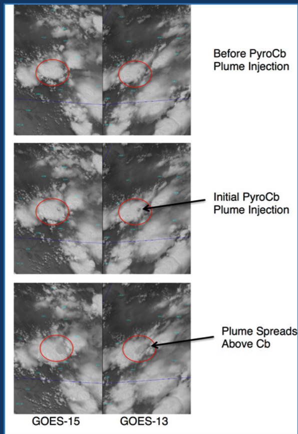
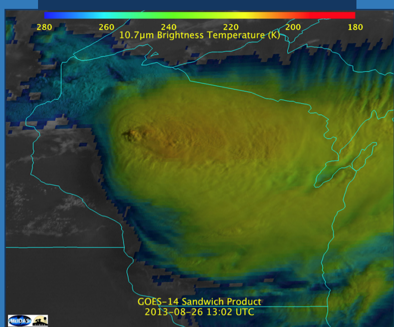
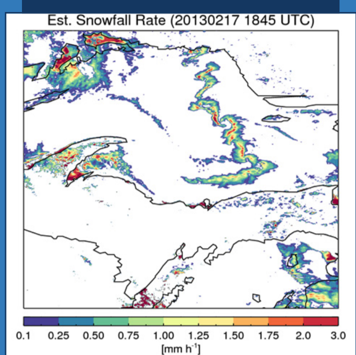
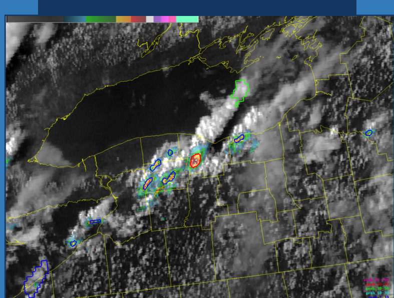
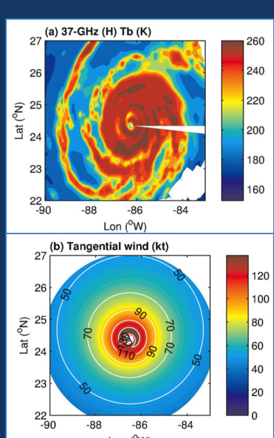






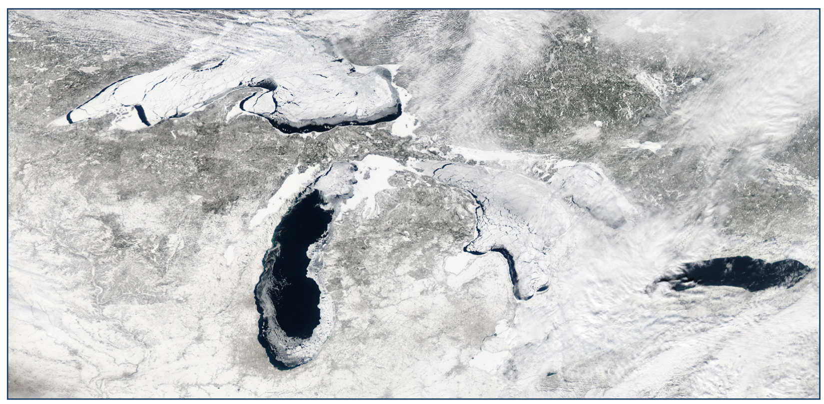




Research to Operations

CIMSS Cooperative Agreement Annual Report

for the period
1 April 2013 to 31 March 2014



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

April 2014

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DISCUSSION...TRENDS IN REGIONAL RADAR IMAGERY...LIGHTNING DATA...AND
CIMSS GOES-R CLOUD TOP COOLING AND OVERSHOOTING TOP PRODUCTS
INDICATED CONVECTION AND EMBEDDED TSTMS CONTINUING TO INCREASE IN
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University of Wisconsin-Madison

Cooperative Institute for
Meteorological Satellite Studies (CIMSS)
http://cimss.ssec.wisc.edu/

Cooperative Agreement Annual Report

for the period
1 April 2013 to 31 March 2014
Cooperative Agreement Number: NA10NES4400013

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National Oceanic and Atmospheric Administration
(NOAA)

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

1 April 2013 to 31 March 2014

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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 forecasting, 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 recently completed 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, 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 8), indicating the strong collaborations between the two organizations. For example, 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' includes: stray light corrections, electronic side switch monitoring, Sounder short-wave noise investigation, addressing Sounder filter wheel issues, Imager co-registration and other issues as they arise. As a specific example of these science support collaborations, on May 22, 2013 GOES-13 experienced an anomaly that stopped it from operating. The probable cause for the outage was a meteorite hitting the satellite. GOES-13 went into storage mode and GOES-14, located at 105W, became operational GOES-East on May 24. GOES-13 was brought out of storage mode on May 28 for testing. CIMSS immediately assisted with this testing as the SSEC Data Center was able to obtain GOES-13 data that was rebroadcast via GOES-14 while GOES-14 data were being operationally disseminated via GOES-13's antenna. The assurance that test data could be collected and analyzed allowed NESDIS to continue with plans to test GOES-13 prior to putting it back in as operational GOES-East. The SSEC Datacenter may be the only place that these test GOES-13 data are now archived.

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. During the past year, a website was developed to host GOES-R volcanic cloud alerts and associated imagery (http://volcano.ssec.wisc.edu). The alerts are stored in a searchable database. Observations from MODIS, GOES-EAST, GOES-WEST, SEVIRI, and MTSAT instruments are currently being processed and alerts sent to the website in near real-time. Operational meteorologists at the Anchorage Volcanic Ash Advisory Center (a-VAAC) are using the volcanic cloud website during ash events. In addition to website development and generating alerts in near-realtime, algorithm improvement and development continues by ASPB/CIMSS scientists.

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. In July of 2013 users began to notice dropped pixels in the GOES-13 Sounder. An unusual anomaly, all 19 bands would experience the same pattern of missing pixels. GOES engineers discovered the problem was the filter wheel changing speeds suddenly, thus causing the data to be dropped from the processing system, but have not discovered why it is happening. CIMSS found some evidence that it has occurred prior to summer of 2013, for example in the summer of 2012. The engineers at OSPO came up with a software solution which should restore these missing pixels. CIMSS assisted in testing and validating the results and a new version of the Sensor Processing System (SPS) software (version 1.4.1) should be released in spring of 2014.

We have very long term collaborations with NOAA developing GOES imager and sounder products. In particular, CIMSS has been involved since the initiation of the NOAA GIMPAP (GOES Improved Measurements and Product Assurance Program) program and continues to make important contributions to this program. Through the GIMPAP program CIMSS scientist are collaborating with NOAA scientist to develop the techniques to use the GOES cloud properties and lead the efforts to ensure the satellite derived 3d hydrometeor fields are beneficial to the NOAA/ESR Rapid Refresh Model (RAP) is the most active model in the field of satellite cloud product assimilation. The RAP uses a cloud/ hydrometeor analysis in which 3-d hydrometeor fields for cloud water and ice mixing ratios modified based on current METAR ceiling and GOES cloud retrieval data. The RAP is the only current NCEP model/ assimilation system to use either GOES or METAR cloud data, making it one the leading NWP model in its use of cloud information from satellites. As part of the project, CIMSS is implementing a real-time feed of GOES-R analog cloud products to the ESRL RAP team. Other GIMPAP activities at CIMSS include:

- Development and testing of Convective Initiation/Cloud Top Cooling (UWCI/CTC) algorithm, designed to identify vertically growing, and hence, cooling convective clouds in GOES imagery both day and night. The cloud-top cooling rates are combined with GOES Cloud Phase retrievals to make convective initiation nowcasts. Forecasters at various test beds have evaluated the UWCI/CTC output over the past four convective seasons.
- Development of a GOES Imager Sky Cover, which employs effective cloud amount, and cloud top pressure products from the current GOES imagers to produce an average sky cover grid, nationwide, once per hour using multiple composited scans from the current GOES imagers.
- The Advanced Dvorak Technique (ADT) is an algorithm designed to provide objective estimates of hurricane intensity from GOES and other geostationary satellites. Its long-term development has been partially supported by GIMPAP, and the latest algorithm is currently being transitioned through a PSDI effort into NESDIS operations at the Satellite

Analysis Branch. The National Hurricane Center (NHC) now routinely accesses the ADT data as part of its hurricane analysis and forecast suite of tools.

- The GOES Wildfire Automated Biomass Burning Algorithm (WFABBA) developed at CIMSS has been an Operational product since 2001, with the Version 6.5 running at NESDIS Operations since 2010, providing fire detections and characterizations, as well as metadata, for the GOES satellites and the Meteosat and MTSAT series of satellites. The WFABBA data is being used in the Hazard Mapping System.
- Researchers are seeking to improve the prediction of downslope wind events at select western U.S. locations using a combination of GOES imagery and numerical models. This works builds on a statistical method developed at CIRA.
- Methods are under development to objectively determine the probability that a growing cumulus cloud object will first produce severe weather in the near-term (0-2 hours) utilizing temporal trends in GOES-derived cloud properties, NWP fields and NEXRAD observations.

CIMSS also has a strong partnership with NOAA in the GOES-R program. 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 is designed to ensure user readiness on Day 1 for GOES-R. To this end, CIMSS scientists help in evaluating the GOES-R AWG by demonstrating algorithms and decision support products, testing enhancements and providing user assessments and feedback to the product developers. CIMSS has demonstrated the utility of these products to operational forecasters for their feedback through the following efforts:

1. Hazardous Weather Testbed (HWT) Spring Experiment (6 May – 7 June). Participants included over 6 CIMSS researchers, 18 forecasters, and 9 visiting scientists.
2. National Hurricane Center (NHC) Tropical Cyclone Demonstration (1 Aug. – 30 Nov.) Participants included forecasters from NHC
3. Aviation Weather Center (AWC) Summer Experiment (12 August – 23 August). 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 NWS forecasters and scientists from the University of Hawaii.
8. NWS Central Region Fog and Low Stratus Evaluation (1 August 2012 – 31 December 2012). Participants included NWS forecasters at Des Moines, IA; Pleasant Hill, MO; Indianapolis, IN; Jackson, KY; Louisville, KY; St. Louis, MO; Marquette, MI; Riverton, WY

CIMSS is heavily engaged with NOAA's ASPB in GOES-R and JPSS decision support satellite-based proving ground testing activities within demonstrations at eight NOAA National Centers and dozens of NOAA NWS Weather Forecast Offices (WFO). Between 2009 and 2013, new GOES-R proxy cloud properties, cloud low cloud/fog, convective cloud top cooling, fire, hurricane intensity estimate, icing, and convective over-shooting top detection information has been transmitted in near real-time to help guide products toward optimal use by NWS operations. Once the satellite-based decision support algorithms have been incrementally matured using the proving ground process, algorithms will then transition to operations.

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 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, education and outreach 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.

Sensor to sensor calibration differences continue to be studied in collaboration with the STAR calibration team. The hyper-spectral measurements from the Infrared Atmospheric Sounding Interferometer (IASI) on the MetOp satellite are used to simulate HIRS observations and to estimate the parameters in the linear models. The approach is to estimate radiance changes for a specific channel due to Spectral Response Function (SRF) modifications and related uncertainty. The linear models are applied to the NOAA and MetOp HIRS data at Simultaneous Nadir Overpass (SNO) locations to estimate the inter-satellite radiance differences. The inter-satellite mean radiance biases are minimized with residual maximum uncertainty less than 1% after the impacts of SRF differences and uncertainties are taken out. With use of the MetOp HIRS as a reference, the optimized SRFs for every NOAA HIRS are found by minimizing the root-mean-square values of inter-satellite radiance difference. These recalibrated HIRS radiance measurements will be reprocessed using algorithms for cloud 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.

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 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. Changes to how supersaturation is controlled in the GDAS/GFS was developed and incorporated into the Gridpoint Statistical Interpolation (GSI) portion of the GDAS. Removing the supersaturation made significant changes to the moisture field within the analysis.

CIMSS is collaborating with the National Severe Storms Laboratory (NSSL) and the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) at the University of Oklahoma, In that collaboration, Observing System Simulation Experiments (OSSEs) are being performed to assess the potential of satellite observations to improve the characterization of storms within model analyses and forecasts. The assimilation experiments are performed using the ensemble Kalman filter (EnKF) algorithm 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 numerical weather prediction (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.

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) CRTM and model output from the WRF-Chem/RAQMS system. For example, simulated data was developed for the May 20, 2013 Oklahoma tornado events for a Weather Event Simulator (WES) case for training at National Weather Service offices. Results from the WRF-Chem simulation of these events shows that the simulation captures well the onset of severe weather that led to the outbreak.

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 under the leadership of ASPB. 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 extended 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. A CIMSS science symposium in the fall 2013 focused on cloud research conducted throughout the building. 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.

UW-Madison continues 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. There are many activities, as described below, where NOAA support is provided to CIMSS researchers to support the JPSS program. Some examples include:

1. 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).
2. A cloud team is developing cloud and aerosol algorithms in support of the Suomi NPP and JPSS programs. This project evaluated the Cloud Optical Properties (COP) products of the JPSS VIIRS team and found major issues in the pre-computed simulations of the radiative transfer, which are stored in look-up-tables. This could be fixed for an improved version of the IDPS algorithm in cooperation with the colleagues from Northrup Grumman. The team also supports the JPSS VIIRS Cloud Mask Cal/Val Team to tune the cloud mask in coordination with other institutes.
3. 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 aerosol products to support VIIRS aerosol product maturity.
4. 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.
5. Experts in retrieval methods and validation are involved with assessment of CrIMSS post launch EDR atmospheric temperature and water vapor retrieved profiles and observed infrared radiances. The assessment of soundings on the 1K/km level and the establishment of a long term set of well-characterized sounding products, requires accurate and on-going validation data. The assessment includes comparison with collocated radiosonde, GPS and Raman lidar measurements.
6. 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.

A long-term goal of CIMSS and NESDIS collaborations is to transition research to operations to meet NOAA goals. To maintain a credible Operations-to-Research (O2R) environment of the NOAA operational weather forecast models, CIMSS personal work with NCEP Global Data

Assimilation System/Global Forecast System (GDAS/GFS) and validation/verification software. The O2R activities are continuous; the various operational forecast models and verification software are updated on an irregular but continuous basis. In order to be capable of transitioning any new assimilation techniques back to the operational NWP centers, these updates must be part of the research test environment. For example, the JCSDA computers are not identical to the NCEP operational computers, so several porting issues must be addressed with each upgrade. Since the JCSDA computers are not bit-reproducible with the NCEP operations computers, extensive testing must be conducted to ensure the answers are consistent and the differences statistically insignificant.

CIMSS sponsored many national and international visitors during this time (Appendix 5). For example: Sung-Rae Chung, Eun-Jeong Cha and Sungwook Hong of the Korea Meteorological Administration (KMA); Jason Dunion of Rosenstiel School of Marine and Atmospheric Science; Tom Fahney, Tom representing the weather interest of Delta Airlines; Gerrit of the of the Division of Space Technology, Lulea University of Technology, Kiruna, Sweden; Kouki Mouri from the Japanese Meteorological Agency (JMA) Meteorological Satellite Center (MSC); Jan Musial from University of Bern, Switzerland; Gemma Narisma, Gemma of the Manila Observatory/Physics Department, Ateneo de Manila University, Philippines and Martin Setvak of the Czech Hydrometeorological 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). Graduate students Michelle Feltz and Jacola Roman have conducted valuable research associated with JPSS mission and presented their results at the 2013 EUMETSAT satellite conference. 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. 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. CIMSS has assisted in the development of courses for the Intern Course, the Tropical Course, the Forecaster Course, the Severe Weather Course and the pending GOES-R Course and Winter Weather Course. Preliminary planning for an Aviation Course is continuing. Data for case studies/training modules has been placed on CIMSS blog. The CIMSS Satellite blog is a valuable education, research and outreach activity [http://cimss.ssec.wisc.edu/goes/blog]. The CIMSS Satellite Blog continues to serve as an expanding, searchable library of satellite products and meteorological case studies

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 Center (NWSTC) and another at the Aviation Weather Center (AWC) in Kansas City, MO. The CIMSS scientists will provide leadership, satellite expertise, and meteorological support for the GOES-R Proving Ground efforts based at the NWSTC.

CIMSS is also active in outreach activities. CIMSS researchers are very active in NOAA's Science on a Sphere (SOS) education program, both locally and nationally, in collaboration with CICS. CIMSS writes the EarthNow blog (http://sphere.ssec.wisc.edu/), a resource for SOS docents that develops and hosts datasets to explain recent weather and climate events, including connections to global climate change.

CIMSS also supports K-12 education. CIMSS continues to distribute its popular CDs on Satellite Applications for Geoscience Education and Satellite Meteorology for Grades 7-12 at various education focused conferences. CIMSS continues to offer its summer workshop for science teachers that focus on the topics of satellite remote sensing, climate literacy and climate change. The GOES-R Education Proving Ground involves the design and development of pre-and post-launch activities for G6-12 teachers and students. Six teachers from three states are developing lessons plans for middle and high school science classes which will be classroom tested in the spring of the 2014 school year and presented at the 2014 Satellites and Education Conference. Informal education efforts related to this initiative involve animations of GOES-14 Super Rapid Scan visible channel images at 1-minute intervals for display on NOAA's SOS exhibits.

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, including the appendices which provide additional detail on CIMSS personnel and metrics.

CIMSS recently underwent its 5-year review. Following a thorough review of the CIMSS, the CIMSS 5-year review panel convened by the NOAA Science Advisory Board unanimously agreed to the highest performance rating of Outstanding.

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 originally formed in 1980 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 CIMSS, the Review Panel unanimously agreed to a performance rating of Outstanding, the highest possible rating.

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.

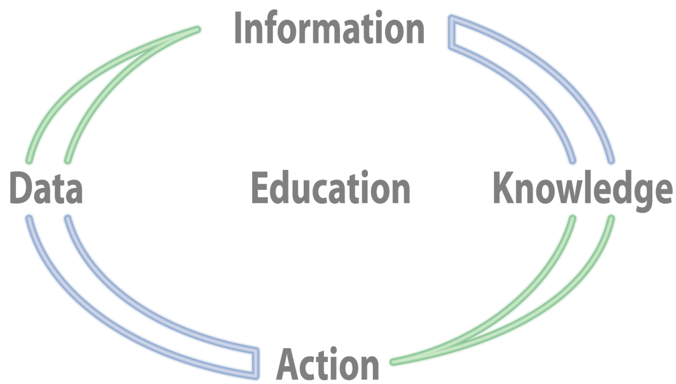
To achieve these mission goals CIMSS conducts a broad array of research and education activities, many of which are projects funded through this Cooperative Agreement with NOAA. This Cooperative Agreement identifies four CIMSS themes:

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 ranging from using GOES measurements to estimate the intensity of Atlantic basin hurricanes to designing the next generation satellite instruments. Our research process is represented in the diagram below.

Algorithms are developed and applied to quality 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) and NCDC (National Climdate Data Center) 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/NCDC 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.

CIMSS maintains a close collaboration with the NOAA Office of Systems Development (OSD) as part of the NOAA support team for the future GOES-R ground system development systems. CIMSS also interacts with the Office of Satellite Data Processing and Distribution (OSDPD) in the transfer of research techniques and algorithms developed at CIMSS in collaboration with ASPB, to NOAA operations. Over two dozen research algorithms developed at CIMSS have been utilized by NESDIS operations. Through specific research projects, CIMSS has a strong research collaboration with the JPSS (formerly the NPOESS Integrated Program Office - IPO), supporting the instrument design and algorithms of the next generation operational imager and sounder on polar satellites.

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. CIMSS scientists are involved with local NWS offices on specific projects, and maintain close ties with NWSFOs in Milwaukee/Sullivan, La Crosse and Green Bay. Finally, CIMSS works with CIRA and the COMET office through the NWS Training Center to participate in the VISIT and SHyMet programs.

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 15 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.

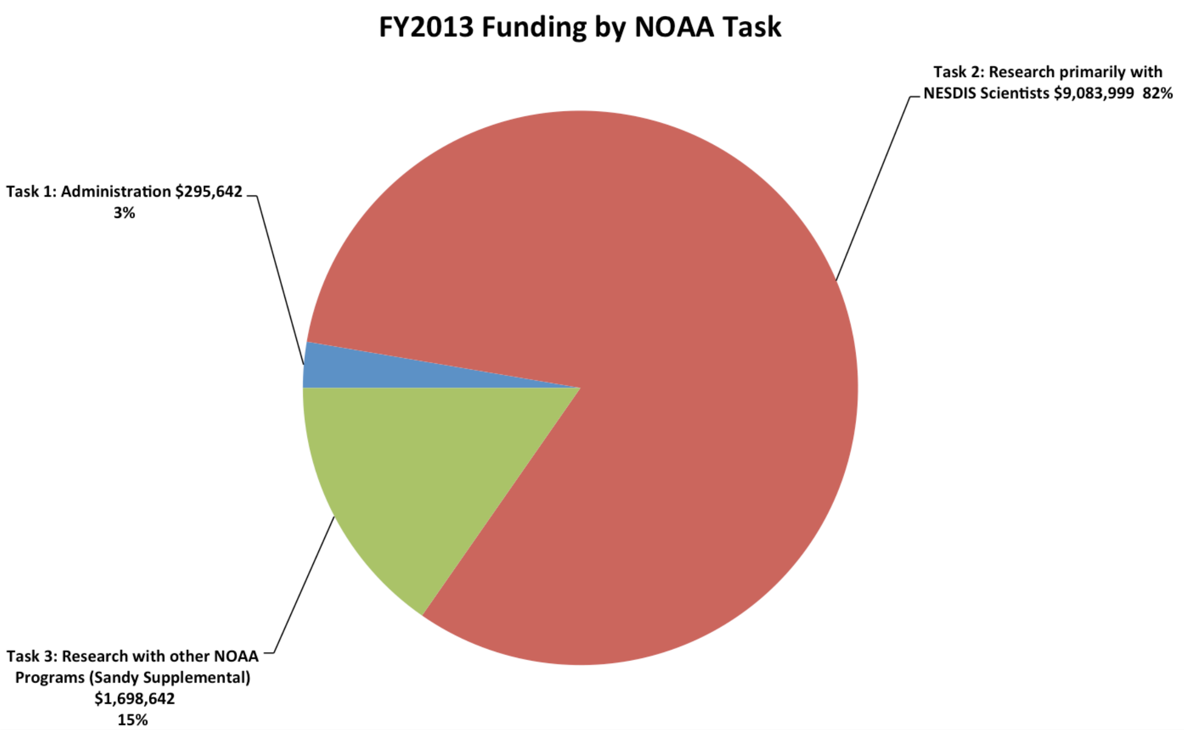
- **Data Center**
  The SSEC Data Center provides access, maintenance, and distribution of real-time and archive weather and weather satellite data. The Data Center currently receives data from 10 geostationary and 9 polar orbiting weather satellites in real time and provides a critical resource to SSEC/CIMSS 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 software is 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.
- **Engineering**
  SSEC provides engineering support for its own instrument programs as well as for campus programs. An important component of SSEC's mission is to serve as a multidisciplinary research center for UW–Madison.
- **Program Management**
  SSEC has participated in several large space programs (e.g. planetary probes, STS missions) and has experienced program managers to support these activities. The Engineering and Program Management teams allow SSEC to conduct ongoing instrument development programs, which can be expanded to support large program initiatives.

3. Summary of NOAA funding to CIMSS in FY2013

In FY2013, funding to CIMSS through Cooperative Agreement NA10NES4400013 totaled $11,078,283. FY2014 funding is not sufficiently known at this time to include in this report. 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 FY2013 funds provided to CIMSS under the Cooperative Agreement that began on 1 July 2010 and covers the 12 month period from 1 October 2012 to 30 September 2013.

FY2013 Funding by NOAA Task

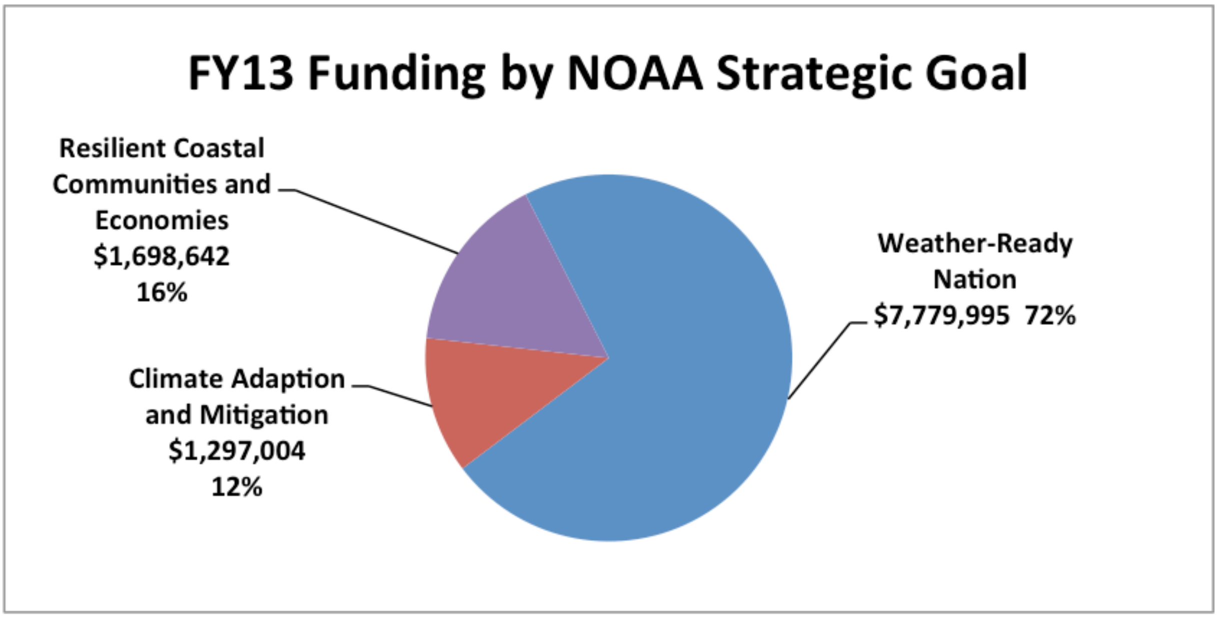
CIMSS Task	Funding in dollars	Percentage
Task 1: Administration	$ 295,642	3%
Task 2: Research primarily with NESDIS Scientists	$ 9,083,999	82%
Task 3: Research with other NOAA Programs	$ 1,698,642	15%
	$11,078,283	



Funding by NOAA Strategic Goal

NOAA Strategic Goal	Funding in dollars	Percentage
Weather-Ready Nation	$7,779,995	72%
Climate Adaption and Mitigation	$1,297,004	12%
Healthy Oceans	$ 0	0%
Resilient Coastal Communities and Economies	$1,689,642	16%
	$10,775,641*	

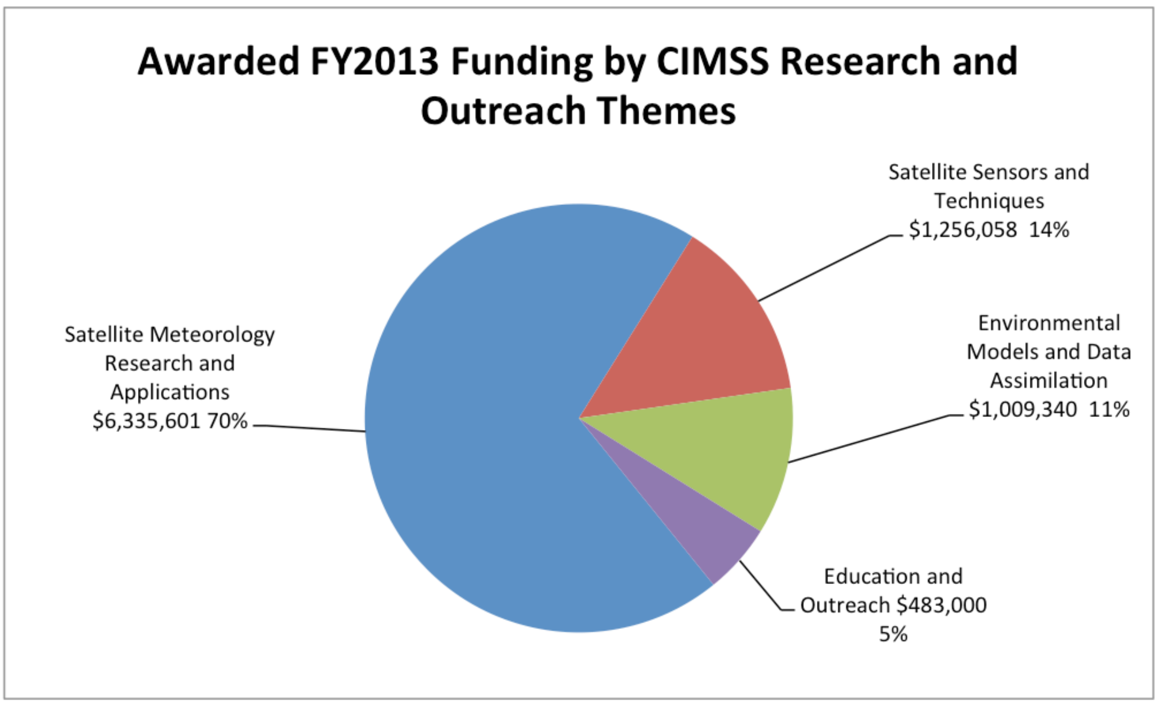
* - does not include the Task 1 funding



Funding by CIMSS Research and Outreach Themes

CIMSS Theme	Funding in dollars	Percentage
Satellite Meteorology Research and Applications	$6,335,601	70%
Satellite Sensors and Techniques	$1,256,058	14%
Environmental Models and Data Assimilation	$1,009,340	11%
Education and Outreach	$ 483,000	5%
	$10,775,641*	

* - 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 Leaders: 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, 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 is to recognize the partnership that occurs between NESDIS and UW-Madison scientists and educators.

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

CIMSS Task Leaders: Margaret Mooney and Steve Ackerman
CIMSS Support Scientists: Scott Bachmeier, Rick Kohrs, Patrick Rowley
NOAA Collaborators: Tim Schmit, Gary Wade, Jim Kossin, Nina Jackson, Frank Niepold, LuAnn Dahlman, 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

On the UW campus, CIMSS 2013 EPO efforts revolved around sharing satellite imagery with visitors and school groups via a 3D sphere similar but smaller than NOAA Science on a Sphere (SOS) exhibits. In June 2013, CIMSS hosted the time-honored CIMSS student workshop; a science camp for high school students that promotes STEM concepts while maintaining a critical pipeline to college and future careers. For two days in July, CIMSS hosted the 9th Annual Cooperative Research Program (CoRP) Science Symposium with the theme of "Toward a Weather-Ready Nation and Resilient Coastal Communities." Over two dozen graduate students and post-docs from around the country gathered to present their work in remote sensing of the environment and benefit from panel discussions on the best ways to advance their careers. Also in July, CIMSS EPO arranged a 1-day educator's workshop at the 2013 Earth Science Information Partners (ESIP) summer meeting for science teachers in North Carolina. In October, CIMSS EPO organized an exhibit booth at the EUMETSAT/AMS Joint Satellite Conference in Vienna Austria. Additionally, CIMSS researchers and staff conducted numerous in-person presentations at formal and informal venues throughout 2013.

In the digital domain, CIMSS shared educational content via on-line curriculum for students and teachers, Facebook, the CIMSS Satellite Blog and the CIMSS EarthNow Blog. Social media initiatives at CIMSS also include maintaining two twitter accounts, one for each blog. An on-line presence is an opportunity for CIMSS to share research and education findings with the public. This year, we were able to greatly expand our social media reach via the CIMSS Facebook page where fans following CIMSS (Figure 1) doubled in 2013. (https://www.facebook.com/CIMSS.UW.Madison)

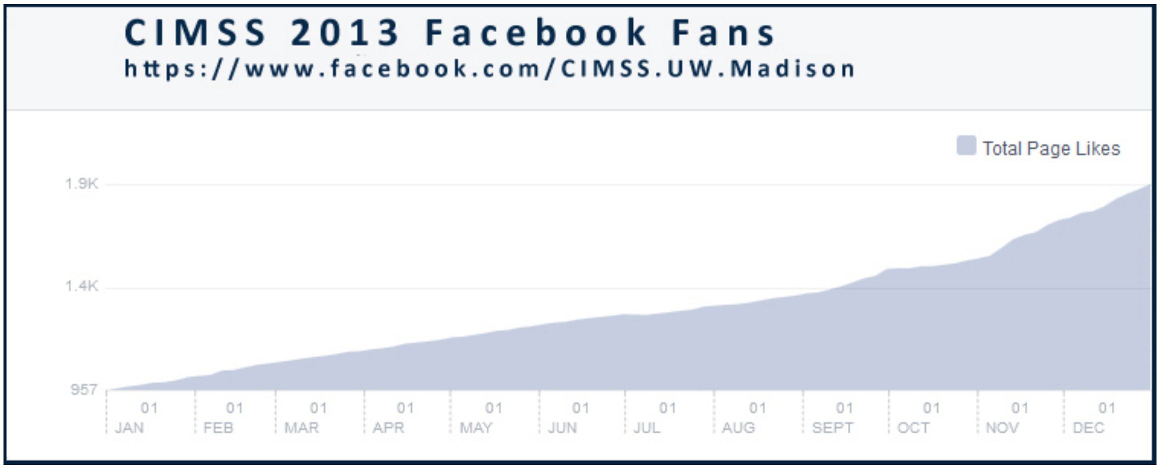


Figure 1. CIMSS 2013 Facebook Fans.

Along with on-going programs like building tours, workshops, web-based resources and social media, CIMSS EPO made great strides towards advancing science literacy though two particular projects in 2103 The first venture involved trainings for SOS docents and a new partnership with the National Park Service. Patrick Rowley and Margaret Mooney from CIMSS conducted an SOS training at the Grand Canyon in November that included demonstration of the monthly Climate Digest product from the CIMSS EarthNow Blog. Developed collaboratively using data from NOAA's National Climatic Data Center and Climate Prediction Center, the Climate Digest provides a global climate brief in less than four minutes. Impressed with the product, the National Park Service immediately incorporated the Climate Digest into its SOS programming three times each hour. Now hundreds of visitors to the Grand Canyon see this content daily.

CIMSS EPO also kicked-off the GOES-R Education Proving Ground in 2013. This initiative involves three teams of two teachers from Wisconsin, New Jersey and Florida working with CIMSS EPO also kicked-off the GOES-R Education Proving Ground in 2013. 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 related to the GOES-R mission. Through the GOES-R Education Proving Ground, teachers and students will be "launch-ready" for new types of satellite imagery and products in the upcoming GOES-R era.

CIMSS became a NOAA Weather-Ready Nation Ambassador in February 2014, formally recognizing CIMSS as a NOAA partner improving the nation's readiness against extreme weather, water, and climate events. As a Weather-Ready Nation Ambassador, CIMSS is committed to working with NOAA and other Ambassadors to strengthen national resilience against extreme weather.

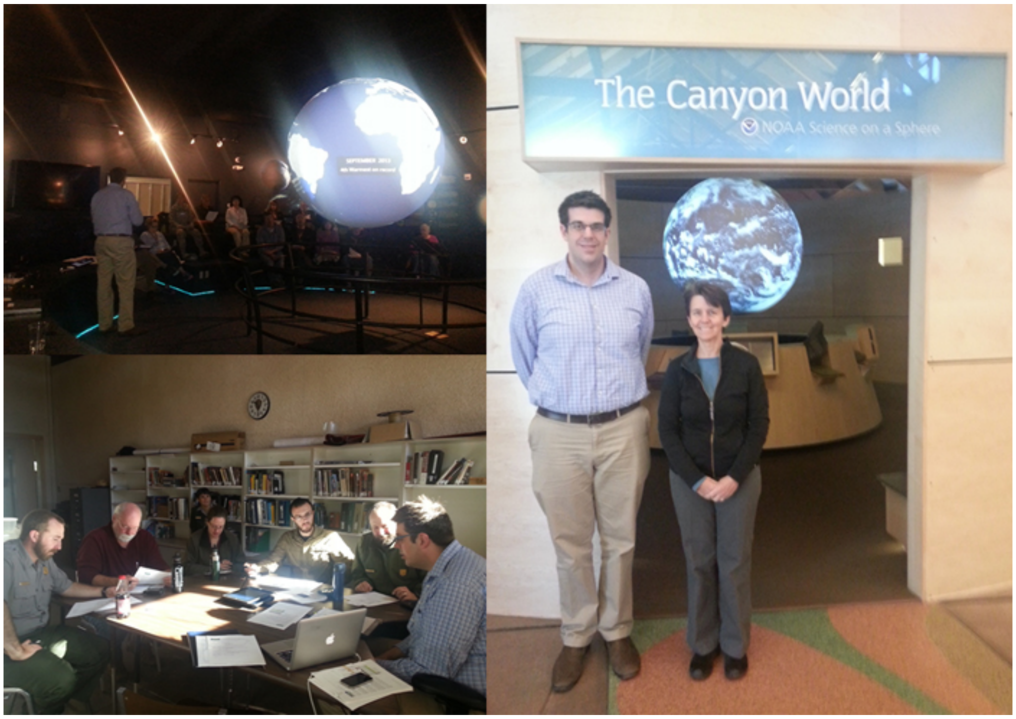


Figure 2. Scenes from 2013 SOS trainings.

Publications and Conference Reports

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

Rowley, Patrick; Mooney, M.; Ackerman, S.; Achtor, T.; Gerth, J.; Gjermo, B. and Wade, G. S. Celebrating 20 years of the CIMSS Student Workshop. Symposium on Education, 22nd, Austin, TX, 6-10 January 2013. American Meteorological Society, Boston, MA, 2013.

Mooney, Margaret; Dahlman, L.; Ackerman, S.; Jackson, N.; Chambers, L. H. and Whittaker, T. The CIMSS iPad Library and ESIP Teacher Workshops. Symposium on Education, 22nd, Austin, TX, 6-10 January 2013. American Meteorological Society, Boston, MA, 2013.

Rowley, Patrick; Ackerman, S.; Arkin, P.; Pisut, D. P.; Kohrs, R. A.; Mooney, M. and Uz, S. Schollaert. Communicating climate forecasts via NOAA's Science on a Sphere: The EarthNow Project. Conference on Applied Climatology, 20th, Austin, TX, 6-10 January 2013. American Meteorological Society, Boston, MA, 2013.

Rowley, Patrick; Schollaert Uz, Stephanie; Ackerman, Steve; Arkin, Phil; Kohrs, Rick; Mooney, Margaret and Pisut, Dan. Communicating satellite data via NOAA's Science on a Sphere: The EarthNow Project. NOAA 2013 Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, College Park, MD, 8-12 April 2013. NASA, Goddard Space Flight Center, GOES-R Program Office, Greenbelt, MD, 2013, poster presentation.

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

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

CIMSS Task Leader: Justin Sieglaff
CIMSS Support Scientists: Lee Cronce and Wayne Feltz

NOAA Long Term Goals:
- Weather-Ready Nation

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

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

Project Overview

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

Summary of Accomplishments and Findings

The proposed UWCI/CTC algorithm enhancements are complete and have been running in real-time using the GOES Cloud Team's optical depth retrievals in the UWCI/CTC algorithm. An improved version of the GOES Cloud Team's optical depth retrieval is currently being implemented into the UWCI/CTC algorithm replacing the older version originally incorporated into the UWCI/CTC algorithm. As was demonstrated in previous years, the UW-CTC output proved useful to NWS forecasters at the 2013 NOAA Hazardous Weather Testbed (HWT). Figure 3 shows an example of lead-time the UW-CTC algorithm provided ahead of a tornadic supercell thunderstorm in the Texas panhandle.

The validation (POD, FAR, and CSI analysis) of added CI/CTC points beneath thin cirrus clouds is complete. The statistics demonstrate the addition of visible optical depth improves algorithm skill; while maintaining sizeable (20-30 minute) lead-time of UW-CTC signals to strong/intense radar signals. The details of the algorithm modifications and validation have been assembled into a published peer reviewed journal article and published in the Journal of Applied Meteorology and Climatology. Additionally, the updated UW-CTC algorithm output is currently streaming to NWS offices, centers, and testbeds. We will assess the official NWS 2013-14 evaluation led by Chad Gravelle to determine if we should seek funding to transition the UW-CTC algorithm to NESDIS operations.

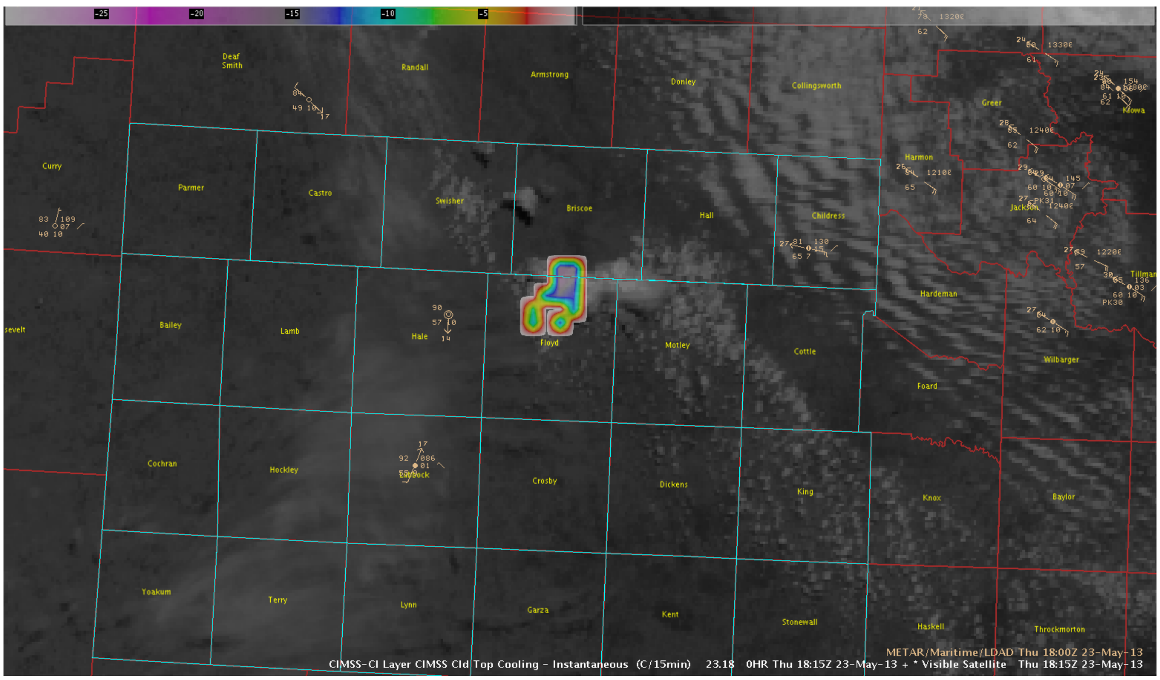


Figure 3. AWIPS-II screen capture from 2013 NOAA Hazardous Weather Testbed. The UW-CTCR data is overlaid atop GOES visible imagery both valid 1815 UTC 23 May 2013. The moderate UW-CTC rates (shaded colors; -16 to -17 K (15 min)-1) identified newly developing convection near Lubbock, Texas along an outflow boundary advancing from the northeast. This storm went on to become tornadic and was initially tornado warned at 1921 UTC 23 May 2013. The UW-CTC product provided 66 minutes of lead-time ahead of the tornado warning.

Publications and Conference Reports

Sieglaff, J. M., L. M. Cronce, and W. F. Feltz, 2014: Improving satellite-based convective cloud growth monitoring with visible optical depth retrievals. *J. Appl. Meteor. Climatol.*, **53,** 506-520. doi: http://dx.doi.org/10.1175/JAMC-D-13-0139.1

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

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

References

Hartung, D. C., J. M. Sieglaff, L. M. Cronce, and W. F. Feltz, 2012: An Inter-Comparison of UWCI-CTC Algorithm Cloud-Top Cooling Rates with WSR-88D Radar Data. *Wea. Forecasting*, **28**, 463-480.

Pavolonis, M. J, 2010a: Advances in extracting cloud composition from spaceborne radiances: A robust alternative to brightness temperatures, Part I: Theory. *J. Appl. Meteor. Climatol.*, **49**, 1992-2012.

Sieglaff, J. M., D. C. Hartung, W. F. Feltz, L. M. Cronce, and V. Lakshmanan, 2013: Development and application of a satellite-based convective cloud object-tracking methodology: A multipurpose data fusion tool. *J. Atmos. Oceanic Technol.,* **30**, 510-525.

Sieglaff, J. M., L. M. Cronce, W. F. Feltz, K. M. Bedka, M. J. Pavolonis, and A. K. Heidinger, 2011: Nowcasting convective storm initiation using satellite-based box-averaged cloud-top cooling and cloud-type trends. *J. Appl. Meteor. Climatol.*, **50**, 110–126.

