS Imagery EDR

The VIIRS Imagery EDR software was released as part of CSPP on March 21, 2014. This CSPP software package for transforms Suomi NPP Visible Infrared Imaging Radiometer Suite (VIIRS) Science Data Record (SDR) intermediate files into reprojected Imagery Environmental Data Record (EDR) products on Intel Linux computers. The Imagery EDR products are remapped into a Mercator projection relative to the satellite (Ground Track Mercator (GTM) projection). This reprojection removes the bow-tie effect and also maintains constant horizontal resolution in the cross-track and along-track directions. VIIRS Science Data Record (SDR) Binary Large OBject (BLOB) and matching .asc files are required input to the CSPP Imagery EDR software. These are intermediate files created as part of the CSPP SDR processing. By default, these files are deleted upon successful CSPP SDR completion; users must execute the CSPP SDR software using the "-e" option (viirs_sdr.sh -e) in order for the intermediate files to be retained.

Output Imagery EDR products are:

- VIIRS I-Bands 1,2,3,4,5 radiances and reflectances or brightness temperatures,

- VIIRS M-Bands 1,4,9,14,15,16 radiances and reflectances or brightness temperatures,
- VIIRS Near Constant Contrast (NCC) albedo created from the VIIRS Day/Night Band,
- and matching Geolocation files.

System requirements are:
- Intel or AMD CPU with 64-bit instruction support,
- 16 GB RAM (minimum),
- CentOS 6 64-bit Linux (or other compatible 64-bit Linux distribution.

The HDF5 format output files created by this package were successfully tested for compatibility with AWIPS2. The Imagery EDR files are routinely created from DB data at SSEC and distributed to the National Weather Service.

Task 2: Development of an integrator portal and portal accessibility
CIMSS/SSEC attended in person the JPSS FTS System Requirements Review at GSFC on April 21, 2014, and via telecon the JPSS FTS Critical Design Review in September 2014.

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. As of April 2015, there were more than 900 registered users of CSPP, and more than 5000 individual downloads had been tracked via the website.

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.

Task 3: Quality assurance and quality control of data products
CIMSS/SSEC cooperated with EUMETSAT in their detailed assessment of the differences between CSPP and IDPS VIIRS SDR data for the EUMETSAT EARS-VIIRS readiness review. Earth view sensor data and geolocation were found by the EUMETSAT review team to be in "remarkably good agreement" for the test data examined. Several differences in metadata contents and formatting were noted during the review were resolved by either (a) expected differences in the processing environment for CSPP vs. IDPS, or (b) were fixed by the CSPP team. Similar reviews by EUMETSAT for the CrIS and ATMS products from CSPP also showed excellent agreement between the CSPP SDR products and corresponding IDPS products. The NASA Atmosphere PEATE at CIMSS/SSEC also examined the range of differences between CSPP and IDPS VIIRS SDRs, and found that for the same versions of the software and calibration LUTs, the CSPP VIIRS SDRs agreed to the level expected by compiler and platform differences (much smaller than the sensor noise).

Task 4: Field terminal user support
CIMSS/SSEC provided prompt support to CSPP users throughout the reporting period, successfully resolving various installation and operational issues at sites including EUMETSAT, Meteo France, SMHI, DWD, FNMOC, NRL, Chapman University, Geoscience Australia, and University of Alaska.

30. 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

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 GOES-derived Atmospheric Motion Vectors (AMVs) in collaboration with the AMV development and applications team at CIMSS. This interest stems in part from recent experimental results showing positive impact of assimilating high spatial/temporal resolution GOES AMVs for tropical cyclone (TC) simulations using 1) WRF/DART (Wu et al., 2014), and 2) HEDAS/HWRF (Aksoy et al., 2014). 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.

In this 2-year effort, we plan to prepare high-resolution AMV datasets for selected TC cases and test the assimilation methodologies in the NCEP operational hurricane prediction system (HWRF) by assessing the impact on TC intensity and track forecasts. The AMV datasets will be examined through a set of experiments using the latest available data assimilation system (hybrid, with rapid cycling) supporting the HWRF model. Testing and evaluation is being done in collaboration with EMC and HFIP guidance.

Summary of Accomplishments and Findings

The first experimental case selected was Hurricane Sandy (2012). Satellite-derived (GOES) AMV datasets were processed by CIMSS and NESDIS-STAR using the latest processing methodologies. The processing takes advantage of the highest frequency available multi-spectral imagery (i.e., rapid-scans) to produce high space and time (hourly) resolution datasets focused on the TC vortex and near environment (outer environment AMVs are also available).

Although the NCEP data assimilation system has the ability to process GOES hourly AMVs, the direct read-in ability for high-resolution GOES AMVs is currently being developed by EMC for the operational HWRF system. However, this new AMV assimilation capability uses the current data thinning and quality control procedures from NCEP's GSI, which are designed for the global data assimilation system. These are likely not optimal for the higher-resolution HWRF model initialization. Therefore, the CIMSS and HWRF DA teams are investigating new AMV quality control and thinning procedures.

HWRF experiments have been completed for the Hurricane Sandy case. The control configuration and other set-up details for these experiments were determined by NCEP-EMC (Vijay Tallapragada). The 'Benchmark' AMVs were generated at CIMSS. The experimental GOES-R algorithm-derived AMVs (Experiment-1) were produced by STAR and then ftp'd to CIMSS where the AMV impact experiments involving the HWRF/Gridpoint Statistical Interpolation (GSI) system were run.

Both the Benchmark and Experiment-1 AMV datasets were assimilated into the HWRF/GSI on the Jet computer for the Hurricane Sandy case. The system configuration employed is what is used operationally at NCEP, and all experiments have been coordinated with our NCEP/EMC partner Vijay Tallapragada. The only deviation from operational practice was to disable the GSI functions that thin and QC the AMV data. The period of evaluation covers the time GOES-14 was in SRSO mode during Sandy: roughly 4.5 days before landfall. The assimilation cycle was every 6 hours. The control run (CTL) used only radiosonde data and GFS analyses as background fields.

Results for the Sandy case have been compiled based on the HWRF track and intensity forecasts. The preliminary results of the forecast impact experiments assimilating the AMVs are encouraging: Both the Benchmark and Experiment-1 AMV forecast errors are lower than the CTL for both track (Figure 101) and intensity at almost all forecast times, and the results are comparable to the full data assimilation operational run. These results are particularly impressive given the already relatively low forecast errors from the CTL and H214 for Sandy.

Publications and Conference Reports

Lewis, W., and C. Velden, 2015: Direct Assimilation of Satellite-Derived AMVs into HWRF: First Results. *69th Interdepartmental Hurricane Conf*., Jacksonville, FL.

References

Aksoy, A., S. Aberson, K. Sellwood, B. Klotz, T. Vukicevic and C. Velden, 2014: HEDAS Vortex-Scale Data Assimilation with Aircraft and Satellite Retrieval Observations: Summary of the 2013 Atlantic Hurricane Season Results. *31st AMS Conf. Hurricanes*, San Diego, CA.

Wu, T.-C., H. Liu, S. Majumdar, C. Velden, and J. Anderson, 2014: Influence of Assimilating Satellite-Derived Atmospheric Motion Vector Observations on Numerical Analyses and Forecasts of Tropical Cyclone Track and Intensity. *Mon. Wea. Rev.*, 142, 49–71.

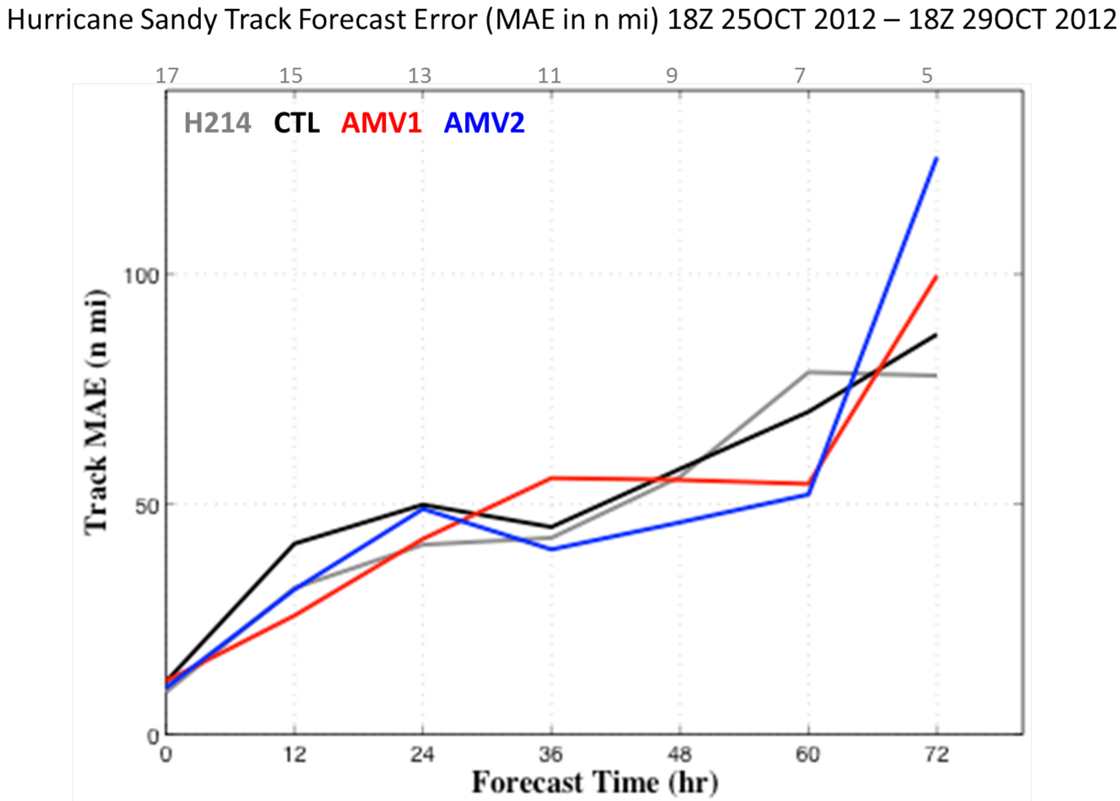

Figure 101. Results of track forecast impact experiments for Hurricane Sandy (2012), where MAE is the Mean Absolute Error. CTL is our experiment Control run with only radiosondes assimilated. H214 is the operational HWRF run with full complement of data including reconnaissance aircraft dropsondes and radar wind data (but no AMVs in core region). AMV1 is the CTL plus GOES AMVs assimilated, and represents the 'Benchmark' GOES AMV datasets processed with the heritage algorithm. AMV2 represents the GOES AMVs processed using the new GOES-R algorithm. The number of verifying forecasts for each forecast time is listed across the top of the graph.

31. Radiance and Retrieval Simulation for NSSL Regional OSSE

CIMSS Task Leader: Jun Li
CIMSS Support Scientist: Zhenglong Li
NOAA Collaborator: Steven Koch (NSSL), Timothy Schmit (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
- 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 allows the University of Wisconsin–Madison (UW–Madison) Cooperative Institute for Meteorological Satellite Studies (CIMSS) to support the Cooperative Institute for Mesoscale Meteorological Studies (NSSL/CIMMS) of University of Oklahoma (OU) on regional Observing System Simulation Experiments (R-OSSEs). CIMSS role includes simulating the advanced infrared (IR) sounder radiances along with sounding retrievals through inverse process from a high resolution nature run, for a typical case selected by CIMMS/OU.

Summary of Accomplishments and Findings

Synthetic geostationary (GEO) Atmospheric InfraRed Sounder (AIRS) radiances have been simulated from the nature run (NR) provided by NSSL. The NR was generated using the WRF-NMM model with a 4 km grid spacing and 61 vertical levels. The data is from 00Z of 6/11/2006 to 00Z of 6/18/20008. For 6/15 and 6/16, the NR is available every 5 minutes. Per NSSL request, CIMSS has processed the data from 6/16 and simulated synthetic GEO AIRS radiances for all time steps, using the University of Wisconsin's radiative transfer model (UWRTM) developed by the joint efforts between University of Wisconsin and Texas A&M University (Wei et al., 2004). Figure 102 shows one example of the simulated GEO AIRS brightness temperature image at 10.8 μm channel from 4 km nature run. Upon examining the imagery of 11 micron brightness temperature, it was found that there appeared to have discontinuity around synoptic times (06, 12 and 18 UTC). The finding was reported to NSSL along with the simulated radiance imagery. And NSSL confirmed the problem and later figured out a way to fix that without CIMSS reprocessing all the data.

A quick regression scheme was developed to retrieve temperature and moisture profiles from the simulated radiances in clear skies (Li et al., 2008; 2009). 5% of all available data were used as training to generate the regression coefficients, which were then applied to all data to generate atmospheric sounding retrievals. The retrievals were quality controlled to remove bad retrievals by comparing the calculated radiances from the regression retrieval with the synthetic radiances. Based on the retrieval results and evaluation, CIMSS has advised NSSL to assimilate sounding profiles away from surface and stratosphere, such as between 150 hPa and 8 levels above surface.

CIMSS has also generated the synthetic radiosonde observations (RAOBs) from the NR using the Eigen Vector technique. The advantage of this technique is that the vertical error correlation is considered in the simulation, making the synthetic RAOB more realistic. Both the retrieval and RAOB have been delivered to NSSL (Heather Reeves) for testing.

Future plan focuses on assisting NSSL in assimilating the sounding retrievals and RAOB. Upon feedbacks from NSSL, CIMSS may refine the retrieval algorithm and the RAOB simulation to better meet NSSL's requirement. Also, in order to increase the data volume of the sounding retrievals, CIMSS may extend from current clear skies only to part of the cloudy skies, such as thin clouds and low clouds. In those situations, the advanced IR sounders may provide accurate sounding profiles with similar quality as clear skies (Li et al., 2009).

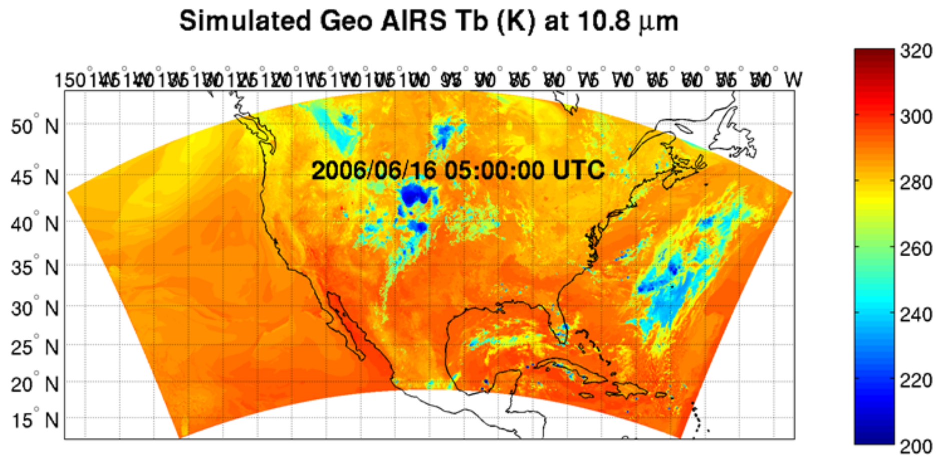

Figure 102. One example of the simulated GEO AIRS brightness temperature image at 10.8 µm channel from 4 km resolution NSSL nature run.

References

Li, Z., J. Li, W. P. Menzel, J. P. Nelson III, T. J. Schmit, Elisabeth Weisz, and S. A. Ackerman, 2009: Forecasting and nowcasting improvement in cloudy regions with high temporal GOES Sounder infrared radiance measurements, Journal of Geophysical Research. - Atmospheres, 114, D09216, doi:10.1029/2008JD010596.

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

CIMSS Task Leader: James Jung
NOAA Collaborator: Mitch Goldberg, 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

This project proposed to develop and evaluate advanced data assimilation techniques, including but not limited, to assimilate infrared and microwave water vapor channels in National Oceanic and Atmospheric Administration (NOAA) operational forecast models, with a goal to improve the model fields within the analysis (i.e., moisture), with a focus on Suomi National Polar-orbiting Partnership / Joint Polar Satellite System (SNPP/JPSS) sensors.

A second component of the project uses Observing System Experiments (OSEs) to quantify the contributions to the forecast made by SNPP/JPSS satellite data. The primary goal of these experiments is to identify the contribution of these data sources in the NOAA operational weather forecast models.

Other responsibilities of this project are to maintain credible Operations to Research (O2R) versions of the NOAA operational weather forecast models and help NESDIS/JCSDA scientists with data assimilation experiment design and coding standards.

Summary of Accomplishments and Findings

Water vapor experiments

Several water vapor channels in the current Cross-track Infrared Sounder (CrIS) subset derived for Numerical Weather Prediction (NWP) were found to be non-responsive. The cause of the problem was traced back to a section of the Gridpoint Statistical Interpolation (GSI) software which modifies the jacobians of these channels in the stratosphere. When this portion of the software is removed, all of the hyperspectral Infrared (IR) instruments (Atmospheric Infrared Sounder (AIRS), Infrared Atmospheric Sounding Interferometer (IASI) and CrIS) water vapor channels respond as expected. This section of the GSI software is under review and is being considered for removal in future upgrades. Current tests include the use of 25 AIRS, 25 IASI, and 30 CrIS water vapor channels.

Returning the water vapor jacobians to their original state revealed several more assimilation problems related to moisture in the stratosphere. It was discovered that the moisture values in the National Centers for Environmental Prediction (NCEP) Global Data Assimilation System/Global Forecast System (GDAS/GFS) stratosphere are too large and continue to increase with time. When the stratospheric moisture in the current GDAS/GFS is compared to the 10 year average derived from the Halogen Occultation Experiment (HALOE) (Grooβ and Russell, 2005), the current GDAS/GFS is too wet by more than a factor of 2. The stratospheric humidity has seasonal cycles, illustrated by Grooβ and Russell (2005), which are not present in the current GDAS/GFS. The root cause of this is that the GDAS/GFS does not use enough water vapor channels to adequately reduce the stratospheric moisture errors in the model.

The static component of the background error was decreased by two orders of magnitude in the top three layers of the model. The dynamic, or ensemble, component of the background error was reduced by about an order of magnitude for all layers above the tropopause. 25 water vapor channels from IASI and 30 water vapor channels were added from CrIS in these experiments. Examples of the stratospheric moisture in this water vapor channel assimilation experiment are shown in Figure 103. The results are consistent with the HALOE and seem to be much more stable. The hydropause is also well defined and closer to observed values.

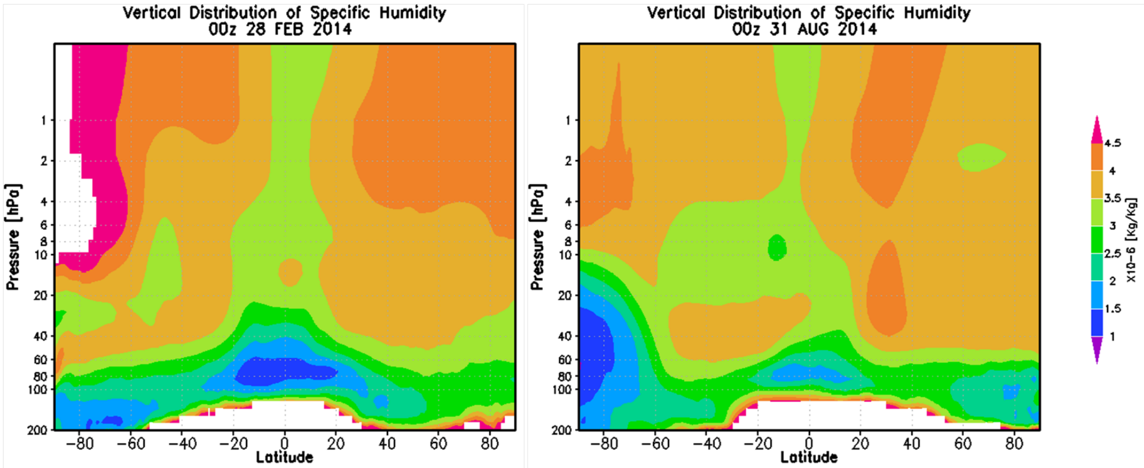

Figure 103. Longitudinal averaged latitude-height plots of stratospheric specific humidity. Left panel is 28 February 2014, right panel is 31 August 2014. HALOE averages are approximately 1-4X10-6 {Kg/Kg}. White regions are values greater than 5X10-6 [Kg/Kg].

In resolving the problems stated above, other problems have appeared. The latest concerns are a cold bias over the winter pole and excessive moisture in the model troposphere. The reason for both of these problems has been identified and solutions are being coordinated with NCEP. I continue to work on issues related to assimilating water vapor channels as time and resources permit.