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

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

CIMSS Task Leader: Andi Walther
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 NOAA/ESR Rapid Refresh Model (RAP) is the most active model in the field of satellite cloud product assimilation. In this project, the RAP team will develop the techniques to use the GOES cloud properties and lead the efforts to ensure the satellite derived 3d hydrometeor fields are beneficial to the RUC/RAP. The RAP uses a cloud/ hydrometeor analysis in which 3-d hydrometeor fields for cloud water and ice mixing ratios modified based on current METAR ceiling and GOES cloud retrieval data. The RAP is the only current NCEP model/ assimilation system to use either GOES or METAR cloud data, making it one the leading NWP model in its use of cloud information from satellites. As part of the project, CIMSS will implement a real-time feed of GOES-R analog cloud products to the ESRL RAP team to allow for experimentation. The GOES-R AWG analog products used here generated using the NESDIS CLAVR-x system.

Summary of Accomplishments and Findings

A list of the accomplishments follows:

- The CIMSS/STAR feed was expanded to include 1 km products from CONUS domains every 15 minutes.
- CIMSS modified the cloud mask based on feedback from the RAP model verification.
- CIMSS has begun using RAP modeling date directly in its retrievals. This replaces the GFS cloudiness information used in 2012.
- CIMSS has begun direct validation of RAP cloud fields using GOES and CALIPSO to augment the work done at ESRL.
- An updated set of experiments was repeated using a more recent warm season (28 May – 4 June 2012) retrospective period (Figure 4). These experiments used an updated version of the RAP model to include recent model improvements as well as a hybrid data assimilation system. The three experiments were similar to those done with the 2011 retrospective period: 1) Baseline case using original satellite data (CTRL-low building), 2) baseline case using original satellite data, full-column cloud building (CTRL-full building), and 3) experiment using ECA, full-column cloud building (ECA-full building).
- The key findings from this work are:
    - The RAP model's moist RH bias in 6 hour forecasts has been largely reduced,
    - This was accomplished with very little impact on 3000' ceiling skill scores for 1 hour and 3 hour forecasts (no impact was the goal).

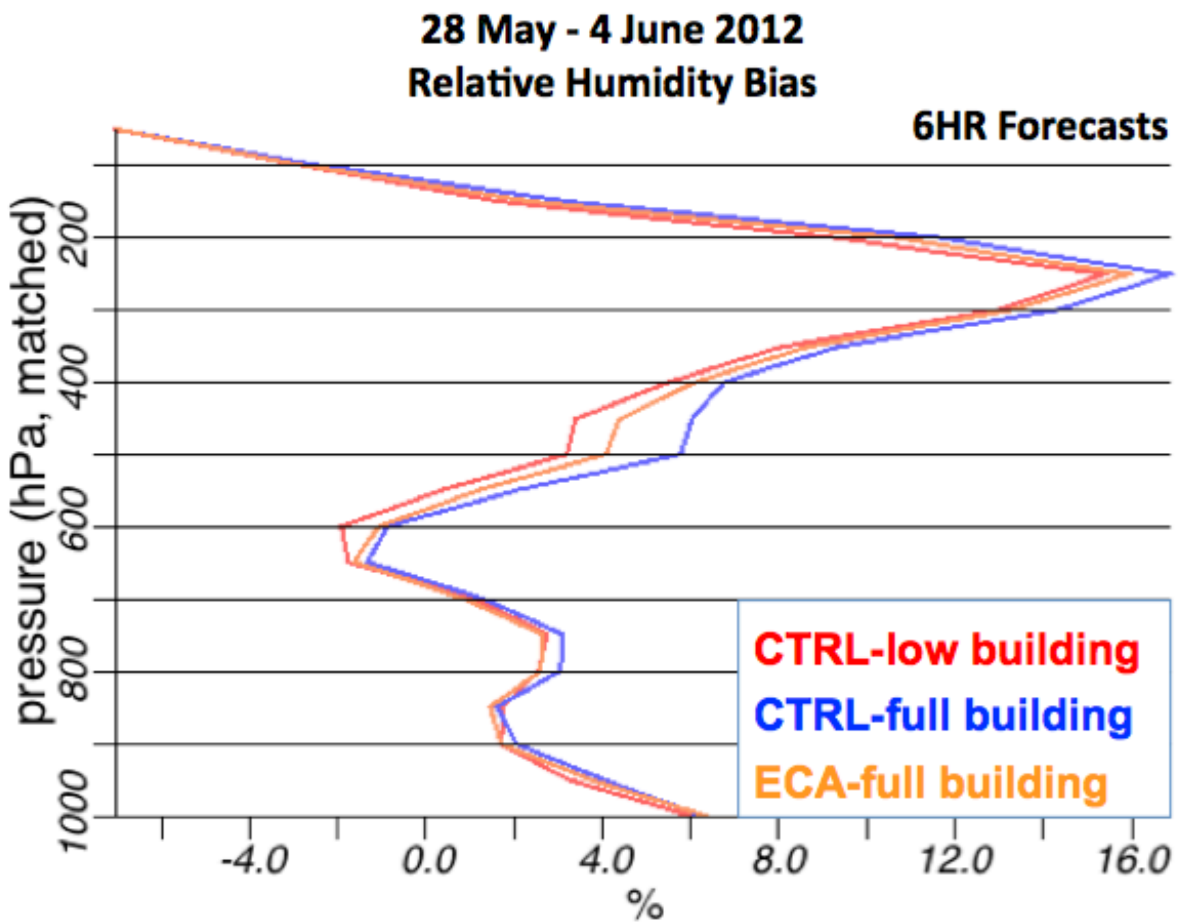


Figure 4. Impact of cloud building on RAP 6 hour forecasts of relative humidity biases. Definitions of experiments given above. Results show that using Effective Cloud Amount substantially reduces the moist bias introduced from full-column cloud building.

Publications and Conference Reports

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

Application of GSI for cloud, radar, and near-surface assimilation within 13-km RAP and 3-km HRRR hourly updated forecast systems. Patrick Hofmann, CIRES/Univ. of Colorado, Boulder, CO; and M. Hu, S. Benjamin, S. S. Weygandt, C. R. Alexander, and D. C. Dowell.

Poster, presented in the 16th Conference on Aviation, Range, and Aerospace Meteorology (ARAM):

Improvements to ceiling/visibility forecasts from the 13-km RAP and 3-km HRRR hourly updated forecast systems. Patrick Hofmann, NOAA/ESRL, Boulder, CO; and M. Hu, S. Benjamin, S. Weygandt, and C. Alexander.

3.3 GOES Imager Sky Cover Analysis Product

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

NOAA 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
- Environmental Models and Data Assimilation

Project Overview
The goal of this project is to increase the frequency of effective cloud amount (ECA), and cloud top pressure (CTP) products from the current GOES imagers. These cloud products are used to produce an average sky cover grid, nationwide, once per hour using multiple composited scans from the current GOES imagers. Recent work has focused on methods and inputs to complete the grid and produce a blended analysis where ECA is not valid indicators of sky cover – the amount of the celestial dome covered with cloud visible to a human observer at a point on earth – as the National Weather Service (NWS) has outlined in their operational requirements.

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

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

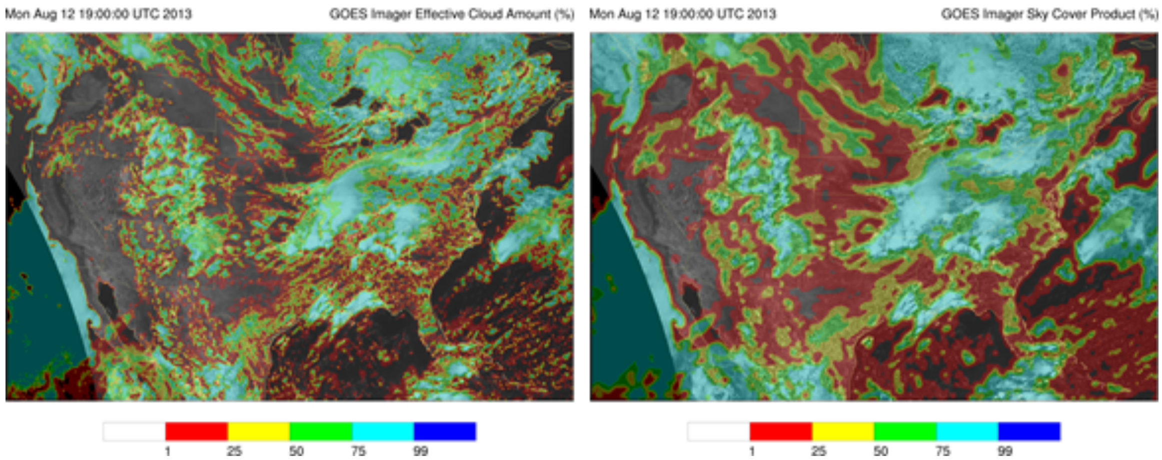


Figure 5. This two-panel plot shows the original GOES Imager Effective Cloud Amount (left) and the GOES Imager Sky Product (right), which accounts for the type of cloud, celestial dome, and cloud trend over the following hour, valid at 19:00 UTC on 12 August 2013. The background image is a visible band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

A blended sky cover analysis is also produced. The blended analysis combines the GOES Imager sky cover product and in-situ surface observations of cloud cover into a single product valid throughout a one-hour window using a methodology which leverages the strengths of each observation type and incorporates the satellite CTP. The advantage of this approach is that the in-situ surface observations are exceptional at detecting low cloud and fog, whereas satellites have difficulty due to the similar emissivity of such features to the ground. Likewise, satellites have greater detectability for high cloud than the surface observations provide. The blended sky cover analysis uses the GOES Imager sky cover product over open oceans, where surface observations are generally unavailable.

The result of the blended analysis combining surface observations with the satellite sky cover product is a more reliable estimation of cloudiness over the continental United States compared to a single source. Compared to the current GOES Sounder ECA, there is greater detection of low cloud and fog, particularly at night. Compared to surface observations, the blended analysis depicts more expansive cirrus cloud shields. As a result, overall cloudiness is increased. The blended analysis is awaiting further evaluation from the NWS to assess its suitability for verifying National Digital Forecast Database (NDFD) cloud cover forecasts. Initial comparisons suggest that the blended analysis, or an optimized variant, is a better source of truth than the existing GOES Sounder ECA implementation in the Real-Time Mesoscale Analysis (RTMA).

Applying relationships between sky cover, mixing ratio, and relative humidity from peer-reviewed literature, a new optimal sky cover quantity is produced from High-Resolution Rapid Refresh (HRRR) output, which is a result of linear and mixed integer optimization of the mean absolute error between moisture variables and the optimal sky cover produced from the blended sky cover analysis. Cloud in the optimized blended analysis is routinely found to correlate with relative humidity and cloud water mixing ratio in the HRRR analysis, particularly in the lower troposphere, with limited relationships to rain mixing ratio and snow mixing ratio.

An optimal HRRR sky cover analysis is produced in addition to three-, six-, and nine-hour forecasts. This is compared to the HRRR cloud cover output and validated against the blended sky cover analysis to demonstrate the skill of an adaptive approach to producing a numerical sky cover forecast closely matched to the NWS expectations. These revised cloud cover forecasts generally have shown better skill than the current output from numerical weather prediction.

Publications and Conference Reports

Sky Cover: Shining Light on a Gloomy Problem, Oral Presentation, CoRP Symposium, Toward a Weather-Ready Nation and Resilient Coastal Communities, Madison, Wisconsin, July 23, 2013

Toward an operational sky cover analysis from geostationary satellite cloud products via a linear optimization methodology, Oral Presentation, AMS/EUMETSAT Meteorological Satellite Conference—Cloud observations from satellites, including 30 years ISCCP, Vienna, Austria, September 19, 2013

Sky Cover: Shining Light on a Gloomy Problem, Oral Presentation, National Weather Association Annual Meeting—General Session VIIb, Charleston, South Carolina, October 15, 2013

Sky Cover, Ph.D. Dissertation Oral Defense, CIMSS/SSEC Seminar, University of Wisconsin, Madison, Wisconsin, December 18, 2013

Sky Cover: Shining Light on a Gloomy Problem, Oral Presentation, American Meteorological Society Annual Meeting—10th Symposium on New Generation Operational Environmental Satellite Systems, Atlanta, Georgia, February 5, 2014

References

Gerth, Jordan J. 2013. "Sky Cover." Order No. 3606423, The University of Wisconsin - Madison. http://search.proquest.com.ezproxy.library.wisc.edu/docview/1492736844?accountid=465.

3.4 Improvements to the Advanced Dvorak Technique (ADT)

CIMSS Task Leaders: Chris Velden and Tim Olander
CIMSS Support Scientist: John Sears
NOAA Collaborators: Mike Turk (SAB), Jack Beven (NHC)

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 Advanced Dvorak Technique (ADT, Olander and Velden 2007) is an algorithm designed to provide objective estimates of hurricane intensity from GOES and other geostationary satellites. Its long-term development has been partially supported by GIMPAP, and the latest algorithm is currently being transitioned through a PSDI effort into NESDIS operations at the Satellite

Analysis Branch. The National Hurricane Center (NHC) now routinely accesses the ADT data as part of its hurricane analysis and forecast suite of tools.

In support of the importance of the ADT in hurricane analysis at the U.S. operational centers, a joint User Request was recently submitted to the NESDIS SPSRB by NHC, CPHC (Central Pacific Hurricane Center), and JTWC (Joint Typhoon Warning Center). The request, Request NO: 1104-0003, Title: “Continue operational transition and upgrade support of the ADT”, was approved by the SPSRB for funding considerations starting in FY12. This GIMPAP project follows the above User Request guidance, and the work planned to enhance the ADT capabilities will (if successful) have an operational transition component proposed upon successful completion.

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

Summary of Accomplishments and Findings

A critical part for the ADT to be able to operate on pre-genesis tropical disturbances is the accurate identification of coherent systems that have a good chance to develop, and this is the primary goal of the CIMSS Tropical Cloud Cluster Identification and Tracking Algorithm. A prototype algorithm to identify and track coherent tropical cloud clusters (TCCs; candidate TCs) has been developed at CIMSS. Adaptation of this TCC-tracking algorithm to operate on real-time imagery has been completed, and assessment is underway. A subsequent methodology to estimate the likelihood of TCC development (probabilistic) has been obtained from collaborators on the project.

The prototype CIMSS Tropical Cloud Cluster Tracking (TCCT) algorithm first identifies clusters by the combination of three parametric fields. The first field is the percent of pixels within empirically-prescribed radii of each grid point in the IR image domain (1-deg. resolution grid), that exceed the 255K brightness temperature (BT) threshold. The second field is a correlation analysis, created by comparing a BT template from a prototypical tropical storm to all grid points in the selected image. The last field is a latitude function, which maximizes at 10 degrees latitude and minimizes outside the climatological zone (95% likelihood) for TC genesis defined by the HURDAT dataset. These three fields are averaged into a single “final score,” where local maxima must exceed an empirically-determined 0.5 in order to be tracked. In a final test, target clusters must persist for 12 hours in order to be identified as an “active”, or invest, system.

The TCCT has been modified to more closely conform to NESDIS/SAB manual procedures. TCCT (version 2.0) integrates new information and has been validated on a large 9-yr dependent datasets. Initial findings yield an average Probability of Detection of approximately 65%.

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.

Sears, J., C. Velden, T. Olander and J. Cossuth, 2014: Automated tropical cloud cluster tracking and analysis as a front-end to the ADT. 31st AMS Hurricanes and Tropical Meteorology Conference, San Diego, CA, March 31-April 4.

References

Olander, T.L. and C.S. 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.

3.5 GOES Biomass Burning Algorithm and Application Improvements

CIMSS Task Leader: Chris Schmidt
CIMSS Support Scientists: Jay Hoffman, Jason Brunner, Elaine Prins (UW-Madison/CIMSS-Contractor)
NOAA Collaborators: Mark Ruminski (NOAA/NESDIS), Robert Rabin (NOAA/NSSL), Phillip Bothwell (NOAA/NWS/SPC)

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

The GOES Wildfire Automated Biomass Burning Algorithm (WFABBA) has been an Operational product since 2001. The upgraded WFABBA Version 6.5 (v65) has been running at NESDIS Operations since 2010, providing fire detections and characterizations, as well as metadata, for the GOES satellites and the Meteosat and MTSAT series of satellites. The WFABBA data is used in the Hazard Mapping System. While the algorithm performs well overall, the false alarm rate can be lowered. This project researches and develops techniques to reduce false alarms in WFABBA data, an issue that has been a challenge for the Hazard Mapping System operators. WFABBA support for Korea's COMS as part of the geostationary fire monitoring network was also proposed. The same was proposed for India's INSAT-3D. CIMSS proposed to continue to work with GEOSS, GTOS GOFC/GOLD, CEOS, and CGMS to foster the development and implementation of a global geostationary fire monitoring network with international involvement and support improved product utilization by supporting integration of the WFABBA into smoke and aerosol forecasting efforts.

Summary of Accomplishments and Findings

The new temporal filter that replaced the original technique that was designed for a GOES temporal frequency of 30 minutes has been applied to the real-time WFABBA data produced at CIMSS and ways to visualize its output have been created. The old technique requires a minimum of 6 scans in the preceding 12 hours to initiate the filtering and count a fire as "temporally filtered" if it was detected two times or more. CIMSS took a number of case studies and ran a set of scenarios on them to see how different filtering criteria would modify the results. The raw results were broken down into 29 categories that were a combination of scenarios such as "the previous fire was detected within 5 (or 5-15, or 15-30, or 30-60, or 60-180) minutes", whether the fire spanned more than 3 hours, and by the fraction of times in the window when it was possible to see a fire. The spatial window was varied from just the fire pixel's location itself to windows that extended out by 1, 2, and 3 pixels in every direction. The 7x7 box approximates the old filtering's use of 0.1° by 0.1° boxes.

For the real-time testing the categories remain the same, however for visualization purposes they are reduced into 5 groups: 1) fires that have detections within a window over the last three hours, 2) fires where the first detection was within the last 24 hours (but not in the last 3), 3) fires where more than half of the images of the last 3 hours had fires in the box, 4) fires where less than half of the images of the last 3 hours had fires in the box, and 5) fires where the matching detection was more than 12 hours in the past, a class that would have been missed by the legacy filter. Figure 6 shows an example, along with the key, of this for COMS data over Vietnam and Cambodia. Category 5 deserves note as these are likely to be false alarms that are recurring due to solar geometry, solar heating, etc. Most of the detected fires have multiple detections within the previous three hours and have the highest confidence that they are fires. In a couple cases an X is visible, indicating fires whose detections are more than 12 hours apart.

CIMSS is continuing its assessment of the new temporal filtering. Figure 7 illustrates the assessment tool that CIMSS developed to monitor behavior of the new technique. The first panel of the first row shows fire detection as a function of fire age, color coded by the fire flag (using the same color legend as in Figure 6). Many detections have an age of zero, and the distribution quickly drops off with increasing age but ramps back up for older fire detections. This indicates that a lot of fires are either first detections of a fire or else they are detections of long burning fires; "short" or "medium" aged fires tend to be relatively rare. The 2nd panel of the first row shows fire by temporal type in solid color code or fire category in dotted color code. The temporal color code is repeated throughout the rest of the image: white is the first detection of a fire, dark blue is where a fire is in less than half of the images in the past 3 hours, green is where a fire is detected in more than half of the images in the past 3 hours, dark red is where a fire has been detected for longer than 3 hours, and red is where a fire is more than 12 hours but it hasn't been detected in the past 12 hours (it would have failed the legacy filter that only looked back 12 hours). The remaining panels cover a variety of metrics including fire detection by solar hour, observations of a particular fire's nearby area over time to assess the frequency of clouds and other things that would prevent fire detection, and so on.

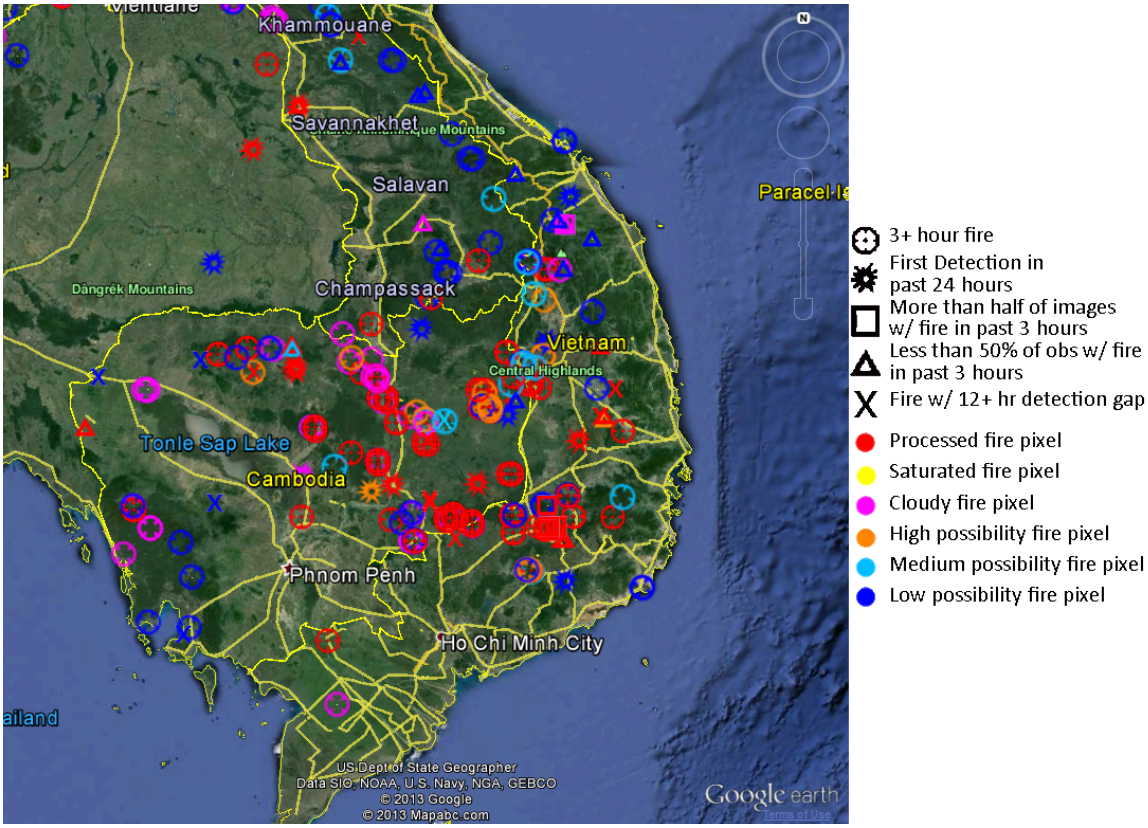


Figure 6. COMS data over Vietnam and Cambodia on 26 February 2014 showing the application of the new temporal filtering.

The behavior of low possibility fires is of particular interest in these plots as they represent the bulk of false alarms and, because of that, can trigger matches in the temporal filter that cause false alarms to appear there. Fires that have a greater than 12 hour detection gap are more likely to be false alarms due to surface heating or reflections, phenomenon that are largely driven by the sun angle. The spike in low possibility detections around local solar noon in the 12+ hour gap plot reinforces the notion and strongly suggests that those matches not be considered to be temporally filtered. The legacy method achieved the same result by limiting the filter to 12 hours. However, in the 5th row, where more than half the images had fire in the area of interest in the last three hours, there is another relatively large spike of low possibility fires, slightly delayed from solar noon. That suggests that the false alarms around solar noon persist for at least an hour or two, and then pass the temporal filtering there. Since these effects are likely due to surface heating and reflection, addressing them completely is a matter of looking at the ancillary data used by the algorithm to determine what, if any, measures can be taken to decrease the false alarms there.

Publications and Conference Reports

Hoffman, Jay P.; Schmidt, C. C.; Prins, E. M. and Brunner, J. C.. Recent developments with the global Wild Fire Automated Biomass Burning Algorithm. Boston, MA, American Meteorological Society, 2014, abstract only.

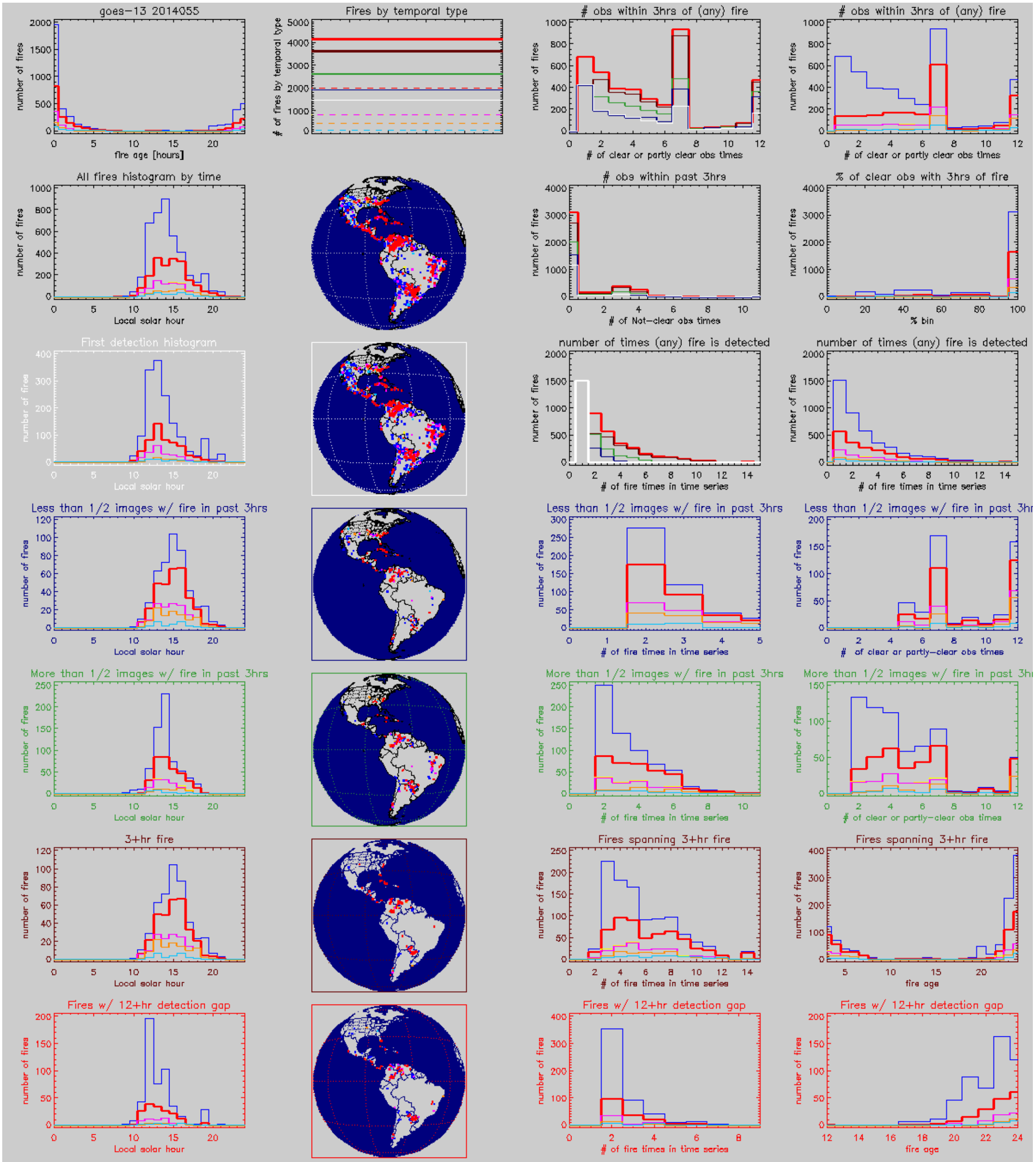


Figure 7. The temporal filtering assessment tool used by CIMSS showing GOES-13 temporal filtering data for 24 February 2014.

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

CIMSS Task Leader: Mark Kulie
CIMSS Support Scientists: Andi Walther, Ralf Bennartz, Joleen Feltz
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
- 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

Lake effect snow (LES) commonly occurs in the Great Lakes region, yet NEXRAD radars often do not detect these important precipitation events at longer distances from the radar site due to the shallow nature of LES structures. In an effort to mitigate NEXRAD radar observational shortcomings of LES events, we propose using satellite data products to improve both nowcasting capabilities and remotely sensed snowfall estimates. Satellite data provide valuable information about LES over the Great Lakes, and we propose developing methods using NOAA Algorithm Working Group (AWG) cloud products to extend NEXRAD coverage in regions currently devoid of radar observations. More specifically, collocated AWG cloud products and NEXRAD observations within ~100 km of Great Lakes radar sites are used to 'calibrate' GOES products for LES events by linking AWG cloud properties to NEXRAD-derived snowfall rates. A GOES LES snowfall rate product will then be created to augment NEXRAD coverage in data void regions and improve nowcasting and LES monitoring capabilities. The product will be demonstrated to Great Lakes region National Weather Service Forecast Offices (NWSFO), and collaborative research efforts will be undertaken to test and improve the product.

Summary of Accomplishments and Findings

Significant progress has been made during the previous year on project-related activities. Software to perform the following steps was produced and tested: (1) convert NEXRAD Level II data to Cartesian-gridded products (reflectivity and snowfall rate) on 1 and 4 km grids to match polar and GOES AWG satellite product grid size, (2) spatiotemporally matching NEXRAD and satellite products for the year-long LES dataset that was compiled, and (3) data fitting routines to generate a best-estimate empirical relationship between NEXRAD-derived snowfall rates (S) and AWG cloud water path (CWP) retrievals. Project feasibility was first demonstrated using coincident NEXRAD-AWG datasets using polar satellite observations, and initial results from this step were reported in the previous project annual report. Figure 8 illustrates initial results using over 20,000 AVHRR-NEXRAD matchups from two radar locations in Michigan and demonstrates the new LES product's potential to improve LES nowcasting and snowfall rate estimation over areas of Lake Superior without adequate radar coverage.

The empirical CWP-S fits have recently been expanded to include a GOES LES dataset that contains over 200,000 GOES AWG-NEXRAD match-ups from over 40 LES cases observed by 9 Great Lakes region radars in the 2012-2013 and 2013-2014 winter seasons. These collocated GOES-NEXRAD data points are spatiotemporally located less than 0.5 km/5 minutes apart in an effort to minimize scatter caused by time/space mismatches. Figure 9 shows the GOES-NEXRAD (4 km grid) CWP-S data density plot compared to a limited AVHRR-NEXRAD (1 km grid) database and highlights the potential CWP-S relationship at higher CWP-S values that is currently not indicated by the less populated AVHRR-NEXRAD dataset. Further research will be performed to populate the 1 km grid results to include more events in an effort to refine these CWP-S relationships and denote any systematic differences between the different horizontal resolution datasets. Furthermore, case-dependent 4 km CWP-S signatures have been observed in the GOES dataset (not shown), and further work may indicate distinctive CWP-S trends that may further reduce the inherent uncertainties associated with the empirical matching procedure. Future work will also entail comparing ground-based snowfall accumulations to our empirically derived snowfall rates.

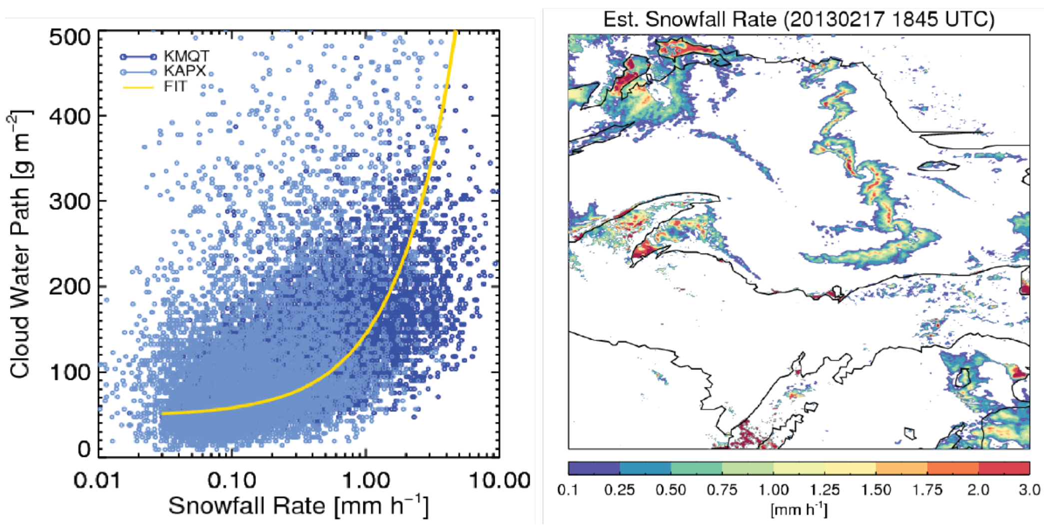


Figure 8. (Left) Scatter plots of collocated NEXRAD-derived snowfall rates from the KMQT (dark blue) and KAPX (light blue) radar sites and the AVHRR-derived AWG cloud water path (CWP) product from 31 January 2013 near 1844 UTC. An empirical fit between CWP and snowfall rate (S) is also indicated (yellow line). This empirical S-CWP relationship is then used to derive snowfall rates directly from the AVHRR CWP product for a case study consisting of multiple mid-lake vortices over Lake Superior on 17 February 2013 (right).

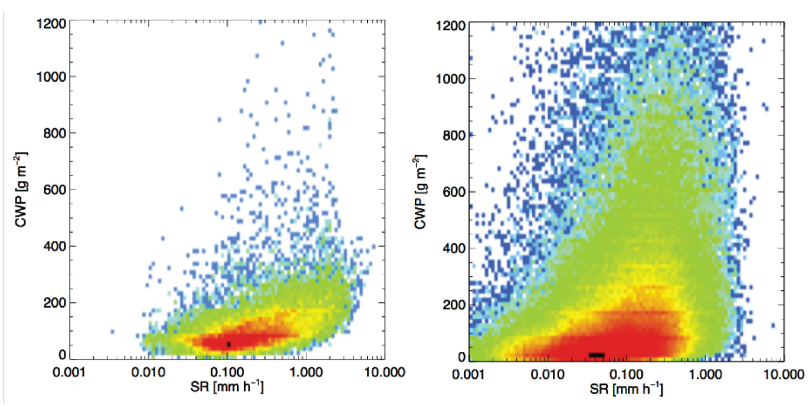


Figure 9. NEXRAD-derived snowfall rate (SR) versus AWG cloud water path (CWP) data density plots for (left) a AVHRR-NEXRAD LES database of 2 lake effect events observed by the Marquette, MI and Gaylord, MI radars and (right) a GOES-NEXRAD lake effect snow (LES) database consisting of over 40 events and 9 Great Lakes radar locations.

Publications and Conference Reports

Kulie, M.S., J. M. Feltz, A. Walther, M. Dutter, S. W. Nesbitt, R. Bennartz, and A. Heidinger, 2014: Improving Lake Effect Snow Nowcasting and Quantitative Precipitation Estimation Using Synergistic Satellite and NEXRAD Products. *4th Conf. on Transition of Research to Operations, 94th American Meteorological Society Annual Meeting*, 2-6 Feb 2014, Atlanta, GA.

3.7 Enhanced Downslope Windstorm Prediction with GOES Warning Indicators

CIMSS Task Leader: Anthony Wimmers
NOAA Collaborators: Daniel Lindsey (Co-PI, CIRA), Randy Graham (NWS SLC), Stan Czyzyk (NWS VEF), Eric Thaler (NWS BOU)

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 aims to improve the prediction of downslope wind events at select western U.S. locations using a combination of GOES imagery and numerical models. A statistical method has been developed previously to predict downslope windstorms in Ft. Collins, CO using only model output (Lindsey et al., 2011), so we are working to add GOES predictors to the model, as well as to create similar models for other locations that are prone to severe downslope winds.

Milestones set for the previous year, continuing through June 2014, include the following:
- Optimize the prediction model that combines the GOES-derived algorithm with NWP model fields,
- Determine whether WRF forecast synthetic imagery is a viable predictor, and
- Set up an experimental real-time forecast system for the chosen sites.

Summary of Accomplishments and Findings

Our progress on these three milestones is given below, in order:

Optimize the prediction model that combines the GOES-derived algorithm with NWP model fields

A set of GOES predictors have been selected for the Fort Collins location. The predictors that show the strongest relationship to downslope wind magnitude at 6 and 12 hours into the future are:

1) Terrain pattern score – which describes the close correspondence in gradient patterns between the topography and the water vapor channel;
2) Fine-resolution downslope drying score – which describes the water vapor channel drying over a mountain slope at the native satellite resolution; and
3) Regression-based satellite wave score – which describes the coherence of the repeating wave patterns in the water vapor channel in lee of the mountains. The score is calculated by regressing the brightness temperatures around the gravity waves with the brightness temperatures one half-phase apart.

For reference, an example of the regression-based satellite wave score (#3) is shown below. The product is sampled at the Fort Collins location to obtain a scalar score value.

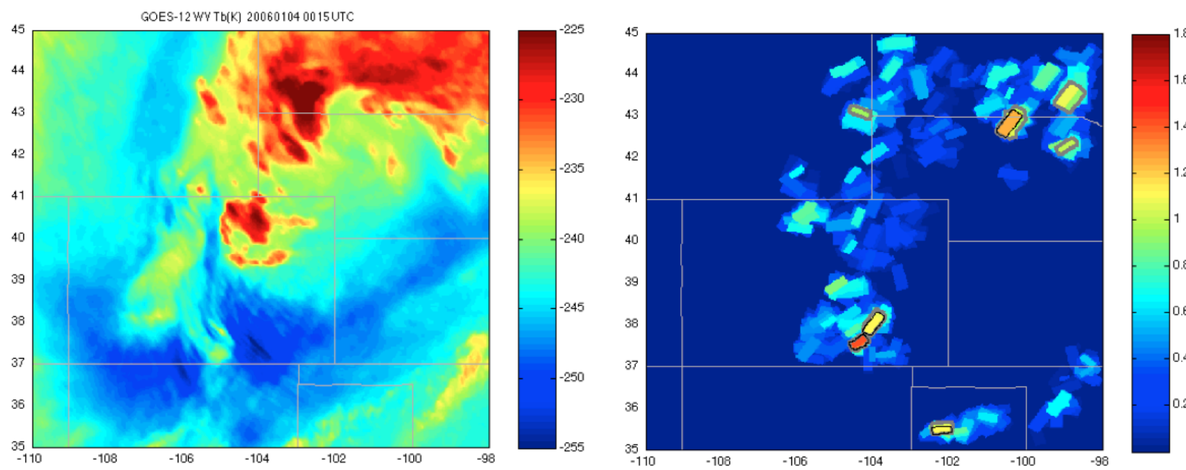


Figure 10. GOES predictor example for 2006-01-04 0015 UTC. Left: GOES Water Vapor Channel brightness temperature for Colorado and the surrounding states. Right: Regression-based satellite wave score, in which hotter colors indicate stronger wave patterns.

Determine whether WRF forecast synthetic imagery is a viable predictor

WRF forecast synthetic imagery continues to be generated and collected, so after the GOES predictors are finalized, we will test the predictors on the forecast synthetic images to see whether a predictor based on the forecast imagery is viable.

Set up an experimental real-time forecast system for the chosen sites

A real-time forecast system using the environmental predictors already exists for Ft. Collins. Work is in progress to begin processing the GOES predictors in real time from CIRA's satellite groundstation. We have set up the changes needed to apply the GOES predictor algorithm to real-time CIRA datastreams rather than SSEC archives. We have also set up the CIRA server account that will run the Matlab code on a crontab and performed a successful proof-of-concept test. The remaining work will be to apply the GOES predictor code to real-time data in steps, and troubleshoot.

A real-time prediction system will also be set up for the Hill Air Force Base location in Utah.

References

Lindsey, D. T., B. McNoldy, Z. Finch, D. Henderson, D. Lerach, R. Seigel, J. Steinweg-Woods, E. Stuckmeyer, D. Van Cleave, G. Williams and M. Woloszyn, 2011: A high wind statistical prediction model for the northern Front Range of Colorado. *Electr. J. Oper. Meteor.*, 2011-EJ03.

http://rammb.cira.colostate.edu/products/fort_collins_high_wind_probability/docs/high_wind_model.pdf

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

CIMSS Task Leaders: John Cintineo, 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
- 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 goal of this project is to utilize temporal trends in GOES-derived cloud properties (e.g., emissivity, cloud phase, optical depth, etc.), NWP fields (e.g., CAPE and shear, etc.), and NEXRAD to objectively determine the probability that a growing cumulus cloud object will first produce severe weather in the near-term (0-2 hours). A flexible statistical model is utilized such that additional data sources (e.g., lightning) can be incorporated at a later time. Results achieved thus far indicate that a statistical model (a naïve Bayesian classifier) fused together with data from each aforementioned observation source can often predict that severe weather is likely to occur 10 minutes or more prior to the issuance of the first National Weather Service (NWS) severe weather warning, without a large increase in false alarms. The end goal of this work is to improve the timeliness and accuracy of severe weather warnings and condense the pertinent information from the "fire hose" of data for NWS forecasters in order to aid in their warning decision.

Summary of Accomplishments and Findings

The statistical model utilizes automated cloud-cluster and storm-cell identification and tracking to identify developing storms in satellite and radar data, respectively, in a similar manner to how humans view these data. The cloud object identification and tracking method (following Sieglaff et al., 2013) has been performing admirably, keeping up in real-time, while having only few miss-identifications. A few minor changes have been employed from Sieglaff et al. (2013), to optimize the tracking to the purposes of this research (from the early stages of satellite growth into maturity). The tracking allows for computation of temporal trends in GOES-derived cloud properties and radar-derived storm intensity estimates, which are used as observational predictors within the statistical model.

In addition to observational predictors, the background environmental conditions are input into the statistical model. The NCEP Rapid Refresh (RAP) model depiction of storm environment instability (most unstable CAPE) and shear (effective bulk shear) are utilized. 2D kernel density estimation was performed for both severe and non-severe training classes of the statistical model, yielding a smooth *a priori* probability table based on these two environmental NWP fields. The mixed-layer lifted index (MLLI) and height of the wet-bulb 0^oC isotherm have also been shown to be skillful predictors of severe convective hazards, and work is on-going to integrate these NWP fields into the *a priori* probability or as predictors in the model.

Thus far, formal evaluation of the model has been fairly subjective, but a manual, quantitative analysis of two convectively active days during the spring/summer of 2013 has been completed. In the validation, a threshold of 50% probability was used to classify the statistical model as a 'yes' prediction of future severe weather. The model results were compared to local storm reports (the first severe weather report a given storm produced, if applicable) as well as the first National Weather Service warning on a given storm, if applicable. The analysis showed the statistical model had slightly lower, yet comparable skill to first NWS warnings but added (in the median) 10 minutes of lead-time on the NWS warnings. These results are exciting that lead-time ahead of current severe warnings can be gained without significant degradation of skill.

The statistical model has been running in real-time at CIMSS uninterrupted since April 2013. The statistical model output is now also being ingested into AWIPS-II, in shapefile format, with contours around radar storm-cells as well as text readout, allowing forecasters to seamlessly add this new product to their radar views within AWIPS-II (Figure 11).

Publications and Conference Reports

Cintineo, J. L., M. J. Pavolonis, J. M. Sieglaff, and D. T. Lindsey, 2014: An Empirical Model for Assessing the Severe Weather Potential for Developing Convection. *Wea. Forecasting*, In press. doi: http://dx.doi.org/10.1175/WAF-D-13-00113.1

Cintineo, J. L., M. J. Pavolonis, and J. M. Sieglaff, 2014: Preliminary evaluation of a fused algorithm for the prediction of severe storms, *22nd Conference on Probability and Statistics in the Atmospheric Sciences,* Atlanta, GA, 7.1.

References

Cintineo, J. L., M. J. Pavolonis, J. M. Sieglaff, and A. K. Heidinger, 2013: Evolution of severe and non-severe convection inferred from GOES-derived cloud properties. *J. Appl. Meteorol. Climatol.*, **52**, 2009-2023. doi: http://dx.doi.org/10.1175/JAMC-D-12-0330.1

Sieglaff, J. M., D. C. Hartung, W. F. Feltz, L. M. Cronce, and V. Lakshmanan, 2013: Development and application of a satellite-based convective cloud object-tracking methodology: A multipurpose data fusion tool. *J. Atmos. Oceanic Technol.,* **30**, 510-525.

Witt, A., M. D. Eilts, G. J. Stumpf, J. T. Johnson, E. D. Mitchell, and K. W. Thomas, 1998: An enhanced hail detection algorithm for the WSR-88D. *Wea. Forecasting*, **13**, 286-303.

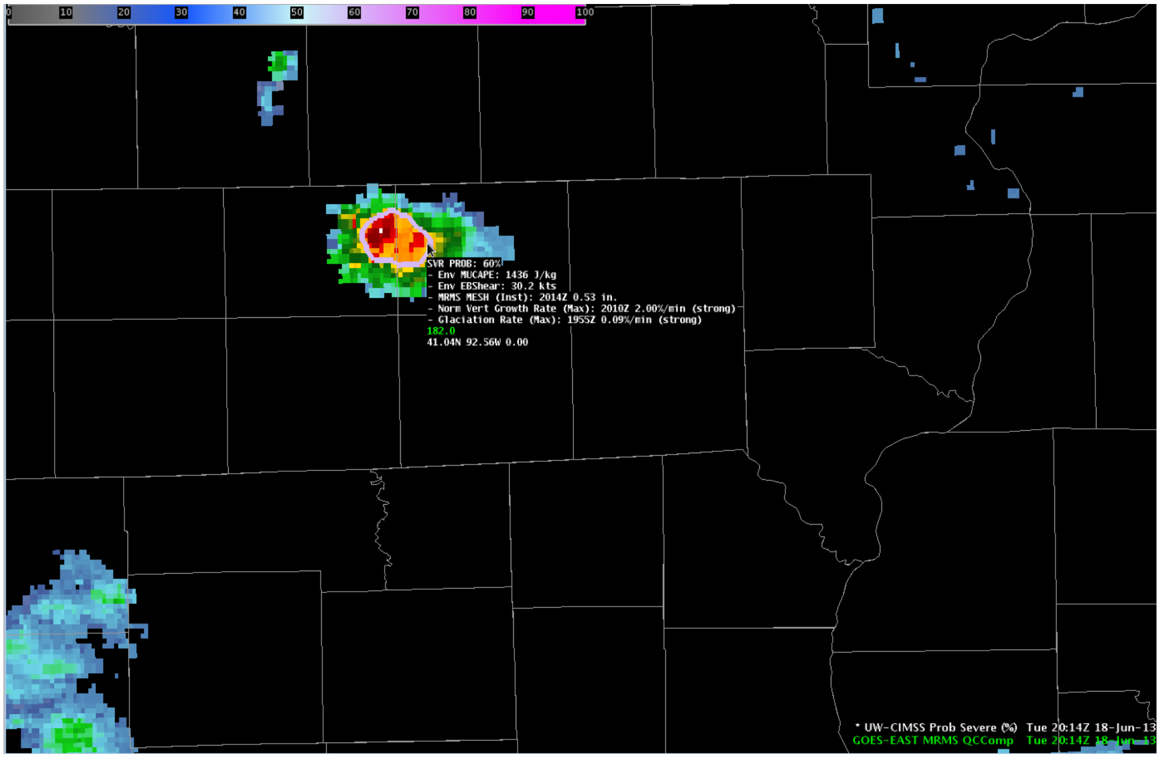


Figure 11. An AWIPS-II screenshot of the statistical model output being displayed over composite radar reflectivity. The colored contour indicates model probability (pink contour) and text readout of the probability and each model predictor is also demonstrated. The storm in the center of the image is a thunderstorm over south-central Iowa on June 18, 2013 at 2014 UTC. On this day widespread severe weather was not anticipated—yet the statistical model generated probabilities greater than 50% (actually 60%) at 2014 UTC that this storm would produce severe weather in the next 60 minutes. This storm went on to produce severe weather at 2059 UTC and became severe warned at 2103 UTC, equating to 45 and 49 minutes of lead-time, respectively.

3.9 GOES Radiance Quality Assurance

CIMSS Task Leader: Mathew Gunshor
CIMSS Support Scientists: James P. Nelson III, Joleen Feltz
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

Working with NOAA NESDIS ASPB, CIMSS supports the quality-assurance of the GOES Imager and Sounder data in a number of ways. This diagnostic or 'science support' includes: stray light corrections, electronic side switch monitoring, Sounder short-wave noise, Sounder filter wheel issues, Imager co-registration and other issues as they arise. Examples include making sure that a stray light correction also includes a bit in GVAR that can alert users that the correction was made, providing the idea to bounce test GOES-13 data off of GOES-14, and showcasing how increased Sounder noise affects products. This independent assessment allows for a more robust system overall and results in meaningful feedback on any operational implementation. Most of these issues arise with little warning, making it difficult to outline exact future milestones or tasks. Quality assurance is a vital component of the GOES mission, given that all imagery and derived applications need quality radiances. CIMSS, working with the SSEC Data Center, is uniquely positioned to provide this critical link in the GOES mission because of its ready access to data, experience, knowledge, and many GOES science algorithms.

Summary of Accomplishments and Findings

Analyzed the GOES-15 Sounder Destriping Correction

Zhenping Li of NOAA/NESDIS developed a destriping correction for band 15 of the Sounder. This band has traditionally been impaired by striping on this and previous GOES Sounders. CIMSS was asked to determine if the destriping correction improved the imagery and subsequently the Sounder products. It was determined that image quality is improved, but there is a minimal effect on products. The minimal effect on products is likely due to two factors: First, this is just one of the 18 IR bands. Second, this is not one of the most significant bands for the products analyzed.

GOES-13 Imager Space Looks Affected by Stray Light

There is a stray light correction that has been applied to GOES-13 that removes most of the effects of stray light on images taken during the so called "eclipse" periods of the year when earlier GOES were unable to continue taking imagery. This has allowed NOAA to make more operational scans during these periods. However, an unanticipated problem was encountered this year. Some users noticed large changes in cloud top temperatures as seen in the 3.9um band at one or maybe two images a day. Figure 12 shows an example CIMSS received from the

Blacksburg, VA forecast office. Unlike with the traditional stray light problem, this seems to be the result of bad space look data which are used to calibrate the image. The theory is that when the imager looks into space for the space look data, it is looking too close to the sun. CIMSS is using a statistical analysis of the 3.9-11 um band differences to provide dates to OSPO to either avoid collecting data or avoid taking space looks (when the sun is just off the Earth where the Imager looks for space look calibration data). This process is still ongoing.

GOES13 "Anomaly" and Subsequent Outage May/June 2013

On May 22, 2013 GOES-13 experienced an anomaly that stopped it from operating. The probable cause for the outage is a meteorite hitting the satellite. GOES-13 went into storage mode and GOES-14, located at 105W, became operational GOES-East on May 24. GOES-13 was brought out of storage mode on May 28 for testing. CIMSS was prepared to immediately assist with this testing as the SSEC datacenter was able to obtain GOES-13 data that was rebroadcast via GOES-14 while GOES-14 data were being operationally disseminated via GOES-13's antenna. The assurance that test data could be collected and analyzed allowed NESDIS to continue with plans to test GOES-13 prior to putting it back in as operational GOES-East. The SSEC Datacenter may be the only place that these test GOES-13 data are now archived.

Due to the location of GOES-14 (west of the typical GOES-East location), the CONUS sectors were not including Puerto Rico. CIMSS researchers were contacted by several from the San Juan forecast office asking if something could be done to restore their coverage from CONUS sectors. Working with the Office of Satellite Products and Operations (OSPO) and others, an adjusted sector was implemented by OSPO on May 31, 2013 at 15:15 UTC. This returned the nominal four views per hour for Puerto Rico, especially important if there are issues with the local radar.

As GOES-13 was tested, CIMSS provided feedback on image and product quality. At the request of Tim Schmit (ASPB), the GOES-13 Sounder was put through a four-day outgassing process with the expected outcome of reduced noise, especially in the shortwave bands. CIMSS assisted with the analysis of the post-outgas data and GOES-13 returned to operations as GOES-East on June 10, 2013.

GOES-15 Stray Light Corrupted Space Looks During Eclipse Season

During satellite eclipse season, the sun is behind the Earth while the satellite is scanning and this can cause problems with image (and radiance) quality. The traditional problem with stray light can be partially mitigated. Another problem that was discovered is that at certain times the Imager scans off the Earth to get space look data for calibration. These data are corrupted if the sun is close to edge of the earth, which causes poorly calibrated data. In some cases brightness temperatures off by 50K were noticed. The effect was particularly noticeable in parts of images with cold cloud tops.

GOES-15 Sounder Patch Temperature Change 12 September 2013

On September 12, 2013 SOCC Engineers changed the GOES-15 Sounder patch temperature from its LOW set point (82 K) to its HIGH set point (85 K) at about 20:35z (4:35 pm ET).

The temperature transition takes approximately 30 minutes during housekeeping and may cause mild striping during the very beginning of the next sounding at 21:00. GOES-15 patch management is necessary to minimize patch fluctuations around each equinox due to the cooler blanket anomaly.

At CIMSS we monitored the effect of the patch temperature change on products which was minimal as only the first image time after the patch was noticeably affected. There was slight banding evident in the longer wave bands and this appeared in the cloud top pressure product.

Low Cloud "Noise" in the GOES Sounder Cloud Product in October 2013

Frequently during the fall and spring, the GOES Sounder cloud mask incorrectly identifies cloud in early morning cool, clear skies. This results in a "noisy" low level cloud pattern over the eastern United States. These faux low level clouds are not supported by independent comparisons with other cloud height algorithms or synoptic observations. This was corrected by "loosening" one of the Low-Level Inversion tests used during processing at CIMSS. The test can be adjusted by changing a variable named TINV, which stands for (current value = -3.00 K).

This information was shared with operations and the NESDIS operational GOES Sounder processing algorithm adopted the switch.

GOES-15 Yaw Flip Maneuver on 23 September 2013

On 23 September 2013, the GOES-15 satellite was flipped. This maneuver has been done on GOES-15 before and must be done during eclipse season to reduce the effects of stray light. CIMSS noticed in before vs. after comparisons that there was a navigation offset in the Imager on the order of 1 pixel.

GOES-13 Co-Registration Issue

GOES-13 (GOES-East) IR Channels 2 (3.9 um) and 4 (10.7 um) registration difference was discovered to be 1 pixel or greater at certain times of day. This can cause false fog data which uses the difference between these two channels. CIMSS helped determine that the 10.7um band was typically aligned with the visible band better and thus was thought to be better navigated. However for fire detection it was important that the 3.9um band not be remapped or resampled. OSPO developed a fix for this issue to balance these needs. For more details see: http://cimss.ssec.wisc.edu/goes/blog/archives/10341

GOES-13 Sounder Dropped Pixels

In July of 2013 users began to notice dropped pixels in the GOES-13 Sounder. An unusual anomaly, all 19 bands would experience the same pattern of missing pixels. GOES engineers discovered the problem was the filter wheel changing speeds suddenly, thus causing the data to be dropped from the processing system, but have not discovered why it is happening. CIMSS found some evidence that it has occurred prior to summer of 2013, for example in the summer of 2012.

The engineers at OSPO came up with a software solution which should restore these missing pixels. CIMSS assisted in testing and validating the results (Figure 12). A new version of the Sensor Processing System (SPS) software (version 1.4.1) should be released in spring of 2014. See http://cimss.ssec.wisc.edu/goes/blog/archives/15184 for more information on this issue.

Provided Code to NESDIS

Provided code for getting the DAY out of GOES VARiable (GVAR) scan-line prefix data to Andrew Bailey (Sr. Scientist: Land and Atmospheric Monitoring Group/IMSG; Operational Products Development Branch - NOAA/NESDIS) on 9/23/2013.

Operational Impacts

CIMSS, along with ASPB, works with OSPO, ESPC and others when problems with GOES radiance quality arise. As this report is being written, a new Sensor Processing System (SPS) is planned to be released in April, 2014. SPS software version (10.4.1) will be released replacing version 10.2. This new version corrects GOES-15 (GOES-West) Sounder shortwave channel (15) striping, GOES-13 (GOES-East) IR Channels 2 (3.9 um) and 4 (10.7 um) co-registration differences, and GOES-13 (GOES-East) Sounder dropped pixels. These are all issues that CIMSS and ASPB have had involvement with by raising the issue, assessing the impact on imagery and products, analyzing the fix, and/or educating users via the CIMSS Satellite Blog.

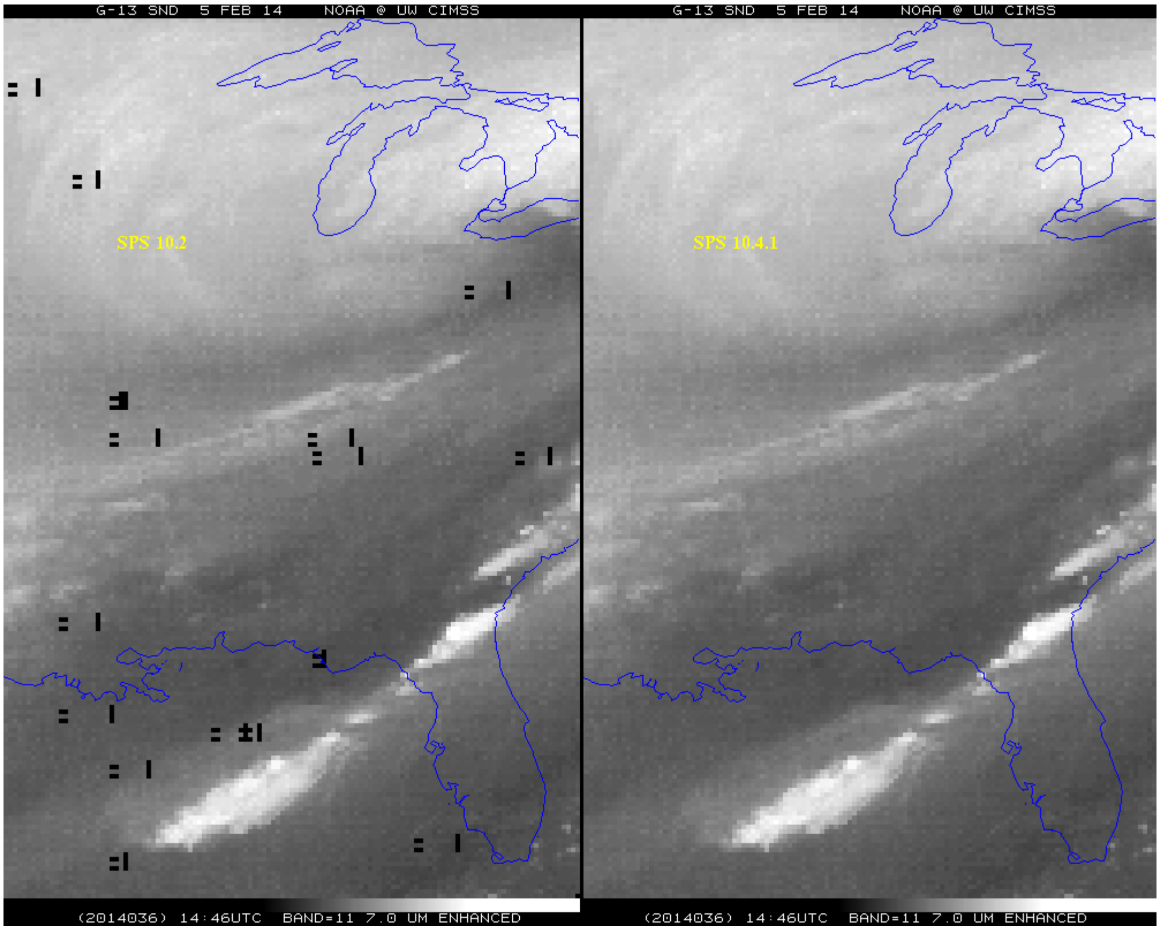


Figure 12. GOES-13 (East) Sounder Band 11 (7 micrometer) on 5 Feb 2014 at 14:46UTC produced with SPS 10.2 (left) and 10.4.1 (right). Note the dropped pixels on the left and how the SPS v10.4.1 has restored them on the right.

Publications and Conference Reports

Multiple phone conference presentations were done by Tim Schmit (NOAA/NESDIS) during the GOES-13 outage in May/June. A PowerPoint presentation was provided to Hyre Bysal (NOAA/NESDIS) concerning the GOES-15 Sounder destriping correction. Multiple PowerPoint documents were presented to OSPO and others concerning the post-yaw-flip navigation issues. Multiple PowerPoint documents were presented to OSPO and others concerning the GOES-13 Sounder pixel dropout issue.

Li, Zhenping et al., “GOES Imager IR channel to channel co-registration correction program”, Image and Signal Processing for Remote Sensing XIX, SPIE Remote Sensing, 23-26 September, 2013, Dresden, Germany, 8892-56.

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. http://remotesensing.spiedigitallibrary.org/article.aspx?articleid=1790703

4. CIMSS Participation in the Product Systems Development and Implementation (PSDI) for 2013

4.1 Operational Implementation of the CIMSS Advanced Dvorak Technique

CIMSS Task Leaders: Chris Velden and Tim Olander
CIMSS Support Scientist: Tony Wimmers
NOAA Collaborators: Liqun Ma and Mike Turk (SAB)

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 Advanced Dvorak Technique (ADT, Olander and Velden 2007) is an algorithm designed to provide objective estimates of hurricane intensity from GOES and other geostationary satellites. Its long-term development has been partially supported by GIMPAP, and this proposed task represents the PSDI-supported transition of the latest version of the algorithm into NESDIS operations at the Satellite Analysis Branch. The National Hurricane Center (NHC) now routinely accesses the ADT data as part of its hurricane analysis and forecast suite of tools.

In support of the importance of the ADT in hurricane analysis at the U.S. operational centers, a joint User Request was recently submitted to the NESDIS SPSRB by NHC, CPHC (Central Pacific Hurricane Center), and JTWC (Joint Typhoon Warning Center). The request, Request NO: 1104-0003, Title: "Continue operational transition and upgrade support of the ADT", was approved by the SPSRB for funding considerations starting in FY12. This PSDI project follows the above User Request guidance, and addresses the operational transition component proposed upon successful completion of new science added to the ADT.

Summary of Accomplishments and Findings
Efforts for this proposed fiscal year were mainly in a supporting role, and focused on adapting the latest ADT version code into the operational framework at OSPO. Specifically, CIMSS:
- Responded to OSPO feedback on ADT v8.1.4 implementation, testing, and performance evaluation during/after transition;
- Performed verification and validation previously assigned to SAB; and

- Updated documentation.

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.L. and C.S. 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.

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

CIMSS Task Leader: Anthony Wimmers
NOAA Collaborator: Andrew Heidinger

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

The Clouds from AVHRR Extended (CLAVR-x) and GOES Surface and Insolation Project (GSIP) are existing operational systems serving data to the National Weather Service (NWS) National Centers for Environmental Prediction (NCEP) and Weather Forecast Offices (WFO). The resolution of the data sets generated today were determined several years ago, and increases in model resolution warrant an increase in the resolution of satellite products served to NCEP. The hdf4 and binary formats provided today are also no longer optimal for NWS. In addition to spatial resolution, the value of higher vertical resolution cloud product imagery is increasing in NWS WFOs. The lack of consistent spatial and temporal coverage at higher latitudes has hampered the use of this information by forecasters, and so the Alaskan WFO has requested composites of cloud height information to assist in their aviation and general forecast duties. This project updates CLAVR-x and GSIP to accomplish this mission and develop compositing codes to integrate this new data in the most readily usable fashion.

Since the development of the CLAVR-x and GSIP programs, the NESDIS/STAR Algorithm Implementation Team (AIT) has developed tools to perform the data formatting and gridding needed for the GOES-R program. These tools have been funded by PSDI and are already mature. The goal for this project is to remap the CLAVR-x level-2 products into the requested NCEP model grid. These remapped data will then feed into the existing AIT tools for conversion into formats expected by NCEP. We use the GSIP mapping tools for this, which are an open source toolkit that will allow the CLAVR-x level-2 files to be converted from swath projection to the NCEP model grids. Most of this work will be done by NESDIS/STAR but CIMSS does participate in the testing of this mapping procedure. CIMSS will make the modifications of the CLAVR-x and GSIP to make the pixel-level swath projection files that are the starting point in this process.

For the data compositing component of this project, we proposed to apply a high-performance “morphological compositing” algorithm to the CLAVR-x and GSIP products (Wimmers and Velden, 2010), which is the blending of data that is “nudged” to fixed composite times by an appropriate advection field. The advantages of morphological compositing are the following:

- **Greater accuracy**: The objective is to present retrievals at their true position at the time of the composite product, rather than at their retrieved position at a different time.
- **Seamless motion**: Data that is “nudged” with the motion of the clouds minimizes the discontinuities in motion as data is incorporated from multiple sources at multiple, irregular times.
- **Greater consistency**: Image sequences (animations) have more consistent resolution.
- **Easier readability**: The focus on accurate depiction of cloud motion allows users of the product to directly interpret the changing characteristics of moving objects (e.g., increasing cloud height), rather than devoting most of the analysis to estimating motion from irregular images.

We proposed to finalize an algorithm that automated the morphological compositing algorithm to incoming GSIP and CLAVR-x data sets, and deliver the algorithm to NOAA NESDIS.

Summary of Accomplishments and Findings

We have completed the algorithm development and delivered the software to NOAA NESDIS on schedule. The Comprehensive Design Review was delivered in February, 2014. Below is an example of the morphed composite product for the greater Alaska domain on the test dataset (Figure 13).

The seamless aspects of the compositing and reduction of artifacts are apparent in the image above. This was produced from four satellite sources – three AVHRR satellite retrievals, nudged to the valid time, and one GOES-West retrieval. The sensor contributions from this product are shown below (Figure 14). In addition to the high accuracy of single images, the advantages of this algorithm are even more evident in the image animations over extended time periods. There it can be seen that a multi-sensor, morphological composite delivers the high accuracy of polar imagery as well as the high temporal consistency of geostationary imagery throughout the greater Alaska domain. Without this contribution from the algorithm, a pure geostationary alternative of the northern portion of the image would have the inaccuracies that come from a high zenith angle, and alternatively, a standard polar composite would have ongoing motion discontinuities as well as long time gaps between satellite scans in the southern portion of the domain.

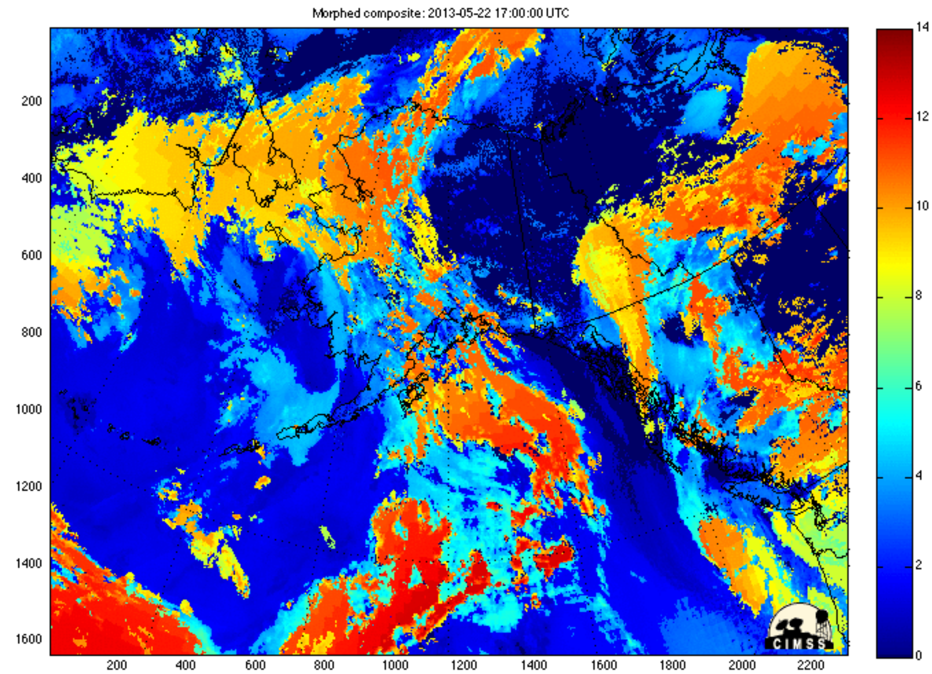


Figure 13. Morphed Composite product of ACHA Cloud Height (km) for 22 May 2013, 1700 UTC.

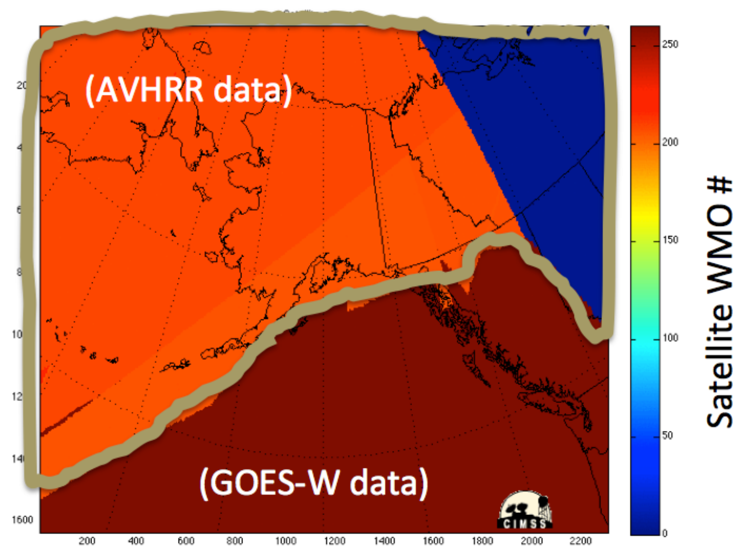


Figure 14. Contribution to the Alaska Morphed Composite Product from AVHRR and GOES-West sensors. Regions are colored according to WMO sensor number.

In the coming months we will work with NOAA NESDIS on the implementation of the algorithm in real-time product compositing, and finish the development of a seasonal product validation algorithm.

Publications and Conference Reports

Wimmers, A. J. and A. Heidinger, Morphing polar-orbiter imagery of cloud products for improved visualization and forecasting, National Weather Association Annual Meeting, Madison, Wisconsin, 2012.

References

Wimmers, A. J. and C. S. Velden, Objectively determining the rotational center of tropical cyclones in passive microwave satellite imagery, *J. Appl. Meteor.*, 49, 2013–2034, 2010.

4.3 Arctic Composite Satellite Imagery

CIMSS Task Leader: Matthew Lazzara
CIMSS Support Scientists: Rick Kohrs and Dave Mikolajczyk
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

Project Overview

The creation and routine generation of the Arctic composite satellite imagery has been demonstrated in a National Science Foundation (NSF) Arctic Natural Sciences funded "proof of concept" research project. Arctic composite satellite imagery is the cousin to the Antarctic satellite composite imagery, which has been produced over the Southern Ocean and Antarctic continent for over 20 years as a part of the NSF United States Antarctic Program. These composites include several infrared channels (shortwave, longwave, window, and water vapor), as well as a visible channel (Lazzara et al., 2011, Lazzara et al., 2003). The Arctic composite product covers the Arctic Ocean basin, Northern polar region in the US Arctic and Alaska, as well as Northern Atlantic and Northern Pacific Arctic regions.

This project aims to transition the Arctic composite satellite generation and products to NOAA operations. The user community for this product includes the Ocean Prediction Center, the Weather Prediction Center (formerly the Hydrometeorological Prediction Center), National Weather Service Alaska, National Ice Center as well as the Satellite Proving Ground for Marine, Precipitation, and Hazardous Weather Applications program. This product aids in improving operational forecasting for the North Pacific and North Atlantic for maritime and aviation operations. Time-lapse imagery and animations assist in the understanding of weather patterns and phenomena, ultimately improving forecasts. With relatively minor enhancements, the Arctic composite satellite product meets users' requested needs.

Summary of Accomplishments and Findings

The generation system for making these composites has been running well for a year with data made available via the Web (http://arctic.ssec.wisc.edu) and via Local Data Manager (LDM) direct to NCEP Central Operations (NCO). NCO in turn makes this data available to the primary end use, the Ocean Prediction Center (OPC). Other end users (e.g., NWS Alaska) use the composites via the Web site. The composite generation system has been setup to meet the end users needs with increased resolution (4 km nominal at 60 degrees North) and specific navigation orientation (170 degrees West longitude). A few errors and bugs in the coding have been revealed and identified during the past year of operations. These have been fixed. A paper that provides an overview of the satellite compositing methodology of these and other composites generated at SSEC has been published (Kohrs et al., 2014). A related publication on the generation of Atmospheric Motion Vectors (AMV) that use a very similar composite has also been published (Lazzara et al., 2014). A combined preliminary/critical design review (PDR/CDR) has been held that identified the need for some additional standardization of the arrangement of the software and scripting. This effort is in progress at this time along with documentation of the production system. The change out of personnel at OSPO a part of this project over the past year, and other schedule changes have been taken into account with a new timeline outlined for project completion. The estimated date for operational production is the end of calendar year 2014.

Publications and Conference Reports

Kohrs, R.A., M.A. Lazzara, J.O. Robaidek, D.A. Santek, and S.L. Knuth, 2014: Global satellite composites – 20 years of evolution. *Atm. Res*., **135-136**, 8-34. doi:10.1016/j.atmosres.2013.07.023.

Lazzara, M.A., R. Dworak, D.A. Santek, B.T. Hoover, C.S. Velden and J.R. Key, 2014: High-latitude atmospheric motion vectors from composite satellite data. *J. App. Meteor. Clim.*, 53, 534-547. doi:10.1175/JAMC-D-13-0160.1.

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Lazzara, M.A., A. Coletti, B.L. Diedrich, 2011: The possibilities of polar meteorology, environmental remote sensing, communications and space weather applications from Artificial Lagrange Orbit. *J. Adv. Space Res*., **48**, 1880-1889, doi:10.1016/j.asr.2011.04.026.

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

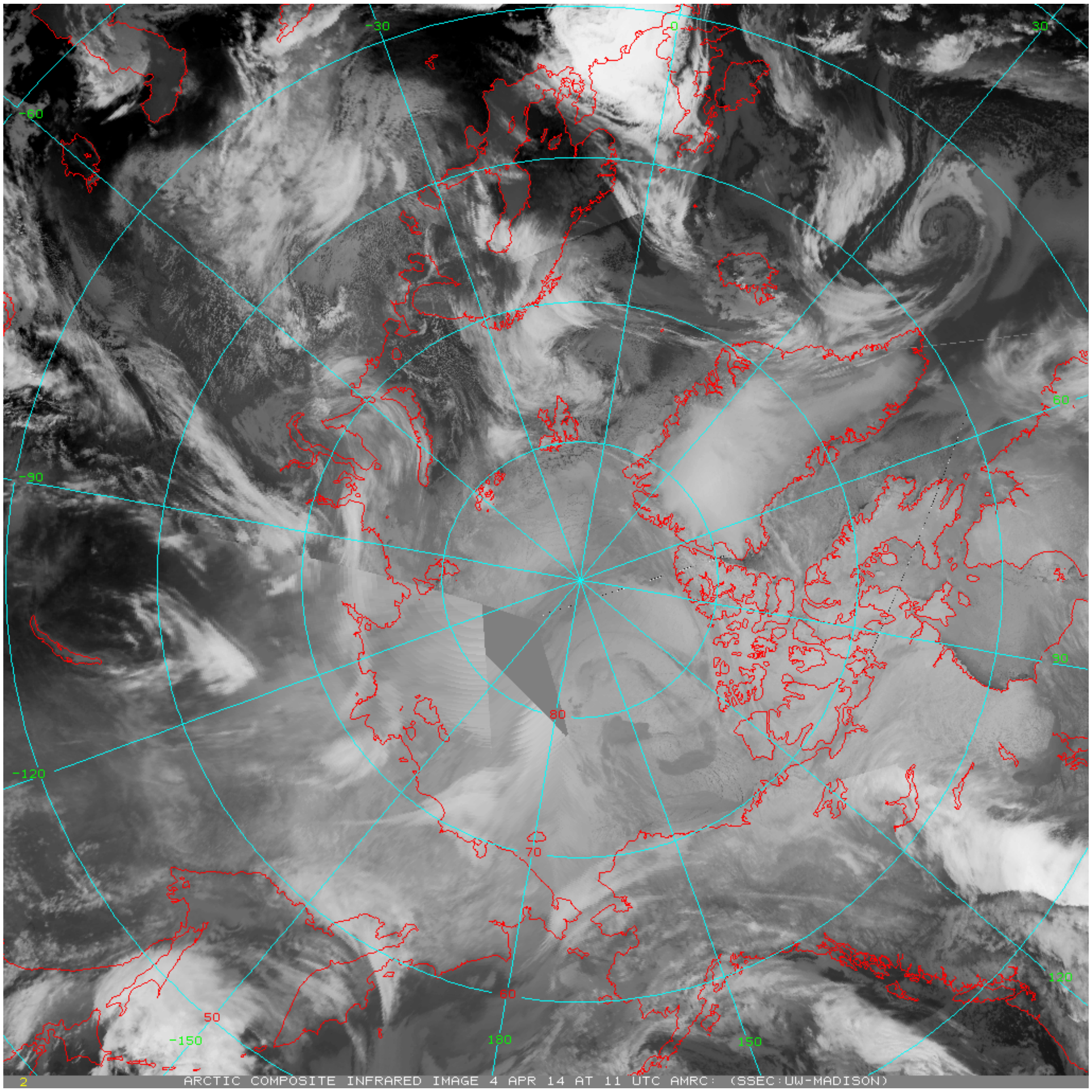

Figure 15. An Arctic Composite Infrared satellite image from 4 April 2014 at 11 UTC over the Arctic basin created from geostationary and polar-orbiting satellite observations. This example image demonstrates very good coverage and only a limited region of no satellite coverage over the central Arctic Ocean.

5. CIMSS Infrastructure Support for Product Development, Demonstration and Operational Transition (Ground Systems)

CIMSS Task Leaders: Steve Ackerman, Wayne Feltz
NOAA Collaborator: Jeff Key

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 Sensors and Techniques

Project Overview

In the coming years, ASPB/CIMSS will play a major role in the recently launched National Polar-Orbiting Partnership (NPP), the future Geostationary Operational Environmental Satellite-R (GOES-R), and the future Joint Polar Satellite System (JPSS). A number of NPP/JPSS and GOES-R application teams are led by ASPB. New products are also being developed with NPOESS Data Exploitation (NDE) and PSDI support, e.g., VIIRS polar winds. For these major NESDIS programs we seek to further develop a local community computing resource rather than continuing to rely on individual systems belonging to specific projects.

The development of a high-end computing system with large storage capacity has greatly benefited the funded NPP, NDE, GOES-R and JPSS projects now and will allow for anticipated growth in the future. Given that the data sets for the upcoming missions are very large, this funding was used to build this system in phases and provide support to build, maintain, and demonstrate the use of the satellite data sets in NWS offices. This support helped ensure the successful development and use of current and future satellite products, and will help train NOAA's next generation work force.

The computing facility is intended to be used primarily by the algorithm development teams. It will be capable of handling very large datasets and multiple processes running concurrently. It will therefore be ideally suited to algorithm testing, validation, and demonstration.

Summary of Accomplishments and Findings

The budget request for computer systems is given in the table below. The majority of the funds were used to purchase computer servers, processors and mass storage, with some funds devoted to system software development and implementation. The computers included in this budget are identical to servers that we already have in service and the software will replicated from an existing cluster to minimize setup and maintenance expenses.

Component	Unit Cost	Qty	Total
Storage Servers	$9,763	3	$29,289
Compute Server	$8,952	1	$8,952
Replacement Server	$6,494	1	$6,494
Total			$44,735

The remaining funds will be used as labor costs to integrate the hardware into the existing high speed Infiniband network and setup the cluster computing environment.

6. CIMSS Participation in the GOES-R Algorithm Working Group (AWG) for 2013

6.1 Real-time Proxy Data Support

CIMSS Task Leaders: Tom Greenwald and Allen Huang
CIMSS Support Scientists: Jason Otkin, Todd Schaack, 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 will generate synthetic ABI baseline products (including 16-band imagery) 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. This effort will be limited to distributing these products to Proving Ground activities and the Algorithm Integration Team (AIT) as needed. The products are available as GOES-R ReBroadcast (GRB) NetCDF files that conform to the current GOES-R Product definition and User's Guide (PUG) conventions. Baseline products produced from GOES-R algorithms using the synthetic ABI GRB files will be run in near-real-time as needed to support Proving Ground activities through GEOCAT, a new capability achieved in last year's effort. We will also provide synthetic ABI imagery to the GOES-R Analysis Facility for Instrument Impacts on Requirements (GRAFIIR) on demand for government instrument waivers. Real-time validation capabilities developed in our previous efforts will not be maintained but will be done on an as needed basis.

Summary of Accomplishments and Findings
- We developed an automated way of delivering our simulated ABI imagery (in Fixed Grid Format) to the AIT in near-real-time for testing their system.
- We delivered to the AIT 16-band imagery for our ABI-West simulation centered instead at 89.5^{o} W longitude, since that is the location where GOES-R may be put into storage soon after launch.
- We created a near-operational Web site (http://cimss.ssec.wisc.edu/goes_r/proving-ground/wrf_chem_abi/ABI-PRODUCTS/wrf_chem_abi_prod.html) displaying animations of 5 products produced from the RAQMS/WRF-Chem/CRTM/GEOCAT processing flow, including total column ozone, total precipitable water, Lifted Index, CAPE, cloud top pressure, and a new RGB (Red-Green-Blue) air mass product.
- Jason Otkin participated in the Experimental Forecast Project (EFP) portion of the 2013 NOAA Hazardous Weather Testbed (HWT) Spring Experiment held in Norman, OK. Our group provided support for the synthetic satellite brightness temperature datasets that we generate each day using output from the NSSL-WRF model and for select members of the CAPS storm-scale ensemble. We also provided satellite expertise for the EFP.
- Two main improvements were made to the WRF-Chem (V3.5) model simulations. We discovered a coding error in the NOAH-MP land surface model that caused the WRF-Chem model to not capture well boundary layer clouds over the eastern Pacific and off the east coast of the U.S. The error was fixed in the V3.5.1 release of the WRF. We also worked with Greg Thompson (NCAR) to improve the snow diameter calculation in the Thompson microphysics scheme. We found modest improvement in comparisons of the simulated brightness temperatures to GOES sounder observations.

- Data focusing on the May 20, 2013 Oklahoma tornado events was prepared for a Weather Event Simulator (WES) case that can be shared and used for training at National Weather Service offices across the nation. Results from the WRF-Chem simulation of these events shows that the simulation captures well the onset of severe weather that led to the outbreak (see Figure 16).
- We validated the three color components of our simulated ABI RGB air mass retrievals with the current GOES sounder RGB air mass retrievals. This was done for hurricane Sandy in which we are preparing the data as another case study for the WES. RGB air mass results show that the simulation did a good job of capturing this aspect of the catastrophic storm (see Figure 17).
- We developed a way of displaying our simulated ABI imagery within AWIPS II. It takes advantage of core Mac-AWIPS to remap the NetCDF files to standard NCEP gridded data files. Other more efficient methods are being considered, such as writing our own plugin.
- We are generating ABI true color images using synthetic ABI 0.47 μm and 0.64 μm bands and observed MODIS 0.55 μm Bidirectional Reflection Distribution Function (BRDF) files from which a green band is simulated. These data will be used as a reference in testing methods that exploit other ABI channel data to reconstruct a green band.
- We enhanced our validation processing system by evaluating simulated ABI RGB air mass and cloud top retrievals against GOES sounder observations. Cloud top pressure comparisons were done for several different cloud optical thickness thresholds and will be used by the AWG Cloud team to validate their cloud algorithms.
- In January, the Bulletin of the American Meteorological Society accepted our proposal to write an article in the Bulletin. We are in the process of writing this article on the work we have done over the past year. The title is “Near-real-time production of simulated GOES-R Advanced Baseline Imager data for user readiness and product validation.” Analyses for hurricane Sandy and the Moore Oklahoma tornado will be used to illustrate the work.

Publications and Conference Reports

Bah, K., T. Greenwald, B. Pierce, A. Lenzen, M. Rogal, J. Nelson, J. Otkin, T. Schaack, J. Davies, E. Borbas, J. Sieglaff, and H.-L. Huang, 2013: Near-Real-Time validation of simulated GOES-R ABI radiances and derived products, using the WRF-Chem model forecast over CONUS for all 16 ABI bands, NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, 8-12 April, College Park, MD.

Greenwald, T., J. Davies, E. Borbas, J. Otkin, Y.-K. Lee, J. Sieglaff and H.-L. Huang, 2013: Near-Real-Time Proxy ABI Products for GOES-R User Readiness, NOAA Satellite Conference for Direct Readout, GOES/POES, and GOES-R/JPSS Users, 8-12 April, College Park, MD.

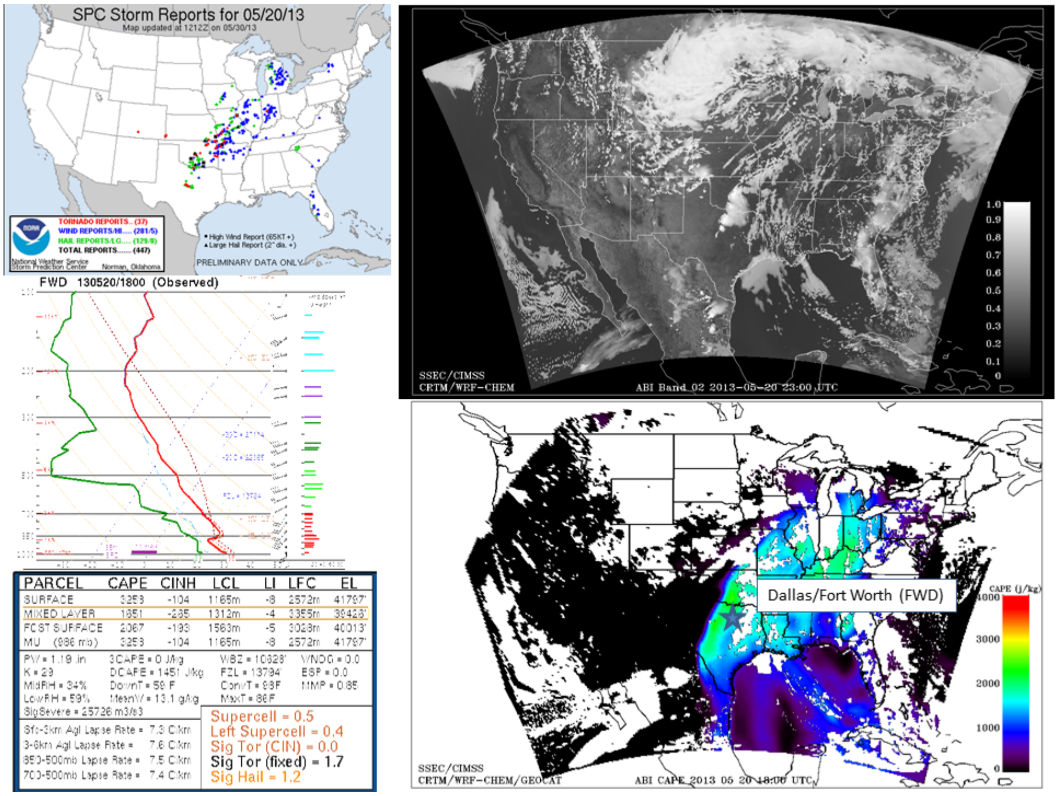

Figure 16. Comparison between observed (left column) and simulated (right column) conditions prior to and during the May 20, 2013 Oklahoma tornado outbreak. The upper left panel shows the SPC storm reports. The lower left panel shows the 18Z sounding from Dallas Fort Worth. The lower right panel shows the retrieved CAPE at 18Z and the upper right panel shows the simulated ABI Band 2 (0.64 µm) channel at 23Z.

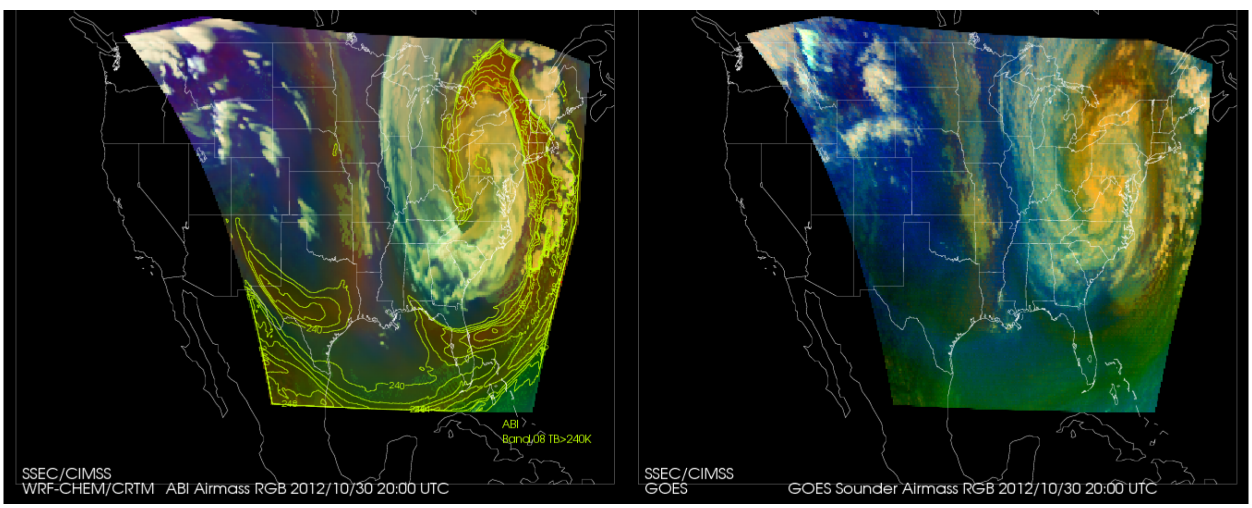

Figure 17. WRF-Chem/CRTM (left) and GOES-E (right) RGB airmass products are remarkably consistent. Yellow contours on the left panel depict 6.19 µm (high level water vapor) brightness temperatures larger than 240 K.