Data addition experiments

NCEP's GDAS/GFS exploits information form a wide and diverse variety of observations. Information from these different observing systems tends to be complementary and, in some cases, redundant. This redundancy makes the GDAS/GFS very robust and minimizes the dependency of any specific observing system. Measuring the contribution of a specific observing system becomes difficult.

A different approach is taken in these experiments. The GDAS/GFS is initially run with a minimal amount of data or a baseline experiment, then a specific instrument is added to this baseline. The results are compared to a control experiment with all available data. The difference between the instrument addition and the baseline provides a better quantitative measure of the information an instrument provides to the GDAS/GFS.

These data addition experiments were designed to quantify the information the hyperspectral infrared (AIRS, IASI, CrIS) and microwave (Advanced Technology Microwave Sounder (ATMS), Advanced Microwave Sounding Unit (AMSU), Special Sensor Microwave Imager/Sounder (SSMIS)) instruments from the various polar orbiting satellite provide to the GFS. The baseline experiment contains the conventional data (rawinsondes, surface synoptic stations, aircraft, buoys, and the Global Positioning System (GPS) – Radio Occultation (GPS-RO)).

The results shown in Figure 104 are the anomaly correlation scores at 500 hPa for the Northern (top panels) and Southern (bottom panels) Hemisphere during August 2014. The infrared instruments (left panels) are generally mixed with each sensor having good and poor performance in the various sectors. In most cases the ATMS and AMSU (right panels) show similar improvements over the baseline experiment. The SSMIS generally shows the least improvements.

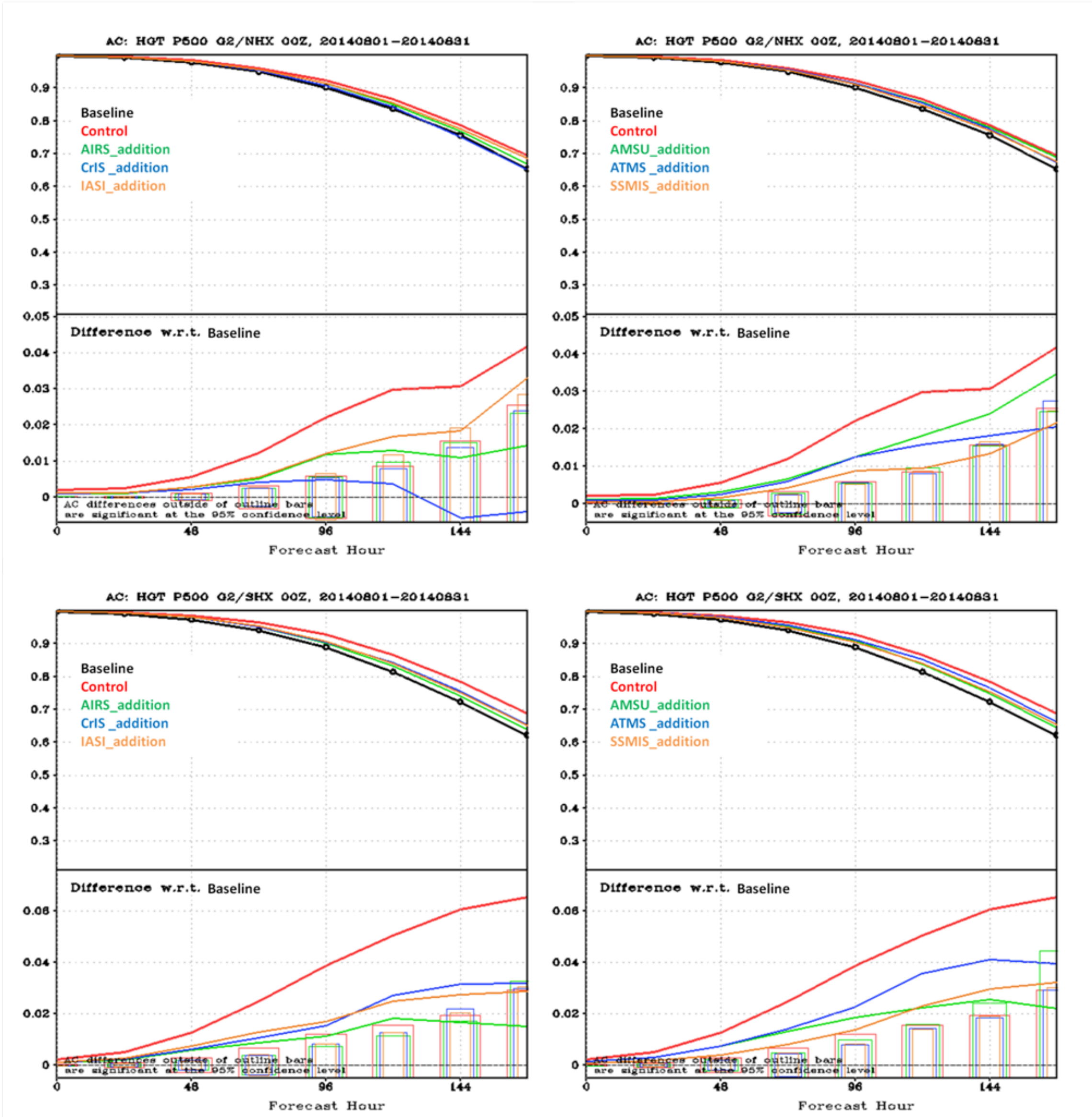

Figure 104. Anomaly Correlations at 500 hPa for the Northern (top) and Southern (bottom) hemispheres during August 2014. The baseline (black) and control (red) simulations bound the addition experiments. The various colors represent the data addition experiments for the infrared addition experiments in the left panels are AIRS (green), CrIS (dk. Blue), IASI (gold). The microwave addition experiments in the right panels are AMSU (green), ATMS (blue) and SSMIS (gold).

Publications and Conference Reports

Jung, J. A. and co-authors 2014: Implementation of Advanced Satellite Data Assimilation. JPSS Proving Ground Science Review. 29 April – 1 May 2014.

Jung, J. A. and co-authors 2014: Water Vapor Radiance Assimilation in the NCEP Global Data Assimilation System, 12th Annual JCSDA Review, 21-23 May 2014.

Le Marshall, J., J. Jung, J. Lee, C. Barnet, and E. Maddy, 2014: Improving Tropospheric and Stratospheric Moisture Analysis with Hyperspectral Infrared Radiances, Aust. Meteor. And Ocean Jnl., in press.

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Grooβ, J.-U., and J. M. Russell III, 2005: Technical note: A stratospheric climatology for O_3, H_2O, CH_4, NO_x HCL and HF derived from HALOE measurements. *Atmos. Chem. Phys*., **5**, 2797-2807.

33. 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.

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 105. 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.

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.

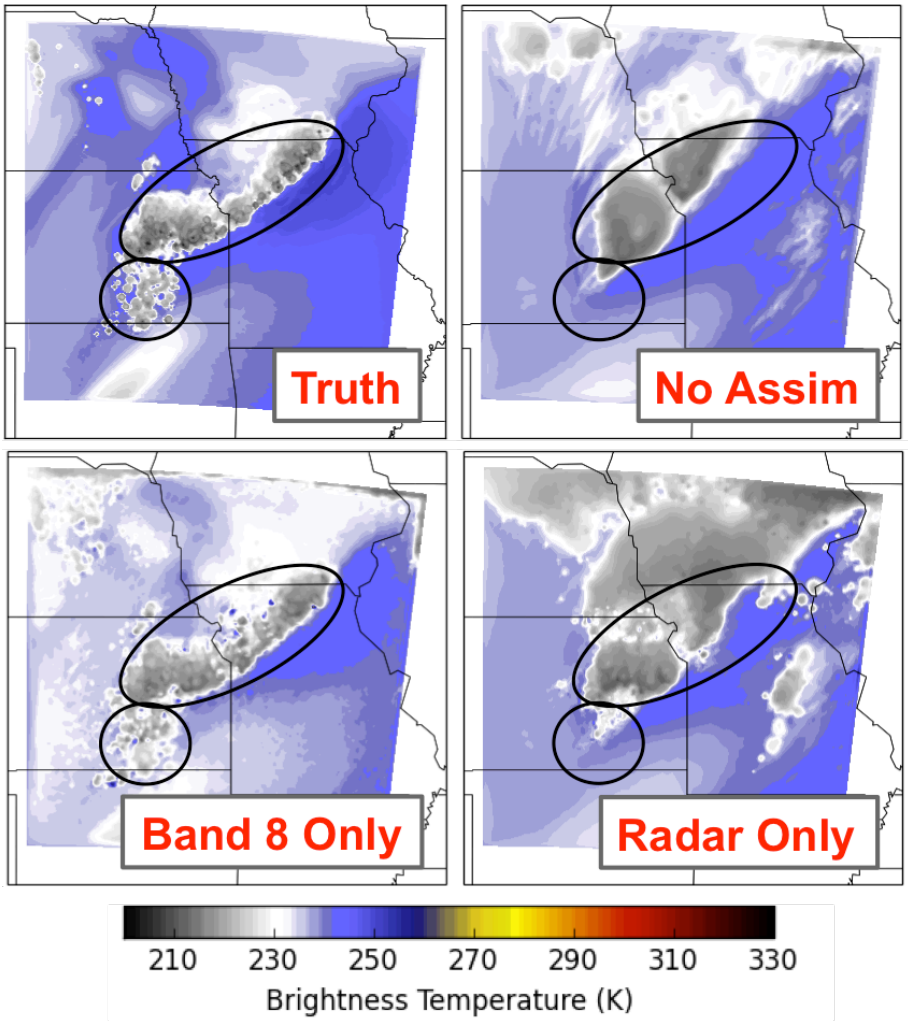

Figure 105. Simulated 6.19 µm brightness temperatures at the end of the 2-hr assimilation period from the (a) truth simulation, (b) control case without data assimilation, and from the (c) satellite-only and (d) radar-only assimilation cases.

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

CIMSS Task Leader: Mathew Gunshor
CIMSS Support Scientists: Jim Nelson, Tony Schreiner
NOAA Collaborator: Timothy J. 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 involves activities CIMSS conducted in support of NOAA/STAR calibration/validation (cal/val) activities. Specifically, this project supports GOES-R Calibration Working Group (CWG) activities with the GOES-R Advanced Baseline Imager (ABI). The primary objective to this project is to support the CWG's efforts with ABI L1b calibration to ensure data quality by leveraging operational experience with heritage instruments. CIMSS assists CWG in collaborating with the Japan Meteorological Agency (JMA) on the calibration and navigation of the Advanced Himawari Imager (AHI) as a GOES-R preparation activity. Also CIMSS studies Image Navigation and Registration (INR) on current GOES as a pathway to understanding future INR activities for the ABI. Any issues that are addressed by CIMSS with calibration or navigation on the current GOES series that affect radiance quality are communicated to the CWG. Knowledge gained from the current GOES will help preparation for GOES-R.

The Calibration Working Group (CWG) is frequently tasked with investigating issues that will affect calibration of ABI data. The CWG holds regular teleconferences (telecons) that are attended to enable CIMSS to get involved with these topics and to report on activities at CIMSS when appropriate. CIMSS supports the CWG's efforts with ABI L1b calibration, including investigations into JMA's AHI, which is nearly identical to the ABI.

Summary of Accomplishments and Findings

CIMSS has had a representative at most Calibration Working Group (CWG) monthly meetings (teleconferences). There have been various presentations from CIMSS at these meetings to show how CIMSS scientists address issues with current GOES. While the CWG is focused on GOES-R, there is overlap in personnel between current and future GOES calibration teams and projects. While the issues affecting current GOES may not be the same for future GOES, the methods and techniques developed now can either be applied later for GOES-R or can provide guidance on how to handle future situations.

One of the topics addressed by CIMSS was an issue of co-registration affecting the GOES-13 Imager. This was an ongoing issue from the previous year. Working with NOAA's Office of Satellite and Product Operations (OSPO), CIMSS provided analysis and feedback on co-registration solutions generated by the GOES instrument vendor and proposed and tested by OSPO. Slides were presented illustrating the process of how the issue was discovered (fictitious fog and clouds in river valleys and along other land/water boundaries) and highlighting the effect of the co-registration problem on products such as cloud top pressure and the cloud mask. Before implementing a possible Co-registration correction technique additional testing by the biomass burning group using GOES-13 Imager data revealed new insights. Rather than alter the 3.9 um band and alter (worsen) the ability to detect and characterize fires, it was decided to alter the other bands instead to reduce the co-registration errors. The original fix for the co-registration created an artificial "jump" in navigation twice a day and CIMSS worked with OSPO and others to see a fix implemented with a smoother transition. This issue was resolved, with a change to the operational processing, in February 2015.

GOES-15 Imager stray light was discovered and reported in October 2014. Figure 106 shows an example in the shortwave window band, but the stray light was evident even in the water vapor band. An advantage of the GOES-13, 14, and 15 series is that thanks to advanced technology from previous GOES satellites they are capable of operating during eclipse when the solar arrays do not receive enough direct sunlight to power the instruments. The disadvantage is that when the sun is on the opposite side of the earth from the satellite it frequently causes issues with stray light. There is software in the ground system to correct for stray light effects, but it did not catch this case. This is applicable to GOES-R because the plan is to operate GOES-R ABI through eclipse as well.

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

- Reviewed select DOE-0 file outputs for the AWG Imagery team. Reviewed parts of the various “RevC.1” PUG volumes, particularly focusing on the L2 version for the Cloud and Moisture Imagery Product (CMIP) files. Compared L2 DOE-0 file content to the PUG documentation. Reported to Randall Race with PUG comments and to Farida Adimi with DOE-0 comments.
- Able to read the DOE-0 L2 CONUS files into McIDAS-V and produce images. These were shared at the January 14, 2015 CWG meeting.
- The PFAAST (or PLOD) fast forward model which is used both operationally by current GOES and also in many research products has been updated with the latest version of the FM1 SRFs. Tested the 101-level version of this code distributed to the interested product teams. There is similar code for the AHI and the teams who need it also have access to that.
- JMA posted one time period of AHI data on their website and CIMSS generated images in McIDAS-V that highlighted the improved spatial resolution. These images were shown at the NOAA Satellite Science week.
    - These data are being used to test the McIDAS-X ADDE server which is still under development.
- Generated a weighting function plot of AHI and ABI IR bands to show their similarities. Though all IR bands are similar, they are not exact duplicates spectrally and will produce slightly different brightness temperatures based on atmosphere.
    - Provided a plot of AHI and ABI weighting functions for the US Standard Atmosphere to CWG colleagues (Figure 107).
- Analyzed AHI data 2km vs 1km (trying to determine if they average or sub-sample, but instead discovered a shift in nav at 2km). A powerpoint was sent to Fred Wu. (AIT)
- An ADDE test server was setup locally at SSEC for AHI data. We have tested this to help find bugs before a public release.
    - Imagery are available (AWG).
    - Radiance to Brightness Temperature checks out. (CWG)
- Since AHI radiances have different units (W/(m2 ster um)) than ABI radiances for IR bands (mW/(m2 ster cm-1)) , conversion factors were generated for each band.
    - A memo from Frank Padula and Changyong Cao from 2011 contained the methodology.
    - Equivalent Band Widths available upon request or at the CIMSS GOES calibration web page: http://cimss.ssec.wisc.edu/goes/calibration/
    - This exercise allowed us to support McIDAS activities to get AHI data on a server because we were also able to convert AHI radiances to wavenumber-based values and then convert to brightness temperature using FK1, FK2, BC1, and BC2 (these values have been posted at the CIMSS GOES calibration web site).
- Wrote memo with instructions on how to convert AHI radiance units to the units we use on GOES and GOES-R for IR bands. http://cimss.ssec.wisc.edu/goes/calibration/Converting_AHI_RadianceUnits_24Feb2015.pdf

- Reported to CWG telecon on March 25, 2015 on AHI post-launch test activities (93-slide powerpoint included results generated under this project, GOES-R AWG teams at CIMSS, and teams outside of CIMSS as well).
    - Multiple methods of reading Himawari Standard Format (HSF) data.
    - INR analysis.
    - L2 Algorithm testing (GOES-R AWG winds, clouds, LST, aviation, CLAVR-x).
    - PFAAST RTM updated.
    - Brightness temperature bias analysis (Calc vs Obs with both PFAAST, CRTM & comparison to MTSAT-2).
    - Stray Light Analysis
        - Pointed out "Cookie Monster" effect to avoid scanning the sun. This is an area of the earth that was not scanned, due to stray light.

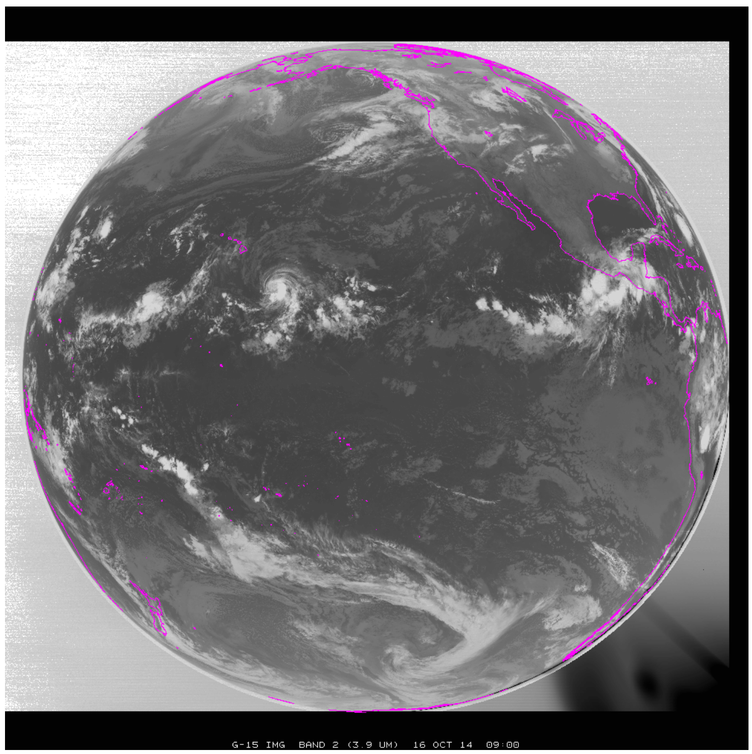

Figure 106. GOES-15 Band 2 (3.9µm) at 09:00 UTC 16 October 2014, with stray light evident in lower right.

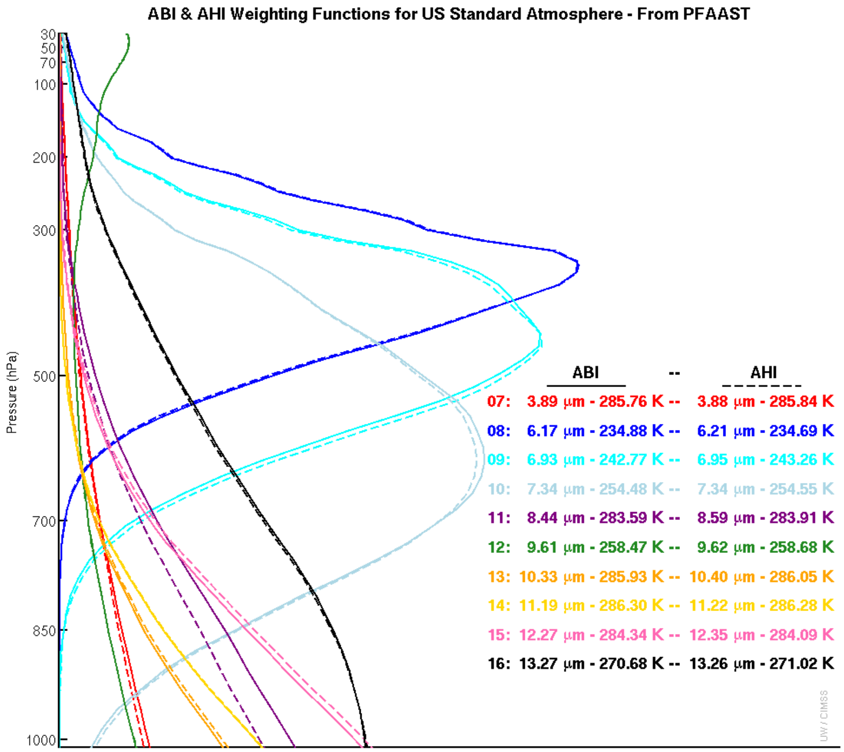

Figure 107. ABI and AHI weighting functions calculated from PFAAST for the US Standard Atmosphere.