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

CIMSS Task Leaders: Allen Huang, Mathew Gunshor
CIMSS Support Scientists: Hong Zhang, Eva Schiffer
NOAA Collaborator: Timothy J. Schmit (ASPB/STAR/NESDIS)

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 proposed tasks for 2013 were:

- Continue to expand features of GRAFIIR to model ABI instrument effects.
- Improve analysis function of GRAFIIR to include other ABI products to extend the study of sensor impacts on products not already analyzed. This would likely require that CIMSS have a working version of the AIT Framework with all algorithms included.
- Provide support and datasets to assist application team members in evaluating and testing of their product algorithms.
- Respond to proposed changes in ABI instrument specifications to assess their potential effects on products.
- Interface with visualization team and AWG science teams to better utilize visualization tools.
- Interface with the Integrated Modeling Working Group (IMWG), or a similar entity, concerning the government's waiver response plan or to respond to a particular waiver request.
- Respond to proposed changes in ABI instrument specifications to assess their potential effects on products. (ABI waiver analysis).
    - Waiver response reports contain the following elements:
        - Description of the proxy data used and how those data were adjusted to reflect the effects of the instrument waiver;
        - Description of the analysis techniques, such as an analysis using AWG algorithms to generate pertinent products;
        - Results with statistical analysis and if possible (and necessary) an assessment of the impacts on product quality (ability to meet product accuracy and precision specifications); and
        - Summary and possible recommendations from the pertinent AWG teams/chairs, including the GRAFIIR team.
- Continue to expand and improve the GRAFIIR analysis tool Glance:
    - New data formats AWG teams plan to use in validation;
    - Expanded capability to analyze current GOES products for validation; and
    - Respond to AWG science team requests to meet the specific needs of their algorithms.

- Continue to interface with visualization team and AWG science teams to better utilize visualization tools.

In addition, upgrades of the file comparison tool Glance would be pushed to the AIT.

Summary of Accomplishments and Findings

The file comparison diagnostic tool, Glance, was improved throughout the project year. Updates of Glance were made available to the AWG's Algorithm Integration Team (AIT). Multiple improvements were made to the GUI. This includes two new plot types, histograms for both input files individually, new colormaps available, button to open a direct view of variable data, and bug fixes.

There were two waiver/deviation situations that arose this year. The GRAFIIR team continues to collaborate with the Product Working Group (PWG) on these issues. These issues included a noisy detector on the 6.19 micrometer band and a co-registration issue which can potentially affect most of the bands.

The potential deviation with ABI band 8 (6.19um) involved a noisy detector that caused visible striping in the imagery. Various scenarios were tested to simulate a potentially out-of-spec noisy detector in this band. The GRAFIIR team made use of proxy team data in GOES Re-Broadcast (GRB)-like fixed grid format (FGF) files to generate GRB-like FGF files with a noisy line. GEOCAT was used to generate sounding products and Glance was used to generate reports which were shared with the Product Working Group (PWG).

To investigate the potential co-registration error a co-registration sensitivity study was performed. A band matrix of potential co-registration errors based on rough data provided by MIT-Lincoln Labs was genderated. Co-registration errors were applied to proxy data for all bands and cloud products with co-registration error data were generated. Additionally, split-window (11-12um) differences with various co-registration errors were analyzed. A report was generated for the Product Working Group (PWG) which included Glance analysis of cloud products generated with spec-compliant vs non-compliant data. The report also included analysis of 11-12um split-window differences. http://www.ssec.wisc.edu/grafiir/GOES_ABI/

There was necessary work done on dataset archival maintenance this year. Archived datasets were formerly stored on four different machines, a by-product of the timing of their generation. Making use of joint project support and a unified storage system, these files are now consolidated on one storage system. There are 40 TB of compressed data archived.

GEOCAT was upgraded to read current GOES Sounder data. A case study using GOES-East Sounder data made use of current GOES Cloud products in GEOCAT. Cloud Mask, Cloud Phase, Cloud Top Height, Cloud Top Pressure, Cloud Top Temperature, and Cloud Type were analyzed.
http://www.ssec.wisc.edu/grafiir/GOES_EAST/
http://www.ssec.wisc.edu/grafiir/GOES_ABI/Pure_6umradsShift_Cloud_test2/

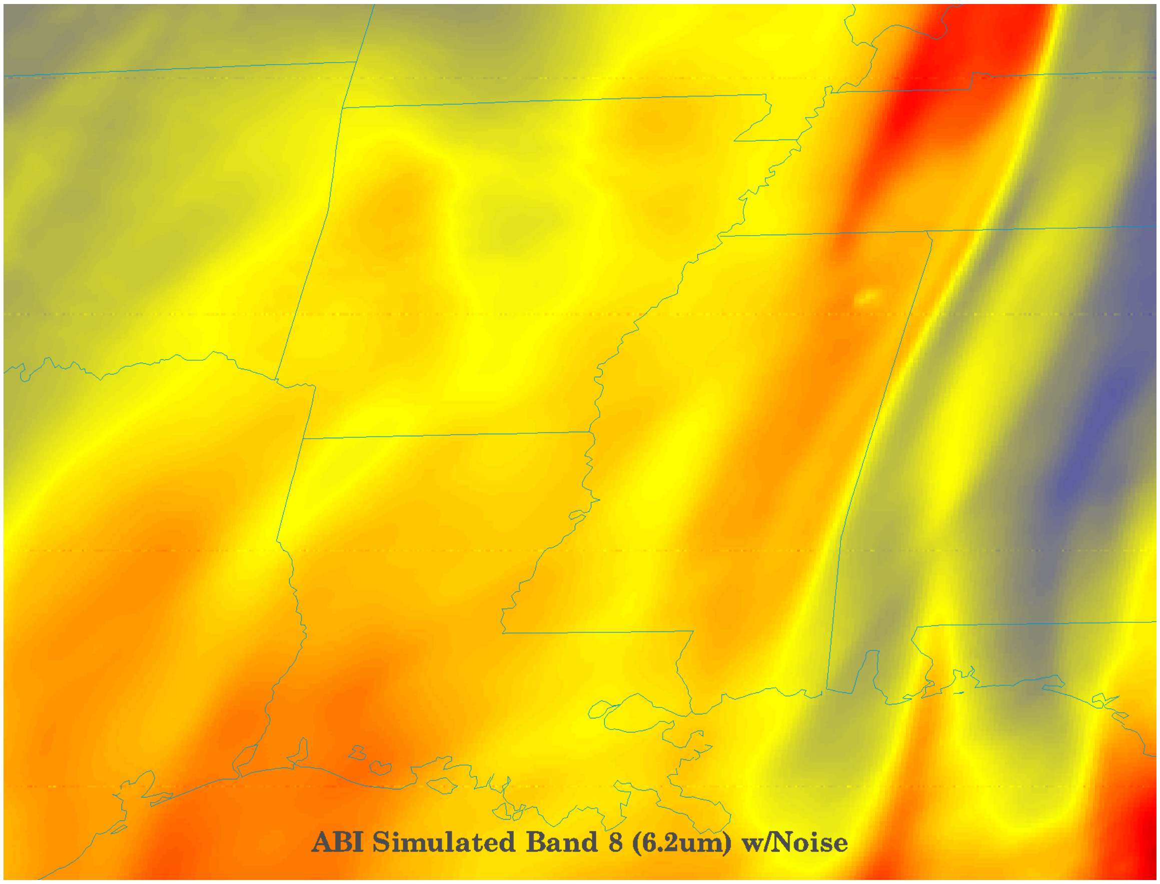

Figure 18. ABI Band 8 (6.19 micrometer) simulated data with a noisy detector creating apparent striping.

Publications and Conference Reports

GRAFIIR poster at the 2013 NOAA Satellite Conference in College Park, MD.

6.3 AIT Technical Support

CIMSS Task Leader: R.K. Garcia
CIMSS Support Scientists: G. D. Martin, E. N. Schiffer, W. C. Straka III
NOAA Collaborator: W. Wolf

NOAA Strategic Goals:

- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Satellite Meteorology Research and Applications

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.

Proposed activities:

- Profile reference algorithm implementations and explore performance, accuracy, and reproducibility improvements.
- Review and update software and deliverables with CIMSS science staff.
- Retain and distribute test and ancillary datasets in support of AWG deliverables.
- 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.
- Assist in implementation of collocation software and framework capabilities needed for Cal/Val of GOES-R data with other data sources including AQUA and TERRA.
- 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.
- Work with proxy team to prepare additional proxy data for Cal/Val.
- Add Himawari-8 (AHI) processing capability to Geocat as a proxy for ABI.
- Work with proxy team to integrate 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.
- This includes TIMs, weekly interchange meetings with AER/Harris/GSP, review of results from GOES-R Ground Segment.
- Review Product Definition and Users' Guide and make recommendations, in coordination with GRAFIIR.
- Management and coordination of schedules, deliveries, software configuration items in cooperation with AWG and Harris/AER.

Milestones:

- Baseline algorithms maintenance delivery
- Harris / AIT TIMs and other interactions
- Publish function-based algorithm / framework API documentation (deferred to FY2013)
- New versions of GEOCAT, including support for provisional operational ABI GRB data format; new releases of ancillary data packages

Summary of Accomplishments and Findings

Test Framework Development

GEOCAT, the CIMSS algorithm development framework, and the NOAA AIT testing framework saw improvements. Additional algorithms were integrated, and the NOAA framework was tested at CIMSS to support GOES-R testing. Use of the reference science implementations in these frameworks has led to clarifications of theory and implementation for the operational code in development. It also led to refinements in the test data sets used for verification of contractor implementations of GOES-R algorithms.

GEOCAT was expanded to process simulated ABI GRB data, aggregated VIIRS data and current GOES sounder data. This will help with determining how the algorithms will perform, as well as help developers make algorithm improvements prior to launch.

Work began on a satellite library which encapsulates functionality common to CLAVR-X, GEOCAT and the AIT framework such as ingest, calibration, navigation and utility routines. This will allow new features and improvements to be more efficiently integrated and shared across multiple processing systems, aid in development of new processing systems and standalone algorithms, facilitate verification of output by eliminating sources of differences, and reduce overall maintenance costs.

Software Delivery and Development Support

CIMSS AIT support for GOES-R prime contractor (Harris Corp., AER) interaction with NOAA and algorithm developers continued. This support included the 100% delivery of the Visibility algorithm to AIT-East for integration, and providing further patch-ports as inconsistencies were uncovered in reference algorithm software, test frameworks and theory documents. Re-delivery of test data, clarifications to responses, ATBD reviews and preparation for upcoming contractor software deliveries were also a part of integration support for GOES-R.

AIT-MW also provided support in evaluating the first datasets provided by Harris using the analysis tool developed at CIMSS by AIT-MW and GRAFIIR, called *glance*. Issues in these datasets were pointed out to the AIT-East and were presented to Harris and the GOES-R program office (GSP). Iterations continue as each issue is addressed.

Support work also broadened to include experimental and demonstration applications of GOES-R algorithms to SNPP sensors as well as simulated ABI data. In the coming year a variety of activities are likely to be continued to be required along these lines, continuing the push toward equivalent software interfaces for software framework and satellite platform research algorithms.

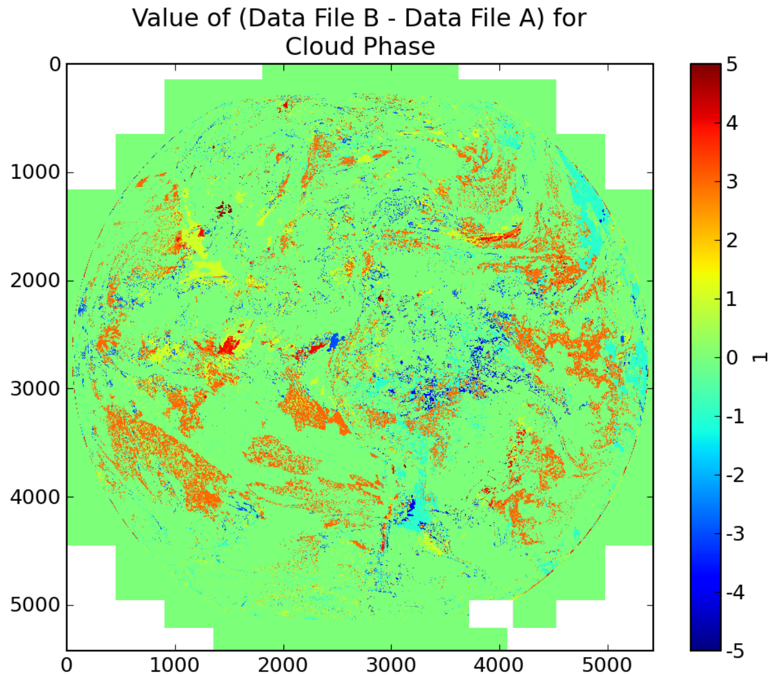

Figure 19. Cloud phase differences plot, produced by glance, between the GOES-R GS output (File B) and the output from the AIT Framework (File A).

Publications and Conference Reports

Sampson, Shanna; Wolf, W.; Fan, M.; Liu, X.; Yu, T.; Rollins, R.; Jose, V.; Garcia, R.; Martin, G.; Straka W. III; Schiffer, E. and Daniels, J.. GOES-R AWG product processing system framework: R2O. Boston, MA, American Meteorological Society, 2014,

Sampson, Shanna; Wolf, W.; Fan, M.; Liu, X.; Yu, T.; Zhao, Y.; Rollins, R.; Jose, V.; Garcia, R.; Martin, G.; Straka W. III and Daniels, J.. GOES-R AWG product processing system framework: Near real-time product generation. Boston, MA, American Meteorological Society, 2014

Straka, William III; Wolf, W.; Sampson, S.; Holtz, B; Quinn, G; Garcia, R.; Martin, G.; Liu, X.; Li, A.; Yu, T; Yu, T; Rollins, R.; MacKenzie; Daniels, J.; Schiffer, E. Routine Validation of the GOES-R Multi-Satellite Processing System Framework. 2013 EUMETSAT Meteorological Satellite Conference, Vienna, Austria, 16-20 September 2013. Proceedings. European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), Darmstadt, Germany, 201

6.4 GOES-R Collocation

CIMSS Task Leader: Robert 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
The AWG collocation project goal is to develop a collocation library based on over 30 years of collocation development at CIMSS and then using these tools, develop a validation system capable validating the GOES-R products with JPSS and NASA EOS observations. 2014 activities are focused on continued development of a centralized GOES-R validation system that will provide near real-time GOES-R proxy (SEVIRI and GOES) validation results using both the NASA A-Train observations (CALIPSO, MODIS, CloudSat) and JPSS (CrIS, VIIRS,ATMS) observations. We are working with the GOES-R products teams to customize the quick look and validation products. This effort will leverage significantly from our JPSS cal/val activities at UW-Madison with the goal of developing the foundation for a validation system for GOES-R post launch cal/val activities and facilitating better integration of JPSS and GOES-R. The site can be viewed at: http://kepler.ssec.wisc.edu

Summary of Accomplishments and Findings
This is the fourth year of funding under the GOES-R program. Accomplishments to date include:
- Porting the AIRS/MODIS collocation software to C++ (Nagle; Holz 2009);
- Developing a test system to validate the new C++ library;
- Inter-comparing the UW-Madison and NOAA versions of the AIRS/MODIS spatial weights;
- Testing the new collocation software by inter-calibrating AIRS and MODIS (both TERRA and AQUA);
- Developed GEO-LEO collocations including JPSS CrIS and VIIRS observations; and
- Validation web interface and products for the GOES-R program. We have successfully implemented into the GOES-R validation system:
    - Cloud Property (SEVIRI GOES-R products),
    - Wind heights (SEVIRI GOES-R products),
    - Aerosol (using SEVIRI operation product as test data), and
    - CALIPSO and MODIS validation products for clouds, winds, and aerosols.

We are currently working on implementing radiance validation capabilities by collocating the operational polar orbiting sounding observations (CrIS and IASI) and imager data (MODIS and VIIRS). Once implemented the system will generate in near real time calibration metrics and long-term trends. This capability will be available at launch and providing an important capability.

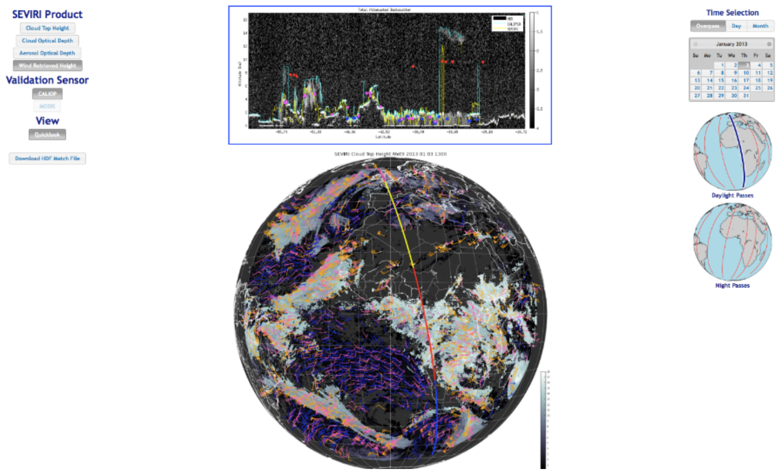

Figure 20. The GOES-R validation web interface is presented above. The GOES-R proxy wind product and cloud top height for SEVIRI is presented in the bottom figure (Globe). The top figure is the CALIOP (lidar) attenuated backscatter profile with the collocated GOES-R wind heights (red dots).

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.

6.5 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 21 shows how post processing comparisons between cloud height and CALIPSO allow the HS3 team confidence in the product. In addition, the cloud algorithms are also being used as part of the University of Alabama, Huntsville Convective Initiation algorithm, in near-realtime, which is discussed in section 7.13 of this report.

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

In the next year, 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.

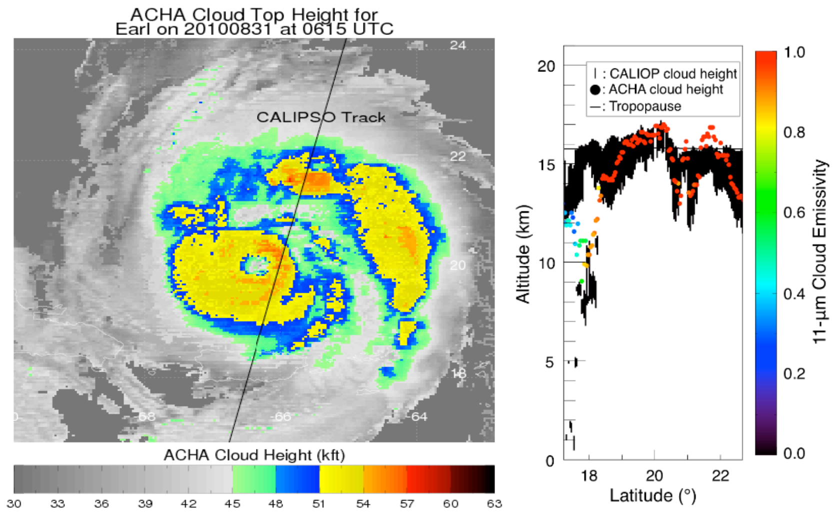

Figure 21. Post hurricane analysis of category 4 Hurricane Earl comparing ACHA cloud heights with CALIPSO. ACHA cloud heights match CALIPSO well in the convective eyewall and outer band.

Publications and Conference Reports

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. 31st Conference on Hurricanes and Tropical Meteorology, 2014, abstract only.

Roebeling, Rob, Bryan Baum, Ralf Bennartz, Ulrich Hamann, Andrew Heidinger, Anke Thoss, Andi Walther, 2013: Evaluating and Improving Cloud Parameter Retrievals. Bull. Amer. Meteor. Soc., 94, ES41–ES44.

Heidinger, A.K.; Foster, M.J.; Walther, A.; Zhao, X. The pathfinder atmospheres extended (PATMOS-x) AVHRR climate data set. Bull. Am. Meteorol. Soc. 2013, doi:10.1175/BAMS-D-12–00246.1.

Stengel, M., Mieruch, S., Jerg, M., Karlsson, K.-G., Scheirer, R., Maddux, B., Meirink, J.F., Poulsen, C., Siddans, R., Walther, A., Hollmann, R., The Clouds Climate Change Initiative: Assessment of state-of-the-art cloud property retrieval schemes applied to AVHRR heritage measurements, Remote Sensing of Environment, (2013), ISSN 0034-4257, http://dx.doi.org/10.1016/j.rse.2013.10.035

Walther, A. and A. Heidinger, Extension of the NOAA AVHRR PATMOS-x cloud climate record to other NOAA sensors (GOES and VIIRS). Talk given at EUMETSAT conference in Vienna, Austria September 2013.

6.6 Active Fire/Hot Spot Characterization

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

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

Summary of Accomplishments and Findings

In 2013 the development of the FDCA project's deep-dive validation tool was put on hold due to funding cuts. The remaining tasks included providing support to the Algorithm Implementation Team (AIT) and the Ground Segment Contractor and generating additional proxy data. Small updates were provided to the reference code and associated test data, which did not alter the FDCA's status as implemented successfully in their system.

Proxy data for fires is difficult to generate, so data from Meteosat Second Generation, specifically Meteosat-10, was used in a modified version of the FDCA to begin the assessment of how real data behaves in the system. Figure 22 is from a proof of concept test case which revealed the differences in the underlying systems that run the FDCA and the WFABBA, as well as a couple small bugs in the code. Differences between the two implementations are represented as black pixels in the center image. A primary difference between the two systems is the land cover dataset used in the implementations – there are differences for rivers and coastlines in particular. There is also a difference in cloud detections, as seen in the upper right where the clouds (white) seen by the FDCA are not in the McIDAS version. While fire clusters matched well between the two, the precise locations did not match. The fires are color coded by type with red being processed fires that have associated properties of instantaneous size, temperature, and fire radiative power (the highest confidence category), yellow being saturated fire pixels, magenta for cloud covered fires, and orange light blue, and dark blue for high, medium, and low probability fires respectively. The differences in fire locations are likely due to the different emissivities used by the two implementations. The WFABBA applies an emissivity based on the land cover type, whereas the FDCA uses emissivities from UW Baseline Fit emissivity dataset. The FDCA approach is more reflective of the true situation and thus the FDCA results are likely more reliable. Retrofitting one system to implement the emissivity approach of the other was outside the scope of the project.

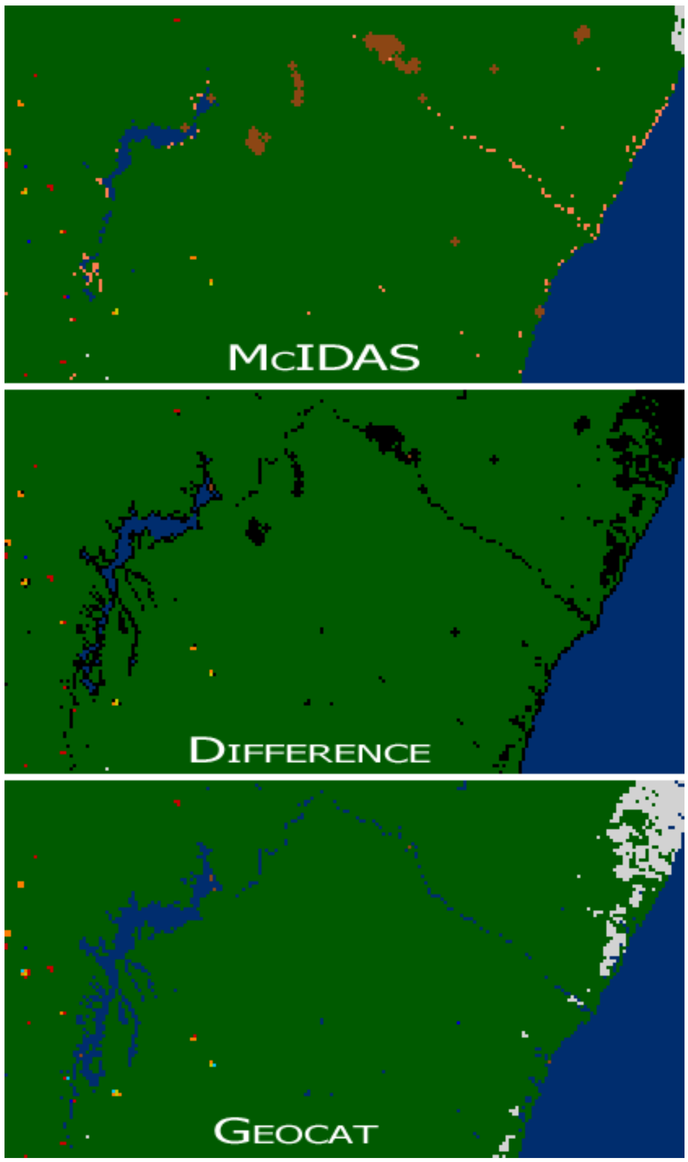

Figure 22. Comparison of Met-10 data produced by the GOES-R FDCA ("Geocat") and the current WFABBA ("McIDAS"). The data is from 24 September 2013 at 16:00 UTC.

As part of the outreach process for GOES-R the FDCA/WFABBA team at CIMSS made contact with two Incident Meteorologists (IMETs) to launch outreach to the National Weather Service. They provided valuable feedback with respect to how the FDCA and current WFABBA data could be presented to them so that it is useful when they are called in to do forecasting for wildfires. Presenting geostationary fire data has been a challenge due to its point nature and the volume and variable frequency of the data, and getting it into the hands of IMETs and others is critical to making full use of the information. For the IMETs the fire's context is very important, so being able to represent the detected fire with respect to terrain and indicating clouds and smoke plumes is a priority. In 2014 this outreach will be greatly expanded.

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

CIMSS Task Leader: Jun Li
CIMSS Support Scientists: Yong-Keun Li, Zhenglong Li, and James P. Nelson
NOAA Collaborators: Tim Schmit, Gary Wade

NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

NOAA Strategic Goals:

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

CIMSS Research Themes:

- Satellite Meteorology Research and Applications

Project Overview

The main focus of this project is to develop the legacy atmospheric profile (LAP) algorithm for the next generation Geostationary Operational Environmental Satellite (GOES-R) Advanced Baseline Imager (ABI) (Schmit et al., 2005) product generation. The algorithm retrieves atmospheric temperature and moisture profiles and the derived products including total precipitable water (TPW), layer precipitable water (PW), lifted index (LI), convective available potential energy (CAPE), total totals index (TT), Showalter index (SI), and the K-index (KI) from the clear sky infrared (IR) radiances within a 5 by 5 ABI field-of-view (FOV) box area. This project requires CIMSS scientists to develop the GOES-R LAP algorithm to be able to process high temporal and spatial resolution ABI data efficiently. This project provides science codes to the GOES-R algorithm integration team (AIT) for algorithm integration and helps the system provider to implement the algorithm and 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 atmospheric temperature and moisture profiles, TPW, LI, CAPE, TT, SI and KI products meet the science requirements and applications.

Summary of Accomplishments and Findings

The FY13 accomplishments are summarized below:

1) GOES Sounder data have been ingested into GEOCAT for real time sounding product generation with GOES-R LAP algorithm.
2) The GOES-R LAP algorithm for GOES Sounder has been implemented in CIMSS GEOCAT.
3) Application of GOES Sounder LAP with GOES-R LAP algorithm demonstrated.

4) Assurance of consistency between STAR AIT and CIMSS AIT output with ABI proxy has been conducted.
5) Validation of GOES-R LAP algorithm with GOES Sounder has been conducted. The datasets (MWR TPW, GPS TPW, RAOB TPW at ARM CART and conventional RAOB sites, AMSR-E TPW, SSMIS TPW) from one year time period are used as reference to validate the GOES-R LAP algorithm in pre-launch stage, the GOES-R LAP algorithm's seasonal, diurnal performance were monitored and analyzed.
6) GOES-R algorithm has been transferred to process MODIS; MODIS LAP products can be generated in real time International MODIS/AIRS Processing Package (IMAPP).

The following sections contain more details on CIMSS GOES-R AWG LAP findings and accomplishments.

GOES Sounder data have been ingested into GEOCAT for real sounding product generation with GOES-R LAP algorithm

CIMSS sounding team worked closely with CIMSS AIT to implement the GOES-R LAP algorithm for real time GOES Sounder product generation in GEOCAT. Weekly meetings have been held between sounding team and CIMSS AIT in 2013, the GOES Sounder GVAR data has been successfully ingested into GEOCAT. The GOES Sounder data are being tested for sounding retrieval processing with GOES-R LAP algorithm. The purpose is to generate real-time GOES Sounder LAP products in GEOCAT for GOES-R validation and proving ground application. Yong-Keun Lee and Zhenglong Li worked on the algorithm implementation for GOES Sounder real time processing in GEOCAT, while Jim Nelson worked on including surface temperature and moisture observation data in GEOCAT sounding retrieval process, the Real-Time Mesoscale Analysis (RTMA) (http://www.nco.ncep.noaa.gov/pmb/products/rtma/) surface products from NCEP are used after discussion at the CIMSS AWG internal meeting held on 22 April 2013. Typical cases were identified to test the GOES-R LAP algorithm both online and offline for consistency check. The GOES-R AWG cloud team (Dr. Heidinger) is implementing the ABI night time cloud mask algorithm for GOES Sounder so that other products (TPW, LAP etc.) can be generated in clear skies. Two configurations/options are designed in GEOCAT for GOES Sounder real time processing: (1) full GOES Sounder spectral channels with GOES-R LAP algorithm; and (2) selected ABI-like channels from GOES Sounder with GOES-R LAP algorithm. The products include the atmospheric temperature and moisture profiles, total precipitable water (TPW) and atmospheric instability indices. The GEOCAT LAP algorithm also has the option of using or not using surface temperature and moisture observations.

Validation of GOES-R LAP algorithm with GOES Sounder

The GOES-R ABI LAP retrieval algorithm is applied to the GOES-13 Sounder radiance measurements (termed the GOES-13 LAP retrieval algorithm) for its validation as well as for potential transition of the GOES-13 LAP retrieval algorithm for the operational processing of GOES Sounder data. The GOES-13 LAP retrievals are compared with five different reference ("true") measurements: radiosonde observation (RAOB) and microwave radiometer measured TPW at the Atmospheric Radiation Measurement Cloud and Radiation Testbed site, conventional RAOB, TPW measurements from the Global Positioning System-Integrated Precipitable Water NOAA network, and TPW measurements from the Advanced Microwave Scanning Radiometer for EOS (AMSR-E). The results show that with the GOES-R ABI LAP retrieval algorithm, the GOES-13 Sounder provides better water vapor profiles than the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) forecast fields at the levels between 300 hPa and 700 hPa. The root mean square error (RMSE) and standard deviation (STD) of the GOES-13 Sounder TPW are consistently reduced from those of the GFS forecast no matter which measurements are used as the truth. These substantial improvements indicate that the GOES-R ABI LAP retrieval algorithm is well prepared to provide continuity of quality to some of the current GOES Sounder products, and the algorithm can be transferred to process the current GOES Sounder measurements for operational product generation.

GOES soundings (GOES-R LAP algorithm) application demonstration

A case study using lifted index imagery of the June 29, 2012 derecho over the Midwest and East Coast area is shown in Figure 23. This derecho was one of the most destructive and fast-moving severe thunderstorm complexes in North American history. It resulted in 22 deaths, widespread power outages and damages across the affected region. The storm was initiated as a small thunderstorm cell in Iowa and continued into the Midwestern United States and into the Mid-Atlantic States. As the storm crossed into Indiana, it became a derecho and wind gusts increased substantially with a well-defined bow echo shape. Around 19 UTC, when the storm traversed north central Indiana, a severe thunderstorm watch with high wind probabilities was issued by the Storm Prediction Center (SPC) for large areas of Ohio and West Virginia, along with parts of Indiana and Kentucky. In addition, several tornado warnings and warnings of extreme wind threats were issued over the derecho track. The derecho crossed over the Columbus, OH area at approximately 21 UTC, with wind gusts reported as 132 km/h which is equivalent to a Category 1 hurricane. It maintained this intensity until early evening. In Figure 23, lifted index imagery is shown at 21 UTC in the middle of the derecho track as a case demonstrating the application of the GOES sounding products to severe thunderstorm forecasting. Figure 23 also includes the locations of wind and hail reports by the SPC between 2130 UTC and 2330 UTC during the derecho period while the derecho headed southeast. Wind and hail reports are from southeastern Ohio, northwestern West Virginia, and parts of Indiana and Kentucky. The lifted index from the GOES-13 LAP, Li et al. (2008) and Ma et al. (1999) retrievals, and the GFS forecast at 21 UTC are presented. The GOES-13 LAP and Li et al. (2008) retrievals show extremely unstable areas well matched with the locations where strong winds and hail were reported, while the GFS forecast shows an unstable area over Kentucky and western West Virginia, further south of the wind and hail report locations. The Ma et al. (1999) retrieval shows weaker instability than the GOES-13 LAP and Li et al. (2008) retrievals over the wind and hail report locations. Note the GOES-13 LAP provides slightly more useful information than Li et al. (2008) by revealing a more unstable environment in the storm region. With the GOES lifted index imagery, forecasters are able to identify the areas of extremely larger instabilities with a substantial lead time ahead of the outbreak of severe storm events.

Assurance of consistency between STAR AIT and CIMSS AIT outputs with ABI proxy data

In May 2013, STAR AIT team provided retrieval results from simulated ABI (fulldisk) using the GOES-R ABI LAP sounding algorithm based on June 04, 2005 WRF simulation. CIMSS also applied the GOES-R ABI LAP sounding algorithm to the same WRF simulation datasets. The (STAR AIT and CIMSS AIT) retrieved temperature/relative humidity vertical profiles were compared with those of the WRF nature run. The initial comparisons of temperature/relative humidity vertical profiles between STAR AIT and CIMSS AIT indicate huge differences. We have investigated the possible causes including version of CRTM, initial guess, cloud mask etc. and provided our feedback to STAR AIT. After further investigation and modification of input, the results between CIMSS AIT and STAR AIT are very small finally, this can assure the consistency between STAR AIT and CIMSS AIT. This consistency is an important step for validating operational GOES-R LAP products.

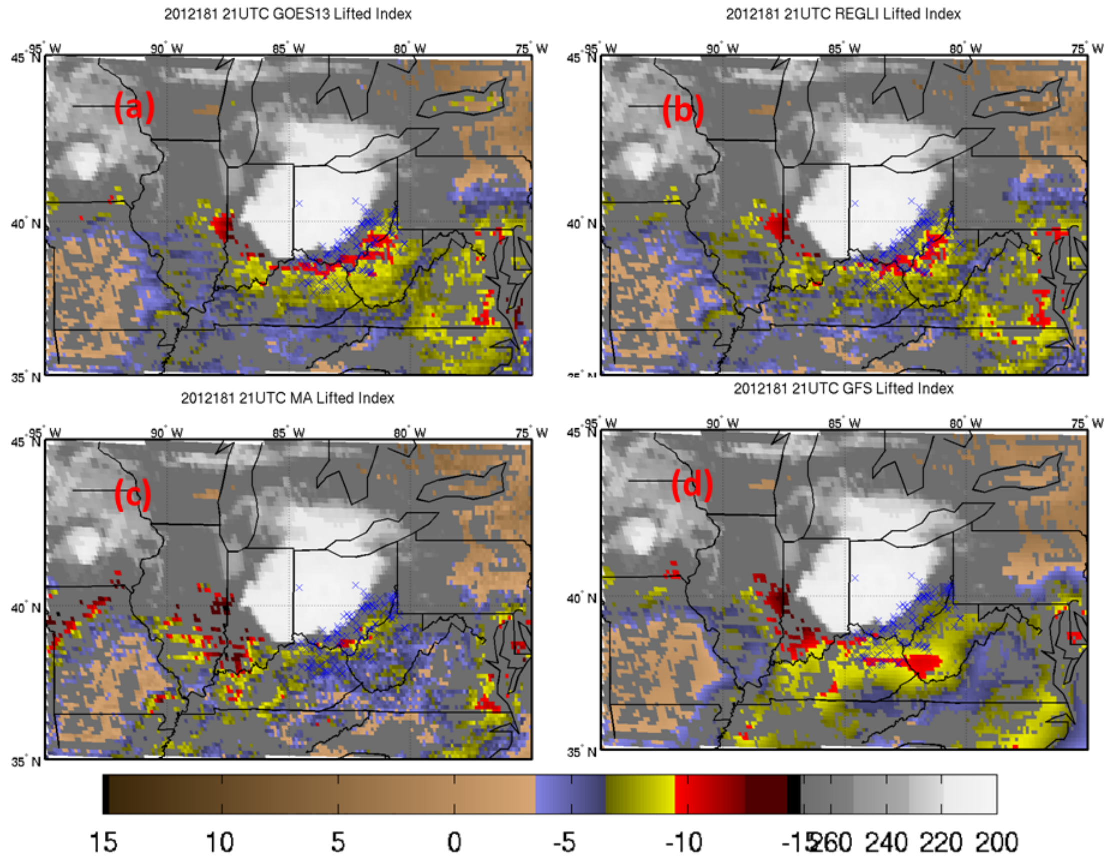

Figure 23. Wind and hail reports (blue cross) between 2130 UTC and 2330 UTC on June 29, 2012 and lifted index for clear skies with brightness temperature for cloudy skies (GOES-13 sounder channel 8, grey color bar) at 2100 UTC on June 29, 2012 during a derecho. (a) GOES-13 LAP retrieval, (b) Li et al. (2008) retrieval, (c) Ma et al. (1999) retrieval and (d) NCEP GFS forecast.

Publications and Conference Reports

Li Zhenglong et al., 2013, Validation of the GOES-R ABI LAP retrieval algorithm using the GOES-13 sounder, poster presentation at the NOAA Science Week Meeting, 18 – 22 March 2013).

Xie, Hua; Nalli, Nicholas R.; Sampson, Shanna; Wolf, Walter W.; Li, Jun; Schmit, Timothy J.; Barnet, Christopher D.; Joseph, Everette; Morris, Vernon R. and Yang, Fanglin, 2013: Integration and ocean-based prelaunch validation of GOES-R Advanced Baseline Imager legacy atmospheric products. Journal of Atmospheric and Oceanic Technology, 30, 2013, 1743–1756.

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

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Jin, Xin, Jun Li, Timothy J. Schmit, Jinlong Li, Mitchell D. Goldberg, and James J. Gurka, 2008: Retrieving Clear Sky Atmospheric Parameters from SEVIRI and ABI infrared radiances. J. Geophys. Res., 113, D15310.

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Li, Jun; Liu, Chian-Yi; Zhang, Peng and Schmit, Timothy J., 2012: Applications of full spatial resolution space-based advanced infrared soundings in the preconvection environment. Weather and Forecasting, 27, pp.515-524.

Li, Z., J. Li, W. P. Menzel, T. J. Schmit, J. P. Nelson, III, J. Daniels, and S. A. Ackerman, 2008: GOES sounding improvement and applications to severe storm nowcasting, Geophys. Res. Lett., 35, L03806, doi:10.1029/2007GL032797.

Xie, Hua; Nalli, Nicholas R.; Sampson, Shanna; Wolf, Walter W.; Li, Jun; Schmit, Timothy J.; Barnet, Christopher D.; Joseph, Everette; Morris, Vernon R. and Yang, Fanglin, 2013: Integration and ocean-based prelaunch validation of GOES-R Advanced Baseline Imager legacy atmospheric products. Journal of Atmospheric and Oceanic Technology, 30, 2013, 1743–1756.

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

6.8 GOES-R AWG ABI 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-9 SEVIRI data as ABI proxy imagery, with the resultant AMVs validated against "truth" data sets. Hourly AMVs from Meteosat-9 will be produced in near real-time and validated against the GFS analysis wind fields. Visible AMVs from band 1 (0.6 μm) are produced hourly from 08 UTC until 19 UTC. Short wave IR (SWIR) AMVs from band 4 (3.90 μm) are run from 00 UTC until 07 UTC and then again from 20 UTC until 23 UTC. Band 1 and band 4 produce complimentary AMVs (low-level only), so our processing strategy does not allow for product overlap. Cloudy water vapor AMVs (upper-level only) from band 8 (6.2 μm) and long wave IR (LWIR) AMVs from band 14 (11.2 μm) are produced every hour. Match files comparing AMVs to the GFS analysis winds are produced 4 times daily at 00, 06, 12, and 18 UTC. We also propose to look at AMV height assignment in more depth with Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations/Cloud-Aerosol Lidar with Orthogonal Polarization (CALIPSO/CALIOP) observations.

Summary of Accomplishments and Findings

During this reporting period, we compiled AMV-GFS analysis match statistics, which are used to measure the performance of the AMV product over oceanic regions. The analysis winds must match the time of the AMV, and are spatially (horizontally and vertically) interpolated to the AMV location. An advantage of this approach is that an AMV/GFS analysis wind collocation match can be generated for nearly all AMVs produced. The temporal time check is the only restriction needed. There is no need to check vertical limits, as the full GFS profile is always available. The maximum vertical spacing between pressure levels in the GFS analysis is 50 hPa. Thus the AMV will be within 50 hPa from a GFS pressure level, which implicitly matches the RAOB vertical match requirement. Horizontal limits are also ignored. Generally, the AMV is within 10 km or less of a model grid point, which is much less than the RAOB requirement of approximately 150 km. In all cases, accuracy, precision and speed bias requirements are being met.

We are also assessing the analysis of AMV height assignments using the CALIPSO observations as a benchmark comparison dataset. AMV-CALIPSO collocations provide a novel way to look into the validity of the AMV height assignment within the GOES-R nested-tracking software. In the example to follow, we look at AMVs from a typical proxy dataset using Meteosat-9 SEVIRI from 15 September 2011 at 00 UTC. To ensure high quality matches, the AMVs must have an internal quality indicator (QI) of 60 or greater, with a maximum of 100. The AMVs must be spatially located within 50 km of the CALIPSO transect location. Lastly, the AMV middle image time is required to be within 30 minutes or less from the CALIPSO profile time. Only CALIPSO profiles with single layer clouds are considered in the match software. Additionally, we require the CALIPSO cloud to have an optical depth of greater than 0.5. This filters out most CALIPSO data that the passive SEVIRI instrument would be unable to sense. The AMV-CALIPSO comparisons are limited to assessing differences in height assignment only. The Figure 24 shows an altitude-time x-section image of the total attenuated CALIPSO (532 nm) backscatter (/km/sr) plotted along with the collocated AMV locations in red, and the CALIPSO cloud top height product in yellow. Only the AMVs in southern Atlantic Ocean off the coast of Africa in the figure above are considered in this image. Good agreement in low-level water cloud tops is observed between the AMV heights compared to the CALIPSO cloud top height product.

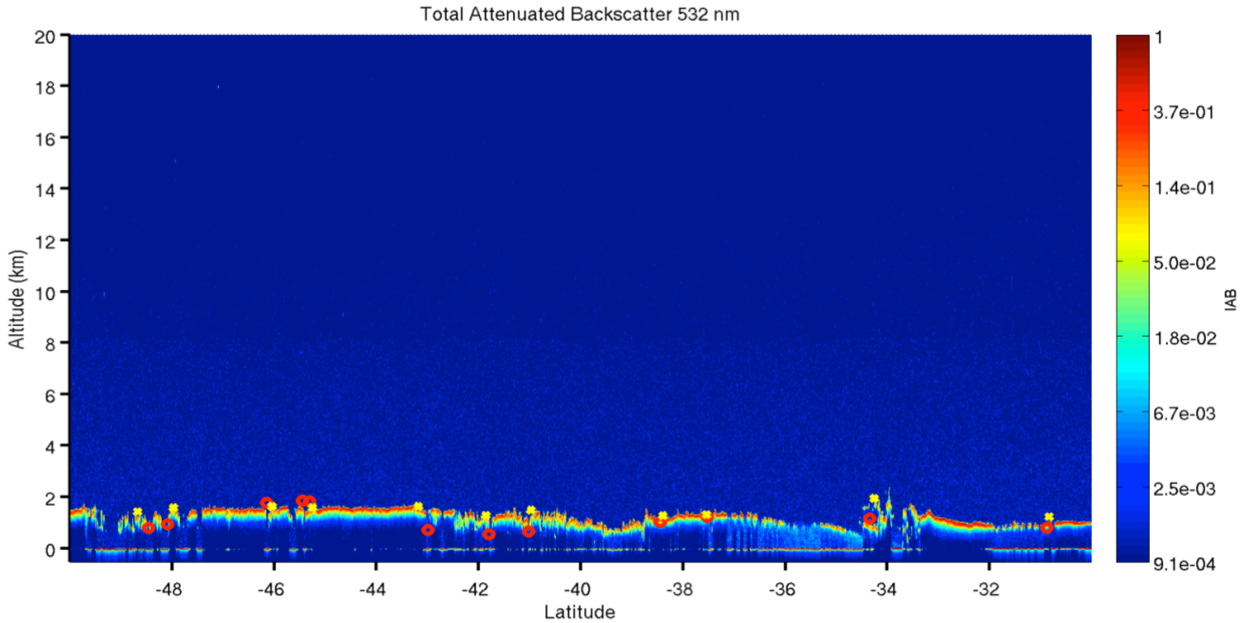

Figure 24. CALIPSO total attenuated backscatter with collocated AMV-estimated cloud height assignments plotted in red, and CALIPSO-estimated cloud tops in yellow.