35. Near Real-time Validation of Polar-orbiting Overpass Atmospheric Products Using Rooftop CIMEL AOD and GPS TPW Measurements

CIMSS Task Leader: Richard Dworak
CIMSS Support Scientist: Lee Cronce
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 Sensors and Techniques

Project Overview

SSEC/CIMSS has acquired or has data access to several advanced, ground-based, remote-sensing instruments. These instruments provide valuable near real time validation and quality control of GOES and POES derived meteorological parameters. We seek support from the NOAA Ground System program to continue to develop an integrated hardware and software system to acquire an archive database and distribute the measurements in dimensions and formats convenient to the user community. This support will facilitate a very useful reference database for NOAA science projects such as including a valuable reference for routine validation of new JPSS and GOES-R algorithm being implemented.

Past GOES-R calibration and validation field support allowed matching resource to acquire the following two instruments for the Atmospheric, Oceanic, and Space Science rooftop instrument suite:

CIMEL sunphotometer

The CIMEL sunphotometer (CSPHOT) is a multi-channel, automatic sun-and-sky scanning radiometer that measures the direct solar irradiance and sky radiance at the Earth's surface. Measurements are taken at pre-determined discrete wavelengths in the visible and near-IR parts of the spectrum to determine atmospheric transmission and scattering properties. This instrument is weather-proof and requires little maintenance during periods of adverse weather conditions. It takes measurements only during daylight hours (sun above horizon). The standard Aeronet processing generates retrievals of aerosol extinction, optical properties and absorption. The CSPHOT also provides measurements of the total precipitable water and the shortwave narrowband radiance.

GPS-MET receiver

The Global Positioning System (GPS) – Met receiver would allow near real-time total precipitable water vapor (TPW) measurements to be made available and provide another measurement location to a network of GPS receivers called SuomiNet. SuomiNet is a university-based, real-time, national Global Positioning System (GPS) network developed for atmospheric research and education. The network is based on a dense network of GPS Receivers located at member universities that will measure phase delays induced in GPS signals by the ionosphere and neutral atmosphere. These delays can be converted into integrated water vapor. More information about SuomiNet can be found here:
http://www.suominet.ucar.edu/index.html

Real-time measurements:
http://www.suominet.ucar.edu/cgi-bin/pw_plots.cgi?site=SSEC

Other existing SSEC/CIMSS rooftop instrumentation includes a Vaisala RS-92 GPS capable rawinsonde launch and receiver system, a Vaisala ceilometer for cloud base height measurements, a standard surface meteorological tower, 4 rooftop sky-view cameras, and a lake buoy with meteorological instrumentation.

With past NOAA NESDIS Ground Systems support this data is displayed and archived in near real-time at:
http://metobs.ssec.wisc.edu/quicklooks/

This effort will support the development of an integrated software system to create and distribute an archive database of measurements made from CIMSS/SSEC facility GPS and CIMEL instruments expanding the suite of instrument information and data access at:
http://metobs.ssec.wisc.edu/

These validation data sets would be distributed via the Web in dimensions and formats convenient to the user community. The support will facilitate a very useful reference database for

NOAA science projects such as JPSS by providing validation for atmospheric retrieval products on a routine basis using ground-based instruments stationed within Madison, WI.

We seek to develop and implement the control system for these instrument data to acquire, manage and distribute instrument data as needed by the science community. An archival system will also allow acquisition of specific historical data sets that will be assessable to the research community via a web interface. It should be noted that routine instrument and system maintenance is supported by other SSEC projects.

The final vision would be development of validation and archival plots and statistics to help guide JPSS and GOES-R algorithm improvements. Linked below are some GOES Cal/Val TPW plots comparing various sounder algorithm versions to our rooftop GPS. We envision taking these routines and modifying for CrIS, MODIS, IASI, and AIRS overpasses to monitor sounding derived TPW (coordinated with Tim Schmit/Jun Li) and Aerosol Optical Depth (coordinated with Brad Pierce) validation.
ftp://stratus.ssec.wisc.edu/pub/rdworak/Nearcasting/GPS/SSEC/2013_06/GPSComp130627.jpg
ftp://stratus.ssec.wisc.edu/pub/rdworak/Nearcasting/GPS/SSEC/2013_06/GPSComp0613Total.jpg

We could then produce easy to access archive calendars like this:
http://cimss.ssec.wisc.edu/snaap/convinit/validation/

Summary of Accomplishments and Findings

In the past year the Near Real-time Validation of Polar-orbiting Overpass Atmospheric Products Using Rooftop GPS TPW Measurements project has accomplished creating a website that visually compares all available clear sky AIRS, CrIS, IASI, MODIS, along with GOES-Li and first guess GFS TPW over Madison, WI to the SSEC rooftop GPS data set from SuomiNet COSMIC (http://metobs.ssec.wisc.edu/aoss/gps/product_image_viewer/view). Plots are produced daily and archived, with easy to retrieve capability through a calendar interface that provides visual comparisons of the past day and week period. If and when the website is ever down, as is during March-April 2015 period due to web-server changes, up-to-date plots will also be available at (ftp://stratus.ssec.wisc.edu/pub/rdworak/Nearcasting/GPS/SSEC/). The website should be back to full capability by May 2015. The website allows for future additions of other instruments such as CIMEL and includes monthly and seasonal statistical comparison capabilities. (Figure 108)

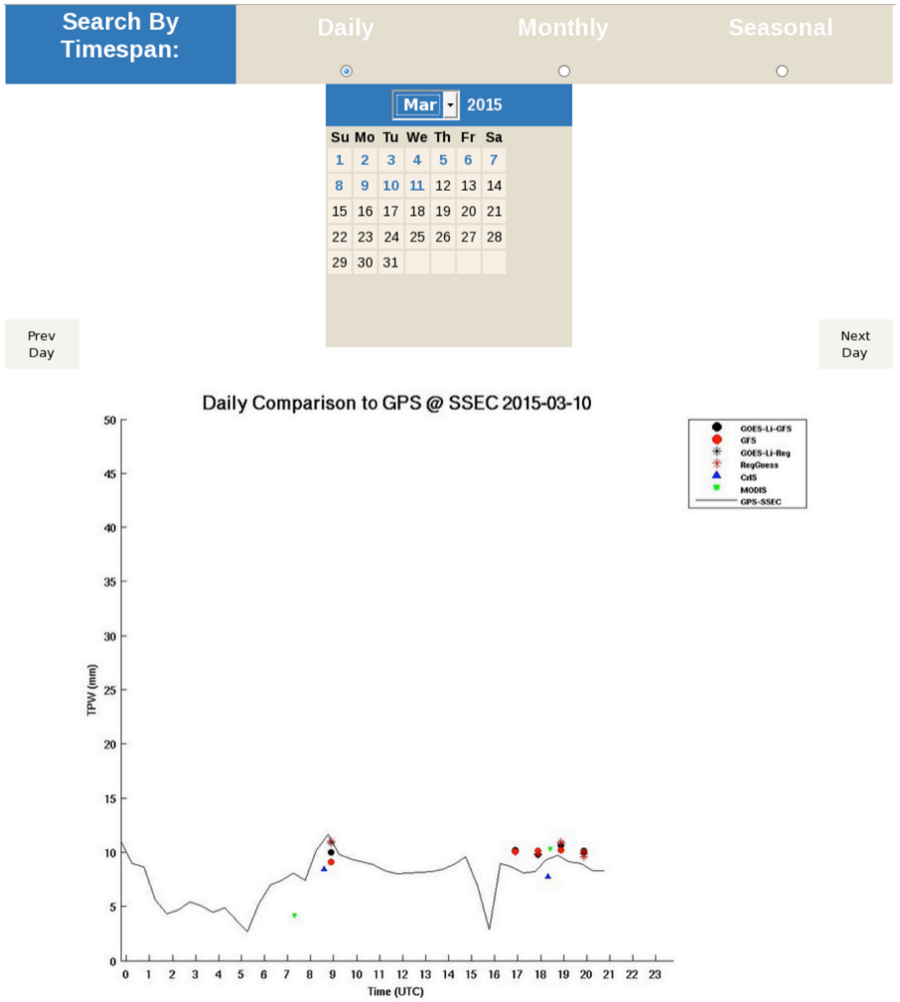

Figure 108. Example display from the website with calendar menu and visual daily comparison to SSEC GPS TPW for 2015-03-10.

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

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.

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
5. Generation of a full level2b merged AVHRR/HIRS record spanning 1979 – present.

During this period of performance progress has been made in each of these tasks.

Task 1 (complete): Collocation code has been created to place the HIRS and AVHRR measurements and geolocation information into a single file. Given a HIRS FOV in degrees, this code locates all AVHRR pixels/indices within each HIRS footprint.

Task 2 (complete): The clavr-x processing system requires constant files for each instrument for which measurements are ingested. In this case files needed to be created for the HIRS instrument. The HIRS Spectral Response Functions were obtained from the STAR website and reformatted for the clavr-x solar and Planck routines. We also obtained the necessary RTM calculations from the PFAAST model, then ran those routines with the reformatted SRFs as input in order to produce new sensor constant files for both AVHRR and HIRS channels.

Task 3 (in progress): 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 will be useful if we increase the FOV through interpolation for HIRS4 or add a "weighted average" collocation scheme. The HIRS and AVHRR footprints differ, and we are still developing our approach to maximize the information content from both sensors (see Figures below).

Task 4 (in progress): A year of the merged AVHRR/HIRS PATMOS-x has been processed, and test scenes have been generated that use HIRS data to inform the cloud detection and height algorithms.

Task 5 (not complete): Generation of the entire record of collocated HIRS/AVHRR files, a prerequisite, is in progress. However, processing the entire merged record is dependent on completion of all prior tasks and as such has not yet begun.

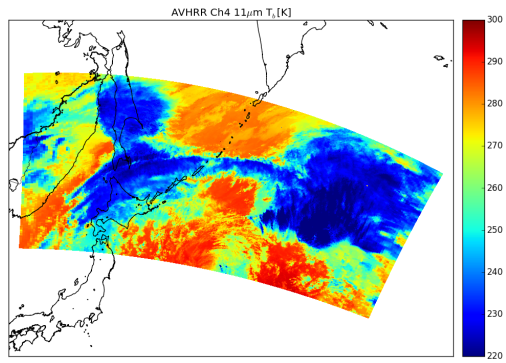

Figure 109. AVHRR measurement coverage for September 29th, from NOAA-19 near Japan.

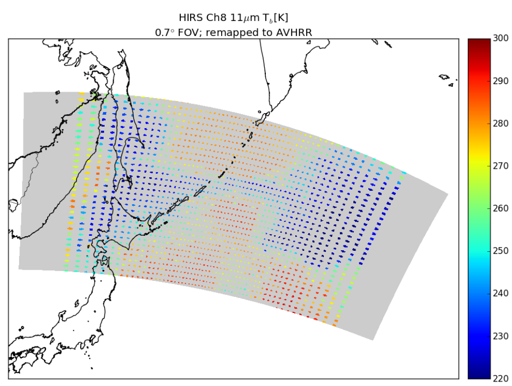

Figure 110. Same as Figure 109 but for HIRS.

Publications and Conference Reports

Foster, M. J. and A. K. Heidinger, 2014: Entering the Era of 30+ Year Satellite Cloud Climatologies: A North American Case Study. *J. Climate*, **27**, 6687–6697. doi: http://dx.doi.org/10.1175/JCLI-D-14-00068.1

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

"Results from a Merged AVHRR/HIRS Cloud Record," EUMETSAT conference, Geneva, Switzerland, September, 2014.

References

Heidinger, Andrew K.; Straka, William C. III; Molling, Christine C.; Sullivan, Jerry T. and Wu, Xiangqian, 2010: Deriving an inter-sensor consistent calibration for the AVHRR solar reflectance data record. *International Journal of Remote Sensing*, Volume 31, Issue **24**, pp.6493-6517.

37. 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.

Summary of Accomplishments and Findings
During the current reporting period the work done was primarily concerned with the following:
- Bulk delivery of the entire PATMOS-x CDR to NCDC for archival and public access. The AVHRR Reflectance FCDR record begins in 1978 while the AVHRR Cloud Properties TCDR begins in 1981, and both exist through present.
- Establish a mechanism of automated delivery to NCDC of near real-time FCDR and TCDR records as they become available.
- Delivery of reports, code, certain ancillary data sets, and supporting documentation.

The AVHRR Reflectance – PATMOS-x FCDR (beginning in 1978) and AVHRR Cloud Properties – PATMOS-x TCDR (beginning in 1981) records were delivered (with accompanying manifest files) and made available through the NCDC CDR Program. Besides the actual processing and delivery of the data, work was done to format the PATMOS-x file metadata to conform to ISO metadata standards. The data was processed using the CIMSS Zara server cluster and took about a month to complete. This data is now available at http://www.ncdc.noaa.gov/cdr/operationalcdrs.html.

Near real-time updates of the CDRs required automation of the retrieval of GAC data and ancillary dependencies and subsequent daily processing of PATMOS-x FCDR and TCDR. Daily files are staged on ftp.ssec.wisc.edu:/pub/patmosx/data/netcdf/YYYY/ for NCDC to pull. Quality Assurance (QA) daily monitoring plots (see Figure 111 for example) are also created and can be found at http://cimss.ssec.wisc.edu/patmosx/data/monitoring/.

The following documents were included as a part of the delivery package:

- Climate Algorithm Theoretical Basis Document (C-ATBD)
- Data Flow Diagram
- Maturity Matrix

The PATMOS-x cloud properties are derived primarily from two retrieval algorithms: the ABI Cloud Height Algorithm (ACHA), which derives Cloud Top Temperature and Cloud Emissivity (Heidinger and Pavolonis, 2009; Heidinger et al., 2010), and the Daytime Cloud Optical and Microphysical Properties algorithm (DCOMP), which derives Cloud Optical Thickness and Cloud Particle Size (Walther and Heidinger, 2012). These parameters, along with various geolocation and other variables deemed necessary for proper usage, make up the AVHRR Cloud Properties – PATMOS-x TCDR. Following discussions with the NCDC IPT team we determined that separate ATBDs should be provided for each algorithm while a single data flow diagram and maturity matrix would be sufficient for both. Those documents were created and then revised based on feedback from the NCDC IPT team. All of this documentation has been submitted and approved. The Submission Agreement was approved after several iterations. The Statement of Work, Implementation Plan, QA Procedure and Summary reports have also been submitted for this period.

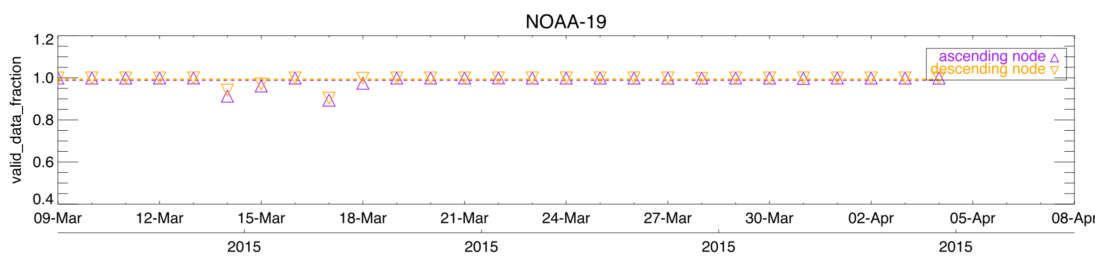

Figure 111. Example QA figure.

Publications and Conference Reports

Foster, M. J. and A. K. Heidinger, 2014: Entering the Era of 30+ Year Satellite Cloud Climatologies: A North American Case Study. *J. Climate*, **27**, 6687–6697. doi: http://dx.doi.org/10.1175/JCLI-D-14-00068.1

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

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Heidinger, A.K., M.J. Pavolonis, R. E. Holz, B. A. Baum, and S. Berthier, 2010: Using CALIPSO to Explore the Sensitivity to Cirrus Height in the Infrared Observations from NPOESS/VIIRS and GOES-R/ABI, J. Geophys. Res., doi:10.1029/ 2009JD012152.

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*

Heidinger, A.K., and M.J. Pavolonis, 2009: Gazing at Cirrus Clouds for 25 Years through a Split Window. Part I: Methodology. *J. Appl. Meteor. Climatol.*, 48, 1100–1116.

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

ACHA C-ATBD:
http://www1.ncdc.noaa.gov/pub/data/sds/cdr/CDRs/AVHRR%20Cloud%20Properties%20-%20PATMOS-x/AlgorithmDescription/CDRP-ATBD-0522%20Rev%201%20AVHRR%20Cloud%20Properties%20-%20PATMOS-x%20(ACHA)%20C-ATBD%20(01B-01b)%20(DSR-653)_mjf.pdf

DCOMP C-ATBD:
http://www1.ncdc.noaa.gov/pub/data/sds/cdr/CDRs/AVHRR%20Cloud%20Properties%20-%20PATMOS-x/AlgorithmDescription/CDRP-ATBD-0523%20Rev%201%20AVHRR%20Cloud%20Properties%20-%20PATMOS-x%20(DCOMP)%20C-ATBD%20(01B-01b)%20(DSR-654).pdf

38. Transition of Polar AVHRR Fundamental and Thematic Climate Data Records to NCDC

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 a three-year project supported by the National Climatic Data Center (NCDC) Climate Data Record Program, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) was the lead of a multi-institutional Cryosphere Product Development Team that created a variety of fundamental and thematic snow and ice climate data records (FCDR and TCDR). The primary CIMSS products developed under that project are the Advanced Very High Resolution Radiometer (AVHRR) Polar Pathfinder (APP) and the extended APP (APP-x). APP-x provides information on high-latitude surface and atmospheric characteristics, providing the data needed to investigate linkages between the cryosphere and atmosphere. APP is essentially an FCDR; APP-x is a TCDR. The two products are described in detail below.

The work supports the NCDC's Climate Data Record Program (CDRP). The CDRP leads NOAA's development and provision of authoritative satellite climate data records (CDRs) for the atmospheres, oceans and land. These climate data records provide information that our Nation needs to successfully adapt to a changing environment.

Summary of Accomplishments and Findings

The APP includes gridded and geolocated AVHRR channel radiances, sensor scanning angle, solar zenith angle, sensor relative azimuth angle, and pixel times at 5-km resolution, twice per day, for both the Arctic and the Antarctic. The daily APP composites are centered on local solar times of 14:00 (high sun, but could be nighttime for some polar areas in winter) and 04:00 for the Arctic or 02:00 for the Antarctic.

The APP-x uses APP as major input for the calculation of cloud fraction, cloud optical depth, cloud particle phase and size, cloud top temperature and pressure, cloud type, surface skin temperature, surface broadband albedo, radiative fluxes, cloud radiative effect ("cloud forcing"), and ice thickness along with atmospheric reanalysis data sets from NASA/MERRA and/or NOAA/NCEP. For computational considerations the original 5 km APP data are subsampled to 25 km by picking up the central pixel in a 5 x 5 pixel box.

The scope of this work includes the climate data record (CDR) transition to Initial Operational Capability, subsequent time series data set updates (forward processing) and stewardship support for the CDR in operations. Our accomplishments include:

- An implementation plan has been develop on describing how the CDR deliverables will be created.
- A totally new calibration procedure on AVHRR GAC data based on PATMOS-x has been adapted in APP generation. APP has been updated using PATMOS-x output. The calibration procedure in Fortran to generate PATMOS-x has been converted to the IDL computer language to be used in the next round of APP generation.
- The CDR Algorithm Theoretical Basis Documents (C-ATBD) for APP and the extended APP (APP-x) have been revised substantially based on our processing revisions and feedback from NCDC
- Data products (CDRs) have been updated for finalization. The data sets cover the period from the beginning of the acceptable instrument record (1982) to the last achievable processing period prior to the CDR delivery date. The data is in NetCDF-4 format. One example is shown in Figure 112.
- Regular updates to the CDR data sets has been implemented using the baseline version of the algorithms, and near real time updates is being generated daily.

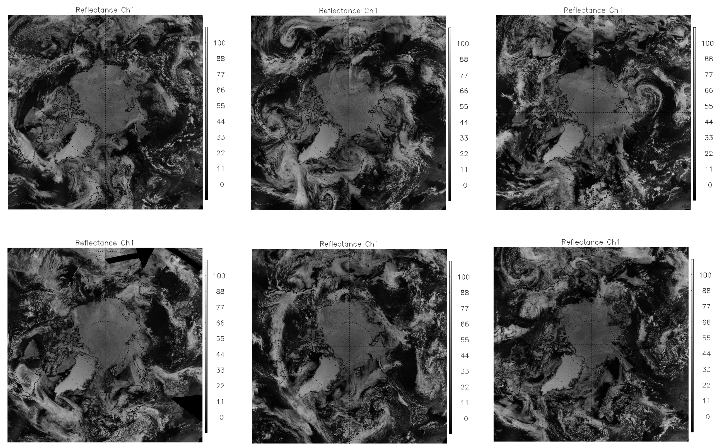


Figure 112. APP channel 1 reflectance (%) at 1400 SLT of north pole on July 1st of the year 1982, 1986, 1989, 1996, 2002, and 2007.

39. Reprocessing HIRS for CTP and TPW

CIMSS Task Leader: Paul Menzel
CIMSS Supporting Scientists: Richard Frey, Eva Borbas, Nick Bearson
NOAA Collaborators: Jeff Privette, Changyong Cao

NOAA Mission Goals:
- Climate Adaptation and Mitigation
- Weather-Ready Nation

NOAA Strategic Plan-Mission 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 SNO and AIRS-IASI recalibrated HIRS radiance measurements will be reprocessed using algorithms for cloud top properties (cloud amount, cloud top pressure, and associated error structures) and clear sky water vapor products (total precipitable water, TPW, and upper tropospheric humidity, UTH) that have been advanced in recent studies with the MODIS (Moderate resolution Imaging Spectroradiometer). Results from SNO recalibration will be compared with AIRS-IASI recalibration where possible. It has been found that relatively small changes in the HIRS radiances can translate into large differences in the cloud and water vapor products. The product consistency during transition periods from one sensor to another will be used as a measure of the recalibration. The resulting radiance climatology of clear and cloudy atmospheric conditions catalogued against the retrieved cloud and water vapor products will enable interpretation of the accuracy of observed trends in radiance in terms of geophysical variables. This provides the needed traceability to international standards (SI).

Summary of Accomplishments and Findings

Python script for converting HIRS/2 Level-1B data to NetCDF was provided. The algorithm theoretical basis documents for Cloud Top Properties (CTP) and Total Precipitable Water-Vapor (TPW) were updated. The software for processing both was tested at NCDC; the one-month benchmark data sets were successfully read, the meta-data documented, the file descriptions understood, and the test data sets reproduced. PATMOS cloud mask ancillary data for 1983 onwards were subsetted and staged for delivery to NCDC. Ten year (2000-2009) CTP and TPW data sets were delivered. A final report was submitted in April 2014 for NOAA Award NA10NES4400003.

For each satellite, daily statistics are recorded in 4 day-night bins (night after midnight designated by “night”, day before noon designated by “morning”, day after noon designated by “afternoon”, and night before midnight designated by “evening” where day is defined by solar zenith angle less than or equal to 85 degrees) to preserve any diurnal signatures. These files are gridded at 0.5 degree resolution using an equal angle projection for high, mid-level, and low-level cloud. Monthly statistics (also in 4 day-night bins - night after midnight, day before noon, day after noon, and night before midnight) of HIRS cloud top pressure and effective cloud amount are produced from a time composite sequence of the operational am and pm satellites. Note that often HIRS data exists from more than the operational satellites; these can be incorporated in other aggregation schemes in later processing. The number of satellites years for each decade is summarized below.

The number of satellites per year for 1980 through 1989 is roughly
1980 - 1 (N6)
1981 – 1.5 (0.5*N6, N7)
1982 - 2 (N8, N7)
1983 - 2 (N8, N7)
1984 - 2 (N8, N7)
1985 - 1 (N9)
1986 - 1 (N9)
1987 - 2 (N10, N9)
1988 - 2 (N10, N9)
1989 - 2 (N10, N11)
Thus there are about 16.5 satellite years in this ten year data set, giving ~200 months

The number of satellites per year for 1990 through 1999 is roughly
1990 - 2 (N10, N11)
1991 - 2 (0.5*N10, 0.5*N12, N11)
1992 - 2 (N12, N11)
1993 - 2 (N12, N11)
1994 - 2 (N12, N11)
1995 - 2 (N12, 0.5*N11, 0.5*N14)
1996 - 2 (N12, N14)
1997 - 2 (N12, N14)
1998 – 2.5 (N12, 0.5*N15, N14)
1999 - 3 (N12, N15, N14)
Thus there are about 21.5 satellite years in this ten year data set, giving ~260 months

The number of satellites per year for 2000 through 2009 is roughly

2000 - 3 (N12, N15, N14)
2001 - 4 (N12, N15, N14, N16)
2002 - 3.5 (0.5*N12, N15, N14, N16)
2003 - 3 (N15, N17, N16)
2004 - 3 (N15, N17, N16)
2005 - 3.5 (N15, N17, 0.5*N18, N16)
2006 - 4.5 (N15, 0.5*M2, N17, N18, N16)
2007 - 5 (N15, M2, N17, N18, N16)
2008 - 5 (N15, M2, N17, N18, N16)
2009 - 5.5 (N15, M2, N17, 0.5*N19, N18, N16)
Thus there are about 40 satellite years in this ten year data set, giving 480 months

The number of satellites per year for 2010 through 2014 is roughly
2010 - 6 (N15, N17, M1, N16, N18, N19)
2011 - 6 (N15, N17, M1, N16, N18, N19)
2012 - 6 (N15, N17, M1, N16, N18, N19)
2013 - 6 (N15, N17, M1, N16, N18, N19)
2014 – 5.5 (N15, N17, M1, 0.5*N16, N18, N19)
Thus there are about 29.5 satellite years in this five year data set, giving ~350 months

For each satellite month the cloud mask, CTP, and TPW files amount to 18.8 GB; thus the whole data set when reprocessed will be about 24.3 Terabytes.

40. Participation in Volcanic Ash Product Development Team Research Activities (FAA)

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

Satellite-based data sets for model verification of volcanic ash dispersion forecasts will be developed and hosted in an online database. The NOAA/NESDIS remote sensing techniques described in Pavolonis et al. (2006), Pavolonis (2010), Pavolonis and Sieglaff (2010), Pavolonis et al. (2013), and Pavolonis et al. (2015 a,b) will be applied to geostationary and low earth orbit satellite data to produce estimates of important volcanic ash cloud properties (ash cloud horizontal bounds, ash cloud height, ash mass loading, and ash effective radius) and their associated uncertainties.

Summary of Accomplishments and Findings

The three volcanic eruptions that will populate the volcanic ash dispersion model verification database have been selected. The eruptions include 2008 Kasatochi (Alaska), 2010 Eyjafjallajökull (Iceland), and 2011 Cordon Caulle (Chile). The NOAA/NESDIS remote sensing techniques (retrievals of ash cloud horizontal bounds, ash cloud height, ash mass loading and ash effective radius) have been processed using low-earth orbit *Aqua* MODIS data for the 2008 Kasatochi and 2010 Eyjafjallajökull events. Figure 113 shows composite false color imagery and retrieved ash cloud height for the descending *Aqua* node on 9 August 2008. The data has been made available to the NOAA/ARL group in NETCDF format. Additionally we have assisted the NOAA/ARL group in interpreting the remote sensing results and how it compares to dispersion model results. The NOAA/NESDIS remote sensing results for the Cordon Caulle eruption will be delivered in 2015 as well as identification of accessible, real-time source of quantitative volcanic ash satellite observations and their uncertainties.

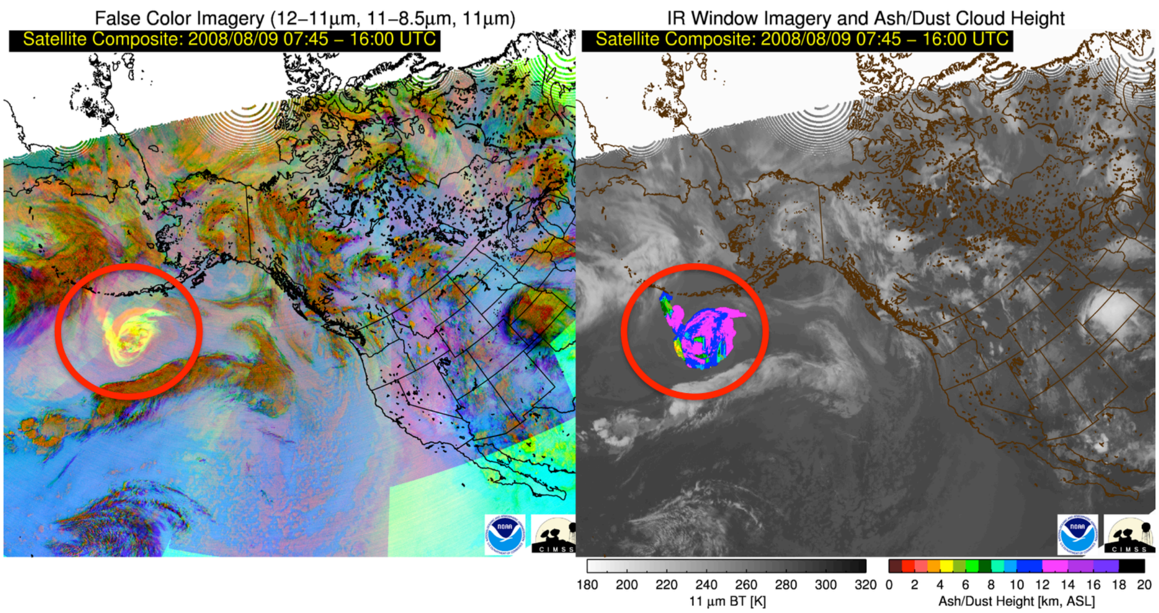


Figure 113. Descending *Aqua* MODIS composite for 9 August 2008 of Kasatochi volcanic cloud. The left panel is a false color image, the volcanic ash cloud is the pink/yellow cloud identified by the red circle. The right panel is the satellite observed IR window brightness temperatures (grayscale) and the NOAA/NESDIS identified regions of volcanic ash and the respective ash cloud heights (color shading). The Kasatochi volcanic cloud is well identified by the NOAA/NESDIS retrieval package. These fields and others have been delivered to the NOAA/ARL group and are being used to validate dispersion model results.

References

Pavolonis, M. J., W. F. Feltz, A. K. Heidinger, and G. M. Gallina, 2006: A daytime complement to the reverse absorption technique for improved automated detection of volcanic ash. *J. Atmos. Ocean. Technol.,* **23**, 1422-1444.

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.

Pavolonis, M., and Sieglaff, M., 2010. GOES-R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document For Volcanic Ash (Detection and Height). *NOAA CSTAR Tech. Doc: Ver. 2.0. June 30, 2010. 72 pp.*

Pavolonis, M., A. Heidinger, and J. Sieglaff, 2013, Automated retrievals of volcanic ash and dust cloud properties from upwelling infrared measurements, *J. Geophys. Res*., 118(3), 1436-1458.

Pavolonis, M. J., J. M. Sieglaff, and J. L. 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: Cloud Object Analysis and Global Application, *J. Geophys. Res. – Atmospheres,* under review.

Pavolonis, M. J., J. M. Sieglaff, and J. L. 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: Multispectral Analysis, *J. Geophys. Res. – Atmospheres,* under review.

41. Advanced Satellite Products in Support of the DOE Solar Forecast Improvement Project

CIMSS Task Leader: Christine Molling
CIMSS Support Scientist: James Nelson
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
- 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 Department of Energy’s SunShot Initiative has funded a Solar Forecast Improvement Project (SFIP) as part of their SunShot effort to make solar power production competitive with carbon-based power production. CIMSS supports two SFIP teams (NCAR and IBM) by supplying Advanced Satellite Products (ASPs): real-time analyses of GOES Imager data every 15 minutes at 1 km nominal resolution. Specifically, these are the cloud properties of type, optical thickness, particle size, water path and top height, as well as related data such as sun and satellite geometry, numerical weather prediction temperature and wind fields at cloud top height, etc. These products are served via ftp. We instruct and advise the SFIP teams regarding their quality and use for diagnosis/prediction of clouds and surface radiation budget components.

Summary of Accomplishments and Findings

For this project, Advanced Satellite Products were produced from GOES-West and GOES-East Imager data at the 1km visible pixel resolution. Previously, the highest resolution at which these same types of products had been available was at the 4km thermal pixel resolution. ASPs provide a 16-times finer resolution than the standard products. Figure 114 shows samples of cloud transmission from simultaneous GOES-West and GOES-East images. This work was presented to the solar community at large at the Sunshot Summit (Molling et al., 2014). ASPs continue to be produced on a real-time basis every 15-30 minutes, according to the GOES Imager schedule.

A computer for dedicated processing (had been running on shared resource) was purchased and the GOES-West and GOES-East processing was transferred to it. The ASPs include such quantities as cloud mask, cloud probability, cloud transmission, cloud top height, cloud top temperature, cloud effective particle size, etc. Ancillary data, such as elevation and numerical weather prediction fields are provided in the files at the same resolution as well. There are at this time 147 different variables in the ASP output, including quality flags and processing information. ASPs are available to the IBM and NCAR teams, as well as any other interested user, at ftp://ftp.ssec.wisc.edu/clavr/goes_west/1kmprocessed/ and ftp://ftp.ssec.wisc.edu/clavr/goes_east/1kmprocessed/. The ASP files are available on ftp within 8-21 min after the last scan line of the image is acquired. A few of the ASPs are displayed in Google Earth format at http://cimss.ssec.wisc.edu/clavr2/google_earth/goes_west_kml1km/ and http://cimss.ssec.wisc.edu/clavr2/google_earth/goes_east_kml1km/. There is also a rolling 24-hour view of the cloud mask and GHI at http://cimss.ssec.wisc.edu/clavrx/quicklook/quicklook_main.html.

A document titled "User's Guide for 1km Cloud Products Derived from GOES Imager Data using CLAVR-x" was delivered to NCAR and IBM team users. This document discusses the basics of the source imagery, the process by which it is turned into Advanced Satellite Products, and considerations users should make when using the data. Validation of selected variables from the older 4km version of the products was also included.

The ASP validation process was begun. It will consist of comparisons between high quality surface data and satellite-derived products. Validation will start with the permanent and mobile SURFRAD sites. Later, ISIS, ARM SGP, and an NREL site will be added. Currently being downloaded daily are the observations at SURFRAD and ISIS sites. A 15 x 15 pixel box of data for each variable in every ASP file is being extracted at the SURFRAD, ISIS, SGP, and NREL sites. These extracts are archived. A web site is being built to show comparisons and statistics from daily through yearly scales. Figure 115 has two samples of the kinds of comparisons and statistics planned for the validation website. The plots show a 5km radius for satellite with a 10 min average of SURFRAD data. Considering the types of variables in the ASPs and the available surface observations, the following ASP variables can be validated:

- Cloud mask via surface radiometric temperature
- Cloud mask via irradiance
- Cloud fraction via total sky imager
- Cloud transmission via irradiance
- Direct/diffuse insolation via direct normal irradiance/diffuse horizontal irradiance

Statistics will include RMSE, average error, probability of correct detection, etc. Year 2 of the project will concentrate on this validation effort.

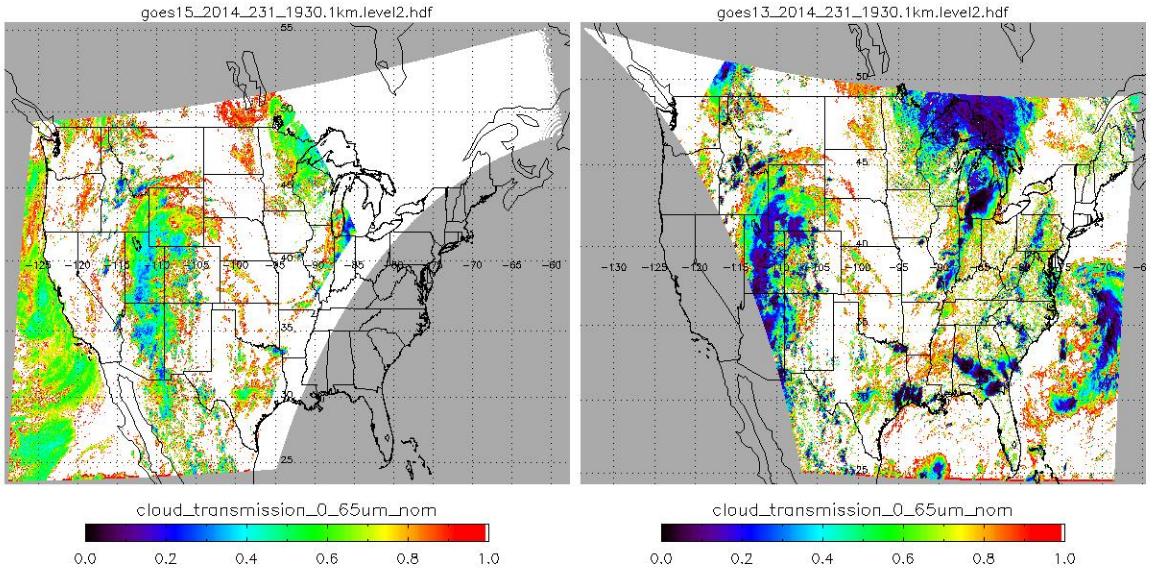


Figure 114. Sample Advanced Satellite Product: cloud transmission calculated from GOES-West and GOES-East Imager at the resolution of the visible band. Images were from Sep 28, 2014 at 1930 UTC.

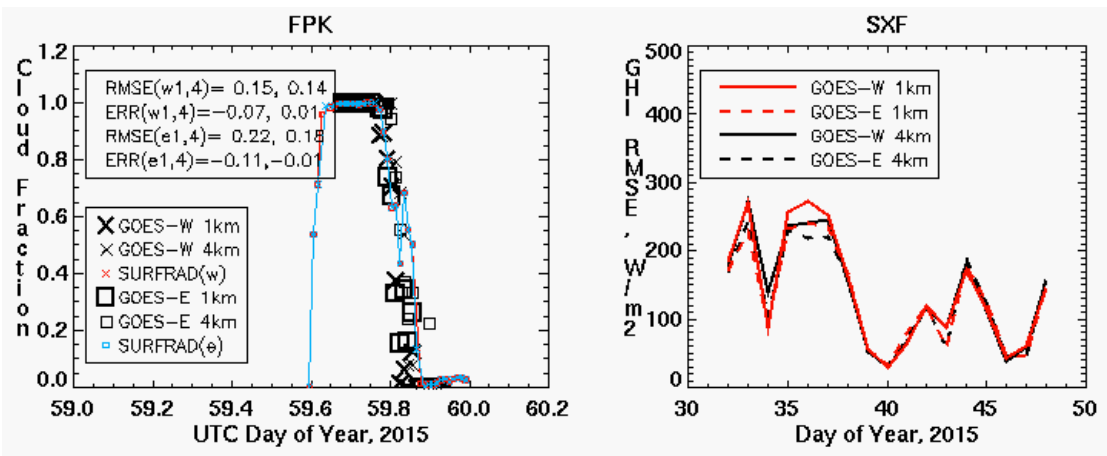


Figure 115. Two samples of data and statistics that will be available on the ASP validation web site. On the left is cloud fraction from both the 4km and 1km resolution products in comparison to data from the SURFRAD site at Fort Peck, Montana. Root mean square error and mean error statistics are shown. On the right is the root mean square error for GHI at Sioux Falls, South Dakota.

Publications and Conference Reports

Molling, C. et al., 2014: NOAA's Contribution to Improving Accuracy of Solar Forecasting. Sunshot Summit, Anaheim, CA, May 20. Invited Poster Presentation and Review.

References

Molling, C. et al., 2014: NOAA's Contribution to Improving Accuracy of Solar Forecasting. Sunshot Summit, Anaheim, CA, May 20. Invited Poster Presentation and Review.

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

CIMSS Task Leader: Allen Lenzen

CIMSS Support Scientist: Andrew Wentland (graduate student)
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

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 in changes in NOx emissions on US air quality during the Aura period.

Summary of Accomplishments and Findings
The first year of the proposal has focused on preparing for the multi-year global reanalysis through global emissions development, generation of global background error co-variances, and adaptation of the NOAA National Centers for Environmental Prediction (NCEP) Gridpoint Statistical Interpolation (GSI) analysis scheme (Kleist et al., 2009) for use by the Real-time Air Quality Modeling System (RAQMS, Pierce et al., 2007).

For global emissions development, RAQMS forecasts have been evaluated for both the standard RAQMS emissions and the Task Force on Hemispheric Transport of Air Pollution (TF HTAP) emissions (EDGAR HTAP_V2). These have been compared with in situ measurements over the Northern Hemisphere (>20N) Central Pacific obtained from the March 2010 NSF HIAPER Pole-to-Pole Observation (HIPPO) campaign.

Seasonal background error co-variances and horizontal and vertical length scales for use in the GSI analysis have been calculated from a year of RAQMS chemical and aerosol forecasts. These background error statistics were calculated with the "NMC" method (Parrish and Derber, 1992) using the 12 and 24 hr RAQMS forecasts for each day.