Publications and Conference Reports

Daniels, Jamie, Bresky, Wayne, Wanzong, Steve and Velden, Christopher: Atmospheric Motion Vectors derived via a new nested tracking algorithm developed for the GOES-R Advanced Baseline Imager (ABI). 10th Annual Symposium on Future Operational Environmental Satellite Systems, Atlanta, GA, 3-7 February 2014. American Meteorological Society, Boston, MA.

Bormann, Niels, Hernandez-Carrascal, A, Borde, R. Lutz, H-J. Otkin, J. A. and Wanzong, S., 2014: Atmospheric Motion Vectors from model simulations. Part I: Methods and characterization as single-level estimates of wind. J. Applied Meteor. Climo., 53, 65-82.

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

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

NOAA Long Term Goals:
- Weather-Ready Nation

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

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

Project Overview

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

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. A vast majority of the work focused on addressing HIE algorithm code questions and issues found by AER/Harris programmers during their conversion process. 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 and existing logic flaws. 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.

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.

6.10 Volcanic Ash

CIMSS Task Leader: Justin Sieglaff
CIMSS Support Scientist: John Cintineo
NOAA Collaborator: Michael Pavolonis

NOAA Long Term Goals:

- Weather-Ready Nation

NOAA Strategic Goals:

- 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

To ensure readiness of the volcanic ash algorithm we continue to 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.

In additional to continued validation utilizing spaceborne lidar, we were able to obtain radar observations of the 2010 Eyjafjallajokull ash cloud from the Iceland Meteorological Office. The validation of the Eyjafjallajokull GOES-R ash cloud heights vs. radar-derived heights (Figure 25) for May 12-18, 2010 shows the GOES-R algorithm accuracy is well within GOES-R requirements (bias: -0.14 km, absolute bias: 1.57 km, with some of the differences are attributed to the C-band radar being sensitive to only larger ash particles than the IR-derived GOES-R algorithm).

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.

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

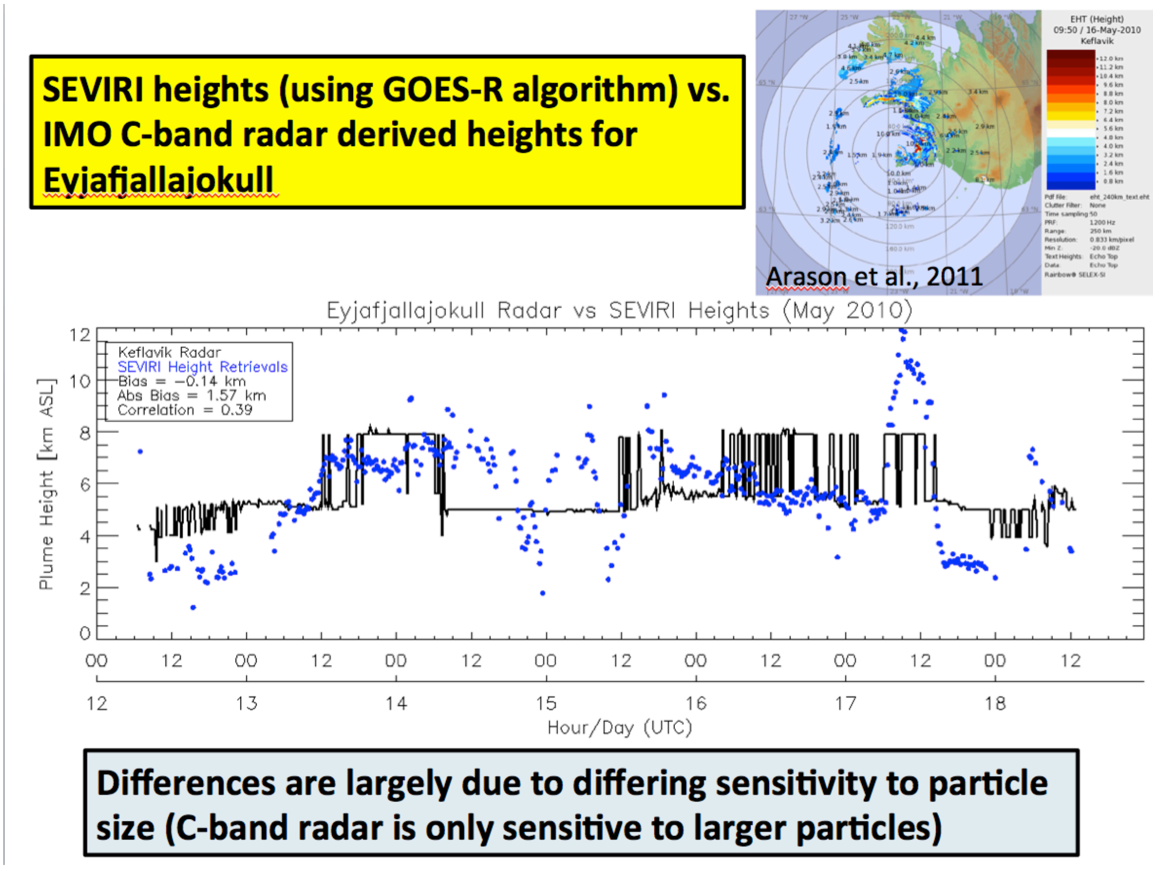

Figure 25. Comparison of Iceland Meteorological Office C-band radar estimate versus GOES-R algorithm ash heights for Eyjafjallajokull ash cloud May 12-18, 2010. The GOES-R algorithm agrees well with the radar estimates (bias: -0.14 km; absolute bias: 1.57 km). The GOES-R algorithm is well within specifications.

6.11 Imagery and Visualization

CIMSS Task Leaders: Mathew Gunshor, David Santek
CIMSS Support Scientists: Tom Rink, Joleen Feltz, Kaba Bah
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
Proposed activities for 2013 included:
- Continuation of product validation activities;

- Product Algorithm maintenance/updates;
- Continued development of product validation tools;
- Update of validation plan;
- Continued Verification Support to GOES-R Ground Segment Contractor (Harris/AER);
- Continue to work with CF-satellite working group on standards for multi-band, calibrated and navigated satellite data, using simulated ABI test cases as a working example. Develop utility classes to generate calibrated radiances;
- Enhance McIDAS-V interface for spatial and temporal subsecting and animation;
- Improvements to the Python-based user-defined computation and scripting, including more robust background processing and development of higher-level user-friendly callable methods for common displays;
- Expand specific McIDAS-V support for algorithm development, validation and evaluation to additional AWG algorithm teams through directly working with team members to identify their needs and improve our software tools;
- Support development of product validation "tools":
    - Develop scripts for routine product validation in McIDAS-V;
    - Implement and demonstrate product validation scripts on current GOES (i.e., static and animated images of each band, posting to a Web site for visualization);
    - Implement product validation scripts for routinely generated proxy data (i.e., static and animated images of each band, posting to a Web site for visualization);
    - Document validation scripts for product validation tool ATBD.
- Support Proxy team efforts by validation of proxy data output;
- Develop optimal strategies for efficient high-resolution imagery display (ongoing);
- Investigate and implement new technologies when necessary to advance the system forward. For example, new 2D/3D rendering libraries, GPU computing to assist display and data fusion;
- Imagery algorithm development to support the maintenance delivery (ongoing);
- Support GOES-R Ground Segment Contractor Verification (on-going);
- Submit monthly reports to Imagery and Visualization AWG Chairs (on-going); and
- Continue working to generate GRB-like and CMIP files that meet the Product Definition and User's Guide (PUG) Volume 4: GOES-R Rebroadcast requirements.

In addition to this the imagery and visualization team was tasked with supporting the ABI Data Operations Support Team (DOST) as they use proxy data generated at CIMSS to test their end-to-end data generation system for the weather service.

Summary of Accomplishments and Findings

GOES-R Fixed Grid Format

The imagery team continues to make progress with the ABI Fixed Grid Format (FGF). Since the ABI data will be remapped to this projection before being rebroadcast as GOES Re-Broadcast (GRB), it is critical that an understanding is gained for this projection. The Imagery and Visualization team at CIMSS has iterated with Harris (the GOES-R ground-system contractor) personnel verifying the ABI FGF. The development of software to compute transforms between the FGF coordinate systems and to (and from) a longitude and latitude coordinate system is done and has been duplicated in McIDAS-V, Matlab, IDL, and Python. The team continues to provide feedback on the GOES-R ABI Product Definition and User's Guide (PUG). Part of the effort includes providing validated proxy datasets to the GOES-R AIT. These data were generated several years ago by the GOES-R Proxy team, but have been updated to a new format that is closer to GRB and continually being updated to meet PUG standards.

Datasets generated by the team typically contain all 3 domains (Full Disk, CONUS, and Mesoscale), all 16 bands, for 7 time periods. The datasets are provided to AIT as a GRB-like file that contains scaled radiances and a validation file which contains all of the derived quantities such as brightness temperature (IR only), reflectance factor (visible/near-IR only), 8-bit brightness values, and 12/14-bit brightness values. These have been called “triplet” datasets. Triplet datasets were generated centered at 75W and 89.5W Longitude and provided to AIT for eventual transfer to the GOES-R ground contractor.

AWG Imagery and Visualization Tools

The co-chairs of the Imagery and Visualization team have emphasized that background processing of satellite, weather data, imagery and products is an essential tool for real-time displays and routine scientific analysis. Scripting tools currently being developed under Imagery and Visualization will provide a simple and efficient means to access the diverse capabilities of McIDAS-V. The team continues to grow and test these capabilities and development follows program needs as they arise. The ultimate goal of this effort is to give the scientists all the tools of the interactive display in a scripting language. This effort will free scientists from repetitive tasks, providing the opportunity for real-time product validation as well as product and imagery generation.

The team continued to improve deep dive and validation tools. Using current GOES-East, the 3.9um band image quality was monitored real-time on the Web. Deep dive program updates utilizing McIDAS-V scripts included accepting an input field, creating an initial mask, assigning groups , and generation of an output file with generalized information (group number, number of pixels in group, area of group, location of group).

Visualization and Data Analysis

The team found new ways to utilize the improved scripting and visualization capabilities of McIDAS-V. McIDAS-V scripting progress was made in multiple areas, including improvements to the annotations, layer labels including band wavelengths, and improvements made to make generation of the sandwich product easier. The sandwich product (see Figure 26) was generated with GOES-14 SRSOR 1 minute data displaying the 11um brightness temperatures with the high resolution visible. A case study fusing SRSOR (super rapid scan for GOES-R) data from GOES-14 with Radar and derived over-shooting top products with McIDAS-V was undertaken. Various loops of SRSOR were put on the Web. Here is a link to a SRSOR GOES-14 sandwich product loop:
http://cimss.ssec.wisc.edu/goes/srsor2013/GOES14_sandwich_larger.mp4

DOST Activity

The imagery team supported the ABI Data Operational Support Team (DOST) in their efforts to incorporate proxy data generated at CIMSS to prepare the National Weather Service for ABI data use. The team automated and generalized the processing system which generates full disk proxy ABI top of atmosphere (TOA) radiances for all 16 ABI bands using GFS data as input to the CRTM. This requires acquiring GFS data, computing cloud particle properties from GFS input, setting up and running the CRTM using GFS input and archiving the proxy TOA radiances. These data are generated in near real-time and remapped from GFS grid to GOES-R east and west FGF. The CRTM & WRF/Chem forecasts are run nightly at CIMSS with the GFS global forecast datasets obtained from NCEP. These data must be processed to full resolution Gaussian grid files for use with the CRTM. The cloud properties (mixing ratios, particle sizes) required by CRTM are computed using modified code taken from the GFS. The GFS data, computed cloud properties and appropriate ABI geometry are used as input to CRTM to compute TOA radiances on the GFS Gaussian grid. Generalized software developed to transfer gridded data sets to the ABI 2km fixed grid. Preliminary results used to begin schedule to ensure that all four proxy data sets will be on time given the real time nature of the project and the limited computer resources available.

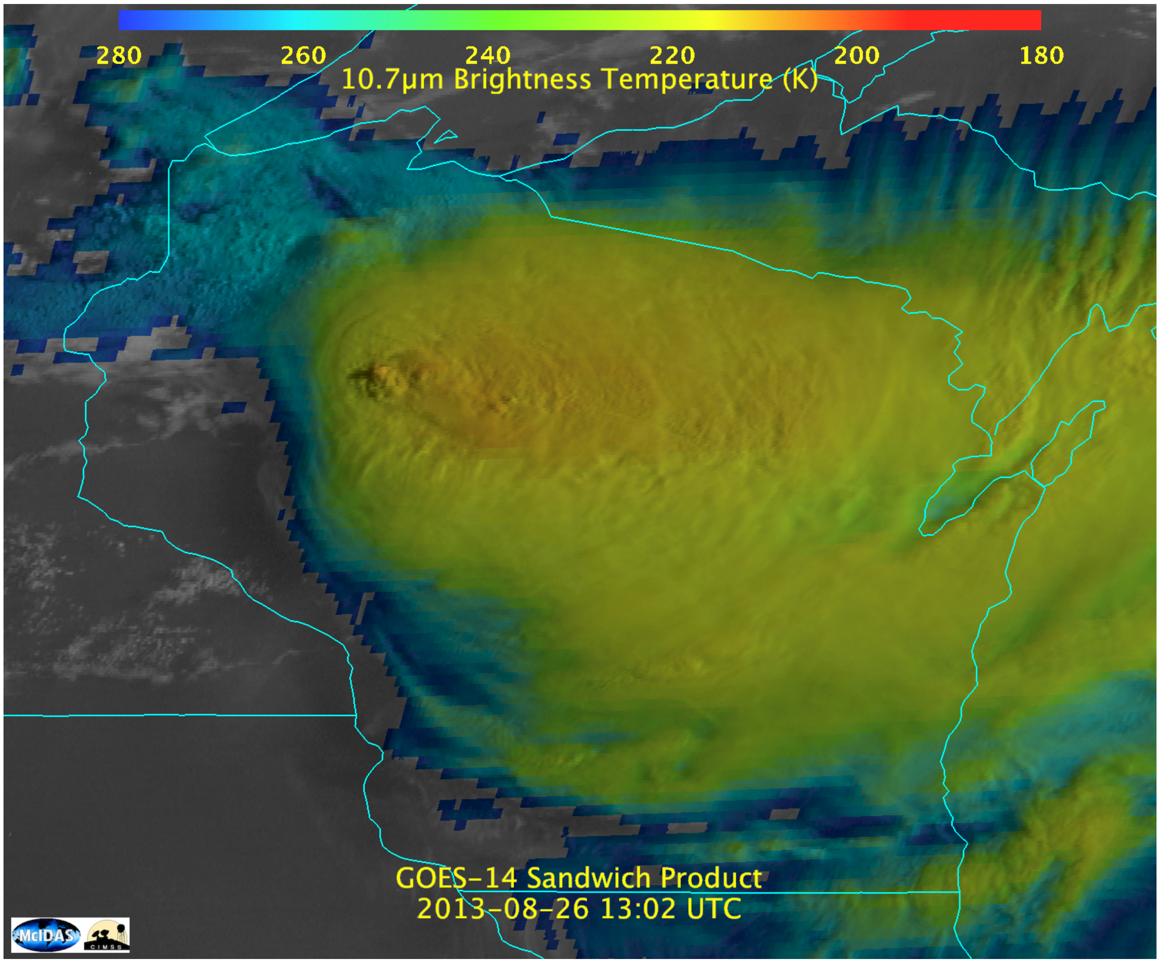

Figure 26. The sandwich product was generated with GOES-14 SRSOR 1 minute data displaying the 11um brightness temperatures with the high resolution visible for August 26, 2013 at 13:02 UTC. This novel display type allows users to see the temperature information from the infrared enhanced visually by the higher resolution visible, making cloud-top features stand out. This image was generated entirely using McIDAS-V.

Publications and Conference Reports

- Several team members attended the 2013 NOAA Satellite Conference in Camp Springs, MD.
- AMS annual meeting presentations by Joleen Feltz and Tim Schmit.
- Automated Visualization and Data Analysis in McIDAS-V, Feltz et al.
  - https://ams.confex.com/ams/94Annual/webprogram/Paper239382.html
- GOES-14 Super Rapid Scan Operations to Prepare for GOES-R, Schmit et al.
  - https://ams.confex.com/ams/94Annual/webprogram/Paper238012.html
- Paper submitted to BAMS on the special 1-minute SRSOR data from GOES-14.
- Five team members presented at the McIDAS Users Group (MUG) Annual meeting.
  - Kaba Bah: Using McIDAS-V to visualize and validate real time simulated WRF-CHEM data sets.
  - Joleen Feltz: Using McIDAS-V Libraries for Data Analysis and Visualization.

  - Mike Hiley: McIDAS-V Scripting in a Python Environment.
  - Dave Santek: McIDAS History and McIDAS-V Status.
  - Tim Schmit: Preparing for the GOES-R by using GOES-14 1-min imagery.
- Attended teleconference with Matt Seybold (NOAA NESDIS Products and Services) and other NOAA attendees to discuss the support of GOES-R ADDE and other questions raised by Mr. Seybold in terms of future support from McIDAS for ABI.

6.12 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.

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

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

of the process: obtaining, evaluating, and implementing the fractional snow cover software, and expanding the validation activities.

The 2013 work has been focused on becoming familiar with the Fractional Snow Cover software package, documentation, and its test data. The software was compiled, tested, and implemented at CIMSS. Running the software on the test data showed and gave the same results as provided by GOES-R AWG AIT. The work done in 2013 is listed briefly as below:

- Obtained the NOHRSC/UCLA Fractional Snow Cover software, documentation, and test data from the AIT;
- Compiled, tested, and implemented software on CIMSS local machines;
- Run the software on the test data and
- Verified the test run results with those provided by the AIT.

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.

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

7.1 Development of a GOES-R Automated Volcanic Cloud Alert System

CIMSS Task Leader: Justin Sieglaff
CIMSS Support Scientist: John Cintineo
NOAA Collaborator: Michael Pavolonis

NOAA Long Term Goals:

- Weather-Ready Nation

NOAA Strategic Goals:

- 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. However, the products are not designed (or required) to issue text alerts to forecasters when a volcanic cloud (ash and/or SO_2) is identified by the algorithms. 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 consistently manually analyze GOES-R imagery and products in real-time. As such, we propose to develop an automated volcanic cloud alert system for GOES-R. More specifically, we propose 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, cloud object based filtering scheme to identify volcanic clouds with high skill. 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 Task Leader J. Sieglaff. Co-I Ronald Thomas (New Mexico Tech) will provide the proxy GLM data and lightning network expertise. Co-I Tony Hall (MIC, 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 and T. Hall are members of the VAWG).

Summary of Accomplishments and Findings

During the past year, a Web site has been developed to host GOES-R Volcanic Cloud alerts and associated imagery (http://volcano.ssec.wisc.edu). The alerts are stored in a searchable database. The following instruments are currently being processed and alerts sent to the Web site in near real-time: MODIS, GOES-EAST, GOES-WEST, SEVIRI, and MTSAT. Operational meteorologists at the Anchorage Volcanic Ash Advisory Center (a-VAAC) are using the volcanic cloud Web site during ash events. Figure 27 shows a false color image from Aqua MODIS with volcanic ash that was re-suspended by strong winds over Katmai National Park in Alaska. The a-VAAC meteorologists used the height information provided by near real-time alerts, indicating ash was lofted as high as 10,000 feet above ground level (AGL). Figure 27 also shows the GOES-R ash cloud heights agree with space-borne lidar (CALIOP) estimates of ash to 3.25 km (~10,600 feet AGL). In this case the GOES-R information was critical because it depicted heights 4,000 feet higher than the rule of thumb used for the Katami ash re-suspension events used by a-VAAC forecasters to this point.

In addition to Web site development and generating alerts in near-realtime, algorithm improvement and development continues. For example, a temporal component was incorporated into the ash detection methodology. This component of the alert system allows optically thin ash clouds to be automatically identified without degrading the detection accuracy. An automated procedure for identifying and filling artificial holes in the ash clouds caused by complexities like multiple cloud layers was developed and implemented into near real-time processing.

We have continued to work with other members of the research team on other tasks of the proposal. Specifically, the results from the alert system are being used to initialize the HYSPLIT dispersion model for select events. Initializing HYSPLIT with results from the alert system will allow for more accurate dispersion forecasts because of better initial horizontal location and vertical height of volcanic ash. The CO-Is at New Mexico Tech have generated a GLM proxy data set using a ground-based lightning detection array that was located in southern Iceland during the 2010 eruption of Eyjafjallajokull. This dataset will serve as proxy for incorporating GLM lightning data into the GOES-R volcanic cloud alert system for electrically active volcanic eruptions.

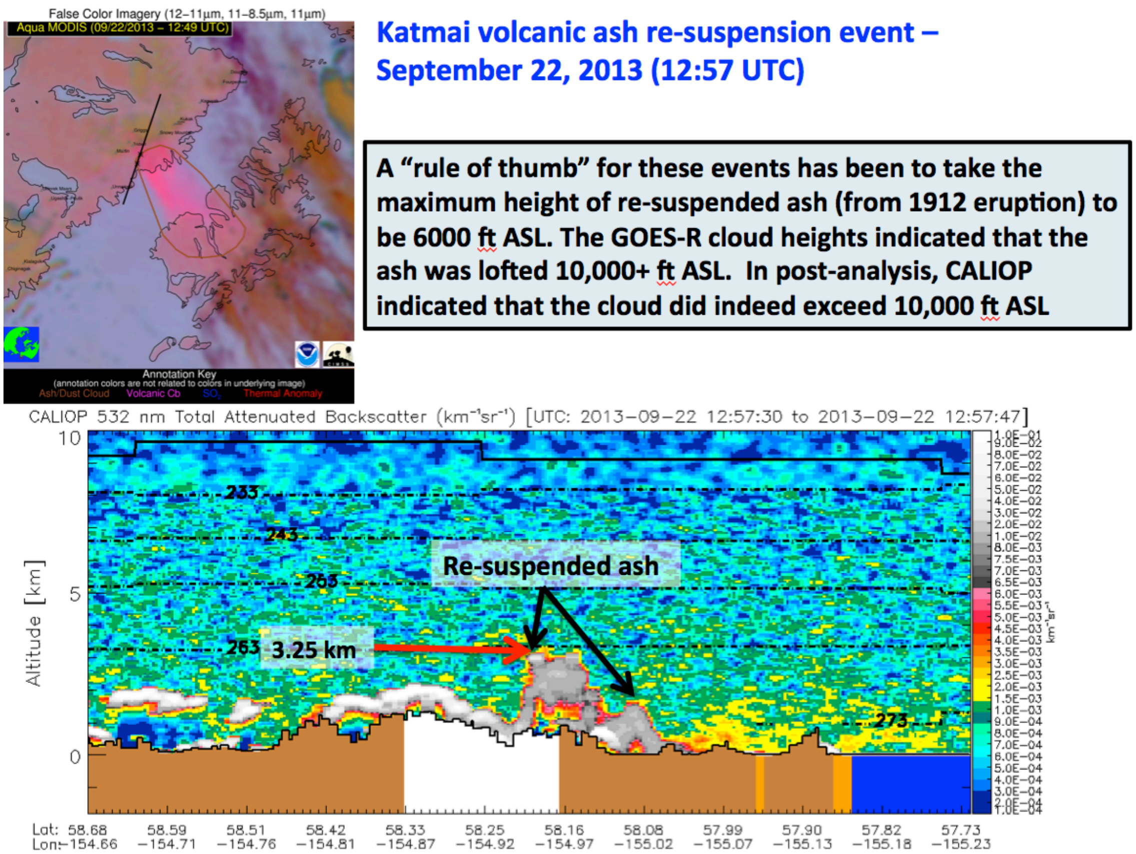

Figure 27. The image in the upper left is a multi-spectral false-color image generated by the GOES-R automated volcanic cloud alert system. The region of automatically detected volcanic ash is highlighted by a brown polygon. The GOES-R ash heights (not shown) indicated re-suspended ash from the Katmai National Park extended to over 10,000 feet above ground level. The bottom figure is the CALIOP total attenuated backscatter with the re-suspended ash annotated (the CALIOP overpass is indicated in the false color image as a black line on the far western portion of the ash cloud). The heights from the CALIOP data reach as high as 3.25 km (or ~10,600 feet)—verifying the infrared-based GOES-R retrieved ash heights.

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.

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

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

CIMSS Task Leader: Wayne Feltz
CIMSS Support Scientists: Sarah Monette and Tony Wimmers
NOAA Collaborator: Tim Schmit
External Collaborators: Kristopher Bedka (NASA SSAI) and Larry Carey (University of Alabama – Huntsville)

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

Project Overview
Convectively induced turbulence (CIT), icing and lightning are all potential in-flight aviation hazards that require aircraft to avoid thunderstorms in order to mitigate the risk of passenger injury and/or aircraft damage. As noted in the Federal Aviation Administration (FAA) Aeronautical Information Manual (AIM, 2010) convective updrafts, downdrafts and their effects (e.g., gravity waves) make up a turbulent system that can extend far beyond the visible and radar detectable boundaries of thunderstorms (Heymsfield et al., 1991; Lane et al., 2003). As such, current FAA guidelines in the AIM (2010) suggest that aircraft avoid severe thunderstorms by at least 20 miles, including under anvil regions and above thunderstorm tops. As a result, large regions of airspace can become unavailable to aircraft traffic on days of widespread convection, causing long flight delays. From FAA statistics, Weber et al. (2006) estimate that thunderstorm related flight delays cost the commercial airline industry approximately two billion dollars annually in direct operating expenses. According to the Bureau of Transportation Statistics (BTS), 66% of National Aviation System (NAS) delays were due to weather, of which thunderstorms are likely a major contributor, while NAS delays were 31% of total flight delays in 2009. Furthermore, turbulence was a cause or factor in 22% of all large commercial aircraft accidents and produced half of the serious-injury accidents from 1997-2006 (National Traffic Safety Board 2010). Importantly, CIT in and around thunderstorms is likely responsible for over 60% of turbulence-related aircraft accidents (e.g., Cornman and Carmichael 1993; Kaplan et al., 2005; Sharman and Williams 2009).

To increase flight safety and decrease delays, it is necessary to develop multi-sensor based algorithms to diagnose the likelihood of CIT and other aviation hazards associated with thunderstorms. Such automated guidance could be used by pilots, dispatchers and air traffic controllers to support the next-generation air transportation system (NextGen) goals of significantly increasing air traffic capacity over the next 20 years (e.g., Sharman and Williams 2009). To be effective, an automated algorithm should use multi-parameter, and if possible, multi-sensor inputs that are widely available and physically and statistically correlated to the thunderstorm microphysics and kinematics that cause aviation hazards. Recent studies utilizing

Doppler radar, cloud-to-ground (CG) lightning, satellite IR and/or numerical weather data separately or in combination have shown early promise in providing useful diagnostic and short-term predictive capability of CIT and other thunderstorm related aviation hazards (e.g., Evans et al., 2004; Megenhardt et al., 2004; Williams et al., 2005, 2006, 2007, 2008, 2009; Feltz et al., 2006; Wolfson and Clark 2006; Yee et al., 2006; Bedka et al., 2007, 2010; Iskenderian 2008; Sharman and Williams 2009).

Combined observations from the planned Geostationary Operational Environmental Satellite-R (GOES-R) series GLM and ABI instruments will provide an unprecedented opportunity to improve the multi-sensor diagnosis and short-term forecasting of CIT and other thunderstorm related aviation hazards. The proposed research will leverage and combine proven capabilities of current members of the GOES-R Risk Reduction (GOES-R3) Lightning Team (Carey, Petersen) and the GOES-R Aviation Algorithm Working Group (AWG) (Feltz, Bedka) in using GLM and ABI proxy cloud top cooling, OT/enhanced-V, and total lightning flash rates and trends for the identification of hazardous convective weather. These distinct yet complementary research capabilities will be synthesized to develop knowledge and techniques toward the goal of demonstrating a new, gap-filling GOES-R integrated GLM/ABI CIT aviation hazard product.

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

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

Summary of Accomplishments and Findings

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

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

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

1. Have established a relationship between EDR-CIT and CTC through a Bayesian scheme that is skilful at predicting CIT with respect to climatology at predicting EDR-CIT within the near future (7 minutes).
2. Continued examination of cases in which total lightning offers valuable flight routing information.
    - Numerous cases identified in which aircraft attempt to navigate the gap between convective cells and then experience moderate or greater turbulence (via EDR report).
    - Multiple cases where inclusion of total lightning data could have offered enhanced turbulence avoidance guidance over radar alone.
3. Conducted multi-platform comparison of convective strength metrics for a severe thunderstorm during SRSO event in North Alabama 09-02-2013 (Figure 28).
    - Total lightning data and trends from Earth Networks Total Lightning Network (ENTLN) were gathered and compared to output from the Northern Alabama Lightning Mapping Array (NALMA) for this SRSO case. Trends between networks are similar though there are significant differences in flash count magnitude. ENTLN flash rates are biased low relative to the NALMA.
    - The storm center was identified using 1-minute resolution lightning flash detections from the NALMA and compared to centroid data from WDSS-II tracking for consistency.
    - The minimum GOES-14 IR brightness temperature (BT) and the presence of an OT detection were noted from each 1-minute image.
    - Vertical penetration magnitude of an OT was derived for the 2-3 September case by measuring the length of the shadow that the OTs cast upon the surrounding anvil.
    - The WSR-88D vertically integrated liquid (VIL), enhanced echo top, and reflectivity time-height cross section were derived from WDSS-II cell tracks of the storm cells of interest.
4. Multi-platform comparison of convective strength metrics for a severe thunderstorm during SRSO event in Missouri and Illinois on 08-16-2013.

- Lack of LMA coverage in this region precludes another comparison between ENLTN and LMA flash data and trends.
- Similar to the 2 September SRSO case, the first OT detections signaled the beginning of storm intensification and rapid CTC occurred in conjunction with a sharp increase in ENTLN flash rates.
- CTC occurred at 2020 UTC, approximately 10 mins before a 2.5 inch hail report.
- At the time of severe hail, ENTLN total lightning and GOES IR BT suggested a weakening of the storm updraft that may have allowed large hail present aloft to fall to the surface.
- Though no severe weather was reported from 2040-2200 UTC, the storm re-intensified and featured colder IR BT and greater ENTLN flash rates than the first half of the storm lifetime.

5. We hope to identify a long-lived tornadic storm observed by GOES-14 SRSO (if one occurred) and perform a similar analysis to that above, ideally in high solar zenith angle conditions so that OT penetration height could be inferred from visible channel shadow length.

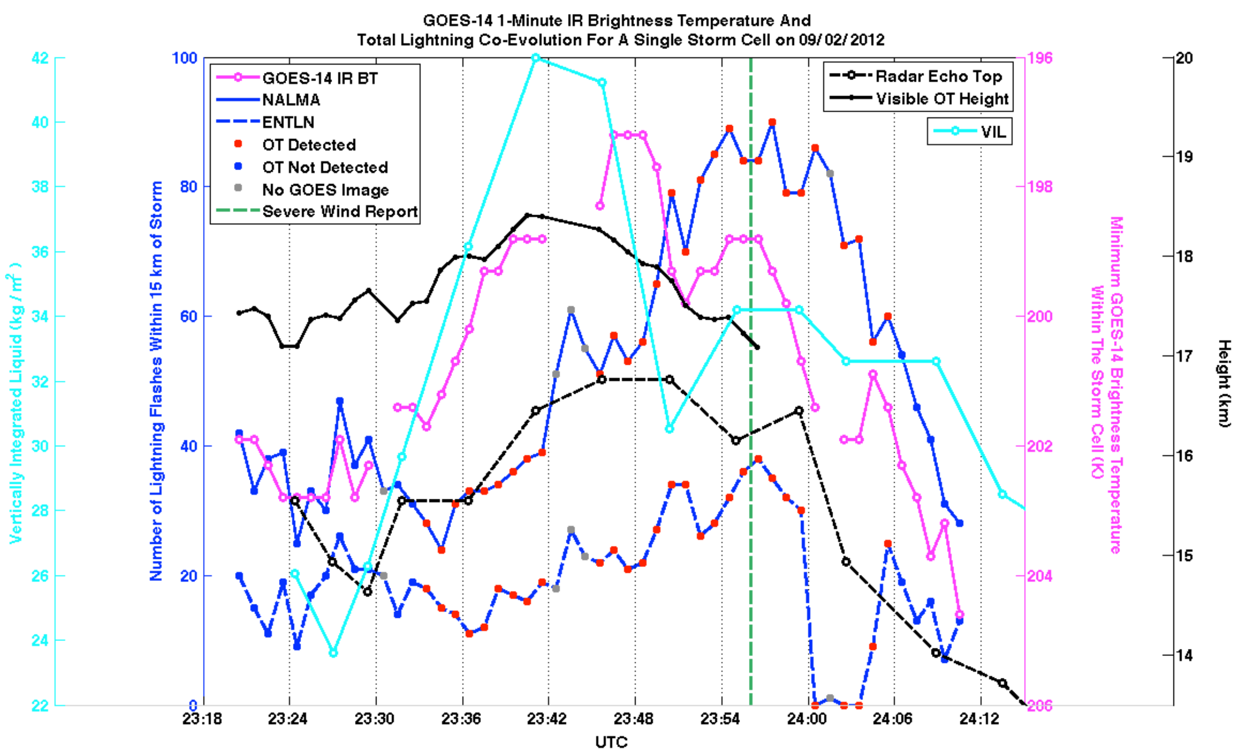

Figure 28. The co-evolution of total-lightning, radar-derived fields, and GOES-14 1-min SRSO observations and overshooting top (OT) detections were analyzed for two individual long-lived and severe convective storm cells.

Publications and Conference Reports

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

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

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

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

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

Journal Articles

Monette, Sarah A., Justin M. Sieglaff, 2014: Probability of Convectively Induced Turbulence Associated with Geostationary Satellite–Inferred Cloud-Top Cooling. *J. Appl. Meteor. Climatol.*, **53**, 429–436.

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7.3 Investigating the Effects of Detector-Averaged SRFs

CIMSS Task Leader: Mathew Gunshor
CIMSS Support Scientist: Szuchia Moeller
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

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

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

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

- Adapt PFAAST (fast forward radiative transfer model) for individual detector SRFs.
    - Code to generate transmittance coefficient files for individual detectors.
    - Code to run the fast forward model on individual detectors.
- Generate transmittance coefficient files for individual detector SRFs for an operational GOES Imager and Sounder.
- Calculate radiances and brightness temperatures for the CIMSS-32 using individual detectors and detector-averaged SRFs.
    - Analyze the comparison between individual and detector-averaged SRFs.
- Progress report detailing the analysis and effects and how it was performed, for possible use with ABI.

Summary of Accomplishments and Findings

As satellite instrument capabilities improve, the instruments become less noisy and the decision to choose a detector-averaged SRF over individual detector SRFs becomes more and more critical. If the difference between detectors exceeds the noise, the data can be adversely affected. For example striping may be detectable in imagery and/or products. The primary tasks for this project were completed in previous years, where it was shown that individual detector differences on the current GOES Sounder do exceed the noise for some bands.

There is work remaining to consolidate and modernize the PFAAST software. This will make it more universal and easier to use. While many users are moving to CRTM, PFAAST remains the operational forward model for current GOES (planned operational through 2020) and is used internationally as well. The remaining funding in this project will be used to continue to make improvements to PFAAST and add new instruments, such as Japan's Advanced Himawari Imager (AHI), nearly identical to the ABI.

Publications and Conference Reports

"CIMSS IAPP Retrieval Software: Updates, Application and Validation" poster presentation by Szuchia Moeller at the International TOVS Study Conference (ITSC-XIX), Jeju Island, South Korea, 26 March – 1 April 2014.

7.4 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
Previously the display of pre-computed atmospheric wind parcel trajectories has been demonstrated by showing the utility, and evaluation, of the NearCast forward trajectory model using McIDAS-V. To extend this capability, we've developed, and are evaluating a forward/reverse trajectory computation through a time series of Eulerian wind field points on a navigated grid. One potential application relevant to GOES-R is to display 3D trajectories through time based on ABI retrieved Aerosol optical depth (AOD) and numerical model wind forecast. Another GOES-R application would be to visualize the forward trajectories of parcels in the vicinity of volcanic eruption with respect to ash/SO2 retrievals. We will enhance our trajectory computation for smooth time interpolation and integrate into the core display library of McIDAS-V. We will develop interactive on-display screen tools so users can drop-in parcel start/stop positions for forward/reverse trajectories. Trajectory ribbons, showing rotation, can be added as well. If time permits, computational efficiency improvements can be investigated, for instance, GPU processing for faster multiple trajectory displays.

Summary of Accomplishments and Findings
Figure 29 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 trajectories can be animated through time – not shown, and display time range will be controlled by the user.

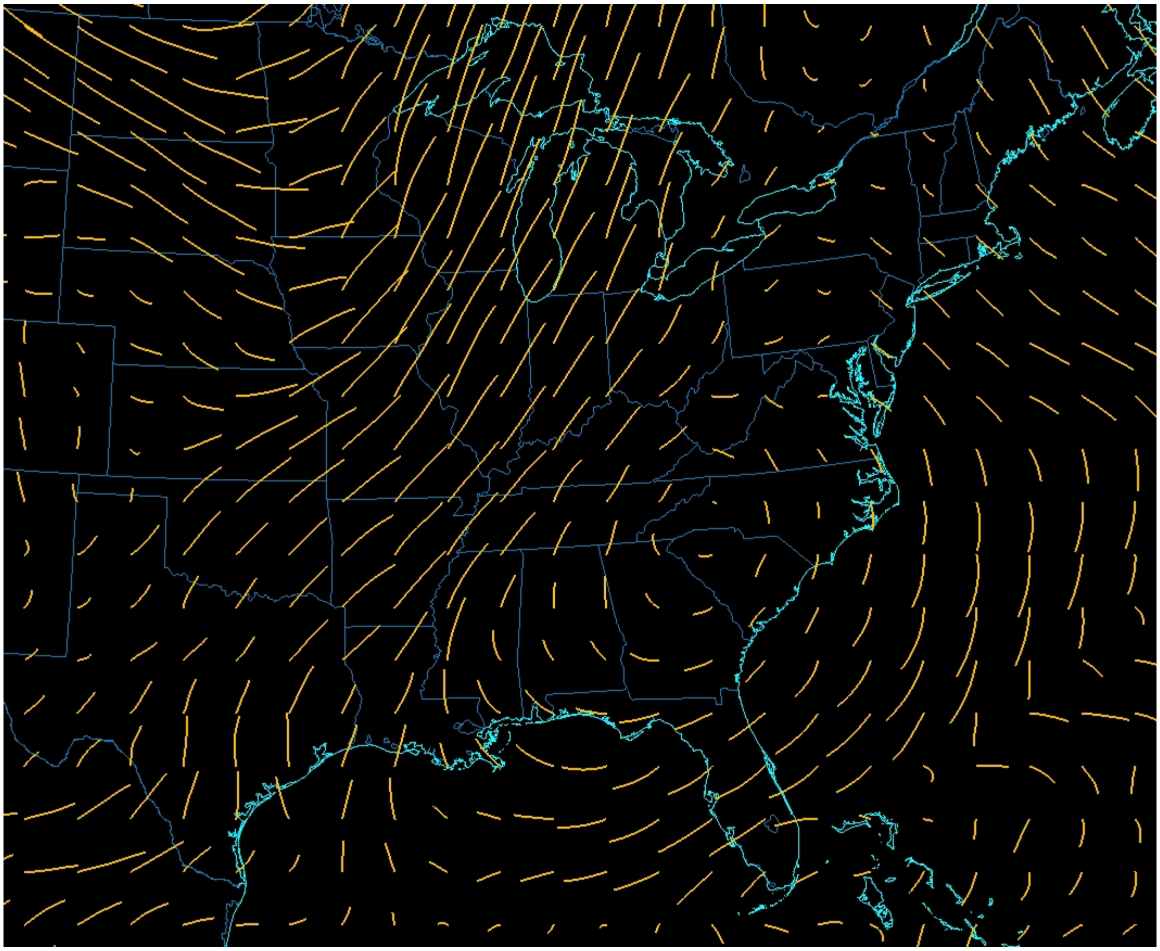

Figure 29. Wind parcel trajectories derived from RUC (Rapid Update Cycle) 750mb level

Publications and Conference Reports

AMS Annual Meeting (IIPS): 2005-2013
AMS Satellite Meteorology Conference: 2007, 2009, 2010, 2012
AGU Fall Meeting: 2005, 2007-2011
SPIE Photonics: 2007-2011
NOAA Direct Broadcast: 2008, 2011
GOES-R User's Conference: 2009 (workshop), 2010, 2011
EUMETSAT Satellite Conference: 2008 (workshop), 2009-2013
International TOVS Working Group Meeting: 2007, 2008, 2010 (workshop), 2012, 2013
McIDAS Users Group: 2006-2013 (workshops 2008-2013)

7.5 Improvements to QPE Using GOES Visible ABI and Model Data

CIMSS Task Leader: Jason Otkin
NOAA Collaborators: Robert Rabin, Robert Kuligowski, and V. Lakshmanan

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

Project Overview

The proposed work addresses the need for remote sensing-based estimates of precipitation in portions of the U.S. and its coastal waters where WSR-88D radar is limited due to the radar beam being blocked and/or overshooting the precipitation. Heavy precipitation poses threats of flash flooding, but existing satellite techniques often perform poorly in pinpointing locations of heavy rain, especially when cloud tops are relatively warm.

Improvements to the existing Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) algorithm will be made using high resolution cloud structure from GOES visible imagery, estimates of cloud top phase and particle size derived from GOES, and moisture and wind fields from numerical weather prediction (NWP) model and NWP+satellite "blended" data. Preliminary work at the National Severe Storms Laboratory (NSSL) indicates that a simple technique used to identify small-scale convective cloud tops in visible satellite imagery performs better than infrared-only techniques in matching radar echoes in many situations.

Summary of Accomplishments and Findings

During the past year, synthetic ABI visible reflectances and infrared brightness temperatures computed each day using output from real-time NSSL-WRF model forecasts were provided to NSSL researchers to investigate relationships between the spatial structure of visible satellite imagery and the model cloud optical depth, cloud top height, and accumulated precipitation. By using synthetic satellite imagery, methods were devised to extract information on precipitation rate versus cloud optical depth and brightness temperature from forecast GOES imagery that were then applied to observed satellite imagery. The cloud optical depth appeared more closely related to precipitation intensity than albedo, which was examined earlier in the project. Optical depth is available from the NSSL-WRF forecasts at hourly intervals, whereas observed GOES optical depth retrievals were obtained from UW-CIMSS. A web-based assessment tool was created to compare real-time GOES imagery with cloud top products and with both observed and estimated quantitative precipitation estimates. A quantitative Statistical Evaluation Tool was also developed for use with the webpage.

7.6 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 Collaborator: Jaime Daniels

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 Atmospheric Motion Vector (AMV) product has been developed for the Geostationary Operational Environmental Satellite (GOES-R) Advanced Baseline Imager (ABI) using a new tracking algorithm developed by the GOES-R Algorithm Working Group (AWG). Proxy data sets were created by applying the 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 ABI Channel 2 (visible), 7 (near infrared), 8 (cloud top water vapor), and 14 (infrared). This proxy data provides the opportunity to improve the AMV algorithm and determine software changes needed for the National Center for Environmental Prediction (NCEP) Global Data Assimilation System (GDAS) with the Gridpoint Statistical Interpolation (GSI) to successfully assimilate these data. GDAS analyses during two different seasons will be used to collect data assimilation statistics for evaluation. Quality control procedures will be 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 is also required. Once assimilation techniques have been selected, any software changes will be reviewed with oversight by NCEP Environmental Modeling Center (EMC).

Summary of Accomplishments and Findings
During this time period, we tested changes to the GOES-R AMV nested tracking algorithm and its height assignment strategies, providing useful feedback to the algorithm developers. Two modifications investigated in detail were using a correlation score in assigning the cluster height and cloud phase matching for targets in the different images. These tests were coordinated and conducted with Jaime Daniels and the GOES-R AMV team.