The Development Testbed Center (DTC) global GSI currently assimilates OMI total column ozone and MLS stratospheric ozone profile data. We have adapted the DTC global GSI so that it is able to read in RAQMS gridded NETCDF restart files instead of the default Global Forecasting System (GFS) spectral binary restart files and are currently testing the RAQMS/GSI ozone assimilation capabilities using operational near real-time OMI and MLS retrievals. Figure 116 shows the results of these RAQMS/GSI ozone assimilation studies for a single analysis cycle at 18Z on March 10, 2015. The RAQMS/GSI OMI increment shows large (+/- 10-20 Dobson unit) column adjustments while the RAQMS/GSI MLS increment shows small (<0.1 Dobson unit) column adjustments, resulting in combined RAQMS/GSI OMI+MLS increments that are nearly identical to the OMI only RAQMS/GSI assimilation. These OMI and OMI+MLS column increments are significantly larger than found using the standard RAQMS Statistical Digital Filter

(SDF, Stobie, 2000) analysis scheme which shows OMI increments of no more than +/- 4 Dobson units. We suspect that the large RAQMS/GSI OMI column adjustments occur because GSI only assimilates MLS data in the upper stratosphere and as a result, there are large adjustments in the stratospheric ozone profile in the RAQMS/GSI OMI assimilation. Within the RAQMS/SDF ozone analysis we assimilate MLS near real-time ozone retrievals down to ~50mb, which results in a tight constraint on the stratospheric ozone column and leads to significantly smaller OMI column increments. Furthermore, we only assimilate cloud cleared OMI data within the RAQMS/SDF ozone analysis so that we do not adversely impact the RAQMS tropospheric ozone analysis due to assimilation of the OMI a priori profile (which is used to fill in the tropospheric ozone column below clouds). Our next experiments will explore the impact of assimilating all MLS data above ~50mb prior to assimilation of the OMI total column retrievals.

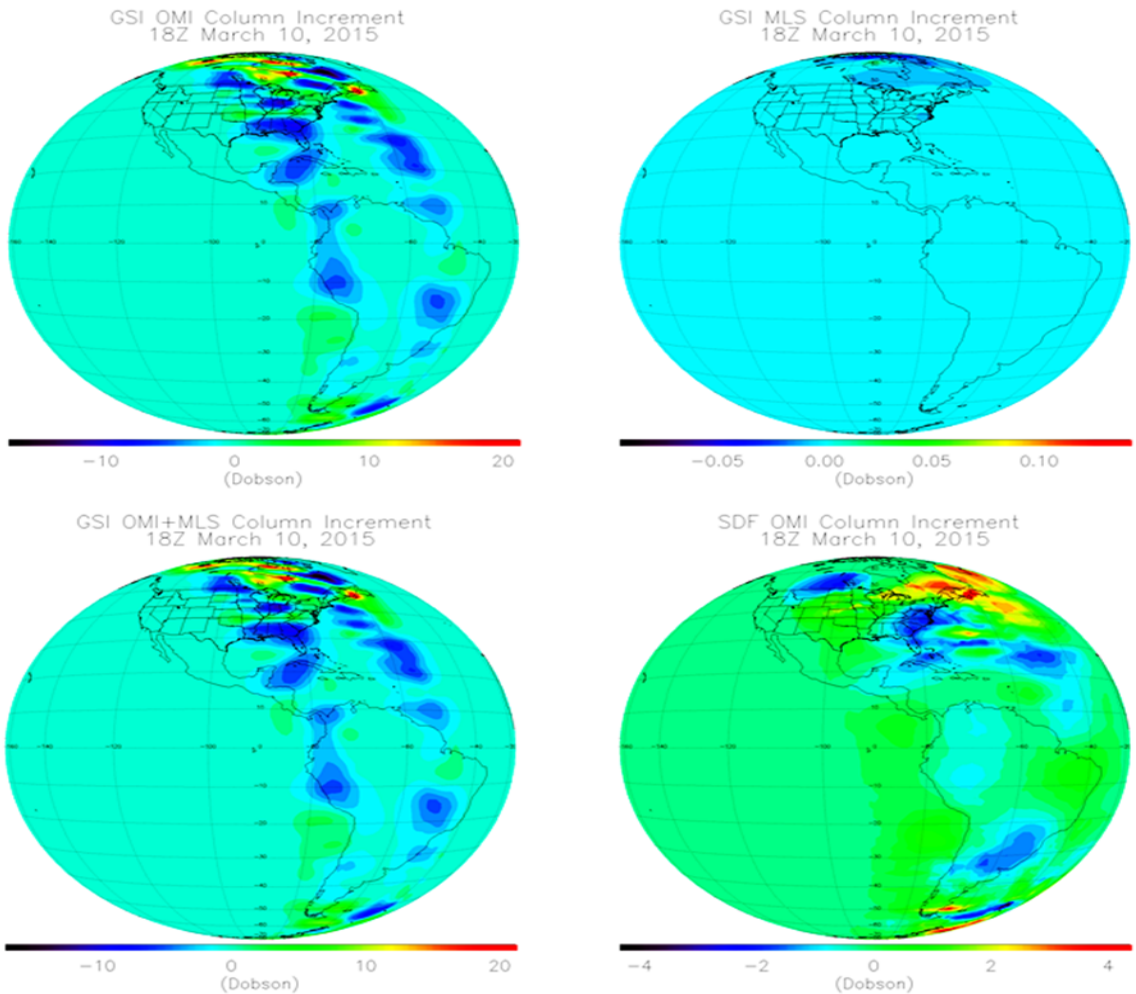


Figure 116. Results from RAQMS/GSI OMI (upper left), RAQMS/GSI MLS (upper right), RAQMS/GSI OMI+MLS(lower left) and RAQMS/SDF OMI (lower right) total column ozone analysis increments (Dobson) at 18Z on March 10, 2015.

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

Parrish, David F., John C. Derber, (1992) The National Meteorological Center's Spectral Statistical-Interpolation Analysis System. Mon. Wea. Rev., 120, 1747–1763.

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.

Stobie, J. M., (2000) Algorithm theoretical basis document for statistical digital filter (SDF) analysis system (stretch-grid version). Data Assim. Off., NASA Goddard Space Flight Cent., Greenbelt, MD.

43. CIMSS Participation in SHyMet for 2014

CIMSS Task Leader: Steve Ackerman
CIMSS Support Scientists: Scott Bachmeier, Scott Lindstrom
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

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

Summary of Accomplishments and Findings

CIMSS has assisted in the development of the previous five SHyMet courses: Intern, Tropical, Forecaster, Severe and Water Vapor Channels. Planning and coordination efforts for a new GOES-R Course, an Aviation Course and a Winter Weather Course are continuing. 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. See, for example, http://cimss.ssec.wisc.edu/goes/blog/archives/15086 for Winter Weather and http://cimss.ssec.wisc.edu/goes/blog/archives/17681 for Aviation training. Training material more specific to the GOES-R Fog/Low Stratus products continues to be added at http://fusedfog.ssec.wisc.edu/ . These case studies can easily be mined for relevant examples to be used for SHyMet.

SHyMet has also leveraged AWIPS (and AWIPS-II) capabilities that have been further refined at CIMSS. A stable AWIPS-II platform at CIMSS allows for manipulation of CIMSS-produced datasets into formats that are compatible with AWIPS-II. Thus, the production at CIMSS of products that forecasters wish to see (for example, GOES-R Fog/Low Stratus Products) can continue into the AWIPS-II era.

Because the Department of Commerce changed Learning Management System (LMS) vendors, all SHyMet lesson quizzes had to be converted to the Sharable Content Object Reference Model (SCORM) format, using Articulate Presenter QuizMaker. During this reformatting, SHyMet lessons that contained outdated information were identified and scheduled for updating.

Publications and Conference Reports

American Meteorological Society, 27th Conference on Severe Local Storms, 03 November 2014, Madison, Wisconsin:

> "The use of Blogs, Twitter and YouTube for outreach at CIMSS", Scott Lindstrom and Scott Bachmeier:
> https://ams.confex.com/ams/95Annual/webprogram/Paper267037.html
>
> "Blogging at CIMSS: Short Compelling Stories using Satellite Observations", Scott Lindstrom and Scott Bachmeier:
> https://ams.confex.com/ams/27SLS/webprogram/27SLS.html

44. CIMSS Collaboration with the NWS Training Center

CIMSS Task Leader: Wayne Feltz
CIMSS Support Scientist: Chad Gravelle
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

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin–Madison proposed to support the training for satellite-based decision support products by placing a CIMSS research scientist at the National Weather Service (NWS) Operations Proving Ground (OPG) in Kansas City, MO. The CIMSS scientist is providing leadership, satellite expertise, and meteorological support for the GOES-R Proving Ground efforts at the OPG.

Chad Gravelle is working closely with UW–Madison/CIMSS researchers, scientists at the NOAA/NESDIS/STAR, the GOES-R Program Office, and the staff at the OPG. The position is with the University of Wisconsin–Madison and the position's duty station is in Kansas City, MO embedded within the NOAA/NWS OPG.

The OPG provides the infrastructure and facilities to effectively transfer new and emerging scientific techniques, products, and services into NWS forecast office operations. The OPG actively engages in the research-to-operations process by supporting applied research, verifying the quality and scientific validity of new techniques and products, and providing a common venue for both forecasters and researchers to engage in developing and testing state-of-the-art weather services.

Summary of Accomplishments and Findings

This project entails activities focused at maximizing the forecast value of geostationary satellite data and products, particularly activities centered on weather forecast office operations to improve forecast and warning services to the nation. The incumbent will interact with NWS operational forecasters and NESDIS satellite analysts to prepare them for new satellite dependent products that will become available operationally after the launch of the GOES-R satellite series.

The principal duties of this position are:

- Serve as a "Satellite Liaison" at the NWS OPG, leading GOES-R Proving Ground efforts on satellite based hazardous 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;
- Serve as "Science Coordinator" for the NWS OPG;
- 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 public weather hazards (e.g., convection, ceiling, visibility, snow, etc);
- Develop and/or document how these satellite dependent products and decision aids may improve the performance of forecasters by improving forecast and warning accuracy and reducing false alarms.
- Participate in routine experimental projects serving as the focal point for all satellite centered activities at the OPG;
- Lead in training operational forecasters on new and emerging satellite-based techniques and tools, particularly those proposed to be transferred into NWS WFO operations;
- Provide satellite expertise in the logistical support of any special or field excursion experiments, such as the planned NWS Impact Decision Support Services (IDSS);
- Coordinate training activities created by the GOES-R proving ground members and cooperative institutes;
- Represent the GOES-R effort within the OPG by contributing to formal scientific publications or attending off-site conferences, symposia, and 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 Aviation Weather Testbed (AWT) in Kansas City, Missouri;
- Perform related duties as assigned.

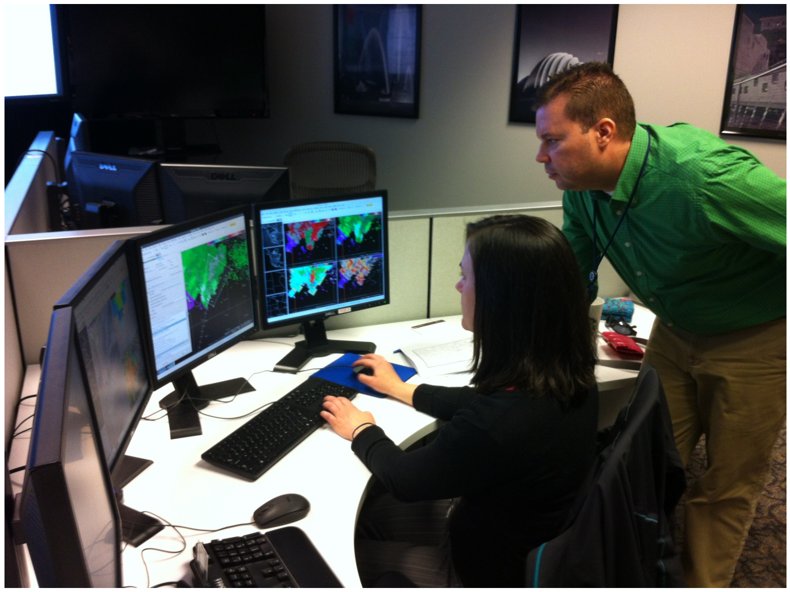


Figure 117. Chad Gravelle (Satellite Liaison; OPG) and Rebecca Mazur (Forecaster; NWS Cheyenne, WY) discuss incorporating 1-minute satellite imagery in the warning decision-making process at the OPG.

Publications and Conference Reports

Publications

Gravelle, C. M., and Coauthors: 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, OK Tornado Outbreak. *Bull. Amer. Meteor. Soc.*, In Press.

Conference/Meeting Oral Presentations

2014 NOAA Testbed and Proving Ground Workshop:
Transitioning the GOES-R Fog and Low Stratus Products from Research To Operations Through the NWS Operations Proving Ground, 17 April 2014.

2014 Satellite Proving Ground/User Readiness Meeting:
Current State of GOES-R/JPSS User Readiness and the Operations Proving Ground, 3 June 2014.

Evaluating GOES-R Scanning Strategies at the Operations Proving Ground, 4 June 2014.

AMS 2014 Conference on Broadcast Meteorology:
Using The Next-Generation Geostationary Environmental Satellite System in Operational Meteorology, 19 June 2014.

August 2014 Joint GOES-R/JPSS Science Seminar:
Satellite Training, 18 August 2014.

2014 EUMETSAT Satellite Conference:
Training Within the GOES-R Proving Ground: Past, Present, and Future, 25 September 2014.

Transitioning the GOES-R Fog and Low Stratus Products from Research To Operations Through the NWS Operations Proving Ground, 25 September 2014.

Using GOES-R Demonstration Products to Bridge the Gap Between Severe Weather Watches and Warnings for the 20 May 2013 Moore, OK Tornado Outbreak, 26 September 2014.

2014 NWA Annual Meeting:
Evaluating the Usefulness and Usability of Different GOES-R Scanning Strategies at the Operations Proving Ground, 21 October 2014.

2015 AMS Annual Meeting:
Evaluating the Usefulness and Usability of Different GOES-R Scanning Strategies at the Operations Proving Ground, 5 January 2015.

Central Michigan University Invited Seminar:
Capabilities of The Next-Generation Geostationary Environmental Satellite System for Operational Meteorology, 17 April 2015.

2015 NOAA Satellite Conference:
Training Within the Satellite Proving Ground: The Satellite Liaison Perspective, 30 April 2015.

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

The position is embedded within the NOAA Aviation Weather Testbed (AWT) at the AWC. The AWT provides the infrastructure and facilities to develop, test and evaluate new and emerging scientific techniques, products, and services. The AWT actively engages in the research-to-operations process by supporting applied research, verifying the quality and scientific validity of new techniques and products, and providing a common venue for both forecasters and researchers to engage in developing and testing state-of-the-art aviation weather services.

Summary of Accomplishments and Findings

This project will entail 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;
- Perform related duties as assigned.

Figure 118. The AWC Satellite Liaison working with forecasters and aviation focal points from various CWSUs and WFOs during the 2014 Summer Experiment at the Aviation Weather Testbed.

Publications and Conference Reports

Current State of Proving Ground User Readiness at the Aviation Weather Center. A. Terborg, Proving Grounds/User Readiness Meeting. Kansas City, MO, June 2014.

Exploration and Implementation of Next Generation Satellite Data at NOAA's Aviation Weather Center: The GOES-R Proving Ground. Terborg A., EUMETSAT Annual Meeting. Geneva, SZ, September 2014.

Using VIIRS/MODIS Dust Enhancement Imagery for the Issuance of Blowing Dust SIGMETs at the Aviation Weather Center. A. Terborg, NWA Annual Meeting. Salt Lake City, UT, October 2014.

Advances and Innovation in Aviation Forecasting: Using Next Generation Satellite Data at the Air Traffic Control Systems Command Center. A. Terborg, AMS Annual Meeting. Phoenix, AZ, January 2015.

The GOES-R Proving Ground at the Aviation Weather Testbed. A. Terborg and S. Lack, 2015 Testbeds/Proving Grounds Workshop. Boulder, CO, April 2015.

Integration GOES-R into Aviation Weather Center Operations and Decision Support Services. A. Terborg, 2015 Southwest Aviation Weather and Safety Workshop. Las Vegas, NV, April 2015.

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

CIMSS Task Leader: Margaret Mooney
CIMSS Support Scientist: Rick Kohrs
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

CIMSS Research Themes:
- Education and Outreach

Project Overview
The GOES-R Education Proving Ground (http://cimss.ssec.wisc.edu/education/goesr/) features the design and development of pre- and post-launch lesson plans and activities for G6-12 teachers and students to ensure that the education community will be "launch ready" for new satellite imagery and improved products that will be available in the upcoming GOES-R era.

A key element of this effort is a core group of educators working with Education and Outreach staff at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) in close coordination with NOAA scientists at the Advanced Satellite Products Branch (ASPB) and members of GOES-R Algorithm Working Group at CIMSS.

Informal education efforts related to the GOES-R Education Proving Ground involve the development of animations for Science On a Sphere (SOS) exhibits using Super Rapid Scan observations, typically in picture-in-a-picture (PIP) style animations.

Summary of Accomplishments and Findings
Currently six teachers are collaborating on the GOES-R Education Proving Ground, three teams of two teachers from three different states: Wisconsin, New Jersey and Florida. Each team developed a GOES-R related lesson plan for middle and high school students during the 2013-14 school year. The Wisconsin team focused on the advantages of the Advanced Baseline Imager (ABI), Florida highlighted the Geostationary Lightning Mapper (GLM) and New Jersey made STEM connections to GOES-R with an emphasis on math inherent in ABI spectral band improvements. All lesson plans link content to the Next Generation Science Standards. After months of telephone conferences, all six educators met in person at the 2014 Satellites and Education Conference XXVII at CIMSS in Madison when they presented their lesson plans for feedback and revision.

A new 90 second video for NOAA Science On a Sphere (SOS) exhibits demonstrating capabilities of the upcoming GOES-R satellite series was released and distributed in December 2014. "GOES R – A glimpse into the future of Weather Satellites" features a June 2013 case study of 1 minute imagery from the GOES 14 satellite and the improved temporal resolution of the Advanced Baseline Imager (ABI) scheduled to fly on the GOES-R satellite series. This is followed by a simulation of Geostationary Lightning Mapper (GLM) data using the same case study. More information and a link to a YouTube video can be found on the Cooperative Institute for Meteorological Satellite (CIMSS) EarthNow Blog at http://sphere.ssec.wisc.edu/goes-r/.

The content was featured on spherical display systems at the 2015 American Meteorological Society (AMS) Annual Meeting at both the University of Wisconsin–Madison Space Science and Engineering (SSEC) booth and the NOAA booth in the AMS exhibit hall.

Figure 119. Screenshot of GOES-R video on YouTube.

Publications, Reports, Presentations

Mooney, Margaret; Schmit, T. J. and Ackerman, S. GOES-R Education Proving Ground. Symposium on Education, 24th, Phoenix, AZ, 4-8 January 2015. American Meteorological Society, Boston, MA, 2015

47. The 27th Satellite Educators Conference: Rotating the Venue to Expand Audience and Awareness

CIMSS Task Leader: Margaret Mooney
CIMSS Support Scientist: Steve Ackerman
NOAA Collaborator: Nina Jackson

NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

NOAA Strategic Goals:

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

CIMSS Research Themes:

- Education and Outreach

Project Overview

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) proposed to host the 27th gathering of the Satellite Educators Conference in Madison, Wisconsin to reinvigorate and expand a time-honored program. The target audience was national and international members of the Satellite Educators Association, regional science teachers and informal educators, satellite remote sensing researchers, members of the aerospace industry, broadcast meteorologists, high school and undergraduate students, MYSPACE program members, National Weather Service (NWS) meteorologists and NWS storm spotters.

The purpose of bringing the conference to a new location was to bolster interest and participation. Ideally the gathering will mark the beginning of a rotating conference venue with the Satellites Educator Conference returning to Madison every third or fourth year.

Summary of Accomplishments and Findings

CIMSS hosted a very successful and exciting Satellites & Education XXVII Conference (http://cimss.ssec.wisc.edu/meetings/27sated/) at the University of Wisconsin–Madison from July 30 through August 1 2014. In attendance were members of the Satellite Educators Association (SEA), middle and high school science teachers from Wisconsin and beyond, broadcast meteorologists, University of Wisconsin faculty and students, National Weather Service (NWS) meteorologists, Science On a Sphere (SOS) docents, and NOAA and NASA science communicators. There were two keynote presentations. One featured NOAA NWS Director Louis Uccellini presenting on "Building a Weather-Ready Nation: Taking Forecasts and Satellite Data to the Next Level," and the other featured Space Science and Engineering Center (SSEC) Director Hank Revercomb presenting "A Suomi Story: The Gadget Guy," which chronicled the career of Verner Suomi, founder of CIMSS and co-founder of SSEC.

The conference also featured the formal launch of 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.

Conference attendees also took a field trip to a nearby SOS facility.

The conference was sponsored by NOAA, the U.S. Navy, SSEC and SEA. SEA is a nonprofit professional organization focused on student engagement in Science, Technology, Engineering and Math (STEM) through space-based technology. SEA launched the first Satellites and Education Conference at West Chester University in Pennsylvania before moving it to California State University in Los Angeles. This year's conference marks the beginning of rotating venues with the goal of serving the broadest audience of educators possible.

Eighty-two people attended and nearly three dozen were educators. Most educators were middle and high school science teachers attending for the full two days. Twenty-seven (27) filled out evaluations. A majority indicated that the overall quality of the conference was excellent (85%) with others choosing the next best category of good (15%).

Figure 120. Satellite 101 presentation at Satellites & Education XXVII.

48. GOES-R Support for International TOVS Study Conference ITSC-19
CIMSS Task Leader: Allen Huang

NOAA Long Term Goals:
- Weather-Ready Nation

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

CIMSS Research Themes:
- Education and Outreach

Project Overview
This task provided partial support for the ITSC-19 Conference held in Jeju Island, South Korea in 2014. The funding supported the conference organization efforts at CIMSS and also supported the publication of the Working Group Report and an update to the ITWG Web pages regarding conference activities.

Summary of Accomplishments and Findings
The International TOVS Working Group (ITWG) is convened as a sub-group of the International Radiation Commission (IRC) of the International Association of Meteorology and Atmospheric Physics (IAMAP). The ITWG organizes International TOVS Study Conferences which have met approximately every 18 months since 1983. The most recent conference, the Nineteenth International TOVS Study Conference (ITSC-19) was held in Jeju Island, South Korea in 2014.

Through the ITWG forum operational and research users of TOVS/ATOVS/AIRS/IASI and other atmospheric sounding data have exchanged information on data processing methods, derived products, and the impacts of radiances and inferred atmospheric temperature and moisture fields on numerical weather prediction, and weather and climate studies.

The conferences include oral and poster presentations, and the formation of working sub-groups to discuss issues and provide actions and recommendations to share with the international community in the following areas important to the science:

- Radiative Transfer and Surface Property Modelling,
- ATOVS/TOVS and other Sounder Data in Numerical Weather Prediction,
- Satellite Sounder Science and Products,
- TOVS/ATOVS in Climate Studies,
- Advanced Infrared Sounders, and
- International Issues and Future Systems.

There are also technical sub-groups which meet informally to co-ordinate ATOVS and EOS direct broadcast processing software, radiative transfer models and frequency protection issues relevant to the ITWG community.

The conference Working Group Report summarizes the recommendations and actions of these working groups. Technical Proceedings of the scientific presentations and posters are also published. The ITWG web site (http://cimss.ssec.wisc.edu/itwg/) contains electronic versions of the conference papers, presentations and posters. Together, these documents and web pages reflect the conduct of highly successful international meetings.

This funding provided partial resources to conduct the 19th ITSC in South Korea from 26 March – 1 April 2014. The final working group report from this meeting is located at:

http://cimss.ssec.wisc.edu/itwg/itsc/itsc19/itsc19_wg_report_final.pdf

196 participants (Figure 121) attended the Conference from 35 organizations, providing a wide range of scientific contributions. Fifteen countries and three international organizations were represented: Brazil, Canada, China, Taiwan, France, Germany, India, Japan, Norway, Russia, South Korea, Sweden, Switzerland, United Kingdom, United States, ECMWF, EUMETSAT, and the WMO. For the fourth successive meeting the number of attendees broke the record for the highest ever attendance. The Working Groups had very productive discussions and it was again encouraging to see a large number of new, younger scientists participating. This was the first time that ITWG met formally as sub-group of CGMS, and the group warmly appreciated this formal recognition, while continuing the important ties with the International Radiation Commission (IRC).

Figure 121. 2014 ITSC-19 Attendees in South Korea.

49. EOY NOAA NESDIS CIMSS Graduate Student Support

CIMSS Task Leader: Steve Ackerman (PI), Robert Holz (Co-I)

NOAA Long Term Goals:

- Weather-Ready Nation

NOAA Strategic Goals:

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

CIMSS Research Themes:

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

Project Overview

This project supported a Graduate Research Fellowship at the University of Wisconsin–Madison (UW–Madison) in cooperation with the STAR NESDIS. The Cooperative Institute of Meteorological Satellite Studies (CIMSS) and the Department of Atmospheric and Oceanic Sciences (AOS), in conjunction with the STAR collaborated to support graduate research. Fellowship recipients at the UW–Madison will have joint mentors from the two institutions and will spend a portion of their research time working with NOAA scientists on topics directly related to STAR and ASPB science thrusts.

Summary of Accomplishments and Findings

This project supported a Graduate Research Fellowship at the University of Wisconsin–Madison (UW–Madison) in cooperation with the STAR NESDIS. The Cooperative Institute of Meteorological Satellite Studies (CIMSS) and the Department of Atmospheric and Oceanic Sciences (AOS), in conjunction with the STAR collaborated to support graduate research. Fellowship recipients at the UW–Madison will have joint mentors from the two institutions and will spend a portion of their research time working with NOAA scientists on topics directly related to STAR and ASPB science thrusts. The Graduate Research Fellowship includes a competitive stipend and the Director of CIMSS and researchers at ASPB will provide guidance to the fellowship recipients throughout their studies. This proposal builds on the success of a previous NASA program that sponsored PhD students.

These fellowships are a sustainable and coherent education program that is consistent with the principles and objectives of the NOAA education strategy to train the next generation of scientists to use satellite observations to an interdisciplinary Earth system science approach.

Students will have joint mentors from the University of Wisconsin–Madison and NOAA/NESDIS working on problems directly related to NOAA's future satellite thrusts. Assistantships are anticipated in the following areas: Radiation and Remote Sensing, Cloud and Atmospheric Physics, Oceanography, Climate Processes and Climate Change, Planetary Atmospheres, Synoptic and Mesoscale Meteorology, Large Scale Dynamics, and Data Assimilation.

Some key elements of this fellowship are:

- Collaboration between the two institutions (UW–Madison and NOAA NESDIS) will be jointly agreed upon by both sides. In particular, research themes will be identified jointly between collaborating researchers.
- The collaborating researchers will serve on the student's committee and participate in the development of the research training of the student.

NOAA STAR is supporting a M.S. research assistantship for Alexa Ross in the area of cloud report sensing.

M.S. Title: Investigating Correlations of Horizontally Oriented Ice and Precipitation in Maritime Clouds Using Collocated CloudSat, CALIOP, and MODIS Observations.

M.S. Description: The Version 3 CALIOP Phase Retrieval Algorithm is able to distinguish between horizontally oriented ice clouds and clouds with randomly oriented ice. By taking advantage of the nearly synchronous orbits of the A-train constellation, an opportune dataset from 2007 is created that includes collocated products from CloudSat, CALIOP, and MODIS. Seasonal and regional variations are found in the relationship between ice orientation and precipitation. Ice orientation also correlates to MODIS cloud properties such as optical thickness and effective radius.

After the first year, it will be the responsibility of the collaborating researchers to jointly support the student through the remainder of the education program.

50. CIMSS Research Activities in the VISIT Program in 2014

CIMSS Task Leaders: Scott Bachmeier, Scott Lindstrom, Steve Ackerman
CIMSS Support Scientists: Tom Whittaker, Jordan Gerth
NOAA Collaborators: Tim Schmit, Robert Aune, Cooperative Institute for Research

in the Atmosphere (CIRA), Forecast Decision Training Branch (FDTB)

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

The focus for the proposed work was on continuing to create Virtual Institute for Satellite Integration Training (VISIT) distance learning modules for a broad satellite meteorology audience, providing valuable satellite imagery interpretation materials that can be used in education and training, and also on maintenance and updates to existing satellite meteorology lesson material.

There remains a lack of adequate satellite-based education and training on a number of important topics that have direct relevance to typical forecast problems. Some of these topics include: identification of deformation zones, jet streaks, cloud patterns related to upper level wind fields, warm and cold moist conveyor belts, fog detection, turbulence signatures, and air quality.

The presence of fully-functioning Advanced Weather Interactive Processing System (AWIPS I and AWIPS II) workstations at CIMSS allows for faster development of new educational materials that address these types of satellite interpretation topics (and also facilitates more frequent updates to pre-existing modules) as new case study examples are observed on a daily basis. This real-time AWIPS capability gives CIMSS the unique ability to present these satellite interpretation topics in a context and format that the National Weather Service (NWS) forecaster is familiar with.

We also proposed to continue exploring the creation of lessons in the self-contained Weather Event Simulator (WES) format, which is an AWIPS training format that is widely used by NWS forecast offices. A pair of WES cases using simulated Advanced Baseline Imager (ABI) data have been developed at CIMSS (headed by Tim Schmit) as part of the GOES-R Proving Ground effort.

We planned to continue to leverage the real-time AWIPS capabilities at CIMSS to collect a variety of satellite and other remote sensing data during interesting or high societal impact weather events that occurred within a variety of regions and seasons. CIMSS also planned to continue to act as a "beta test site" for the next-generation AWIPS II, serving as a testbed for new satellite products in an operational environment (as was successfully accomplished with the "MODIS Products in AWIPS" and the "POES and AVHRR Satellite Data in AWIPS" projects). Imagery from the Suomi National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) instrument is also now being created in an AWIPS format, with the infrastructure in place to distribute these high spatial resolution satellite images to NWS forecast offices. A VISIT lesson "VIIRS Satellite Imagery in AWIPS" was developed to help ensure forecaster readiness in concurrence with the flow of VIIRS data to their AWIPS workstations.

Summary of Accomplishments and Findings

Twenty "live" instructor-led VISITview teletraining sessions were given to a total of 21 NWS forecasters during this period, on the following eight topics: (1) "Interpreting Satellite Signatures," (2) "TROWAL Identification," (3) "Suomi NPP VIIRS Satellite Products in AWIPS," (4) "Mesoscale Convective Vortices," (5) "Objective Satellite-Based Overshooting Top and Enhanced-V Anvil Thermal Couplet Signature Detection," (6) "Basic Satellite Principles," (7) "Convective Cloud-Top Cooling and UW Convective Initiation," and (8) "Forecaster Training for the GOES-R Fog/Low Stratus (FLS) Products." These VISIT lessons – along with all other VISIT and satellite-related training lessons – are also available for NWS staff to access via the US Department of Commerce Learning Center (CLC). Because the Department of Commerce has changed CLC vendors, there was considerable effort to change the Quiz Formats associated with the online training modules.

In addition, CIMSS made significant contributions to the development of MetEd modules "Advanced in Space-Based Nighttime Visible Observation," "GOES-R ABI: Next Generation Satellite Imaging," and "Suomi NPP: A New Generation of Environmental Monitoring Satellites."

An Articulate Presenter teletraining ("NUCAPS Soundings in AWIPS") was developed for the Hazardous Weather Testbed, in collaboration with Bill Line (NOAA/CIMSS/SPC), Dan Nietfeld (NWS OAX), Chris Barnet and Antonia Gambacorta (STC).

During the 01 April 2014 to 31 March 2015 period, 150 new posts were added to the CIMSS Satellite Blog: http://cimss.ssec.wisc.edu/goes/blog (the top hit in a Google search for the term 'Satellite blog'). The CIMSS Satellite Blog continues to serve as an expanding, searchable library of satellite products and meteorological case studies that can be used in the development of future VISIT teletraining modules. The CIMSS Satellite Blog also acts as an important source of "Just-In-Time" satellite training material for weather events that have recently occurred (or to announce important changes in operational satellites or satellite products). Although not directly supported by VISIT, there were also 78 posts on the 'Fused Fog' Blog: http://fusedfog.ssec.wisc.edu. VISIT does support funding for training on the GOES-R IFR Probability Fields that are described in the blog.

Members of the CIMSS VISIT team also participated in GOES-R Proving Ground teleconference calls and VISIT/SHyMet teleconference calls. These activities are important because they help in the identification and prioritization of new satellite training topics, especially related to GOES-R proxy data that are helping prepare NWS forecasters for the GOES-R era. In addition, members attended the GOES-R User Readiness meeting in Kansas City (June 2014) and the NOAA Satellite Science Week in Boulder (February 2015).

51. Sea Ice Thickness from Aqua and Terra Data Acquisition, Evaluation and Applications

CIMSS Task Leader: Xuanji Wang
CIMSS Support Scientist: Yinghui Liu
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

This project focuses on the estimation of sea ice thickness using our newly developed One-dimensional Thermodynamic Ice Model (OTIM) (Wang et al., 2010) with satellite-derived forcing fields, and the one using Lagrangian tracking method (Fowler et al., 2004) that was developed at the University of Colorado (CU) by our collaborators, which calculates ice age first and then generates a proxy thickness data set based on age vs. thickness relationships (Maslanik et al., 2007). The main goals of this project are to develop, evaluate, and use improved data sets to assess fundamental changes in sea ice thickness, volume and age for the purpose of use of these data for evaluating the performance of sea ice simulations within a state-of-the-art climate model.

Research at CIMSS focuses on the generation and estimation of ice thickness from optical (visible/infrared) sensors such as AVHRR, MODIS, and VIIRS. This is the last annual report for this project.

Summary of Accomplishments and Findings

This report covers the period from 1 April 2014 to 31 March 2015. During this period, specific tasks included:

Activity: An extended MODIS Polar Pathfinder composite dataset (MPP-x), in addition to basic MODIS composite dataset (MPP), for the period of 2003~2013 has been reprocessed several times with frequent OTIM updates. MPP and MPP-x are similar in form and function to the APP and extended APP (APP-x) datasets. The inter-comparisons have been done between OTIM and other ice thickness products from other satellites, aircraft, and numerical model. Climatological changes in sea ice were also performed for both poles. Specific tasks included:

- All MPP-x data starting from 2003 to 2013 (half year for 2013) were reprocessed for the Arctic and the Antarctic, daily composites of MPP-x data at local solar times of 04:00 (Arctic)/02:00 (Antarctic) and 14:00 (both Arctic and Antarctic) were generated on the EASE grid with cloud mask, ice surface temperature, ice thickness, and ice age information.
- APP-x data were also reprocessed and now cover the period of 1982 ~ 2013 for both poles.
- OTIM has been improved and modified several times, and is still undergoing improvement for better ice thickness and ice age dataset.
- APP-x and MPP-x have been reprocessed several times to incorporate improvements in OTIM.
- Sea ice thicknesses from six datasets in addition to the MPP-x have been collected and compared that are: the Extended AVHRR Polar Pathfinder (APP-x), ICESat from the Jet Propulsion Lab, CryoSat-2 from the Alfred Wegener Institute, SMOS from the

University of Hamburg, and NASA IceBridge aircraft flights. Additionally, the satellite products are also compared to ice thickness from the Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS).

- Trends in sea ice thickness in the Arctic and Antarctic over 1982~2013 have been generated with APP-x data, and analyzed for climate study.

Findings: The APP-x and MPP-x sea ice thickness data retrieved with OTIM were used to perform comparisons with sea ice thickness products from satellites, aircraft, and numerical model, and also used to analyze polar region sea ice thickness change associated with polar region climate change.

- The inter-comparison is complicated by the fact that the datasets cover different time periods and spatial resolutions, with the APP-x and PIOMAS having the longest record (1982 – present). Comparisons are done for the period of overlap between all datasets, with PIOMAS as a reference data set. Results show that biases relative to PIOMAS range from -0.3 (SMOS) to +0.5 (CryoSat-2, ICESat, APP-x, MPP-x). SMOS is intended for thin ice estimates only. All products show thinning Arctic sea ice since 1980.
- Trends range from less than 1 cm/year to 6 cm/year for some areas in the Arctic Ocean. Multiyear ice is far less prevalent now than 20 years ago. Such a change is significant given that young, thinner ice melts more easily, deforms much more easily, moves faster, and is therefore exported more readily.

IceBridge period is from March 31 2009 to April 25 2013. Sea ice thickness data from APP-x, MPP-x, ICESat, CryoSat-2, SMOS, IceBridge, and PIOMAS were averaged for March only over 2009-2013 because of very few data available in other months from IceBridge. Figure 122 shows the monthly mean sea ice thickness in March from APP-x, MPP-x, CryoSat-2, SMOS, PIOMAS, and IceBridge over 2011-2013. The average sea ice thickness is 2.94 m with standard deviation of 0.57 m, 2.37 m with standard deviation of 0.48 m, 2.53 m with standard deviation of 0.61m, 1.44 m with standard deviation of 0.29 m, 2.41 m with standard deviation of 0.58 m, and 2.36 m with standard deviation of 1.03 m, respectively for APP-x, MPP-x, CryoSat-2, SMOS, PIOMAS, and IceBridge.

Analyses of the changes in sea ice extent, concentration, thickness and volume from OTIM with APP-x data products were carried out to update the previous time series of the changes. Analysis of the time series of sea ice in terms of ice extent, thickness, concentration, and volume over 1982-2013 indicates clearly that the Arctic Ocean is losing its ice much more than its counterpart, the Antarctic Ocean. Figure 123 shows the Arctic sea ice trends in terms of ice extent, concentration, thickness, and volume for the cold (March) and warm (September) periods over 1982-2013 for the Arctic Ocean part northward of 60oN. Significant declining trends in sea ice extent and volume have been found at the decadal rates of -1366000 km2 and -3813 km3 for the cold (represented by March) period, and the decadal rates of -1484000 km2 and -1095 km3 for the warm period (represented by September), respectively. Arctic sea ice has been thinning at a decadal rate of -4.65 cm in the cold period while ice concentration has been increasing at a decadal rate of 1.67%. In the warm period, there is a small positive trend (0.10 cm per decade) in sea ice thickness, but the trend is not statistically significant. The ice concentration in the warm period shows a decreasing trend at the decadal rate of -1.71%.

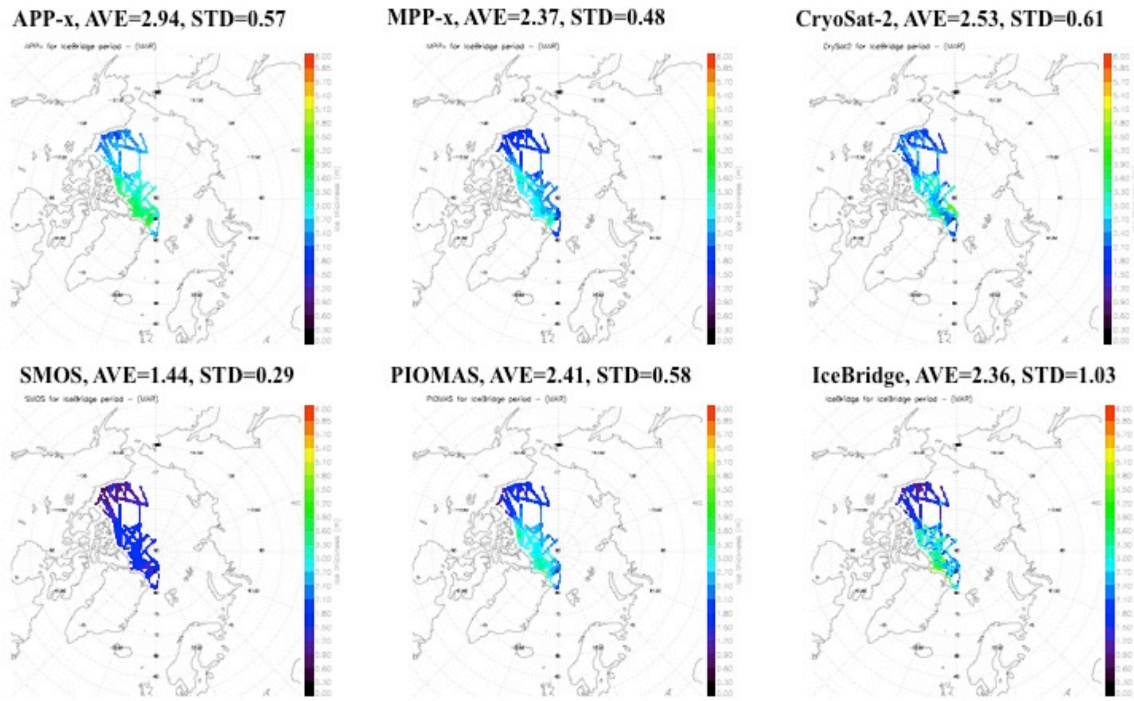


Figure 122. Monthly mean sea ice thickness in March from APP-x, MPP-x, CyroSat-2, SMOS, PIOMAS, and IceBridge over 2011-2013.