The current height assignment for both the infrared (IR) and cloud top water vapor (CTWV) AMVs uses the mean cloud top height from the tracked cluster's individual motion vectors. Each vector gets an equal weight. The first modification we tested incorporates the correlation score of each individual vector to compute a weighted mean of the cluster's height. This modification was applied to 20 days of the proxy data set for both the IR and CTWV AMVs. Testing the AMVs with these modified heights in the NCEP GDAS revealed a slower speed bias for AMVs in the highest levels of the troposphere and a faster speed bias for AMVs at mid-levels; the overall fit to the model background was worse. This impact was significant and provided guidance that this modification would not improve the performance of the GOES-R AMV data within the NCEP Global Data Assimilation System.

The second modification tested was an addition to the tracking algorithm to include cloud phase. The cloud phase of the targets in each image must now match when finding the candidate motion vectors. The set of vectors grouped into a cluster were also required to be the same cloud type. Once again, a short data set (8 days) was reprocessed with this change to collect fit statistics with the NCEP GDAS. The results from this change was positive, the mean AMV speed departure was reduced in both the mid and upper levels. Using the NCEP GFS to investigate algorithm modifications with short simulations to collect fit statistics has provided quick and effective feedback to the algorithm developers. The impact of algorithm changes on departure of AMV speed and direction from the NCEP GFS analysis state has been considered along with comparisons to collocated rawinsondes to give the developers the most information to evaluate scientific modifications.

After investigating several parameters specific to the new GOES-R AMV algorithm, a new parameter was selected to be included in the quality control procedures of the infrared (IR) AMVs. This new parameter, which is a measure of the clusters standard deviation divided by the distance the cluster traveled, is called PCT1. In clusters with large values of PCT1, the AMVs showed a slow speed bias with respect to rawinsondes. The AMV speeds compared to the GFS background showed consistent relationships where AMVs with large values of PCT1 tended to have negative speed departures. Likewise small values of PCT1 were also shown to be associated with AMVs which had positive speed departures for AMVs which have passed the QI and EE requirements (Figure 30). Clipping both ends of the PCT1 distribution, by limiting PCT1 to an allowable range, was therefore included as a quality control procedure for IR AMVs.

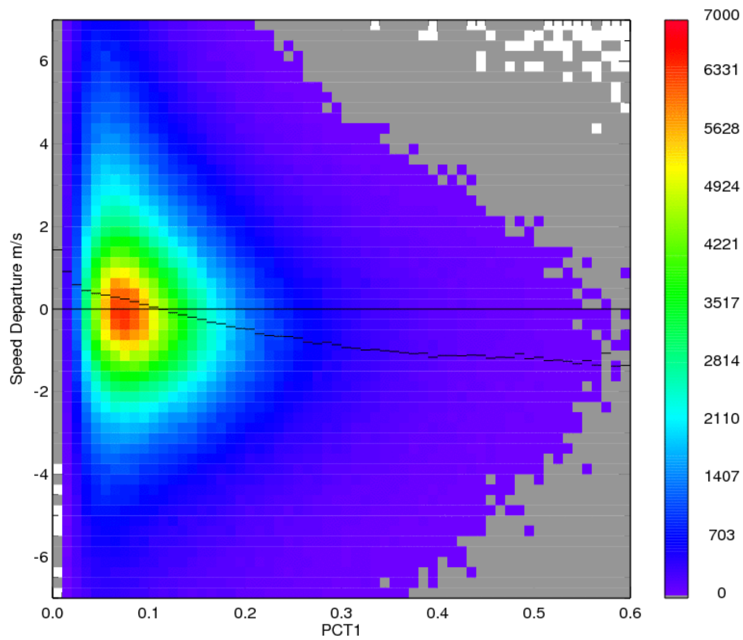

Figure 30. Density plot of IR AMV speed difference with GFS background (AMV-GFS) and the nested tracking parameter PCT1 for June 2012. The black line at each PCT1 bin shows the mean speed departure value. AMV number in the x/y bin range from 0 to 7000.

Results from the first year of this project established that the AMV observation error for 6-hourly GOES-R AMVs would have greater influence on the NCEP GFS analysis state with a setting at 75% of the original GOES AMV error values. Quality control settings using the Quality Indicator (QI, Holmlund, 1998) and Expected Error (EE, Le Marshall et al., 2004) were selected. These simulations also included a Log Normal Vector Departure (LNVD) check to screen AMVs which were too different in speed and/or direction from the analysis state to be successfully assimilated by the GSI.

Using the selected quality control procedures and the adjusted observation error profile, a two season observing system experiment was conducted using the NCEP GDAS-Hybrid with the GEOS-R AMV proxy data using all 4 AMV types: visible, near infrared, cloud top water vapor, and infrared. These experiments were conducted at the NCEP operational resolution of T574 with 64 vertical layers. The corresponding controls, which used no AMVs from SEVIRI, were completed as well. Both seasons of the observing system experiment are nearly complete. At this time, results indicate the assimilation of the GOES-R AMVs have neutral to slightly positive impact on the GFS forecast skill in the southern hemisphere (Figure 31). Results and modifications to the GSI code have been shared with EMC to begin the code and scientific review for implementation of GEOS-R AMVs in the future.

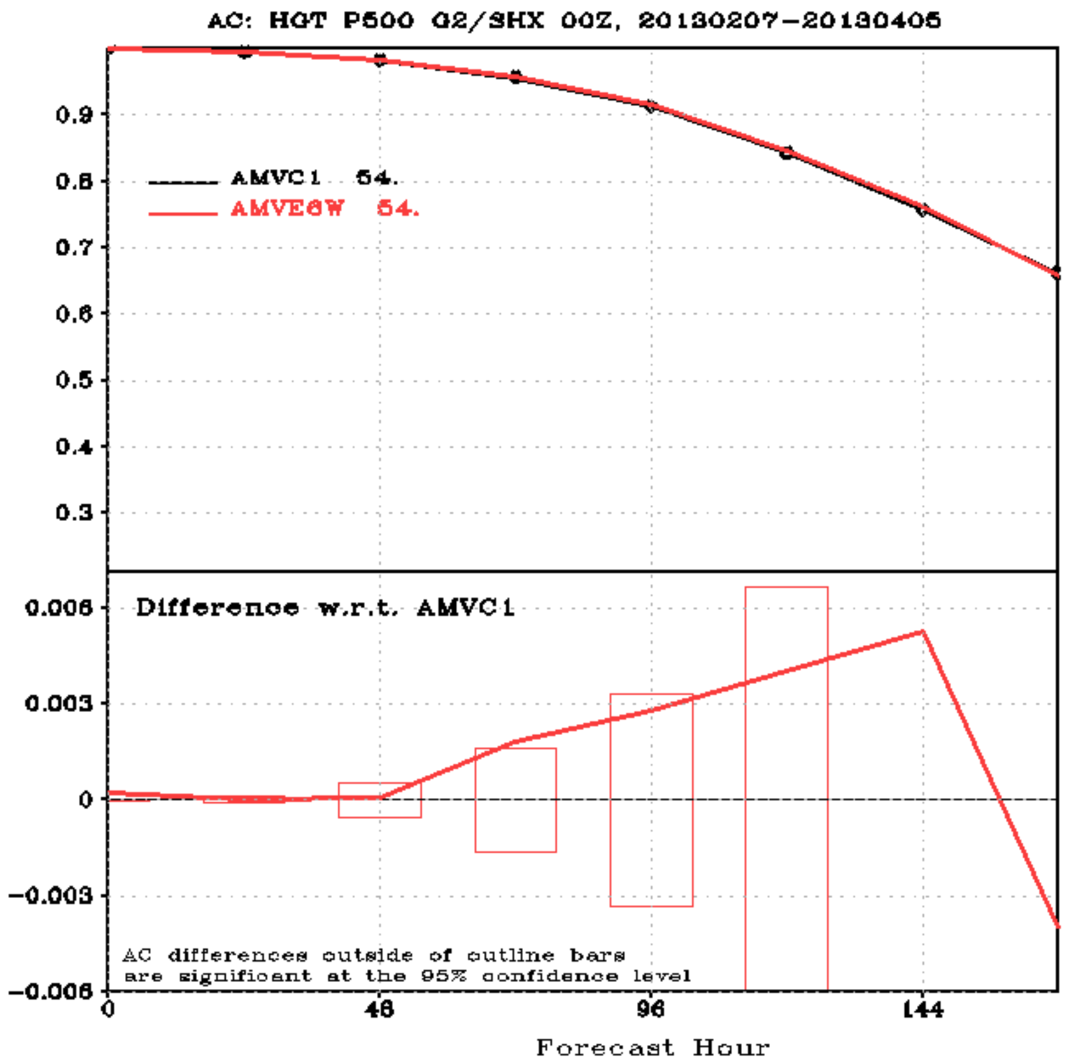

Figure 31. GFS 500 hPa Southern hemisphere height anomaly correlation for the 7 day forecasts from the control simulation AMVC1 and the experiment AMVE6W which included GOES-R AMVs for 7 Feb to 6 April, 2013.

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

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

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

CIMSS Task Leader: Ralph A. Petersen
CIMSS Support Scientists: William Line, Lee Cronce, Richard Dworak, William Straka
NOAA Collaborators: Robert Aune, Gary Wade, William Line (NOAA Affiliate, SPC)

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 overall objective of this effort is to provide data driven tools to help NWS forecasters expand their use of GOES moisture and temperature soundings by 1) enhancing and expanding existing observations using clear-air variables that GOES observes and 2) adding new products to forecast the near-future state of the pre-storm environment. (Note: GOES clear-air sounder data are used only sparingly in operational NWP model over land.) As originally funded, the project has three primary tasks: 1) to determine how information contained in ancillary asynoptic data sets (including GPS-Total Precipitable Water (GPS/TPW), AMDAR aircraft profiles, Raman Lidar observations from the ARM CART site and hyperspectral POES retrievals) could be used to enhance GOES-R products by identifying and removing biases and also facilitating combination of GOES-R data with soundings from existing GOES satellites and then using these products in NearCasts covering the next 6-9 hours, 2) to incorporate these enhanced sounding products into multi-layer and isentropic versions of the NearCasting analyses and short-range forecasts, and 3) to perform assessments and validations of the NearCasting products using objective scores and at participating GOES-R Proving Ground sites. This project is in its last year and builds on 10 years of effort. Due to funding reductions, the assessment/validation aspects of task 3 were eliminated. The basic version of the NearCasting system has been successfully tested at the Storm Prediction Center, Aviation Weather Center and the European Severe Storms Laboratory (using SEVIRI data as a surrogate for GOES-R ABI). Products tests at the Weather Prediction Center and Ocean

Prediction Center are being scheduled for spring 2014 as part of the GOES-R Visiting Scientist program.

Summary of Accomplishments and Findings

Task 1 – Improving Quality of GOES Moisture Retrievals

Alternative approaches have been developed to calibrate the GOES retrievals using other surface-based systems including operational AMDAR WVSS-II aircraft observations, GPS /TPW and research-quality Raman Lidar profiles from the ARM CART site. Additional work using the combination of POES and GOES profiles was performed using data from AIRS retrievals that are classified as being "completely cloud free", showed that the largest errors in the GOES TPW retrievals occurs in situations of scattered clouds, pointing to the importance of improving future cloud-clearing techniques (Figure 32a). Biases in the GOES TPW products are largely the result of biases in the NWP first guess fields from the NCEP-GFS used during the retrieval reprocess. Not only do the GOES sounding products mirror biases in TPW from the short-range GFS forecasts, the biases in the 3-layer GOES PW products also match the vertical variation in errors in the GFS in those layers. Errors in the GFS moisture fields also show strong changes in biases from cycle. GOES moisture data showed the greatest improvement in random errors over NWP products occurred during the warm months, a time of year when short-range NWP precipitation forecasts have their least skill. A bias removal method for the multi-layer GOES moisture data has been developed based on normalized bias statistics (Figure 32b). Tests will continue as long as residual project funds remain available.

Task 2 - Converting the NearCasting System from an Isobaric to an Isentropic Framework

This effort was designed to enhance the impact of the satellite products in short-range forecasts and to provide forecasters a more complete picture of the total amount of moisture and energy observed by GOES in clear skies and being transported adiabatically into areas of interest and an improved understanding of near-term vertical motions. Figure 33 shows results of the original isobaric and new isentropic versions of the NearCast model for the case of a tornadic thunderstorm complex that formed around after 2300 UTC over far west-central IA. By 0000UTC, dry/cool air aloft (lower θe, upper left panel) was predicted to move over lower-level warm/moist air (higher θe, lower left panel), creating an area of increasing convective instability over far western IA at the time and location of the rapid storm development. Although the isentropic NearCasts show a similar area of destabilization moving into far western IA, the lower-level moisture supply moving northward from the Gulf and upper-level dryness overlaying it from the southwest are more distinct and well defined. The isentropic output also adds information showing sudden lifting as the lower-level parcels reach western IA where the convective destabilization is occurring. The isentropic depiction also allows areas that are prone for rapid development of severe convection to be separated from those that are being primed for heavy precipitation. Specifically, areas of heavy convective precipitation were found ahead of regions where the total moisture transport in lower-level isentropic layers [defined as the combination the isentropic mass (inverse static stability) and layer-average mixing] was maximized. This work formed the basis of William Line's MS Thesis, with publication planned for the coming year. Additional studies have been conducted on several cases, including of a severe convection event in Europe (unforecast by NWP models) using SEVIRI as a GOES-R ABI surrogate using the original isobaric model have shown positive results, with 40% increases in analysis data coverage and indications of substantial lower-level moist energy in areas when/where storms formed.

Task 3 - Testing at GOES-R Proving Grounds

NearCast products have been tested at SPC for 3 years and AWC for 2 years. SPC results showed that Forecasters better prepared than in previous years and used the added improvements in color bar selections, etc. to advantage. Specific comments included:

- "Love the theta-e difference on Nearcast."
- "The theta-e difference showed unstable air over Montana. When the storms entered this unstable air they did strengthen quite a bit, several becoming severe."
- "The [NearCast] product showed enhanced chances for convection all the way to the Lubbock area. Especially the theta-e difference product as it placed a tongue of mid-level unstable air just where high based thunderstorms finally evolved… the product helped a lot to focus on the anticipated area of initiation."
- "The storms . . . formed right on the low-level maximum of theta-e, so it did very well."
- "The theta-e difference showed stable air moving into the area, and along with [another product], was used in the forecasting of the dissipation of the storms."

The next step toward making the system operational is ongoing training and evaluation at SPC operational forecasting desks. Plans are also underway to test products at the Weather Prediction Center and Ocean Prediction Center in 2014 as part of the GOES-R Visiting Scientist program.

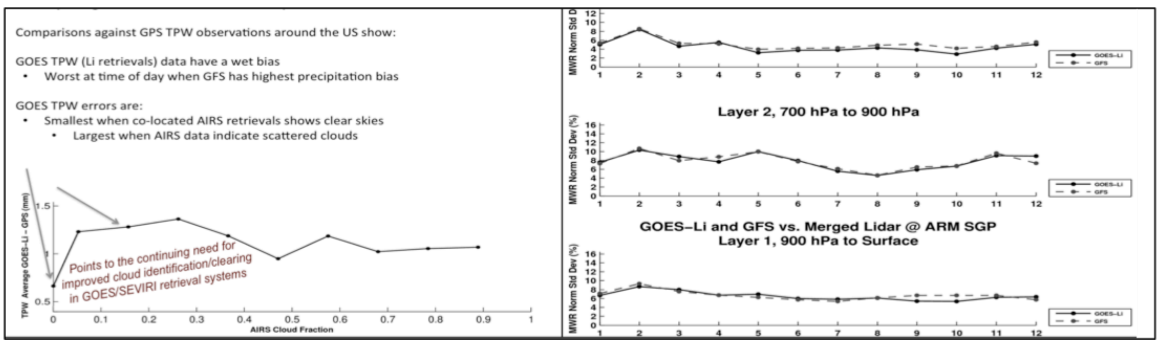

Figure 32. Left - Variation of GOES "LI" retrieval TPW Bias by AIRS cloudiness in 2011. Right - Normalized 3-layer "Li" retrieval error vs. ARM CART Raman Lidar observations.

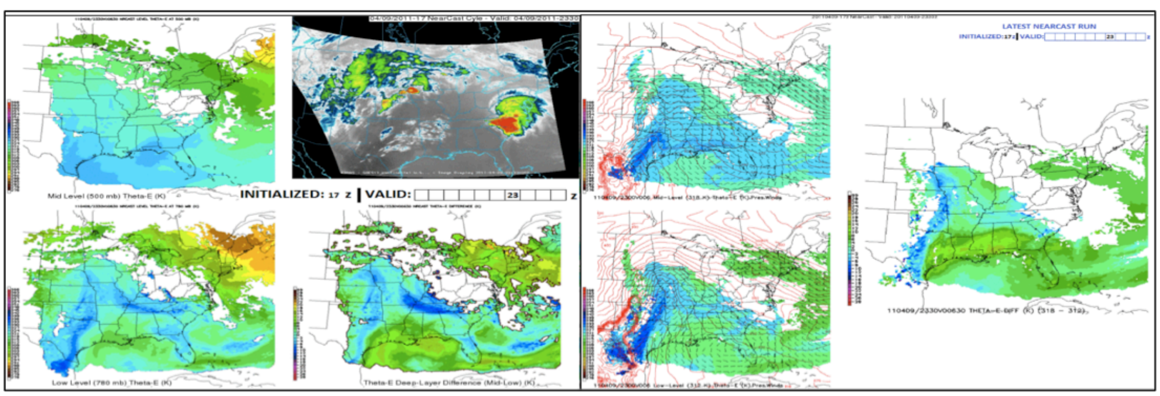

Figure 33. Left – Counter-clockwise from upper right - Validating satellite image for 2330 UTC 9 April 2012, 6.5 hour Isobaric NearCast of Mid-level θe, Lower-level θe NearCast and derived Convective Instability (vertical θe difference between isobaric surfaces), all valid at 2330 UTC. Right - Counter-clockwise from upper left – 6.5 hour Isentropic NearCast of Mid-level (318K) θe, Lower-level (312K) θe, and derived Convective Instability (vertical θe difference between isentropic surface.) all valid at 2330 UTC. Pressure topography of isentropic surfaces and wind NearCasts also included as contours and barbs in left panels.

Publications and Conference Reports

Posters:

- Petersen et al. at NOAA Science Weeks in Kansas City, MO and College Park, MD (April 2012/13)
- Dworak et al. at NOAA Science Weeks in College Park, MD (April 2013)
- Line et al. at EUMETSAT Users Conference (Sept. 2013)

Presentations:

- Petersen et al. at EUMETSAT Users Conference and Conf. Report (Sept. 2013)
- Dworak et al. at EUMETSAT Users Conference and Conf. Report (Sept. 2013)
- Petersen et al. at NOAA Science Weeks in Madison, WI (March 2014)
- Petersen et al. at EUMETSAT Convection Working Group Workshop (April. 2014)

7.8 Convective Storm Forecasting 1-6 Hours Prior to Initiation

CIMSS Task Leaders: Chris Velden, Steve Wanzong
NOAA Collaborators: Dan Lindsey (RAMMB), Bob Rabin (NSSL)

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

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

In thunderstorm forecasting, one of the largest difficulties continues to be convective initiation (CI), i.e., predicting where and when thunderstorms will form. After storms form and precipitation begins falling, radar is the primary tool used by forecasters to issue nowcasts, assess the storms' severity, and issue severe thunderstorm and tornado warnings. However, without precipitation-size particles, radar can only provide information on surface boundaries that sometimes help trigger convection. This information is generally used subjectively by forecasters, in combination with surface observations, numerical model output, and satellite imagery, to decide where and when new storms will form.

Up to this point, the majority of satellite-based CI research has focused on nowcasting which growing cumulus or towering cumulus clouds will develop into precipitating thunderstorms during the next 30-60 minutes. Despite the importance of this forecast problem, very little research has focused on determining what short-term predictive (e.g., during the next 1-6 hours) information is available from satellite data *prior to* cumulus cloud formation, or whether there is information within an initial field of shallow cumulus clouds about whether (and which) of these clouds will eventually become storms, or what regions are more likely to generate new deep convection.

GOES-R will provide us with a wealth of new infrared information, and when combined with improved radiometrics and much greater spatial and temporal resolution, there is potential to greatly improve the forecasting of CI. The ultimate goal of this work is to develop an automated, objective system to predict where and when storms will form between 1 and 6 hours prior to their initiation. Given this lofty goal, this proposed task is designed to begin the research necessary to develop such a predictive system.

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

Summary of Accomplishments and Findings

The funding for this effort wrapped up very early in this reporting period. Therefore, no new accomplishments or findings can be highlighted. However, this study did demonstrate the ability to compute mesoscale Atmospheric Motion Vectors (AMVs) over selected domains using simulated NSSL WRF fields as a proxy, and consider what diagnostics from this output could be used as a CI predictor. Given the improved temporal and spatial resolution expected with GOES-R, the AMVs should allow for the identification of mesoscale features such as associated with low-level regions of convergence perhaps not evident in model forecast fields.

7.9 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
CIMSS Support Scientist: Rebecca Cintineo
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 CONUS 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 2012 and 2013 HWT Spring Experiments. Since the ensemble forecasts employ different cloud microphysical and planetary boundary layer (PBL) 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 imagery will be made available in near real-time 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 GOES-R.

Summary of Accomplishments and Findings

The main accomplishments during the past 12 months include publishing an article describing the use of simulated satellite imagery for evaluating the accuracy of model parameterization schemes and generating simulated satellite imagery during the 2013 HWT Spring Experiment. Simulated GOES-R, GOES-13, and GOES-15 infrared brightness temperatures were computed each day during the 2013 HWT using model output from 20 CAPS ensemble members. Simulated satellite imagery and derived products such as the probability of 10.7 μm brightness temperatures being less than certain threshold values indicative of deep convection were displayed via the CAPS model Web page (http://www.caps.ou.edu/%7Efkong/spring13/). User feedback was generally positive with comments typically indicating that the forecast imagery allowed them to quickly assess the accuracy of the model forecasts and to examine the evolution of the forecast cloud field and areas of deep convection.

Synthetic GOES-13 infrared brightness temperature observations generated during the 2012 HWT were also used to evaluate the ability of different cloud microphysics and PBL schemes employed by the Weather Research and Forecasting (WRF) model to accurately simulate cloud characteristics. Results from this study were recently published in *Monthly Weather Review*. Four double-moment microphysics schemes predicting both the mass mixing ratio and number concentration for at least one cloud species and five PBL schemes using either local or non-local mixing were evaluated. The accuracy of the simulated cloud field was evaluated using multiple techniques, such as 6.7-10.7 μm brightness temperature differences (BTD). Various 6.7-10.7 μm BTD thresholds were used to examine the areal extent of clouds in the lower, middle, and upper troposphere. The thresholds used here are -30 to -10 K for low-to-midlevel cloud tops, -10 to 0 K for upper level clouds, and > -2 K for overshooting tops.

The temporal evolution of the ratio between the observed and simulated spatial area covered by each cloud type for each ensemble member is shown in Figure 34. Area ratios greater (less) than one indicate that a given ensemble member contains more (fewer) clouds than observed. Large differences were found in the simulated cloud cover, especially in the upper troposphere, when using different microphysics schemes. Overall, the results revealed that the aerial extent of low-to-midlevel clouds (Figure 34a) is consistently too low during the entire forecast period for all of the PBL and cloud microphysics schemes evaluated during this study. For upper level clouds (Figure 34b), their aerial extent was most accurately depicted by the Thompson microphysics scheme, which remained fairly close to the 1:1 area ratio throughout the forecast period. The Milbrandt-Yau and Morrison microphysics schemes tended to produce too many upper level clouds, whereas the WDM6 scheme did not produce enough high clouds. Smaller differences occurred in the cloud fields when using different PBL schemes, with the greatest spread in the ensemble statistics occurring during and after daily peak heating hours. For overshooting cloud tops (Figure 34c), the best forecasts were achieved when the Thompson scheme was used, though the Morrison scheme also performed well. At the peak convective time of the day (forecast hours 18-25), all of the ensemble members except for the WDM6 contained too many overshooting cloud tops.

Publications and Conference Reports

Cintineo, R., J. A. Otkin, F. Kong, and M. Xue, 2014: Evaluating the accuracy of planetary boundary layer and cloud microphysical parameterization schemes in a convection-permitting ensemble using synthetic GOES-13 satellite observations. *Mon. Wea. Rev*., **142**, 163-182.

Cintineo, R., J. A. Otkin, M. Xue, and F. Kong, 2014: Using Synthetic Satellite Observations to Evaluate the Performance of Planetary Boundary Layer and Cloud Microphysical Parameterization Schemes in Convection-Permitting Model Simulations. *22nd Conference on Numerical Weather Prediction*, Atlanta, GA.

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.

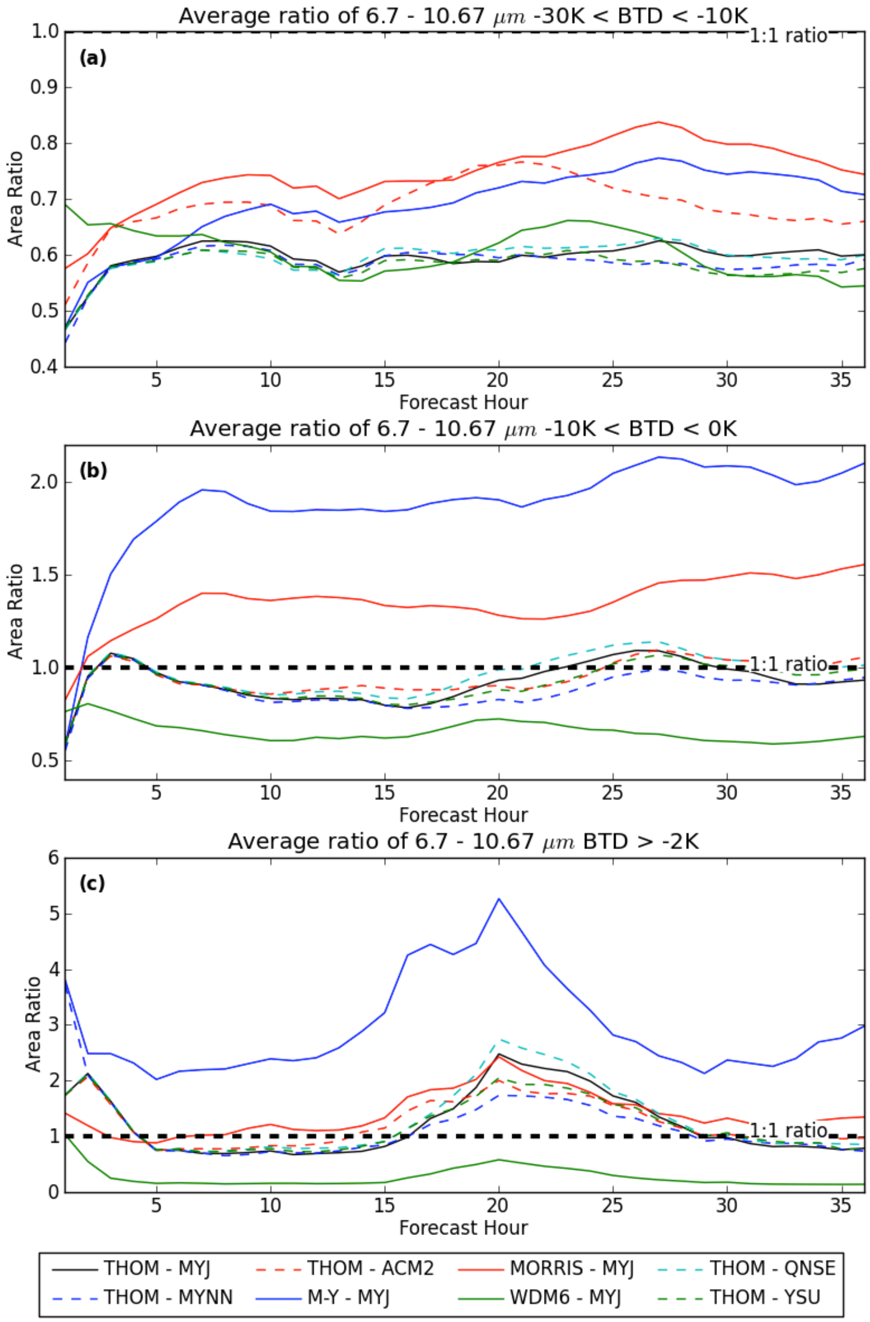

Figure 34. Ratio of forecast to observed 6.7 - 10.7 µm brightness temperature difference area within a threshold of (a) -30 to -10 K, (b) -10 to 0 K, and (c) > -2 K.

7.10 Satellite Meteorology Resources and a GOES-R Education Proving Ground

CIMSS Task Leaders: Margaret Mooney and Steve Ackerman
CIMSS Support Scientist: Tom Whittaker
NOAA Collaborators: Nina Jackson

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

CIMSS Research Themes:

- Education and Outreach

Project Overview

The CIMSS "Education Proving Ground" features the design and development of activities for G7-12 teachers and students in preparation for the launch of GOES-R. Our goal is to have CIMSS and ASPB scientists work with students virtually during post-launch GOES-R checkout activities. A key element of this effort will be sustained interaction between CIMSS EPO staff and a core group of committed educators recruited specifically to collect feedback for iterative improvements to the classroom activities prior to launch. The Education Proving Ground will rely on close coordination with CIMSS/ASPB scientists. In this way, teachers will be ready to run similar activities with their students following the 2016 GOES-R launch and be ready for the new types of satellite imagery and products which will be available in the upcoming GOES-R era.

The intended outcomes of this project are:

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

Summary of Accomplishments and Findings

CIMSS scientists regularly participate in student and teacher workshops to facilitate the use of satellite data in education, which includes maintaining and distributing the CIMSS "Satellite Meteorology for Grades 7-12" CD and on-line course (http://cimss.ssec.wisc.edu/satmet/). In 2011, this course underwent a complete makeover to create a modernized and visually appealing interface. Content updates included a new module featuring the Suomi NPP Satellite, JPSS and GOES-R. These revisions were completed in time for the 25th Satellite Educators Conference in August 2012 where the new module was presented by project partner Paul Ruscher and 100 CD's were distributed. Margaret Mooney from CIMSS presented similar content at the 2013 Satellite Educators Conference. CIMSS will host the 2014 Satellite Educators Conference in Madison.

2013 Activities – Updating Satellite Applets to HTML5

CIMSS has several applets that educate around the topic of satellite meteorology. In 2013 three applets that provide an understanding of what instruments sense in different parts of the spectrum -- visible, IR and water vapor – were updated to HTML5. By manipulating surface temperature or land cover type, plus the altitude or thickness of a cloud, the scene changes to illustrate the view from a geostationary satellite. CIMSS recast the original applets into the HTML5 "stack" of technologies so that they may be used on modern computing platforms, such as tablets, widely used in education.

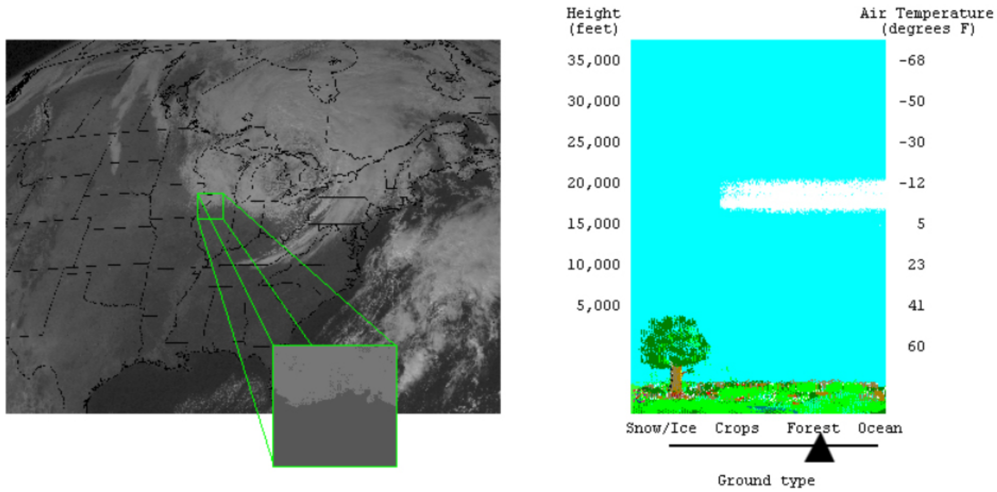

Figure 35. Screen shot of the revised "Interpreting Satellite Imagery" applet.

Publications and Conference Reports

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

Whittaker, Thomas M.; Ackerman, S. A. and Jasmin, T. From Java to Flash to HTML5: Chasing technologies for interactive applets. Symposium on Education, 21st, New Orleans, LA, 22-26 January 2012. American Meteorological Society, Boston, MA, 2012.

Mooney, Margaret; Dahlman, L.; Ackerman, S.; Jackson, N.; Chambers, L. H. and Whittaker, T. M. The CIMSS iPad Library and ESIP Teacher Workshops. Symposium on Education, 22nd, Austin, TX, January 2013. American Meteorological Society, Boston, MA, 2013, abstract only.

Rowley, Patrick; Ackerman, S.; Arkin, P.; Pisut, D. P.; Kohrs, R. A.; Mooney, M. and Uz, S. Schollaert . Communicating climate forecasts via NOAA's Science on a Sphere: The EarthNow Project. Conference on Applied Climatology, Austin, TX, January 2013. American Meteorological Society, Boston, MA, 2013.

Mooney, M., Ackerman, S. A., Achtor, T. H., and Brunner, J., 2004: Development of satellite meteorology teaching materials for grades 7-12. Symposium on Education, 13th, Seattle, WA, 11-15 January 2004 (preprints). American Meteorological Society, Boston, MA, 2004.

7.11 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 forecasting remains a primary goal of TC research. However, TC structure change is another challenging aspect of TC forecasting that deserves 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 proposed to conduct a multi-institutional project consisting of NOAA/CIRA and UW-Madison/CIMSS collaborators to develop a variety of GOES-R related tools that will improve the diagnosis and forecasting of TC structure change. The NOAA/CIRA Project Lead and NOAA collaborators are completing tasks that incorporate 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. In the last year, 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 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. It should be noted that the data from all sensors, which have varying spatial resolution, were interpolated to a common grid with a radius of 600 km. Once this large historical dataset was established, two varieties of algorithms to relate microwave imagery (MI) to the TC wind field were developed.

One series of statistical models created in this study uses the CIRA extended best track data to describe overall storm size. Here, azimuthal-mean properties of the MI, namely empirical orthogonal functions (EOFs) that describe the azimuthal mean T_b structure from storm center out to 600-km radius, along with some environmental predictors, are related via linear multiple regression to the 850-hPa, azimuthal mean tangential wind at a radius of 500 km. The non-MI based features of the model include the current intensity and latitude of the TC center, but also include simple environmental features as well. The tangential wind at 500 km and the non-MI based features come from best track data and from a six-hourly global model analyses data for the years 1995-2012. The MI are quality controlled to mask out land and also such that the satellite swath captured a sufficient amount of the TC precipitation structure surrounding the TC center.

This estimate of the outer winds is used to empirically estimate the radius of 5 kt winds, a measure of TC size. This algorithm provides a method for determining the overall size of a TC from microwave imagery, which is advantageous over data sparse regions. It is found that reliable algorithms can be developed for various microwave channels, with 37-GHz (horizontal polarization) T_b providing the most skillful algorithm, more skillful than similar algorithms developed from geostationary satellite infrared (IR) data (Knaff et al., 2014). Results from the MI-based algorithms that estimate overall TC size will be provided in the forthcoming manuscript of Rozoff et al. (2014).

A second series of statistical algorithms is designed to estimate the wind structure of TCs from MI using a high-resolution wind dataset from aircraft reconnaissance missions into Atlantic and Eastern Pacific basin TCs. This dataset includes many storms that were observed via aircraft reconnaissance from 1995-2012, is two-dimensional and interpolated to 6-h fixes at the synoptic times of 00, 06, 12, and 18 UTC. The data are also cast into polar coordinates and contain high-resolution presentation of the full horizontal winds associated with observed TCs. These high-resolution wind data allow for the estimation of the TC inner-core winds from passive MI after appropriately matching optimal microwave passes over TCs with flight-data. We note CIRA is creating a similar algorithm using IR data in parallel with the CIMSS effort. Our current algorithm is based on the parametric "Holland-B" wind profile (Holland 1980) for the azimuthal-mean radial structure of the tangential wind and a simple parameterization of azimuthal wavenumber-1 and -2 asymmetries in the tangential wind related to the storm motion and vertical shear of the horizontal wind. Similar to the first series of algorithms, the Holland-B parameters are related via linear regression to various features, including EOFs of the radial T_b structure. Models are being developed for each of the MI channels. An example of this algorithm as applied to Hurricane Rita (2005) is provided in Figure 36. A revised version of this model is currently being developed to allow for more structural freedom that the Holland-B profile permits in the wind field.

Finally, CIMSS is working with CIRA to complete an empirical model to predict TC structure change out to 5 days. This model will exploit infrared satellite imagery and MI to exploit the relationships between latent heating and TC wind structure evolution.

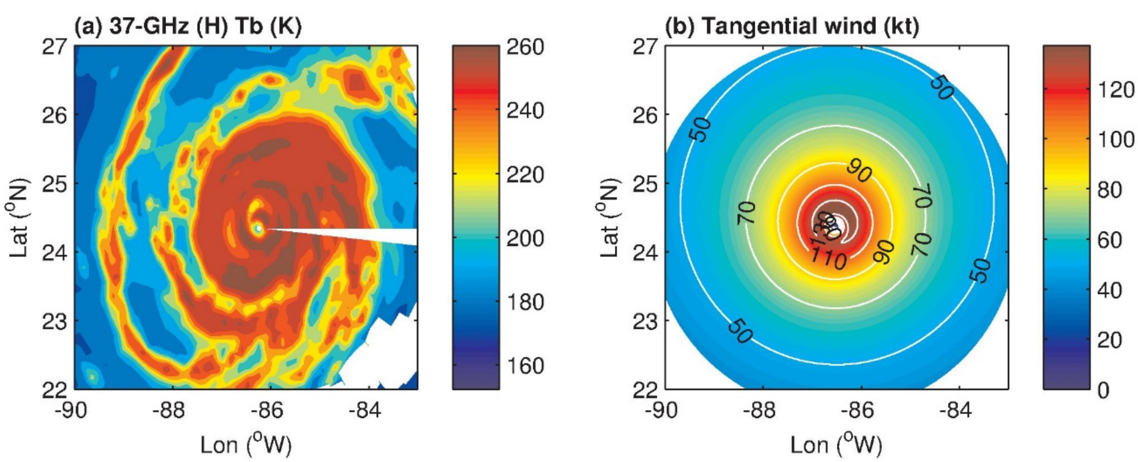

Figure 36. (a) AMSR-E 37-GHz (Horizontal Polarization) brightness temperatures (K) and (b) predicted tangential wind field (kt) for Hurricane Rita at 1918 UTC 21 September 2005.

Publications and Conference Reports

Rozoff, C. M., J. A. Knaff, M. Amin, J. P. Kossin, 2014: Objective estimation of a tropical cyclone's wind field from passive microwave imagery. *J. Appl. Meteorol. and Climatol.*, in preparation.

References

Holland, G. J., 1980: An analytic model of the wind and pressure profiles in hurricanes. *Mon. Wea. Rev.*, **108**, 1212-1218.

Knaff, J. A., S. P. Longmore, and D. A. Molenar, 2014: An objective satellite-based tropical cyclone size climatology. *J. Climate*, **27**, 455-476.

7.12 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

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

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/.

Several WFOs and National Centres have participated in various live GOES-R AWG FLS training sessions. After training, numerous forecast offices in the NWS Alaska, Eastern, Central, and Western Regions have been formally evaluating the GOES-R AWG FLS products in the form of questionnaires and surveys. The feedback we have received has indicated the vast majority of forecasters thought the products were useful. One statistic that proves that forecasters are using the products is the number of local area forecast discussions (AFDs) where the GOES-R FLS products were mentioned. The GOES-R FLS products have been cited in ***at least*** 70 AFDs in 2013 and early 2014. This number grows each week as more forecasters are getting comfortable using the products and use them in their daily routine. Along with the WFOs formally evaluating the products, several other NWS WFOs are receiving the GOES-R FLS products via a local data manager (LDM) feed and are looking at them using AWIPS. We are working with those WFOs to organize evaluation efforts, but even before this is set up, public mention of the GOES-R FLS products appears to show that they are being well-received and used in everyday operations (see Figure 37 and Figure 38).

Along with continuing the effort of training new users on using the new products, there was a relatively significant upgrade applied to the GOES-R FLS algorithm as well. The naïve Bayesian model used to calculate the GOES-R FLS probability products was initially trained using data from the Rapid Update Cycle (RUC) NWP model. However, the Rapid Refresh (RAP) replaced the RUC as the operational NCEP model on May 1, 2012. Initially we were forced to use the old LUTs created using the RUC data until we were able to gather enough data (12 weeks – once week for each month of 2013) to retrain the model with RAP data. The retraining of the model using RAP data was accomplished early in 2014 and is currently being evaluated to ensure that products continue to perform at a high level. A paper describing the GOES-R FLS probability products is currently being produced and will be published in the summer of 2014.

Figure 37. GOES-R LIFR probabilities were used at the Eagle County airport to assist in identifying the clearing of fog that had caused a Ground Stop on December 29, 2013.

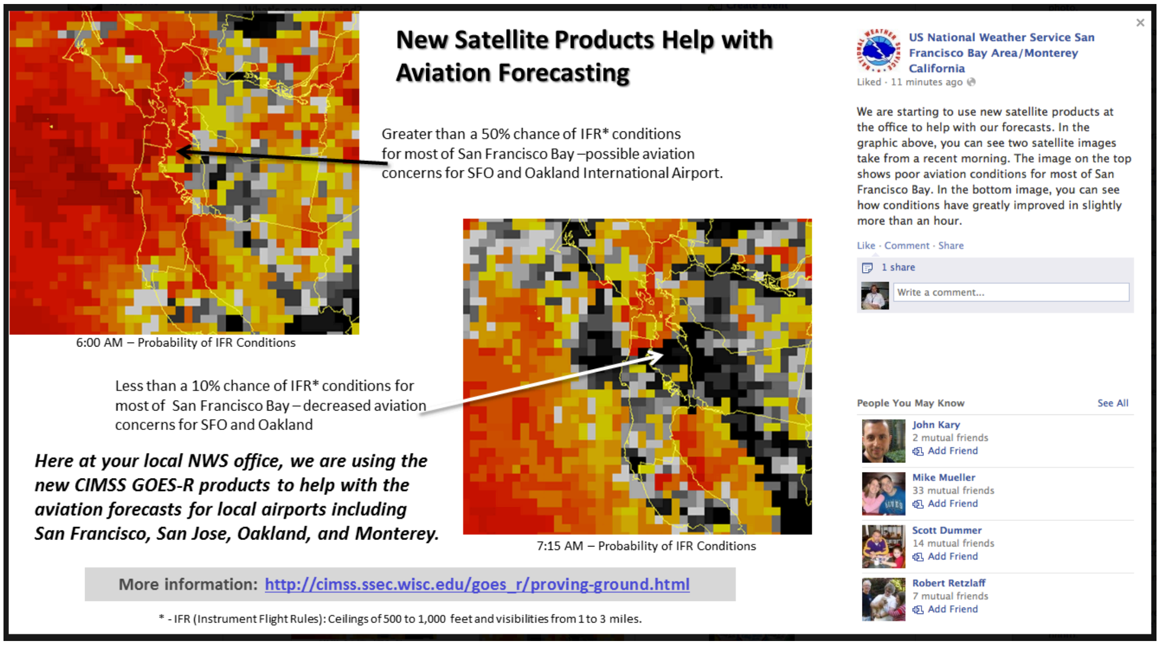

Figure 38. The NWS in the San Francisco Bay area posted a snapshot of the GOES-R IFR probability product and how it was productively used to help with aviation forecasts for the surrounding airports.