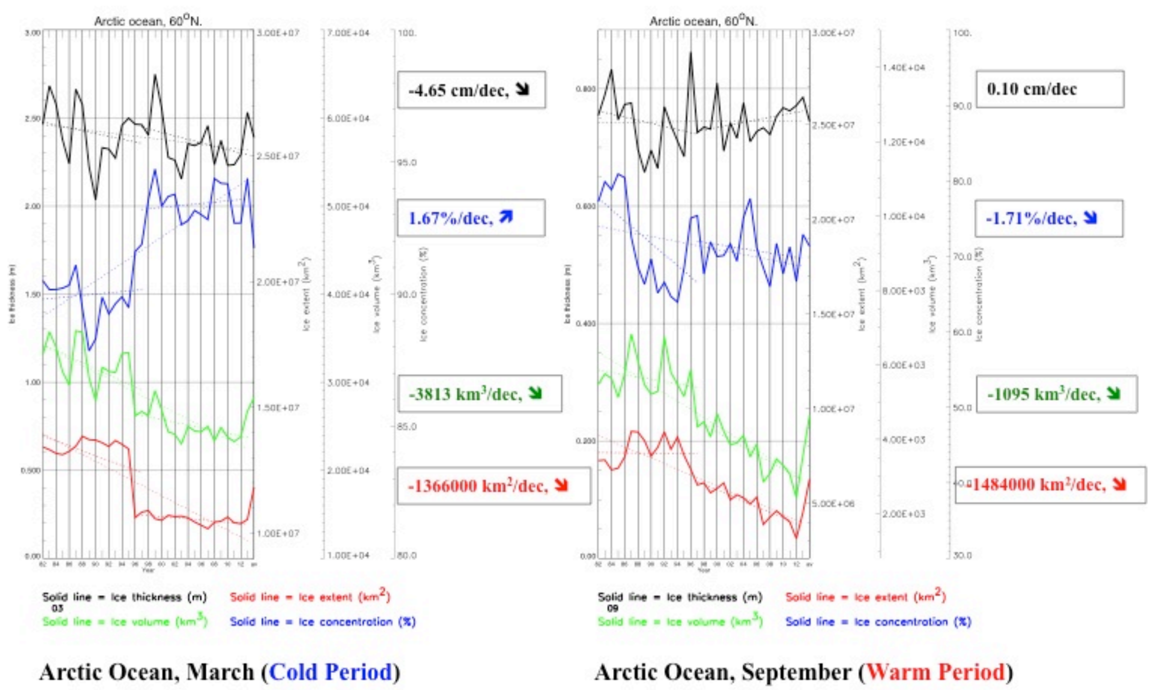


Figure 123. Arctic sea ice decadal trends in terms of extent, concentration, thickness, and volume for the cold period (March) on left-hand side and warm period (September) on the right-hand side over 1982-2013. The black line is ice thickness, the blue line is ice concentration, the green line is ice volume, and the red line is ice extent. The numbers on the right side of each plot are the decadal trend values, the arrow marks on the right side of the numbers indicate the corresponding trends statistically significant.

One of the objectives of this task is to assess the degree to which the OTIM model + satellite-derived ice thicknesses correlate with the CU age product, and to use the comparisons to estimate relationships between age and thickness. Data used spanned the period from 1982-2011. However, since there are some uncertainties in the quality of the AVHRR temperature data 2006 onward, the bulk of the analysis is limited to 1982-2011. As Figure 124 shows, the OTIM data is consistent with the age product in terms of showing the heaviest ice within the central Arctic, and particularly in a year like 2005, when the thickest ice is found along the Canadian sector of the Arctic Ocean. Calculation of mean thickness per age category finds the expected difference between first-year and multiyear ice (defined here as ice at least 2 years old). However, there is no noticeable difference in thickness across age categories. This is the case for different portions of the time period as well as the full period.

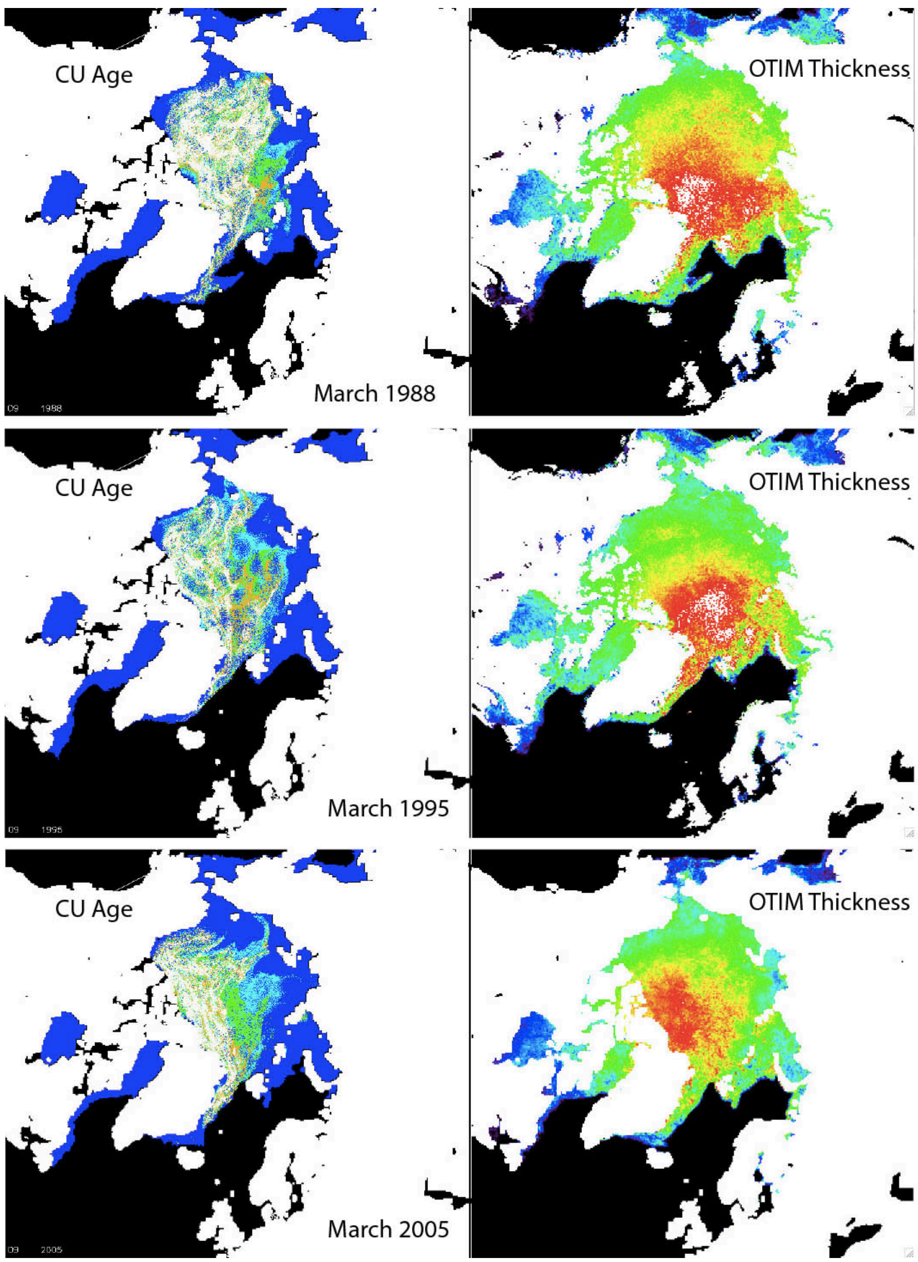


Figure 124. Comparison of CU age (left) and OTIM ice thickness (right). Warmer colors represent older ice and thicker ice respectively.

Publications and Conference Reports

Wang, X. and J. R. Key, 2015, Sea Ice Thickness from Satellite, Aircraft, and Model Data, *2015 NOAA Satellite Science Week*, 23-27 February, 2015, Convening at the Center Green Campus of the University Corporation for Atmospheric Research, 3080 Center Green Drive, Boulder, CO, USA.

Wang, X. and J. R. Key, 2014, Insight into Arctic and Antarctic climate changes over 1982~2013 from satellite observations, The 9th SPIE Asia-Pacific Remote Sensing Symposium, Beijing, China, 13-17 October 2014.

Key, J.R. and X. Wang, 2014, Intercomparison of Sea Ice Thickness from Satellite, Model, and Aircraft Data (Talk), The Climate Symposium 2014, Darmstadt, Germany, 15 October 2014

Wang, X., Ron Kwok, Jinlun Zhang, Yinghui Liu, and Jeffrey R. Key, 2013, Arctic Sea Ice Thickness from Satellite Observations, Aircraft Field Campaign Measurements, and Numerical Model Simulations, 2013 AGU Fall Meeting, 9-13 December 2013, San Francisco California, USA.

Key, J. R., X. Wang, and Y. Liu, 2013, Monitoring Change in the Arctic In <<Satellite-based Applications on Climate Change>>, J. Qu, A. Powell, M.V.K. Sivakumar (eds.), Springer, 371 pp., ISBN 978-94-007-5872-8, 2013.

Key, J. R., R. Mahoney, Y. Liu, P. Romanov, M. Tschudi, I. Appel, J. Maslanik, D. Baldwin, X. Wang, and P. Meade, 2013, Snow and Ice Products from Suomi NPP VIIRS, JGR-Atmospheres, VOL. 118, 12,816–12,830, doi:10.1002/2013JD020459, Dec 2013.

References

C. Fowler et al., 2004: Satellite-derived evolution of Arctic sea ice age: October 1978 – March 2003. IEEE Geosci. & Rem. Sens. Ltrs., Vol. 1, #2.

J. Maslanik et al., 2007: A younger, thinner Arctic ice cover: Increased potential for rapid, extensive sea-ice loss. Geoph. Res. Ltrs., 34, L24501.

X. Wang, J. Key, and Y. Liu, 2010, A thermodynamic model for estimating sea and lake ice thickness with optical satellite data, J. Geophys. Res., Vol. 115, C12035, 14 PP., 2010, doi:10.1029/2009JC005857.

Appendix 1: List of Awards to Staff Members

2015

Jessica Gartzke: Reid Bryson Award

Sarah Griffin, Derrick Herndon, Tim Olander, John Sears, Dave Stettner, Chris Velden, Steve Wanzong, and Tony Wimmers: AMS Special Award

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"

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

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

2014

Steven Ackerman: AMS Fellow

Steven Ackerman: Colorado State University's Atmospheric Science Outstanding Alumni Award

Denis Botambekov, Corey Calvert, Richard Dworak, Richard Frey, Bob Holz, Yue Li, Yinghui Liu, Min Oo, Andi Walther, and Xuanji Wang: NOAA-CIMSS Collaboration Award: "For increasing the scientific value of the Suomi satellite environmental cryosphere data products to meet NOAA users' needs"

Wayne Feltz, SSEC/CIMSS: University of Wisconsin Police Chief's Award for providing weather forecasts for Camp Randall Stadium home football games 2000-2014

Wayne Feltz: Graduate School – Committee on Academic Staff Issues Certificate of Appreciation for serving as Vice Chair of committee since July 2009 from Dean Martin Cadwallader

Mathew Gunshor, Scott Lindstrom, and James Nelson: NOAA-CIMSS Collaboration Award: "For contributing to restore GOES-13 to operational service following a major anomaly

Bormin Huang: NVIDIA CUDA Fellow

Bormin Huang: Intel Parallel Computing Center

Dave Tobin, Jacola Roman, and Jonathan Gero: Best Poster Presentations at ITSC-19 (Gold, Silver and Bronze, respectively)

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. Note that data for 2015 is incomplete.

During the period 2013-2015, 48.0% of peer reviewed articles included one or more NOAA co-authors.

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	23	19	5	1	1	0	8	3	0	41	46	5
Non Peer Reviewed	2	0	0	1	0	0	0	0	0	1	0	0

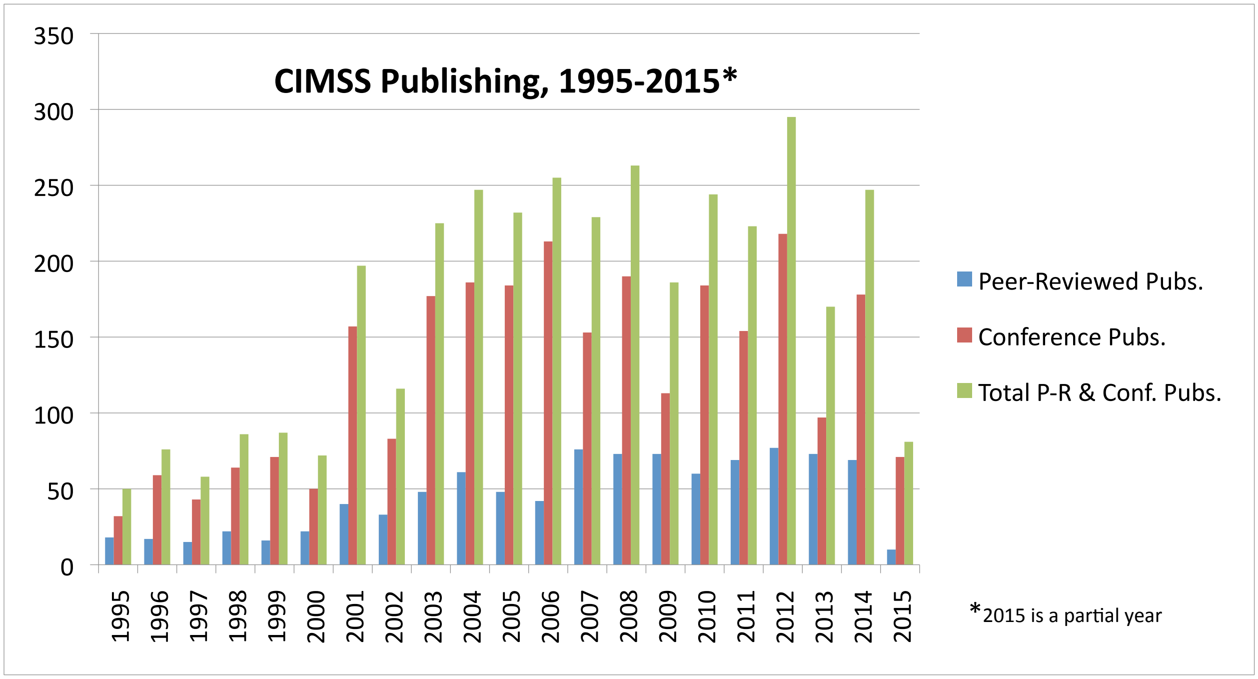
*2015 incomplete: does not include forthcoming papers or papers submitted for publication.

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	120	109	9	22	19	3	47	33	8
Non Peer Reviewed	5	0	0	2	0	0	0	0	0

*2015 incomplete: does not include forthcoming papers or papers submitted for publication.

Table 3. CIMSS Publishing History, showing peer reviewed and conference publications for the period 1995-2015.



*2015 incomplete: does not include forthcoming papers or papers submitted for publication and for all years, does not include non-reviewed papers.

Appendix 3: CIMSS Staff and Student Hours on NOAA Cooperative Agreement Projects

Period Covered: Apr14 - Mar15

Name	Category	Total Hrs	FTE %
Bachmeier, Anthony	Researcher II	1,763.0	100%
Bah, Momodou	Researcher II	1,763.0	100%
Botambekov, Denis	Researcher I	1,763.0	100%
Calvert, Corey	Researcher I	1,763.0	100%
Cintineo, John	Researcher I	1,763.0	100%
Cronce, Lee	Researcher I	1,763.0	100%
Cureton, Geoffrey	Manager I	1,763.0	100%
Gerth, Jordan	Researcher I	1,763.0	100%
Gravelle, Chad	Researcher II	1,763.0	100%
Han, Hyo-Jin	Scientist, PostDoc	1,763.0	100%
Jung, James	Scientist II	1,763.0	100%
Lee, Yong-Keun	Researcher III	1,763.0	100%
Li, Jinlong	Researcher II	1,763.0	100%
Li, Yue	Researcher I	1,763.0	100%
Mindock, Scott	Computer Scientist II	1,763.0	100%
Rogal, Marek	Researcher I	1,763.0	100%
Straka, William	Researcher III	1,763.0	100%
Terborg, Amanda	Researcher I	1,763.0	100%
Wanzong, Steven	Researcher II	1,763.0	100%
Gunshor, Mathew	Researcher II	1,758.0	100%
Walther, Andi	Researcher II	1,712.0	97%
Sieglaff, Justin	Researcher II	1,696.0	96%
Dworak, Richard	Researcher III	1,612.0	91%
Lim, Agnes	Researcher I	1,588.0	90%
Hoffman, Jay	Researcher III	1,529.0	87%
Li, Zhenglong	Researcher III	1,508.0	86%
Zhang, Hong	Researcher II	1,504.0	85%
Nelson, James III	Researcher III	1,495.5	85%
Schiffer, Eva	Computer Programmer I	1,408.0	80%
Hiley, Michael	Researcher I	1,404.0	80%
Wang, Pei	Student, Graduate	1,350.0	77%
Foster, Mike	Researcher III	1,336.0	76%
Davies, James	Computer Programmer II	1,332.0	76%
Strabala, Kathleen	Scientist II	1,332.0	76%
Li, Jun	Scientist II	1,324.0	75%
Liu, Yinghui	Researcher I	1,304.0	74%
Moeller, SzuChia	Researcher II	1,295.0	73%
Garcia, Raymond	Computer Scientist III	1,286.0	73%
Griffin, Sarah	Researcher II	1,280.0	73%
Braun, Jessica	Manager I	1,240.0	70%
Bearson, Nicholas	Researcher I	1,231.0	70%
Brunner, Jason	Researcher II	1,229.0	70%

Stettner, David	Researcher I	1,224.0	69%
Lenzen, Allen	Researcher III	1,213.3	69%
Martin, Graeme	Computer Scientist II	1,187.0	67%
Lindstrom, Scott	Researcher II	1,173.0	67%
Merrelli, Aronne	Researcher I	1,144.0	65%
Huang, Hung-Lung	Scientist III	1,139.0	65%
Rink, Thomas	Computer Scientist I	1,096.0	62%
Smith, Nadia	Researcher II	1,083.9	61%
Nebuda, Sharon	Researcher I	1,078.4	61%
Feltz, Michelle	Student, Graduate	1,072.5	61%
Letterly, Aaron	Student, Graduate	1,050.0	60%
Weisz, Elisabeth	Researcher II	1,036.0	59%
Greenwald, Thomas	Scientist I	1,009.0	57%
Santek, David	Scientist I	999.8	57%
Hoese, Dave	Computer Programmer III	997.0	57%
Quinn, Greg	Computer Programmer II	968.0	55%
Gartzke, Jessica	Student, Undergrad	964.0	55%
Herndon, Derrick	Researcher I	964.0	55%
Jasmin, Tommy	Computer Scientist II	955.0	54%
DeSlover, Daniel	Researcher II	954.9	54%
Wang, Xuanji	Scientist, PostDoc	928.0	53%
Mooney, Margaret	Outreach Specialist II	924.0	52%
Vasys, Egle	Outreach Specialist I	916.9	52%
Cintineo, Rebecca	Researcher I	914.0	52%
Avila, Leanne	Documentation Specialist III	907.3	51%
Hubbard, Shane	Researcher I	891.0	51%

Schaack, Todd	Researcher III	858.0	49%
Schreiner, Anthony	Researcher III	844.0	48%
Plokhenko, Youri	Researcher III	840.0	48%
Razenkov, Ilya	Electronics Technician I	830.2	47%
Daloz, Anne-Sophie	Scientist, PostDoc	811.5	46%
Lewis, William	Researcher I	783.0	44%
Feltz, Wayne	Scientist I	746.5	42%
Dengel, Russell	Computer Programmer III	741.8	42%
Olander, Timothy	Researcher II	734.0	42%
Hoover, Brett	Researcher II	725.0	41%
Feltz, Joleen	Researcher II	711.0	40%
Gumley, Liam	Scientist I	708.0	40%
Maddux, Brent	Student, Graduate	682.5	39%
Moeller, Christopher	Scientist I	682.0	39%
Ross, Alexa	Student, Graduate	630.0	36%
Zhu, Feng	Student, Graduate	630.0	36%
Borg, Lori	Researcher III	604.8	34%
Holz, Robert	Scientist II	592.0	34%
Kuehn, Ralph	Researcher II	592.0	34%
Wimmers, Anthony	Scientist I	580.0	33%
Otkin, Jason	Scientist I	576.0	33%
Gjermo, Britta	Student, Undergrad	533.4	30%