7.13 Collaboration with UAH

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

NOAA Long Term Goals:
- Weather-Ready Nation

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

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

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

Summary of Accomplishments and Findings

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

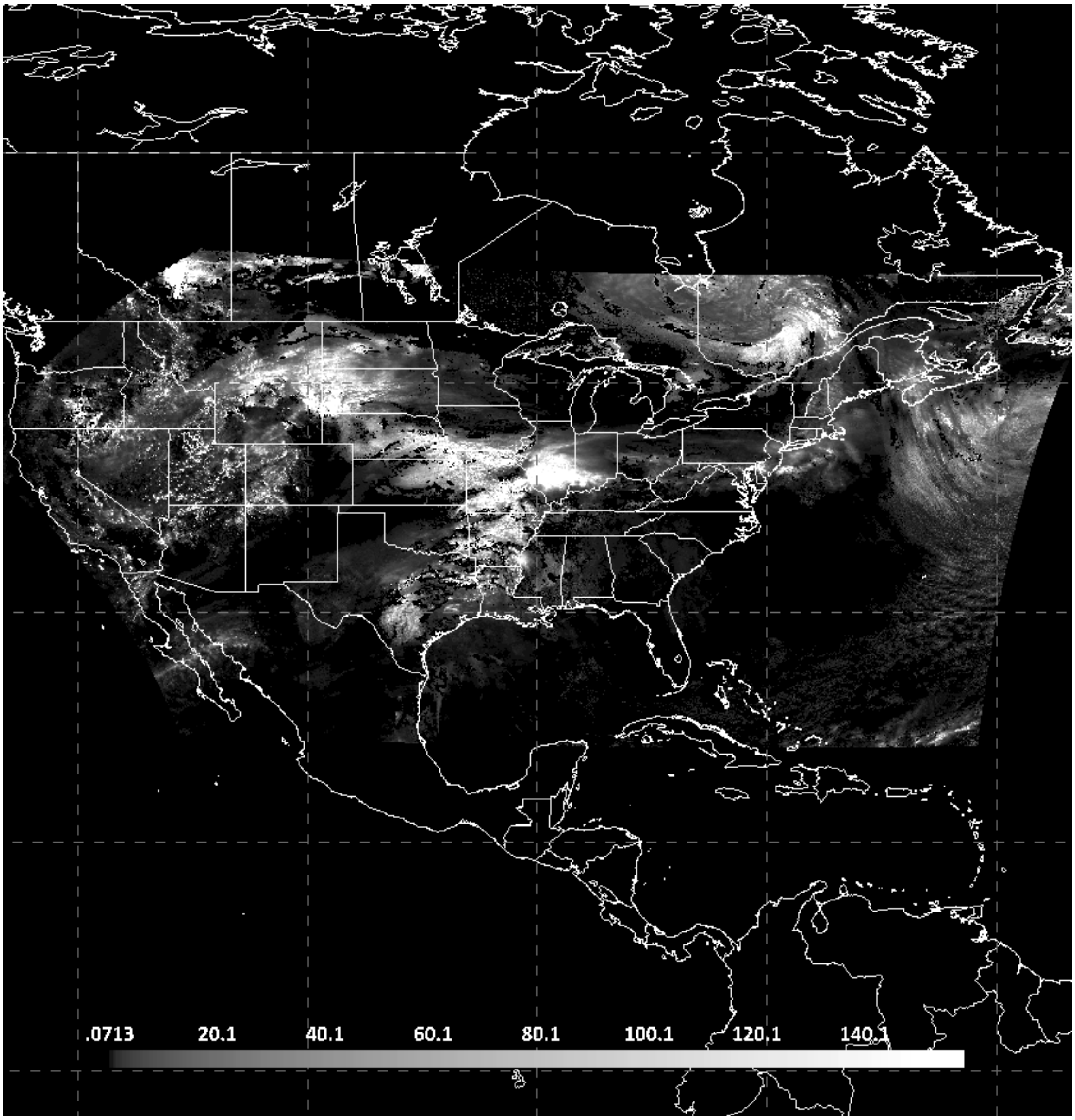

Figure 39. Example cloud optical depth calculation at the nominal wavelength of 0.65 μm.

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

CIMSS Task Leader: Wayne Feltz
CIMSS Support Scientists: Chris Velden, Sarah Monette, Scott Bachmeier, Scott Lindstrom, Lee Cronce, Justin Sieglaff, Kaba Bah

NOAA Collaborators: Michael Pavolonis, Andy Heidinger, Tim Schmit, Gary Wade

NOAA Long Term Goals:

- Weather-Ready Nation

NOAA Strategic Goals:

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

CIMSS Research Themes:

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

Project Overview

This proposal is for continued support to the NOAA GOES-R Proving Ground that will test and validate satellite-based algorithms and products before they are integrated into operational use. The Proving Ground mission is designed to ensure User Readiness on Day 1 for GOES-R. To this end, we are seeking assistance via the GOES-R Proving Ground in evaluating the GOES-R Algorithm Working Group demonstration algorithms and baseline/future satellite capability decision support products, testing enhancements and advanced products (Risk Reduction), and providing user assessments and feedback to the product developers. CIMSS researchers will expand partnerships with NWS Forecast Offices and NOAA National Centers to provide these products, train forecasters in their applications, and evaluate their utility. This work will help to ensure that GOES-R products will be available and useful to forecasters soon after launch.

Summary of Accomplishments and Findings

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 2013 – 30 March 2014 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 (6 May – 7 June). Participants included over 6 CIMSS researchers, 18 forecasters, and 9 visiting scientists;
2) National Hurricane Center (NHC) Tropical Cyclone Demonstration (1 Aug. – 30 Nov.) Participants included forecasters from NHC;
3) Aviation Weather Center (AWC) Summer Experiment (12 August – 23 August). 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 NWS forecasters and scientists from the University of Hawaii; and
8) NWS Central Region Fog and Low Stratus Evaluation (1 August 2012 – 31 December 2012). Participants included NWS forecasters at Des Moines, IA; Pleasant Hill, MO;

Indianapolis, IN; Jackson, KY; Louisville, KY; St. Louis, MO; Marquette, MI; Riverton, WY.

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-CIMSS decision support products are listed below as reported in the GOES-R PG 2013 Annual report and HWT/AWC/NHC Testbed final evaluation reports located at: http://www.goes-r.gov/users/proving-ground.html

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

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) Simulated Satellite Forecasts as of July 2013 are available in AWC operations (experimental).
3) The Cloud Top Cooling (CTC) product was transitioned into AWC operations (experimental) in Fall 2012 and the use of the product has continued to gradually increase within the past year
4) SRSO (Super Rapid Scan Operations) whenever GOES-14 is activated, is made available to AWC operations for display in N-AWIPS in addition to Fog/Low Stratus and GOES-R Cloud Top Phase proxy. SRSOR 1-minute imagery was reactivated for the later part of August, allowing forecaster evaluation during the AWC Summer Demonstration (2013) and NHC Demonstration (2013). 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/srsor2013/GOES-14_SRSOR.html

1. *WRF Simulated ABI Synthetic Satellite Cloud and Moisture Imagery (Baseline)*

***HWT input*:**

Roughly 70% of forecasters participating indicated they would use the imagery, most of which indicated utility in pre-storm environment.

AWC input:

While all of the products were well received, the Simulated Satellite Forecasts were by far the most popular amongst participants and consistently were praised with very positive feedback. In fact, many forecasters requested use of this data during their shifts and it is anticipated that these Baseline products will be at the top of the list for implementation.

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

***NHC Tropical Cyclone demonstration*:**

The availability of GOES-14 provided numerous opportunities to obtain SRSOR imagery. GOES-14 was made available to the PG and science teams during its out-of-storage testing and made it possible to obtain 28 images per half hour. The SRSOR data have greater utility for monitoring changes in convective activity, especially for storms such as Hurricane Isaac when it was in the central Gulf of Mexico, where the inner core circulation is the formative stage. TAFB forecasters found the SRSOR data useful for their tropical weather discussions, and helped document convection within tropical waves. Hurricane Specialist Unit (HSU) and TAFB forecasters indicated that the full value of the SRSOR data will realized when it is fully exploited in atmospheric motion vector algorithms and then assimilated into hurricane forecast models. This work is underway through support by the GOES-R program office and the Hurricane Forecast Improvement Project (HFIP)

AWC input:

Overall forecasters were very pleased with the SRSOR1-minute imagery and look forward to seeing it in operations on a permanent basis come the launch of GOES-R. This imagery, whenever GOES-14 is activated, is made available to AWC operations for display in N-AWIPS.

3. *Fog and Low Stratus Detection (Future Capability)*

High Latitude and Arctic Testbed 2013

Two versions of the Fog and Low Stratus (FLS) product are available on AWIPS at the NWS in Alaska: a version derived from GOES West and a version derived from MODIS. Some "false positive" noise signals over Alaska's interior in the GOES-derived version of the FLS product have been detected and are attributed to a stray light issue with the GOES satellite. Ways to mitigate this issue are being assessed. The MODIS-derived FLS has proven to have much less of a problem with such "false positive" signals in Alaska.

NWS Central Region FLS Evaluation 2012

a. The majority of forecasters thought the GOES-R FLS products were successful at providing probabilistic guidance of exceeding flight-rule thresholds and would use the products again in operations.
b. The majority of forecasters thought that the GOES-R FLS products performed well when compared to surface observations (69%) and the legacy channel difference product (71%).
c. The probabilistic products provided confidence to the majority of users that FLS was present during an unobstructed view to the liquid water clouds as well as when high clouds were present.
d. Forecasters suggested, at least currently, that the GOES-R FLS products should be used in combination with more traditional FLS detection tools.
e. The WFO POCs (points-of-contact) suggested that additional research should be completed on how the Fog Depth product can be used to diagnose the dissipation time for the liquid cloud layer.
f. The WFO POCs thought the product training was more than adequate for the evaluation, but thought some forecasters did not understand the basics of probabilistic guidance.
g. The majority of forecasters (67%) used the Simulated Satellite Forecasts to update their short-term forecasts.
h. The Simulated Satellite Forecasts were included in 19 NWS Area Forecast Discussions.
i. Almost half of forecasters thought the Simulated Satellite Forecasts were extremely or very useful and 86 percent were either extremely or very likely to use the products again.
j. Despite model limitations and errors in the forecasts, results from the Simulated Satellite Forecast evaluation show there is a need for this type of information when producing short-term forecasts.

4. *University of Wisconsin Convective Cloud Top Cooling Rates (Future Capability)*

***HWT input*:**

Roughly 70% used and were comfortable with the Convective Cloud Top Cooling rate,

***AWC Input*:**
The improvements made to the GOES-R CI over the past year, including the generation of the new fused version and the change of formats to increase the loading speed, showed a great amount of potential as a forecast tool in the 0-2 hour period, but also was often used in tandem with the CTC to increase confidence in convective behavior, from growth to maturity and cessation. This was particularly important at the CSIG and NAM desks, as both are responsibility for convection forecasting during this time period.

5. *Legacy Temperature and Moisture Profile - Nearcast Atmospheric Stability Indices (Risk Reduction)*
   ***HWT input*:**
   Similarly, about 78% indicated the benefit of having the NearCast data available within the 1 to 3 hour forecast period, while 67% also reported that it was useful in the 3 to 6 hour period.
   ***AWC input*:**
   The Nearcasting model has drawn the interest of forecasters, its fields providing valuable information on both the likelihood of convection initiation and the behavior of ongoing convection in the 1-9 hour period.

6. *Volcanic Ash*
   High Latitude and Arctic Testbed 2013
   With regard to volcanic ash, MODIS imagery has been used not only when volcanoes erupt, but even in cases of "re-suspension" when winds pick up ash from historic eruptions.

Test and apply algorithms for new satellite data imagery/products in support of local Milwaukee Sullivan office

This activity was delayed in 2013-2014 due to anticipated installation of AWIPS-II, schedule slippage moved testing of various GOES-R PG decision support data sets into the 2014-2015 time frame.

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 and Conference Reports

Lazzara, Matthew A., Richard Dworak, David A. Santek, Brett T. Hoover, Christopher S. Velden, Jeffrey R. Key, 2014: High-Latitude Atmospheric Motion Vectors from Composite Satellite Data. J. Appl. Meteor. Climatol., 53, 534–547. doi: http://dx.doi.org/10.1175/JAMC-D-13-0160.1

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9. CIMSS High Impact Weather Studies for GOES-R with Advanced IR Sounder measurements

CIMSS Task Leader: Jun Li
CIMSS Support Scientists: Jinlong Li, Pei Wang, Kevin Baggett
NOAA Collaborators: Tim Schmit (NESDIS/STAR), Vijay Tallapragada (EMC/NWS), Mark DeMaria (NHC/NWS)

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 high impact weather (HIW) project is to study the applications of high spatial and temporal resolution water vapor information from GOES-R on improving severe storm warning and short-range forecasts. To take advantage of high vertical resolution information, the advanced IR sounder measurements from polar-orbiting satellites (NPP/JPSS, NOAA, MetOp-A/B) are used together with GOES-R water vapor measurements for HIW warning and forecasting. Focuses are on improving the utilization of high temporal and spatial resolution GOES-R water vapor information in pre-convection environment for severe storm warning, and on improving severe storm over CONUS (e.g., 2013 Colorado heavy precipitation) and tropical cyclones (TCs) (e.g., 2012 hurricane Sandy) in regional numerical weather prediction (NWP) models.

Summary of Accomplishments and Findings

The FY13 accomplishments are summarized below:

1) Forward operator is developed for layer precipitable water (LPW) within GSI for assimilating GOES-R water vapor information;
2) 2013 high impact weather events are well forecasted with satellite data assimilation in a regional NWP;
3) Forecast verification technique is developed with GOES Imager and GOES-R ABI IR radiances; and
4) Research conducted on how to handle clouds when assimilating thermodynamic information in cloudy skies, those research outcomes can be transferred to NOAA operation to improve the utilization of satellite data in operational NWP models.

Forward operator for layer precipitable water has been developed for assimilating GOES-R water vapor information

Due to the challenge on assimilating high temporal resolution moisture information in the current GSI system, it is worthwhile to study the assimilation of layer precipitable water (LPW) instead of the direct use of radiances. In addition, in regional HWRF, satellite radiance observations are not well assimilated, the main issue with radiance data is that the HWRF model top is too low (50 hPa). The GOES Sounder channels usually have Jacobian values above 50 hPa, assimilating 300 – 700 hPa LPW can avoid this model top issue. The 300 – 700 hPa LPW has the best moisture information sensitivity from GOES Sounder and GOES-R ABI infrared radiances; it has been demonstrated to improve the GFS forecasts when compared with radiosondes, ground-based microwave radiometer and ground-based GPS-Met (Lee et al., 2014, JTECH). In order to assimilate GOES Sounder and GOES-R LPW information, a forward operator has been developed and implemented within GSI assimilation system, which will help us understand the difficulties in using water vapor channel radiances and to find possible solutions for better use of moisture information (radiances or LPW) in GSI.

HIW events are well forecasted with satellite data assimilated in a regional NWP

With satellite data including GOES Sounder radiances assimilated into a regional NWP (WRF) with NOAA GSI assimilation system, the forecasts on HIW events are consistent with observations. For example, the 2013 Colorado floods are a natural disaster occurring in the U.S. state of Colorado. During the week starting on September 9, 2013, a slow-moving cold front stalled over Colorado, clashing with warm moist air from the south (see lower left panel of Figure 40). This resulted in heavy rain and catastrophic flooding along Colorado's Front Range from Colorado Springs north to Fort Collins. The situation intensified on September 11 and 12. Boulder County was worst hit, with 9.08 inches (231 mm) recorded September 12 and up to 17 inches (430 mm) of rain recorded by September 15, which is comparable to Boulder County's average annual precipitation (20.7 inches, 525 mm). The flood waters have spread across a range of almost 200 miles from north to south, affecting 17 counties (see upper left panel of Figure 40). The 72 hour cumulative precipitation forecasts from CIMSS research system (lower right panel) started at 18 UTC on 10 September 2013 corresponds to the observation well, and the cumulative precipitation over Colorado was well forecasted by our system.

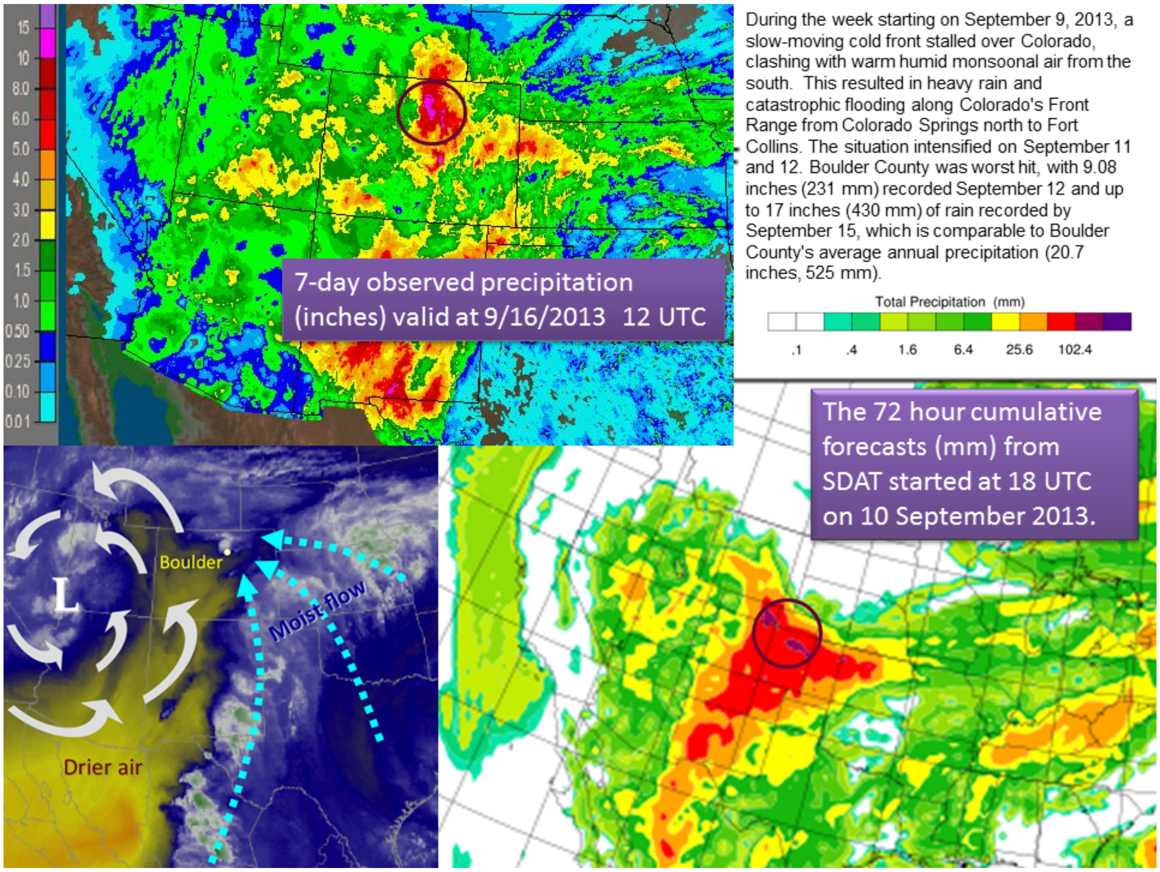
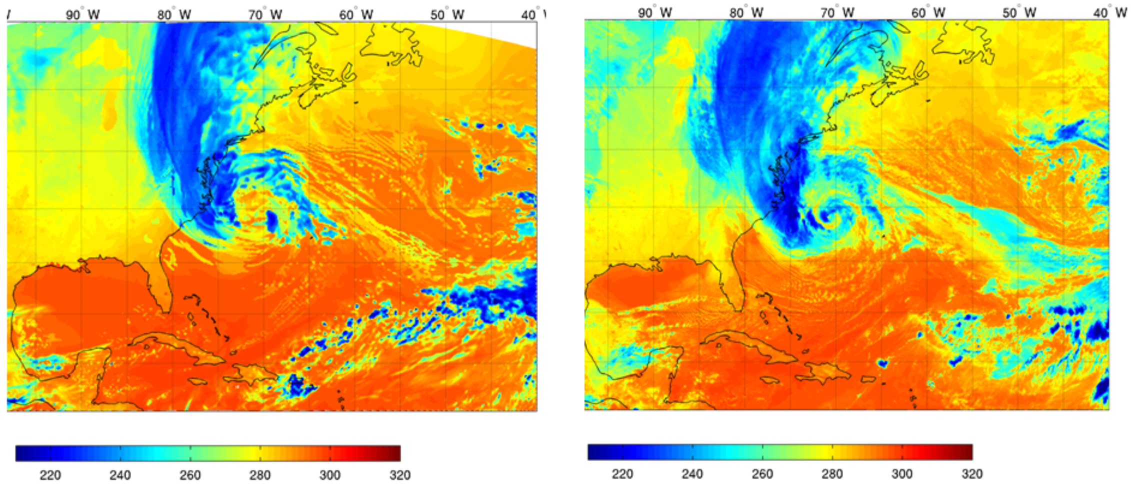


Figure 40. The 72 hour cumulative forecasts (lower right) from WRF/GSI started at 18 UTC on 10 September 2013, and observations (upper left).

Verification of satellite sounder impact using GOES Imager observations

The CIMSS experimental forecasts are converted to GOES-13 Imager 11 µm brightness temperatures (BTs) and verified with GOES-13 BT measurements. Figure 41 shows the forecasted GOES Imager 11 µm BT (left panels), along with the GOES-13 Imager BT measurements (right panels) at 06 UTC (60 hour forecasts) and 12 UTC (66 hour forecasts) on 30 October 2012, the forecasts are started at 18 UTC on 27 October 2012. After the satellite data are assimilated, the CIMSS experimental forecasts reveal very good cloud system and mesoscale features indicated in the GOES Imager BT measurement images.



Simulated GOES-13 Imager 11 μm BT from SDAT experimental forecasts

GOES-13 Imager 11 μm BT observations

Figure 41. The forecasted GOES Imager BT with satellite data assimilated, along with the GOES-13 Imager BT measurements (right panels) at 06 UTC (60 hour forecasts) and 12 UTC (66 hour forecasts) on 30 October 2012, the forecasts are started at 18 UTC on 27 October 2012.

Research on handling clouds conducted

In hyperspectral infrared (IR) radiance assimilation, currently the sounder alone method is used by most operational numerical weather prediction (NWP) centers, which might result in treating some cloudy footprints as clear in the assimilation and cause bias in the analysis. How to detect cloud accurately in sounder sub-pixel is a very important question in this project in order for better assimilating the hyperspectral IR radiances in NWP models. We have studied the synergistic use of high spatial resolution imager (e.g., MODIS) and high spectral resolution sounder (e.g., AIRS) data for improving the assimilation of sounder radiances in NWP models. The AIRS sub-pixel clear detection can be easily derived based on the collocated MODIS cloud mask, there are four possible categories for one MODIS pixel with 1 km spatial resolution: confident clear, probably clear, uncertain and cloudy. Only the AIRS sub-pixels filled with MODIS confident clear mask are considered clear footprints for assimilation and forecast experiments. After the sub-pixel cloud detection with collocated 1 km MODIS cloud mask product, the AIRS clear radiances are then assimilated in the GSI system, it is found that accurate AIRS clear radiances improve the atmospheric temperature and moisture analysis, and hence results in a better forecast.

As an example, the coverage of AIRS radiance data assimilated under clear sky conditions are shown in Figure 42 for AIRS channel 210 (709.5659 cm^{-1}) with weighting function peaking at about 450 hPa, in which upper left panel indicates the GSI AIRS stand-alone cloud detection while the middle left panel shows the sub-pixel cloud detection with MODIS 1 km cloud mask. It can be seen that the locations of clear AIRS radiances with stand-alone cloud detection are in general close to that from MODIS cloud detection. However, there are some mismatched areas in the West Atlantic and north of South America. As mentioned, only channels detected as cloud-free are assimilated by GSI, therefore, the reduced data amount is due to the more accurate cloud detection with MODIS high spatial resolution cloud mask product. The mismatched areas are the cloudy region according to the MODIS cloud mask, while the GSI cloud detection failed to reject them and assimilated them as clear sky radiances, which would bring inaccurate environmental information into the analysis.

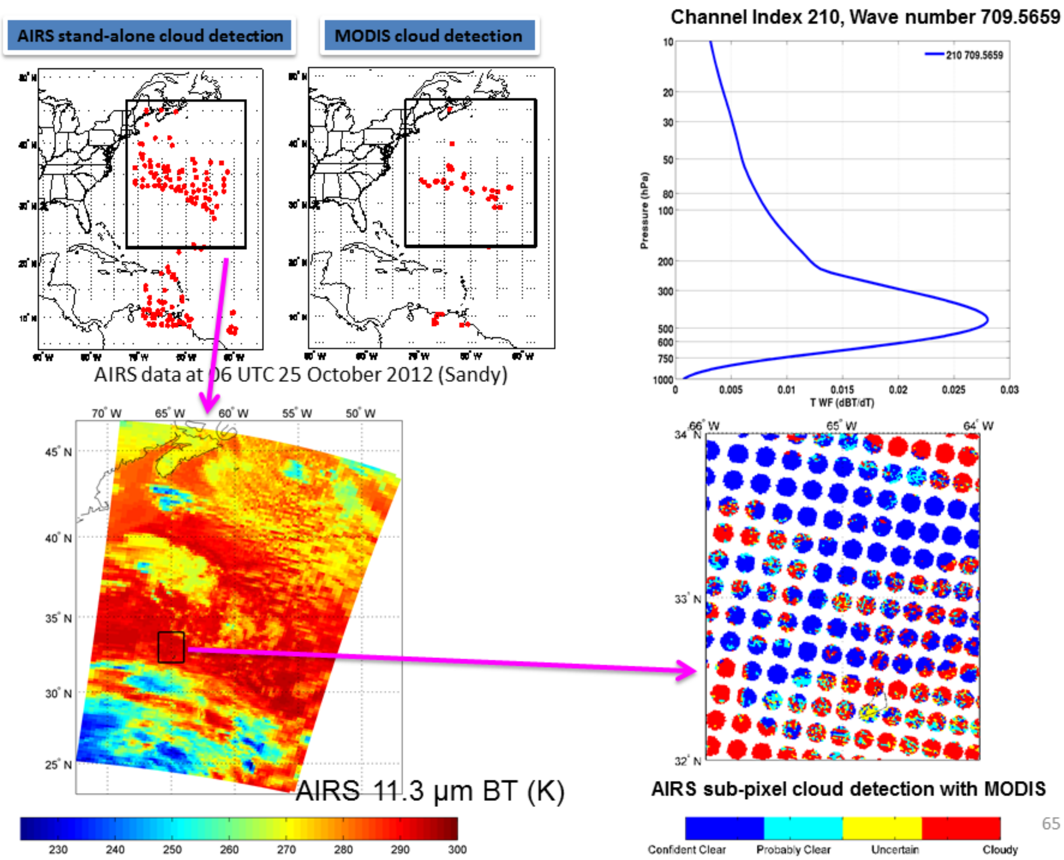


Figure 42. The GSI cloud detection (upper left) and MODIS cloud detection (middle left) for AIRS radiance assimilation. The AIRS sub-pixel cloud detection with MODIS 1 km cloud mask is illustrated in lower right panel for a small box in one AIRS granule (lower left panel).

The difference of temperature analysis field between AIRS (MOD) and AIRS (GSI) at 06 UTC on 25 October 2012 are shown in the left panel of Figure 43. At 500 hPa the AIRS (MOD) is warmer and the temperature difference at 500 hPa is more than 1.2 K at the east coast of the continent. It appears that the GSI AIRS stand-alone cloud detection failed to reject some cloudy pixels and assimilated them as clear radiances. The impact of the cloudy radiances on the analysis could result in colder temperatures than that from AIRS (MOD) since the cloudy radiances are usually colder than that of clear skies. The right panels of Figure 43 show the root mean square error (RMSE) of the hurricane track (top), minimum sea level pressure (middle) and the maximum wind speed (bottom) of 72-hour forecasts. The GTS+4AMSUA+AIRSrad (GSI) (blue) is using the AIRS stand-alone cloud detection, and the GTS+4AMSUA+AIRSrad (MOD) (red) is using the MODIS sub-pixel cloud detection method. Here GTS represents all the conventional data and 4AMSU represents AMSU data from four satellites (NOAA15, NOAA18, Aqua and MetOp –A). From the hurricane track, it indicates that the RMSE of hurricane track is smaller with the MODIS cloud detection method, especially after 30-hours, the difference between GSI cloud detection and MODIS cloud detection is obvious. For the minimum sea level pressure, the results with MODIS cloud detection is slightly better in the first 12-hour forecasts, while after 18-hour forecasts, the RMSE of minimum sea level pressure with MODIS cloud detection is smaller. For the maximum wind speed, the forecasts with MODIS cloud detection are better after the 12-hour forecasts, but worse at 42-hour and 60 hour. So for wind speed, the results of the two experiments are competitive.

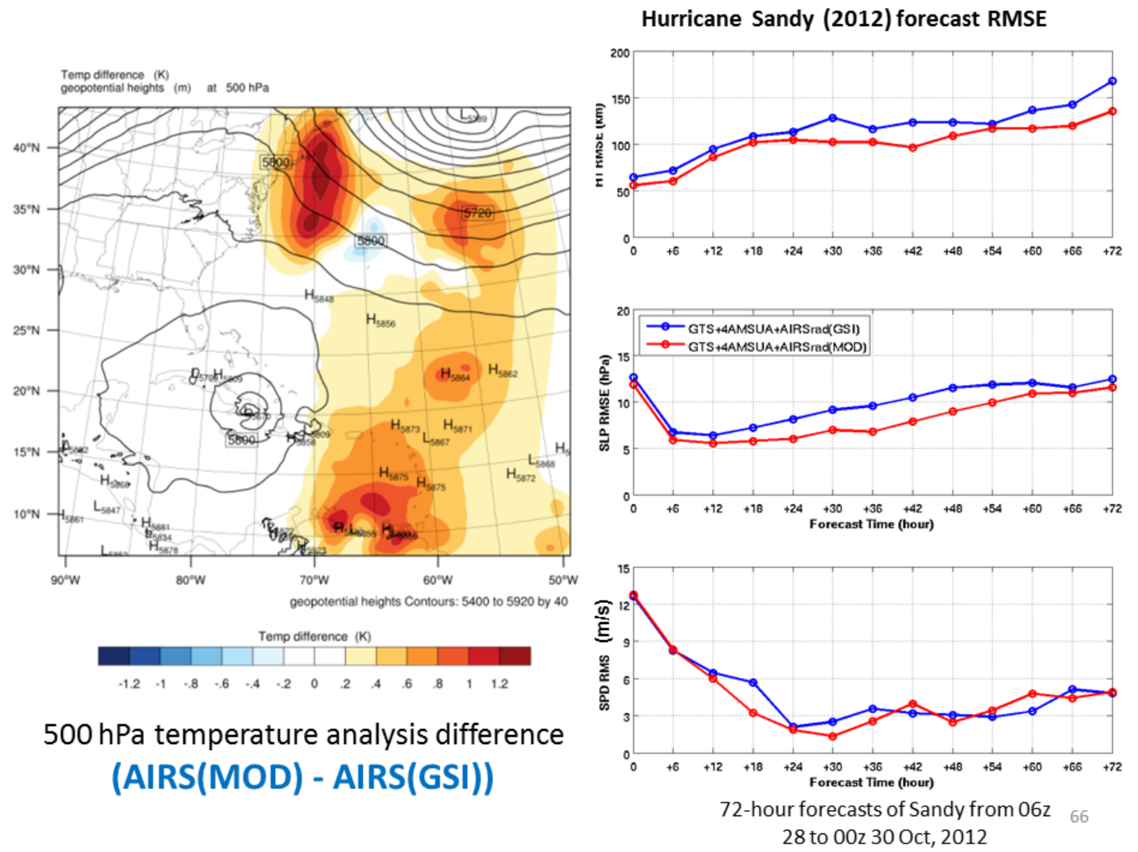


Figure 43. The difference of temperature analysis field between AIRS (MOD) and AIRS (GSI) at 06 UTC on 25 October 2012, and the RMSE of the hurricane track, minimum sea level pressure and the maximum wind speed of 72-hour forecasts with GTS+4AMSUA+AIRSrad (GSI) (blue) and GTS+4AMSUA+AIRSrad (MOD) (red).

Publications and Conference Reports

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

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

Li et al. 2013, Regional forecast improvement with GOES-R water vapor and LEO sounder measurements, Warn-on-Forecast and High Impact Weather Workshop,
06 – 07 Feb 2013, Norman, Oklahoma

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

Li, Jinlong et al., 2013: A near real-time regional satellite data assimilation system for tropical cyclone forecast improvement studies, The 11th JCSDA Science Workshop on Satellite Data Assimilation, 05 – 07 June 2013, NOAA Center for Weather and Climate Prediction.

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Li, J., Jinlong Li, Pei Wang, Tim Schmit, Zhenglong Li , and Chris Velden, 2013; A near real time JPSS/GOESR data assimilation system, GOES-R/JPSS Web Seminar, 18 November 2013.

Zheng, J., Jun Li, T. J. Schmit, Jinlong Li, 2014: Study on the assimilation of atmospheric temperature and moisture profiles from Atmospheric InfraRed Sounder (AIRS) measurements for improving hurricane forecasts, Advances in Atmospheric Sciences (in revision).

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10. Investigations in Support of the GOES-R Program

10.1 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

Remote Sensing Bootcamp

From 8 to 12 July 2013, as part of the two weeks Remote Sensing Bootcamp, I gave lectures on Applications with MODIS, VIIRS, CrIS, and ATMS. The agenda for the first week was as follows:

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

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

Collaborations with EUMETSAT

Upon invitation from EUMETSAT, I co-chaired (along with Herve Roquet from MeteoFrance) a Meteosat-Third Generation (MTG) Infrared Radiation Sounder (IRS) Workshop on Nowcasting Applications. A key objective was to get the nowcasting community interested in the potential of hourly hyperspectral sounder observations. After an organizing meeting held in Rome 30-31 May, the workshop was held in Darmstadt 25-26 July. Recommendations that emerged are

- To prepare the operational users of MTG-IRS data and products EUMETSAT should:
    - Support the development of easy accessible data objects and data access and post-processing software for the handling of MTG data by the end users,
    - Identify partners as part of a network of user preparedness for MTG-IRS,
    - Prepare Effective training material,
    - Explore as soon as possible the opportunities provided by EUMETrain and VLab to support training of operational users, and
    - Align its training activities for MTG-IRS with the WMO 5-year training strategy.
- EUMETSAT to organize another workshop to discuss progress made and plans updated.

Coordinating with Indian Scientists on INSAT-3D Utilization

With the successful launch of INSAT-3D nears, I initiated a joint review of ISRO/SSEC progress in getting ready to make use of the anticipated new remote sensing measurements. To this end I proposed and ISRO agreed that a few SKYPE conferences should be organized wherein some of the principals in past collaborations give short presentations on the status of (a) development of multispectral applications from INSAT-3D (including soundings and winds), (b) assistance in assimilation of INSAT-3D soundings in regional forecast models, (c) leo-geo intercal with IASI and AIRS, and (d) improving visualization capabilities (with McIDAS and other software systems). The first presentation on soundings is being organized for early November; this will be followed by a presentation on winds and thereafter using INSAT-3D soundings in a regional model. These virtual conferences are intended to serve as a catalyst in renewing our joint collaborative momentum.

Mentoring Young Scientists - Intern from Germany Visits CIMSS

Philipp Ratz, an intern from Germany, successfully completed a six week internship at the CIMSS from 15 July to 27 August 2013. The internship included a work project and a short course on remote sensing. The work project entailed synchronizing and displaying imagery from the building's roof top camera (RTC) and geostationary satellites (Figure 44 is an example). The RTC and geostationary visible images were successfully displayed on the Web: http://cimss.ssec.wisc.edu/goes/rtc/ and http://cimss.ssec.wisc.edu/goes/rtc_goes_east/ (for GOES-14 and -13, respectively). The remote sensing short course included materials on Radiation and the Radiative Transfer Equation, Spectral signatures from Earth's surface and atmosphere, Multi-spectral monitoring of land, ocean, and atmosphere, Sounding using infrared high resolution spectral data and Microwave detection of vertical changes of moisture in the atmosphere.

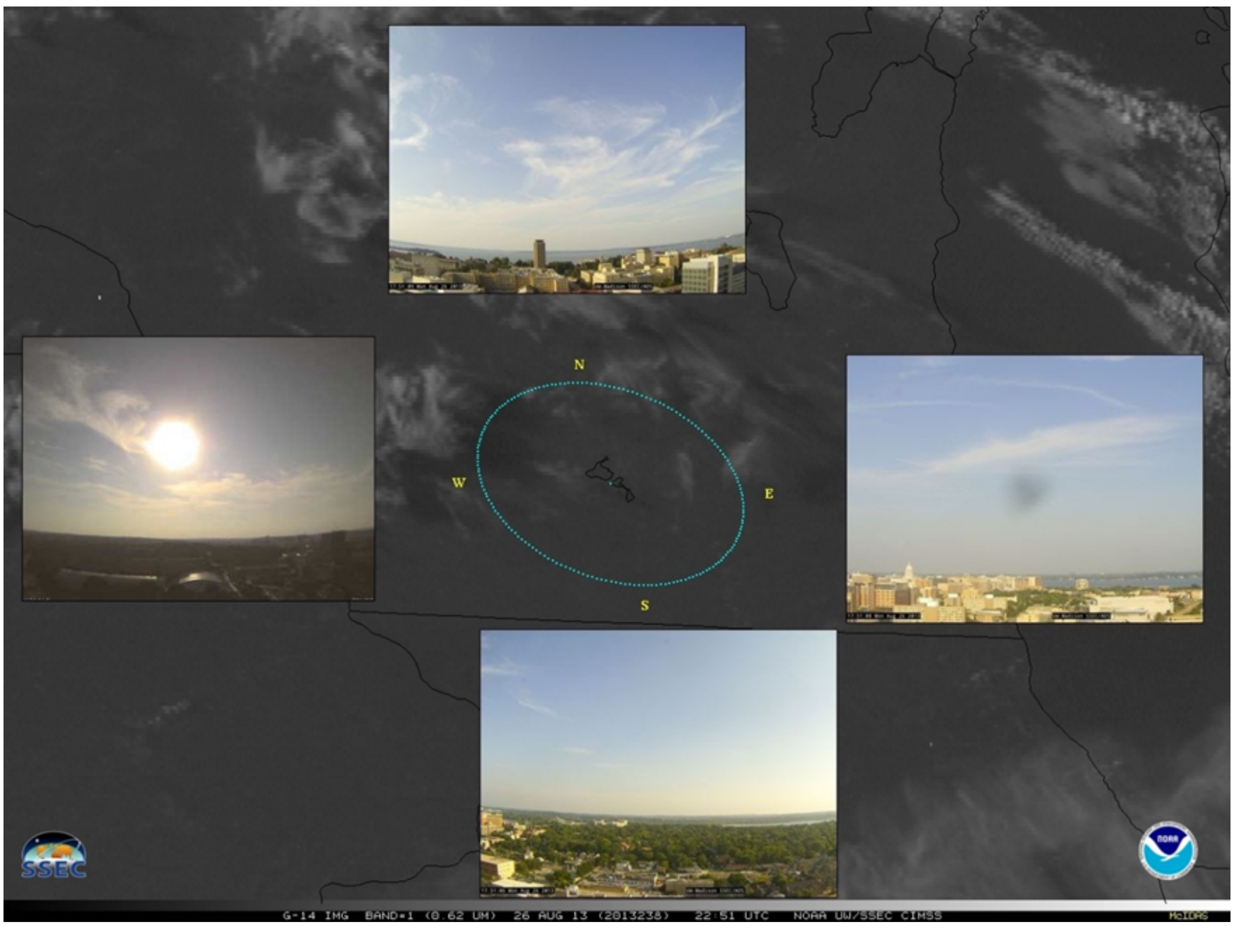

Figure 44. GOES-14 Imager visible image with time synched Roof Top camera images.

A nice example of wind shear detected by the four RTCs can be found at http://cimss.ssec.wisc.edu/goes/rtc/index.php?action=view_animation&req_method=nframes_enddate&enddate=20130824&endtime=1830&nframes=30&band=1&res=1&aniwidth=1200&aniheight=850

11. CIMSS Studies on Advanced IR Sounder for Geostationary Orbit with regional OSSE

CIMSS Task Leaders: Jun Li, Zhenglong Li
CIMSS Support Scientists: Pei Wang, Agnes Lim, Jason Otkin, Todd Schaack, Jinlong Li, Kevin Baggett
NOAA Collaborators: Tim Schmit (STAR/NESDIS), Robert Atlas (AOML/OAR), Sid Boukabara (JCSDA/NESDIS), Brad Pierce (STAR/NESDIS)

NOAA Long Term Goals:
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CIMSS Research Themes:
- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques
- Environmental Models and Data Assimilation

Project Overview
The primary goal of the Cooperative Institute for Meteorological Satellite Studies (CIMSS) studies on advanced IR sounder for geostationary orbit (GEO) – regional OSSE (R-OSSE) project is to study the unique value of a geostationary advanced infrared (IR) sounder for regional severe weather forecasting, as well as to develop methodologies for simulating the geostationary advanced IR sounder data for typical weather events such as hurricanes for R-OSSE, along with the application of the geostationary advanced IR sounder data in forecasting severe weather. GEO hyperspectral IR sounders have capability to observe the earth and the atmosphere with very high temporal and vertical resolutions. Such information is critical to and expected to have positive impacts on short-term severe weather forecasting. This project will quantitatively evaluate such impacts.

Summary of Accomplishments and Findings
As part of the R-OSSE project, CIMSS is responsible for generating the simulated radiances and brightness temperature (Tb) from future instruments. As a representative of future instrument, an AIRS (Atmospheric InfraRed Sounder) onboard geostationary satellite, positioned at GOES-13 (-75 degree), is assumed and used. Major achievements and findings include:

1) Generate the simulated AIRS Tb spectrum in GOES-13 orbit using 10 days of WRF (Weather Researching and Forecasting) nature run data provided by AOML, for all four domains.
2) Generate the simulated AIRS Tb spectrum in GOES-13 orbit using 2 months of ECMWF nature run data (T511) for JCSDA.
3) Methodologies are developed to perform cloud classification. A GEO (geostationary) AIRS field of view (FOV) is identified to be under clear sky if there are no clouds presented. A specific channel for a GEO AIRS FOV is identified as clear channel if clouds do not affect the radiance simulation of that channel. Using clear channels instead of clear FOVs significantly increases the number of observations for assimilation.

4) Methodologies are developed to convert the simulated GEO AIRS radiance observations to BUFR format, which may be directly digested by GSI. BUFR data are available in both clear sky only and clear channels
5) BUFR files encoded from the simulations using WRF nature run are delivered to AOML; BUFR files encoded from the simulations using ECMWF nature run are delivered to JCSDA.
6) Provide assistance to AOML in assimilating GEO AIRS radiance simulated from WRF nature run, including:
    a. Improve the forward simulation in upper channels and
    b. Improve bias correction to reduce bias between observations and backgrounds.
7) Provide assistance to JCSDA in assimilating GEO AIRS radiance simulated from WRF nature run, including:
    a. Improve forward simulations of ozone channels using ECMWF nature run
    b. Improve forward simulations of surface channels using CRTM-generated surface emissivity instead of a flat value
    c. Encode simulated radiances to BUFR with and without noise. The without-noise is performed to line with the fact that global OSSE observations are noise free.
8) Methodologies are developed to generate temperature and moisture sounding retrievals from the simulated radiances in clear sky and some of the cloudy regions. And retrievals are converted to PREPBUFR format, which may be directly digested by GSI. Data are delivered to AOML and assimilated in OSSE.
9) A quick OSSE is performed at CIMSS to evaluate the added value from the GEO AIRS compared with LEO AIRS on Hurricane Sandy forecast.

Detailed progress can be found from:
ftp://ftp.ssec.wisc.edu/ABS/ROSSE/Rpt_ROSSE_CIMSS_Annual2013_FY14_20140121.pdf

For example, a quick OSSE was carried out at CIMSS to evaluate the added value from the future GEO hyperspectral IR sounder compared with LEO on tropical cyclone forecast. AIRS and Hurricane Sandy (2012) are assumed in this quick OSSE study. This quick and much simplified OSSE is complementary to what AOML do. It also helps CIMSS to better understand the OSSE framework, and possibly improve the simulation of synthetic observations.

The nature run is generated from WRF-ARW V3.2.1 with a horizontal spatial resolution of 6 km. The model top is located at 10 hPa with 75 levels. The physics schemes used include:

- Microphysics: New Thompson et al. scheme
- Longwave Radiation: RRTM scheme
- Shortwave Radiation: Dudhia scheme
- Planetary Boundary layer: ACM2 PBL

The model starts the run at 18 UTC on Oct 25 2012 and ends at 00 UTC on Oct 28 2012 for a total of 54 hours. Verifications have been carried out to ensure the proper simulation of Hurricane Sandy. The track, central sea level pressure (SLP) and maximum wind speed (SPD) are reasonably different from the observations. Three types of synthetic observations were simulated: the RAOB, the LEO AIRS and the GEO AIRS. Errors with vertical correlations are added to the true profiles to simulate the RAOB profiles. They are available only at real RAOB locations at 00 and 12 UTC on Oct 26 2012. The GEO AIRS were simulated at WRF's resolution of 16 km. They are available every 30 minutes. However, due to the limitation of assimilation system, they are only assimilated every 3 hours with the assimilation window of +/- 1.5 hours. This actually underestimates the impact of GEO AIRS. The LEO AIRS were simulated at real AIRS locations and real AIRS observation times. The nearest neighbor method is used to perform the spatial interpolation. Figure 45 shows the coverage of each of the three observations. The GEO AIRS has a full coverage of the domain with a refresh rate of 30 minutes, although the assimilation is only every 3 hours. The LEO AIRS only has limited coverage at a refresh rate of about 12 hours. It is therefore expected that the GEO AIRS has more positive impacts than LEO AIRS on Hurricane Sandy forecast.