Rozoff, Christopher	Researcher III	456.0	26%
Roman, Jacola	Student, Graduate	450.0	26%
Knuteson, Robert	Scientist I	443.0	25%
Tobin, David	Scientist I	429.0	24%
Antonelli, Paolo	Researcher II	424.0	24%
Smith, Eric	Student, Undergrad	423.0	24%
Flynn, Bruce	Computer Scientist II	413.0	23%
Nelson, Kyle	Student, Graduate	392.2	22%
Menzel, Wolfgang	Scientist III	388.8	22%
Monette, Sarah	Researcher II	388.0	22%
Molling, Christine	Researcher III	383.6	22%
Petersen, Ralph	Scientist III	377.3	21%
Frey, Richard	Computer Programmer III	365.0	21%
Taylor, Joseph	Engineer II	364.0	21%
Velden, Christopher	Scientist III	361.5	21%
Ackerman, Steven	Scientist III	353.9	20%
Melnik, Katerina	Researcher I	344.0	20%
Nagle, Frederick	Post Retirement Rehire	322.0	18%
Zhong, Yafang	Researcher I	305.9	17%
Borbas, Eva	Researcher II	272.0	15%
Schmidt, Christopher	Researcher III	252.0	14%
Revercomb, Henry	Scientist III	248.0	14%
LaPorte, Daniel	Researcher III	230.0	13%
Hosley, Kyle	Student, Graduate	225.0	13%
Bunge, Carissa	Outreach Specialist I	207.0	12%
Lawson, Martin	Engineer I	206.0	12%
Cheng, Kai-Yuan	Student, Graduate	205.6	12%
Burgess, Genevieve	Student, Undergrad	204.5	12%
Smith, William, Sr	Scientist III	200.8	11%
Kohrs, Richard	Researcher II	186.0	11%
Bellon, Willard	Data Manager II	183.5	10%
Loken, Eric	Student, Undergrad	181.8	10%
Dutcher, Steven	Computer Scientist III	176.0	10%
Oo, Min Min	Scientist, PostDoc	168.0	10%
Sears, John	Researcher I	168.0	10%
Huang, Bormin	Scientist II	158.0	9%
Gero, Jonathan	Researcher II	124.0	7%
Lazzara, Mathew	Researcher III	121.4	7%
Klabunde, Hayden	Outreach Specialist I	110.0	6%
Han, Yi	Student, Undergrad	109.0	6%
Mikolajczyk, David	Researcher I	108.0	6%
Kulie, Mark	Researcher I	106.7	6%
Pettersen, Claire	Researcher I	106.0	6%
Best, Fred	Manager III	102.0	6%
Heck, Patrick	Researcher II	98.0	6%
Vasys, Victoria	Student, Undergrad	97.0	6%
Wentland, Andrew	Student, Graduate	90.0	5%
Thielman, Donald	Engineer III	88.6	5%
Robus, William	Manager I	74.0	4%
Olson, Erik	Computer Scientist I	68.0	4%

Ciganovich, Nikola	Engineer, Assistant/Technician	65.8	4%
Hartwick, Samuel	Student, Undergrad	64.5	4%
Mindock, Maxwell	Student, Undergrad	43.5	2%
Baum, Bryan	Scientist II	40.0	2%
Spangler, Roseann	Data Center Specialist	37.0	2%
Hammacher, Chance	Student, Undergrad	36.3	2%
Beavers, Jonathan	Computer Programmer III	36.0	2%
Parker, David	Computer Scientist II	32.0	2%
Ratcliff, Douglas	Data Center Specialist	32.0	2%
Werner, Mark	Engineer III	30.0	2%
Bromley, Gabriel	Student, Undergrad	26.5	2%
Mulligan, Mark	Manager III	19.5	1%
Yan, Yu	Student, Graduate	13.9	1%
Heinzelman, Jay	Researcher II	11.0	1%
Ziesemer, Mitchell	Student, Undergrad	10.0	1%
Costanza, Carol	Researcher I	9.0	1%
Wu, Wenhua	Business Service Provider	4.0	0%
Baggett, Kevin	Computer Programmer III	3.0	0%
Scheele, Christopher	Student, Undergrad	3.0	0%
Hackel, Denny	Computer Programmer II	2.0	0%
Garcia, Joseph	Computer Scientist II	1.0	0%
Stroik, Jesse	Technical Computing Specialist III	0.0	0%

Appendix 4: Research Topics of Current CIMSS Graduate Students and Post-Doctors

NOAA Funded Graduate Students

Barbara Arvani
Ph.D. research: Working with Dr. Brad Pierce and other CIMSS scientists on linking particulate matter (PM) measured at ground with satellite Aerosol Optical Depth (AOD) retrievals within the Po Valley, Italy and implementation of the IDEA-International aerosol forecasting system at the University of Modena and for air quality assessments/forecast.

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 infrared sounder data. A sounder and GPS RO profile-to-profile matchup methodology was developed for the comparison of the sounder temperature profiles to GPS RO. This methodology is applied to products from multiple sensors and platforms, including the NASA AIRS, NPP CrIMSS, NOAA IASI, and CDAAC COSMIC and GRAS profile products. Additionally, forward calculations allow for a comparison in radiance space. This work focuses on the stratospheric temperature and is motivated in part by the need for instruments that can provide climate quality datasets.

Jordan Gerth (Graduated)
Post Doc Research. PhD Thesis title: "Sky Cover." A blended sky cover analysis comprised of in-situ and remote observations is developed. The blended analysis provides the best depiction of cloud cover over the contiguous United States due to a logic structure that accounts for the relative strengths of both ground-based ceilometer measurements (e.g., fog and low cloud) and geostationary satellite effective cloud amounts (e.g., high cloud). A framework to develop a mathematical and physical relationship between the new sky cover analysis and existing numerical forecast model cloud and moisture variable output is proposed. During the test period, the framework identified relative humidity and cloud water mixing ratio in the lower troposphere as most consistently contributing to the overall sky cover for a given location.

Amanda Gumber
The research is focused on studying the 3D radiative effects of clouds using MODIS satellite data. Using a time series 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

MS title: Evaluation of tropical cyclone forecast models with hyper-spectral IR sounder measurements. This research uses advanced infrared (IR) sounder (AIRS and CrIS) to evaluate the capability of NWP models (GFS, HWRF) on simulating the water vapor transportation in tropical cyclone environment. Forecast data from three models will be used: GFS (NOAA operational), HWRF (NOAA operational) and SDAT (CIMSS research system), the evaluation will be performed based on the comparisons between the calculated and the observed AIRS/CrIS brightness temperatures, and the community radiative transfer model (CRTM) will be used in brightness temperature (BT) calculation for AIRS/CrIS channels peaking at different atmospheric layers. The objective is to understand the capability of NWP models on simulating the water vapor and its transportation in TC environment and help improving the advanced IR sounder radiance assimilation.

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: Study of 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. Also 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.

William Line *(Graduated)*
M.S. Thesis title: "Using Isentropic Techniques to Improve the Utility of GOES Moisture Observations."
The CIMSS NearCasting model is a lagrangian trajectory model that dynamically projects GOES sounding observations of temperature and moisture forward in time to provide detailed, hourly updated information about the moisture and stability structure of the pre-convective environment 1-9 hours in advance. This study seeks to develop an improved version of the model by computing trajectories in an isentropic framework, since the GOES IR retrievals are made under clear sky conditions, where flow is primarily adiabatic. In addition to providing more accurate stability and shear information, the isentropic NearCasting model allows for the depiction of lift and total isentropic layer moisture, improving forecasts of the timing, location, and type of convection that may occur.

Michael Pavolonis
Ph.D. Thesis title: "Satellite retrievals and analysis of volcanic ash cloud properties." Volcanic clouds impact climate, biogeochemical processes, cloud physics, human health, and aviation (airborne volcanic ash can severely damage aircraft). While all of these impacts are important, the primary motivation behind this dissertation is to utilize satellite data to improve the accuracy and timeliness of the volcanic ash cloud guidance that is operationally provided to the aviation community through improved understanding of the physical behavior of ash clouds. The main objectives of the research are:
-Develop and validate a robust physically based methodology for determining the dominant composition of clouds using weather satellites, with the primary goal of objectively identifying volcanic ash clouds.
-Develop and validate a physically based methodology for retrieving the height, mass loading (mass per unit area), and effective particle radius of volcanic ash clouds using satellite-based infrared measurements commonly available on weather satellites.
-Utilize the satellite-derived ash cloud properties and numerical weather prediction model fields to characterize the macro-physical, micro-physical, and dynamical properties of airborne volcanic ash in space and time, within the context of the background atmospheric state.

Jacola Roman
PhD Thesis title: "Using the Climatological Relationship between Precipitable Water Vapor and Precipitation for Probabilistic Forecasts of Extreme Precipitation." There is a strong link between precipitable water vapor (PWV) and precipitation and by exploiting this relationship an early warning system for extreme precipitation can be created. The goal of this research is to create a tool for estimating the probability of precipitation with a range of potential precipitation amounts by integrating observations from the JPSS NUCAPS algorithm using the ATMS/CrIS sensors on NPP. This tool will be developed for application to direct broadcast (CSPP) where it will be demonstrated in real-time over CONUS land areas and compared against similar microwave only precipitation products. The observed relationship between PWV and precipitation is based on a 10-year climatology of satellite observations from NASA AIRS and TRMM for the entire globe. The conditional probability of precipitation is calculated on a 1ox1o grid along with a potential precipitation amount based on the PWV. Observations from the Suomi-NPP CrIS/ATMS instruments can be used in near-real time to create a decision making tool. Based on the PWV

observation, a probability for precipitation and potential precipitation amount can be given for that exact location within 10 minutes of the observation. The NUCAPS products also provide CAPE and CIN as potential predictors to refine the likelihood of extreme rain events and a moisture thickness to quantify orographic precipitation effects.

Alexa Ross

M.S. Title: "Investigating Correlations of Horizontally Oriented Ice and Precipitation in Maritime Clouds Using Collocated CloudSat, CALIOP, and MODIS Observations." The Version 3 CALIOP Phase Retrieval Algorithm is able to distinguish between horizontally oriented ice clouds and clouds with randomly oriented ice. By taking advantage of the nearly synchronous orbits of the A-train constellation, an opportune dataset from 2007 is created that includes collocated products from CloudSat, CALIOP, and MODIS. Seasonal and regional variations are found in the relationship between ice orientation and precipitation. Ice orientation also correlates to MODIS cloud properties such as optical thickness and effective radius.

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. Thesis topic: Accurate cloud detection is very important for infrared (IR) radiance assimilation; improved 67 cloud detection could reduce cloud contamination and hence improve the assimilation. Although 68 operational numerical weather prediction (NWP) centers are using IR sounder radiance data for 69 cloud detection, collocated high spatial resolution imager data could help sounder sub-pixel 70 cloud detection and characterization. IR sounder radiances with improved cloud detection using 71 AIRS/MODIS were assimilated for Hurricane Sandy (2012). Forecast experiments were run with 72 WRF (Weather Research and Forecasting) as the forecast model and the 3DVAR-based GSI 73 (Gridpoint Statistical Interpolation) as the analysis system. Results indicate that forecasts of both 74 hurricane track and intensity are substantially improved when the collocated high spatial 75 resolution MODIS cloud mask is used for AIRS sub-pixel cloud detection for assimilating 76 radiances. This methodology can be applied to process CrIS/VIIRS onboard Suomi-NPP/JPSS 77 and IASI/AVHRR onboard the Metop series for improved radiance assimilation in NWP.

Andrew Wentland

M.S. Thesis: "Evaluating the RR-Chem Model using DISCOVER-AQ and FRAPPE 2014 Field Observations." In this work, the Rapid Refresh with Chemistry model (RR-Chem), a regional, Eularian chemical transport model, is employed using the most recent National Emissions Inventory emissions database (NEI 2011) to simulate air chemistry in Colorado's Front Range.

Utilizing a variety of measurements made during the FRAPPE and DISCOVER-AQ field campaigns from ground, aerial in situ, and satellite observations, a physical and chemical assessment of the RR-Chem model is conducted.

Students Funded on other projects than NOAA

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.

Willem Marais

Ph.D. Thesis title: "A new approach to inverting and de-noising scatter properties from lidar observations."

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.

John Rausch

Ph.D. Thesis title: "Improvement of MODIS Cloud Property Retrievals through an Adiabatic Method." This work involves estimating MODIS cloud optical depth and multispectral effective radius retrievals for stratiform boundary layer clouds through the use of an adiabatic retrieval method rather than the vertically homogeneous method currently employed in the MODIS Cloud Product. The goal of this research is to provide a more realistic estimate of boundary layer cloud microphysical properties as well as establish a metric of the subadiabaticity of cloud liquid water content profiles.

John Sears *(Graduated)*

M.S. Thesis title: "Investigating the Role of the Upper-Levels in Tropical Cyclogenesis." Recent studies on genesis have been primarily focused on the lower portions of the troposphere. Utilizing a unique satellite wind data set from a recent field study, this research focuses on the upper level dynamics behind tropical cyclogenesis and seeks to determine the role of the upper levels in facilitating lower level development.

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.

William Smith, Jr.

Ph.D. Thesis title: "Using Satellite Data to Improve the Representation of Clouds and their Effects in Numerical Weather Analyses and Forecasts." New cloud products derived from CloudSat and CALIPSO data form the basis for a technique developed to retrieve the vertical distribution of cloud water from passive satellite observations. The technique is applied to GOES data over North America and adjacent oceans and the cloud products ingested into the NOAA Rapid Update Cycle (RUC) assimilation system. The impact of the satellite data on RUC model analyses and forecasts is assessed.

Appendix 5: Visitors at CIMSS 2014-2015 (visits of 3 days or more and key visitors)

Yufei Ai, Peking University

Barbara Arvani, University of Modena

Jing Bai, Xidian University

Hao Chen, Harbin Institute of Technology

Haipeng Chen, Jilin university

Prof. Choi & students, Ewha Women's University (Seoul, Korea)

Pete Francis, UK Met Office

Yuquan Gan, Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences

Xiaohui Gao, Xi'an Institute of Optics and Precision Mechanics, Chinese Academy of Sciences

Olga Gershenzon, ScanEx RDC (Moscow, Russia)

Lingjia Gu, Jilin University

Christopher Hughes, University of Buffalo, NY

Dave Johnson, NASA Langley

Burcu Kabatas, University of Istanbul

Marianne Koenig, EUMETSAT

Ahreum Lee, Seoul National University

Leon Majewski, Australian Bureau of Meteorology

Terhikki Manninen, Finnish Meteorological Institute

Brian Mapes, Rosenstiel School of Marine and Atmospheric Sciences

Adrian McDonald, University of Canterbury (Christchurch, New Zealand)

Lisa Milani, Institute for the Sciences of the Atmosphere and Climate, National Council of Research, Rome, Italy

Martin Mlynczak, NASA Langley

Kouki Mouri, Japanese Meteorological Agency

NOAA Satellite Science Week (55 Registrants)

Aku Riihela, Finnish Meteorological Institute

Satellite Educators' Conference (85 registrants)

Johannes Schmetz, EUMETSAT

Dave Schneider, USGS

Wenjing Shi, China Meteorological Administration

Yasuhiko Sumida, Japanese Meteorological Agency (JMA)

Samantha Tushaus, University of Michigan

Hiroaki Tutiyama, Japanese Meteorological Agency (JMA)

Louis Uccellini, NOAA/National Weather Service

Bruce Wielicki, NASA Langley

Xin Wu, Xidian University

Cong Zhou, Shanghai

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, 2014-2015

CIMSS Peer-Reviewed Publications and Conference Presentations, 2014-15

2015 Peer-Reviewed: Accepted for Publication

Gravelle, Chad M.; Mecikalski, John R.; Line, William E.; Bedka, Kristopher M.; Petersen, Ralph A.; Sieglaff, Justin M.; Stano, Geoffrey T., and Goodman, Steven J., 2015: 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, OK tornado outbreak. Bulletin of the American Meteorological Society, Early Online Release, http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-14-00054.1.

Greenwald, T.J.; Pierce, R. Bradley; Schaack, T.; Otkin, J.A.; Rogal, M.; Bah, K., and Huang, H.-L.: Near real-time production of simulated GOES-R Advanced Baseline Imager data for user readiness and product validation. Bulletin of the American Meteorological Society, in press.

Hennon, C.C.; Knapp, K.R.; Schreck, C.J., III; Stevens, S.E.; Kossin, J.P., et al,: Cyclone center: Can citizen scientists improve tropical cyclone intensity records? Bulletin of the American Meteorological Society, in press.

Kossin, J.P., 2014: Validating atmospheric reanalysis data using tropical cyclones as thermometers. Bulletin of the American Meteorological Society, in press.

LeMarshall, J.; Jung, J.A.; Lee, J.; Barnett, C., and Maddy, E.S., 2014: Improving tropospheric and stratospheric moisture analysis with hyperspectral infrared radiances. Australian Meteorological and Oceanographic Journal, 64, in press.

Otkin, J.A.; Shafer, M.; Svoboda, M.; Wardlow, B.; Anderson, M.C.; Hain, C., and Basara, J., 2015: Facilitating the use of drought early warning information through interactions with agricultural stakeholders. Bulletin of the American Meteorological Society, in press.

Walsh, K.J.E.; Camargo, S.J.; Vecchi, G.A.; Daloz, A.S.; Elsner, J.; Evanuel, K.; Horn, M.; Lim, Y.-K.; Roberts, M., Patricola, C.; Scoccimarro, E.; Sobel, A.H.; Strzzo, S.; Villarini, G.; Wehner, M.; Zhao, M.; Kossin, J.P., et al, 2014: Hurricanes and climate: The U.S. CLIVAR working group on hurricanes. Bulletin of the American Meteorological Society, in press.

2015 Peer-Reviewed Publications

Cureton, Geoffrey P. Retrieval of higher order ocean spectral information from sunglint. IEEE Transactions on Geoscience and Remote Sensign v.53, no.1, 2015, pp36-50.

Daloz, Anne S.; Camargo, S. J.; Kossin, J. P.; Emanuel, K.; Horn, M.; Jonas J. A.; Kim, D.; LaRow, T.; Kim, Y.-K.; Patricola, C. M.; Roberts, M.; Scoccimarro, E.; Shaevitz, D.; Vidale, P. L.; Wang, H.; Wehner, M., and Zhao, M. Cluster analysis of downscaled and explicitly simulated North Atlantic tropical cyclone tracks. Journal of Climate v.28, no.4, 2015, pp1333–1361.

Gultepe, I.; Zhou, B.; Milbrandt, J.; Bott, A.; Li, Y.; Heymsfield, A. J.; Ferrier, B.; Ware, R.; Pavolonis, M.; Kuhn, T.; Gurka, J.; Liu, P., and Cermak, J. A review on ice fog measurements and modeling. Atmospheric Research v.151, no.2015, pp2-19.

Hoover, Brett T. Identifying a barotropic growth mechanism in East Pacific tropical cyclogenesis using adjoint-derived sensitivity gradients. Journal of the Atmospheric Sciences v.72, no.3, 2015, pp1215–1234.

Kossin, James P. Hurricane wind-pressure relationship and eyewall replacement cycles. Weather and Forecasting v.30, no.1, 2015, pp177–181.

Lubin, Dan; Kahn, Brian H.; Lazzara, Matthew A.; Rowe, Penny, and Walden, Von P. Variability in AIRS-retrieved cloud amount and thermodynamic phase over west versus east Antarctica influenced by the SAM. Geophysical Research Letters v.42, no.4, 2015, pp1259–1267.

Otkin, Jason A.; Anderson, Martha C.; Hain, Christopher, and Svobada, mark. Using Temporal Changes in Drought Indices to Generate Probabilistic Drought Intensification Forecasts. Journal of Hydrometeorology v.16, no.1, 2015, pp88–105.

Saide, P. E.; Spak, S. N.; Pierce, R. B.; Otkin, J. A.; Schaack, T. K.; Heidinger, A. K.; da Silva, A. M.; Kacenelenbogen, M.; Redemann, J., and Carmichael, G. R. Central American biomass burning smoke can increase tornado severity in the U.S. Geophysical Research Letters v.42, no.3, 2015, pp956-965.

Straka, William C. III; Seaman, Curtis J.; Baugh, Kimberly; Cole, Kathleen; Stevens, Eric, and Miller, Steven D. Utilization of the Suomi National Polar-Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) day/night band for Arctic ship tracking and fisheries management. Remote Sensing v.7, no.1, 2015, pp971-989.

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