In the experiments, the same WRF-ARM V3.2.1 is used together with GSI V3.0 for assimilation. The horizontal spatial resolution is much courser at 16 km. And the physics schemes include:

- Microphysics: WSM6 scheme
- Longwave Radiation: RRTMG scheme
- Shortwave Radiation: RRTMG scheme
- Planetary Boundary layer: Yonsei University scheme
- Cumulus Parameterization: Grell scheme

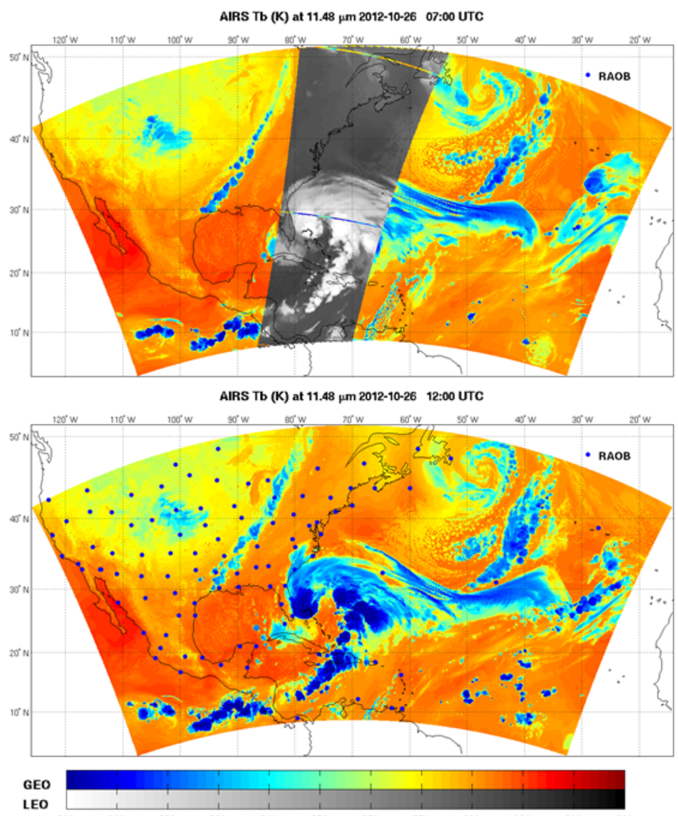

Figure 45. Synthetic observations (RAOBs, LEO AIRS, GEO AIRS) simulated from WRF nature run for Hurricane Sandy at 07 UTC (upper) and 12 UTC (lower).

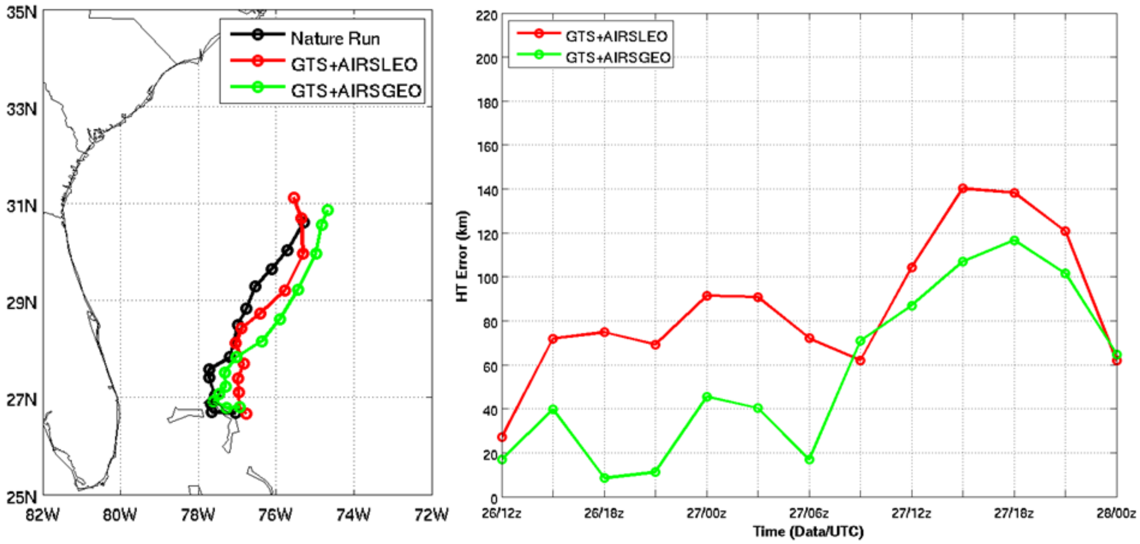

Figure 46. Validation of track forecasts for Hurricane Sandy. (left) the forecast and nature run tracks and (right) the track error. The red lines represent experiments assimilating RAOB (GTS) and LEO AIRS radiances, and the green lines represent experiments assimilating RAOB (GTS) and GEO AIRS radiances.

Experiments start at 18 UTC on Oct 25 2012. The assimilations were carried out every 3 hours for 5 times between 00 and 12 UTC on Oct 26 2012. The control run assimilates RAOB and LEO AIRS. And the experiment assimilates RAOB and GEO AIRS. The 36-hour forecast of Hurricane Sandy is validated using the WRF nature run. Figure 46 (left) shows the track forecasts along with nature run. It appears that the LEO AIRS plus RAOB is closer to nature run than the GEO AIRS plus RAOB. However, the track error (right of Figure 46) shows that GEO AIRS plus RAOB actually has smaller track error during the 36-hour forecast, indicating the GEO AIRS could have more positive impacts on the tropical cyclone track forecast. Figure 47 (left) shows the minimum sea level pressure along with nature run. It is clear that the GEO AIRS agrees with nature run better than the LEO AIRS for the first 15 hours of forecast. After that the advantage is subtle. This is also evident from the error of minimum sea level pressure on Figure 47 (right). We also examined the maximum wind speed, which does not show any advantage of GEO AIRS over LEO AIRS. However, that is primary due to the fact that the algorithm used to find the max wind speed is not sophisticated enough. As a result, the max wind speeds found are spread out in the hurricane region. A more sophisticated algorithm will be used in the future to improve the quantification of the maximum wind speed.

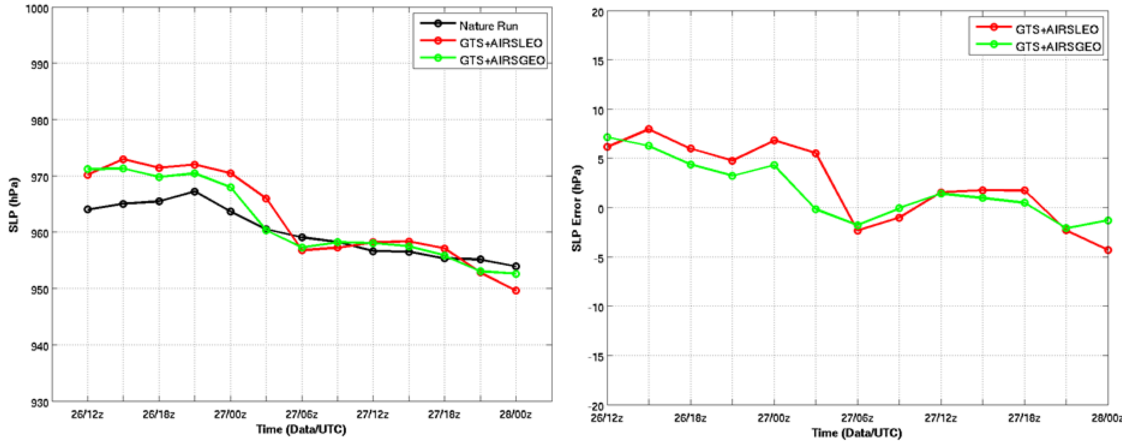

Figure 47. Validation of minimum sea level pressure for Hurricane Sandy. (left) the forecast and nature run tracks and (right) the track error. The red lines represent experiments assimilating RAOB (GTS) and LEO AIRS radiances, and the green lines represent experiments assimilating RAOB (GTS) and GEO AIRS radiances.

Publications and Conference Reports

Agnes LIM, Zhenglong LI, Jason OTKIN, Wenguang BAI, Hung-Lung Allen HUANG and Jun LI, (2013), The Simulation and Assimilation of High Temporal Hyperspectral Imaging Sounding Data -A Flash Flood Case Study, EUMETSAT Meteorological Satellite Conferemce, Vienna, Austria, 16 - 20 September 2013.

Li, Zhenglong, Jun Li, Pei Wang, Agnes Lim, Timothy J. Schmit, Robert Atlas, Sean Casey, Bachir Annane, and Tomislava Vukicevic, 2014: OSSE study on geostationary advanced infrared sounders: radiance simulation, validation and impacts on forecasting, ITSC-19, 26 March – 01 April 2014, Jeju Island, Korea.

References

Li, Z., J. Li, W. P. Menzel, T. J. Schmit, J. P. Nelson III, J. Daniels, and S. A. Ackerman (2008), GOES sounding improvement and applications to severe storm nowcasting, Geophys. Res. Lett., 35, L03806, doi:10.1029/2007GL032797.

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Strow, L. L., S. E. Hannon, S. De Souza-Machado, H. E. Motteler, and D. Tobin (2003), An overview of the AIRS radiative transfer model, IEEE Trans. Geosci. Remote Sens., 41, 303–313.

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

12. GOES-R Calibration/Validation Field Campaign Support

CIMSS Task Leader: Wayne Feltz
CIMSS Support Scientists: Richard Dworak, Allen Lenzen, and Todd Schaack
NOAA Collaborators: Brad Pierce, Andy Heidinger and Shobha Kondragunta

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

Summary of Accomplishments and Findings

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

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

During the first year of this project we have added a CIMEL sun photometer to the UW-Madison SSEC roof-top instrumentation suite and become a member of the Aerosol Robotic Network (AERONET) federation. The CIMEL Sunphotometer is installed on the roof of the Engineering Research Building on the University of Wisconsin-Madison (UW-Madison) campus on November 01, 2012 (Figure 48). The instrument is approximately 55 m off the surface. The instrument was leveled and aligned and the "AUTORUN" feature was started. Data were collected manually during the first 2 weeks of November and transferred manually to the Aeronet group using the K7 file transfer Web page. Automatic data collection began on November 26, 2012.

Figure 48. Photo of CIMEL Sun Photometer at UW-Madison Engineering Research Building, 1500 Engineering Drive, Madison, WI 53706

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

Global Positioning System Total Precipitable Water Evaluation

During January 2014, a test period of validation comparisons over the summer (1 Jun – 31 Aug) of 2013 was completed from an archived setting. The SSEC GPS from Suominet is compared against satellite derived Total Precipitable Water (TPW) measurements from primarily hourly GOES-Li, GFS and regression, and limited available daily comparisons made against AIRS, CrIS and IASI, with results shown in Figure 49 and Figure 50. Results from the summer 2013 experiment indicate that the GOES-Li regression retrieval has the lowest Standard Deviation and RMS difference, and therefore outperforms the GFS, GOES-Li with GFS and regression first guess. The completed daily, monthly and season results are provided on ftp://stratus.ssec.wisc.edu/pub/rdworak/Nearcasting/GPS/SSEC/.

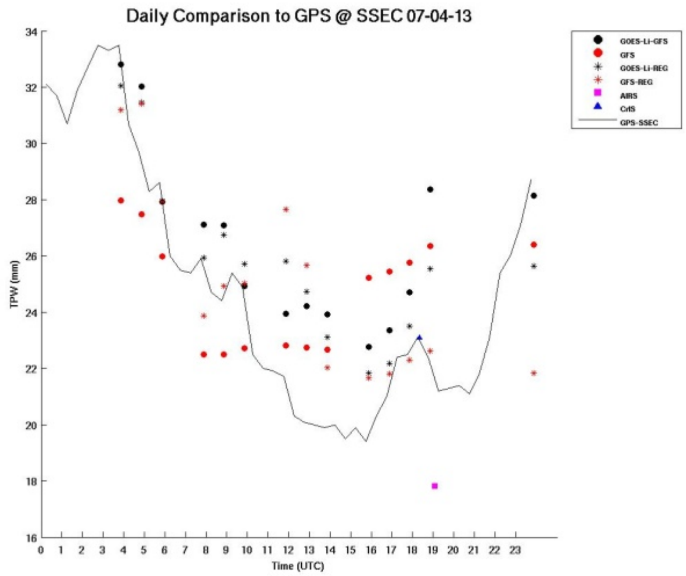

Figure 49. The daily comparison of TPW (y-axis) from GPSunit at SSEC, Madison, WI (line) versus satellite derived soundings (GOES, AIRS, CrIS etc) and the first guess (points) for 4 July 2013 with time on x-axis.

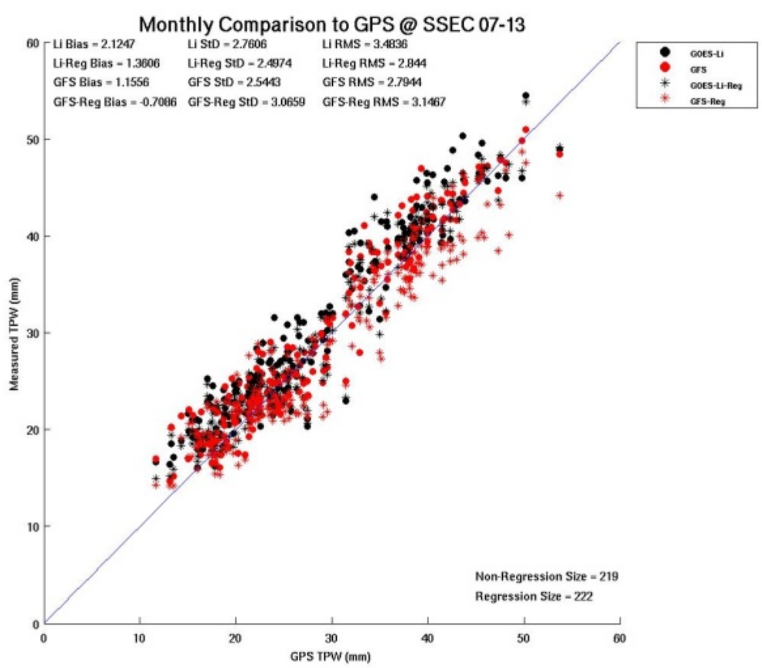

Figure 50. The monthly comparison of GPS TPW (x-axis) and TPW from GOES-Li and first guess (y-axis) with bulk monthly statistics provide above.

Currently, the foundation of getting the above results in an automated setting has been completed. The process has been set to work on nearcasting.ssec.wisc.edu to retrieve measured TPW values from AIRS, CrIS, IASI and GOES from the previous day over Madison, WI, if available. An issue with getting the previous day's TPW from SSEC GPS has arisen since 1 Feb, 2013. Lee Cronce has been investigating the problem and current evidence indicating that the GPS unit as functioning properly with the problem originating from Suominet. When the problem is resolved, the next stage of this project should commence, which is feeding the TPW comparisons available from the previous day as seen in Figure 49 and Figure 50 to the UW-SNAAP quicklooks page http://cimss.ssec.wisc.edu/snaap/convinit/quicklooks/.

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

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

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

Figure 51 summarizes the airborne sampling by the NSF GV aircraft during TORERO and the combined NSF GV and NASA DC8 sampling during DC3. During TORERO the GV flew primarily out of Costa Rica and sampled outflow from maritime deep convection with additional survey flights along the South American Coast. Very little aerosol was observed during TORERO so our validation efforts will focus on cloud and temperature retrievals. During DC3 the GV and DC8 flew coordinated flights that targeted continental deep convection with the DC8 sampling low-level inflow and the GV sampling upper level outflow. Both aircraft sampled heavy aerosol loading due to extensive biomass burning that occurred over the western US and northern Mexico during DC3 so our validation efforts will focus on cloud, aerosol, and temperature retrievals.
The results of the NOAA AWG Cloud Height Algorithm (ACHA) run on GOES-13 where compared to the cloud heights from the University of Wisconsin High Spectral Resolution Lidar (HSRL). Results for June 2012 over the Norman, OK site are shown in Figure 52. The heights from the HSRL are determined by inspection of the extinction profiles. The truth height from HSRL is computed by the height where the integrated extinction reaches unity or the physical midpoint of the cloud (whichever is higher). This “effective” cloud height from the HSRL should correspond to the height sensed by the infrared ACHA algorithm. The results indicate good performance by ACHA for optical depths greater than 0.5. This performance is within the specification placed on the GOES-R algorithm.

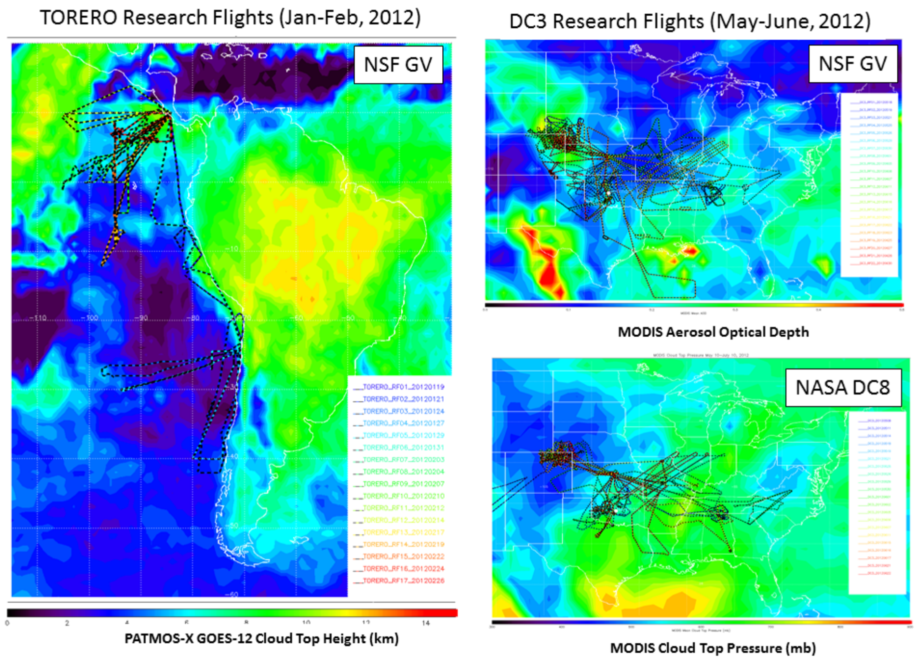

Figure 51. NSF GV and NASA DC8 flight tracks during TORERO (left) and DC3 (right) field campaigns. Mean January-February, 2012 PATMOS--X GOES-12 Cloud Top Height (km).

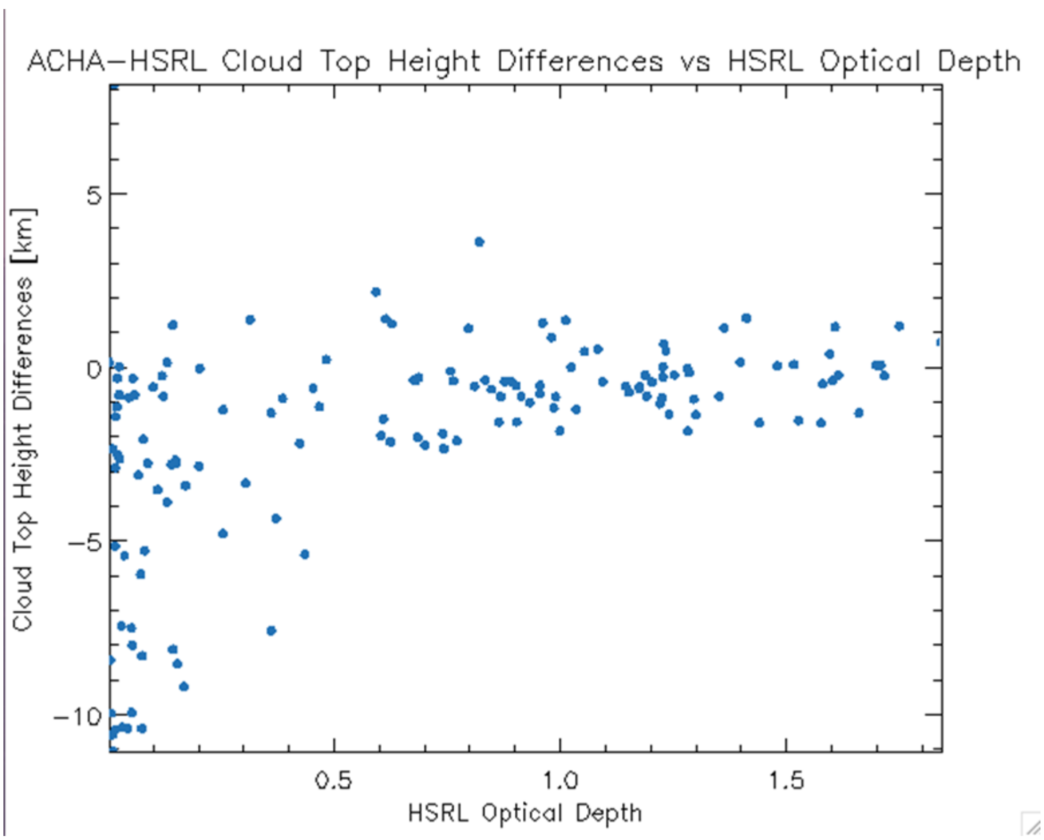

Figure 52. Variation of cloud top difference (ACHA-HSRL) over Norman, OK site. ACHA is the NOAA AWG Cloud Height Algorithm developed for GOES-R but modified for the spectral content of the current GOES Imagers.

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

Figure 53 shows a comparison of SSFR retrievals from the ground-based installation at Boulder to those from GOES for May 25, 2012. GOES data were processed through GOES-R AWG Algorithms. Since the SSRF retrieval uses transmission viewed from below, it should be able to retrieve higher (and more accurate) optical depths for thick clouds. This appears to be the case here (optical depth > 60). Also, we expect SSFR particle radii to be generally less than those from GOES and this also appears to be true. GOES-R's higher temporal and spatial resolution should increase the accuracy of these comparisons.

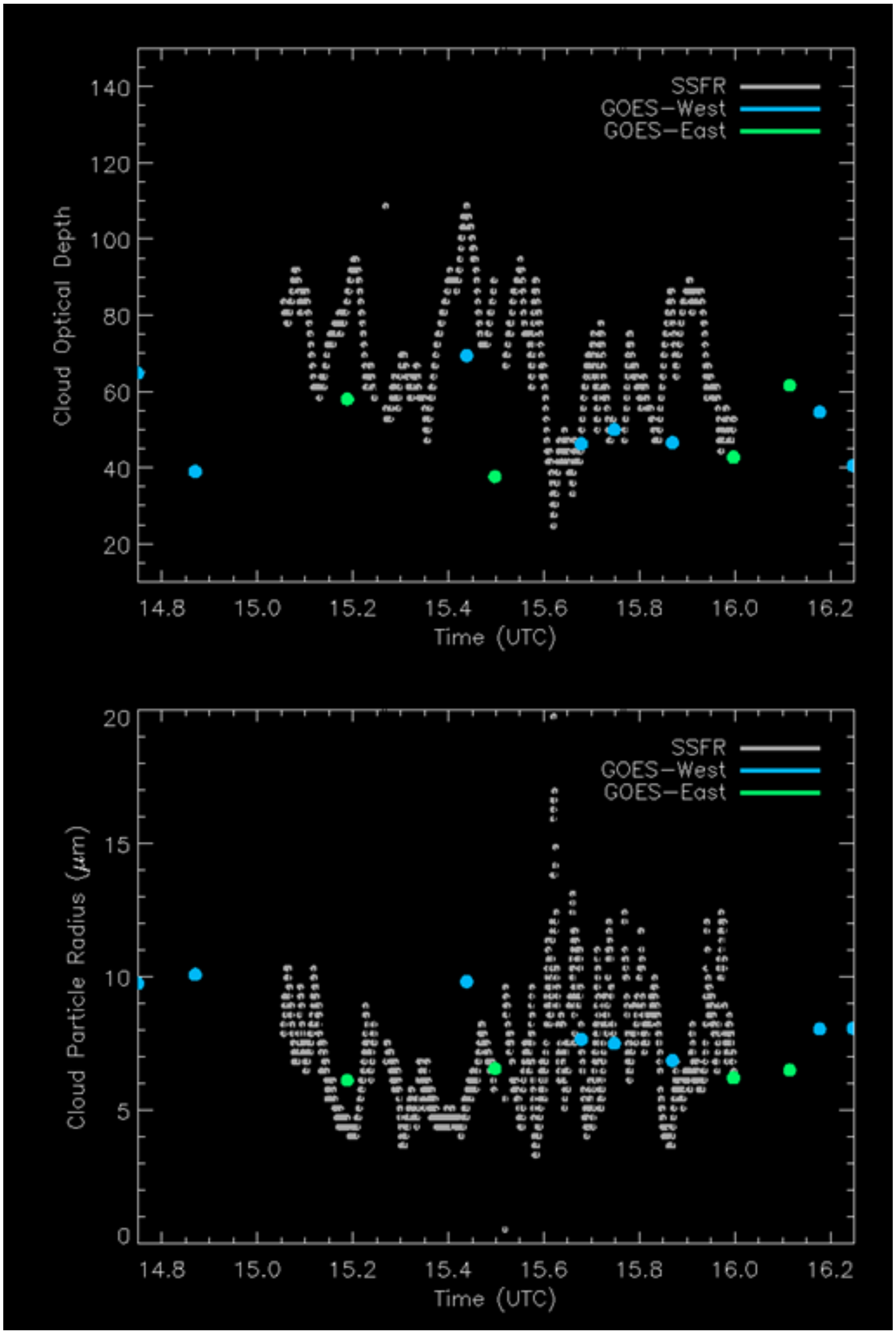

Figure 53. Validation of GOES-R AWG cloud Optical Thickness (COT) and Cloud Particle Radius (Reff) retrievals using GOES-West (blue) and GOES-East (green) observations and SSRF retrievals (white) on May 25, 2012 at Boulder, CO.

13. Providing Support for GOES-R and Other Geostationary Satellites in the Community Satellite Processing Package (CSPP)

CIMSS Task Leader: Liam Gumley (PI)
CIMSS Support Scientists: Scott Mindock, Graeme Martin
NOAA Collaborator: Steve Goodman

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.

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.

Summary of Accomplishments and Findings
Test data for this project has been obtained from the SSEC GOES archive (GOES-15 Imager, 2014 Jan 26 21:00 UTC), and was originally created by the SSEC Satellite Data Ingestor (SDI) hardware. SSEC SDI hardware is commonly used in the GOES direct broadcast community, so it forms a good basis for testing. We have also solicited GVAR test data from vendors including SeaSpace, Global Imaging, and Enterprise Electronics Corporation (EEC), but to date have only received test data from Seascape. At this time we are using the SSEC GVAR data stream for testing since it is controlled locally and well understood.

Conversion from GVAR to AREA
Software has been developed to scan the GVAR raw data and create index files that encode information such as start line/pixel and end line/pixel in a given dataset. The index files allow

data from observation modes such as Full Disk, Northern and Southern Hemisphere, and CONUS to be extracted. At this time we are only supporting these imaging modes: support for subsets of these modes will be added later.

Software has been developed to scan the GVAR data and associated index files and create area files (one per GOES Imager band) on disk in native satellite projection.
For step (c), software has been developed to reproject the area files to a standard projection (usually just a satellite projection for a certain day and time). This step is required so that GEOCAT can exploit Imager time sequence data to improve the quality of the retrieved products.

Current Status:

1) Have ported code from McIDAS to read GVAR data and write areas using ADDE server as data source. Resulting areas are usable in McIDAS: Calibration and Navigation are good.
2) Have ported code from McIDAS to read SDI GVAR and index files and write areas. Results are usable in McIDAS, however calibration is disabled. McIDAS loads and navigates the areas.
3) Areas from step (2) been ingested by GEOCAT. GEOCAT runs to completion but results are empty (since no calibration)
4) Have ported remap code from McIDAS. It is necessary to pre-process areas before use in GEOCAT, because of cloud algorithm requirements.
5) Have contacted SeaSpace about sample GVAR data. Data and documentation has been provided.
6) Have contacted Global Imaging about sample GVAR data. Data has been promised but not provided.
7) A software repository has been created and is being used to store software produced.
8) Software has been developed to allow remapping to satellite projections.

Level 1 and Level 2 Product Generation with GEOCAT

The initial CSPP GEO software package supporting the current GOES Imager will include GEOCAT executable code and driver scripts for 64-bit Intel Linux systems. The primary input format will be McIDAS area files. The format for output products will be HDF4. Any dynamic ancillary data will be identified and downloaded automatically at runtime (e.g., GDAS surface pressure). Source code will be made available in a separate package.

Current Status:

1) Identified algorithm versions for demo release in cooperation with algorithm developers, obtained algorithm source code.
2) Identified GEOCAT version, built GEOCAT with algorithms and supporting COTS libraries, resolved build issues.
3) Verified output from test case versus output from reference real-time processing system at CIMSS, resolved differences with assistance from algorithm developers.
4) Identified test dataset for demo release and obtained ancillary datasets.
5) Started automation scripting: will be minimal (bash only) for initial version and more sophisticated (bash / python) for future versions.
6) Tested GVAR converter / GEOCAT workflow, currently resolving calibration and area directory issues.

Current GEOCAT Product List for CSPP GEO Release

Level 1B Products
- 0.65 and 3.9 um reflectance
- 3.9, 6.7, 11.0, and 13.3 um brightness temperature

Level 2 Cloud Products
- Cloud mask
- Cloud phase/type
- Cloud top height
- Cloud top temperature
- Cloud top pressure
- Cloud 11 um emissivity
- Cloud visible optical depth
- Cloud effective radius
- Cloud liquid water path
- Cloud ice water path

Level 2 Fog / Low-Cloud Products
- Probability of Marginal Visual Flight Rules (MVFR)
- Probability of Instrument Flight Rules (IFR)
- Probability of Low Instrument Flight Rules (LIFR)
- Low cloud geometric thickness

The project is on track to release a demo version of the CSPP GEO software package supporting current GOES Imager by the end of May 2014. The initial release will be tested by GOES direct broadcast system vendors including: SeaSpace, Global Imaging, EEC, and Orbital Systems. It will also be tested by GOES-R Working Group partners (M. Pavolonis; A. Heidinger), and other collaborators including GINA (U. of Alaska), CIRA, and SPORT.

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

14.1 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 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

- Clouds Aerosols and Radiation

Project Overview

This project supports the JPSS VIIRS Cloud Mask Cal/Val Team for 1 year. The goal of this effort is to use our previously developed tools and tune the cloud mask. NPP/VIIRS was launch in November 2011. This work is coordinated with other member at other institutes.
We intend to leverage our efforts within the existing NPP PEATE located at the University of Wisconsin. Through this project, we intend to continue to interact with our NGST colleagues (Keith Hutchison and Eric Wong) and the Air Force Weather Agency (AFWA) in Omaha, Nebraska (Tom Kopp). This project will also aim to discover bugs and potential fixes in the VIIRS Cloud Mask (VCM). 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 the 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

Developed tools are used to plot global composites of VCM (Figure 54), validate them with the other cloud mask algorithm products (NOAA PATMOS-x, MODIS C5 and C6, etc.), analyze the quality of the clear radiances, and compare the performance of the VCM over all regions. We use these tools to identify large scale errors and differences between the VIIRS and MODIS cloud masks. These tools are capable of processing large amounts of data. We operate these tools periodically to track the performance changes of the VCM as it is tuned and refined.

Developed CALIPSO – VIIRS match-ups collocation tools are used to generate many days of results and to also track changes in performance as the VCM is tuned (Figure 55). The tools allow making a statistical comparison with the other cloud mask products.

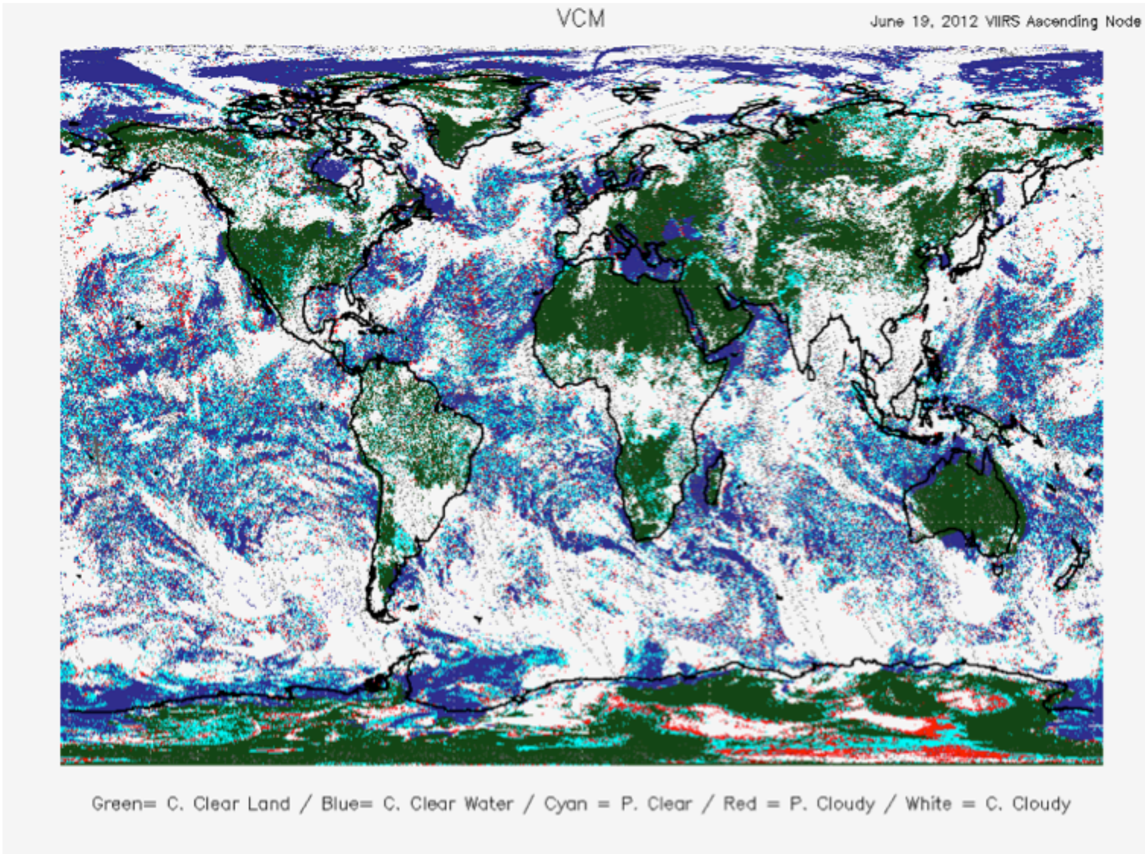

Figure 54. VCM performance on June 19, 2012 ascending node (day time).

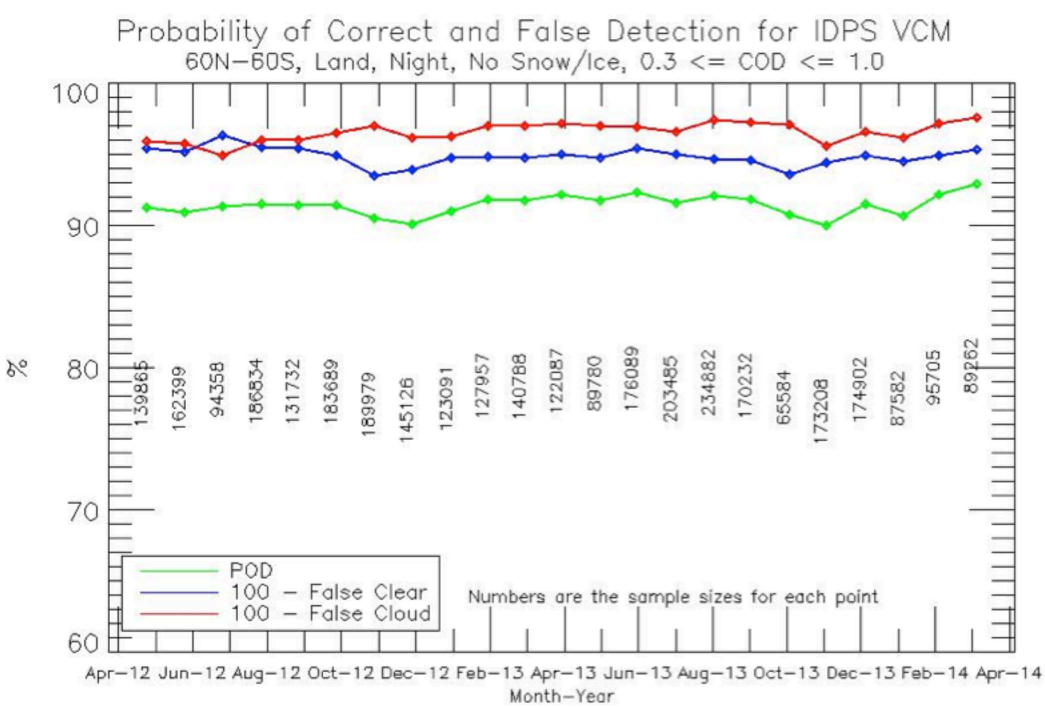

Figure 55. VCM – CALIPSO performance time series over 60N-60S, Land, Night, No Snow/Ice.

Publications and Conference Reports

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, doi:10.1002/2013JD020458. [Available at http://onlinelibrary.wiley.com/doi/10.1002/2013JD020458/pdf]

14.2 Cloud Optical Property and Cloud Top Properties Algorithm

CIMSS Task Leader: Andi Walther
NOAA Collaborator: Andrew Heidinger

NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

NOAA Strategic Goals:

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

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

This project aims to evaluate 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** parameters in the first months, the here reported period focused on evaluation of the **physical properties** and algorithm modules.

We found major issues in the pre-computed simulations of the radiative transfer, which are stored in look-up-tables. This could be fixed for an improved version of the IDPS algorithm in cooperation with the colleagues from Northrup Grumman. Figure 56 shows an example evaluation of the cloud reflection function in the CIMSS retrieval CLAVR-x and in IDPS.

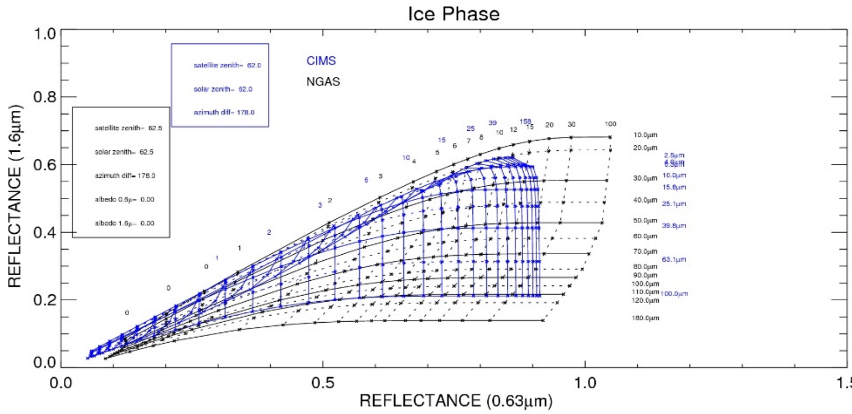

Figure 56. Comparison of cloud reflection simulations for CIMSS algorithm and IDPS.

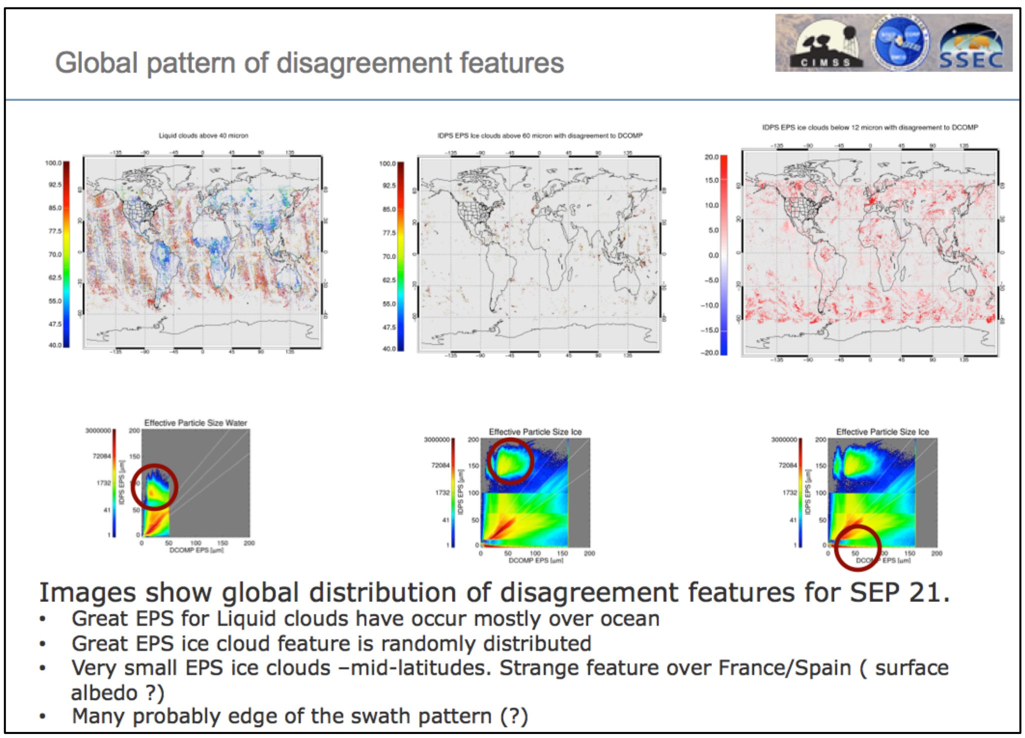

Figure 57. Disagreement features of IDPS retrieval with CLAV-x for Cloud Particle Size.

We evaluated IDPS retrieval output for long-term period and communicated the results in biweekly telephone conferences and in a report. We still had to identify major issues in defining quality flag information. The IDPS retrieval still shows artificial angular-dependent artifacts, which lead to artificial pattern in global results images. Within this project we gave advice how to fix major issues and how we think the retrieval could be improved.

Publications and Conference Reports

Heidinger et al., 2012: The JPSS Cloud Cal/Val Team for the JPSS project: JPSS Cloud Algorithm Performance Report, October 2012

14.3 McIDAS Support for Suomi NPP

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:
- 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
- Satellite Sensors and Techniques

Project Overview

The primary goal for JPSS-related McIDAS-V development in 2013 is adding support for VIIRS Imagery Environmental Data Records (EDRs). This includes products such as the Near Constant Contrast (NCC) data, derived from the Day/Night Band, and the VIIRS Cloud Mask Product. The difficulty stems from an unexpected artifact originating in the creation of these products. A variable number of across-track scans are missing geolocation data at the beginning and ending of granules. This is expected behavior for generation of these products, and special coding in McIDAS-V is required to handle it. CIMSS realizes the ability to visualize and validate VIIRS Imagery EDRs is a strong need for the NESDIS/StAR Imagery Team, and this is CIMSS' #1 Suomi NPP VIIRS task.

Suomi NPP data poses many programming challenges not previously seen during McIDAS-V development. One of these is the task of saving and restoring the state of the application when working with such data. At present users are unable to create bundles (.mcv files) for any JPSS data. This will be addressed in 2013.

It has come to SSEC's attention that there are additional data in all VIIRS granules that would be useful for researchers to have access to. For example, solar and lunar angles, and various quality flag information. We will extract these data (some which are bit-level fields) and make them available in the McIDAS-V Field Selector for users.

Summary of Accomplishments and Findings

Full support for all VIIRS Imagery EDRs was added in McIDAS-V release 1.4 (October 2013). An example is shown Figure 58. This includes aggregation of granules, with support for expected behaviors such as subsetting across adjacent granule boundaries. Bundle support for Suomi NPP products (VIIRS, ATMS, and CrIS) was also added in release 1.4.

SSEC implemented the capability to access any geolocated data in VIIRS granules for visualization and analysis. This functionality is very useful when working with McIDAS-V from the Jython scripting environment. McIDAS-V is also now in a general way extracting and making available any bit-fields packed into Quality Flag variables, providing a wealth of new information to scientists and researchers. McIDAS-V allows users to probe any Quality Flag to display the meaning of the data at that Earth location.

As a result of participating in the monthly VIIRS Imagery Team Meetings, coordinated by Don Hillger (StAR JPSS Imagery Team Lead) and Thomas Kopp (Aerospace Corp. Validation Lead), SSEC has helped confirm and resolve several post-launch JPSS problems, through the process of demonstrating and clearly defining the issues, and filing Discrepancy Reports (DRs) with NASA. Among the DRs filed are:

- DR 7490 – Correction of inconsistent EDR product names
- DR 4451 – Correct unparseable XML Product Profiles
- DR 4765 – Supply Range minimum and maximum values for VIIRS Band M13
- DR 7426 – Correct valid data range on VIIRS NCC EDR product

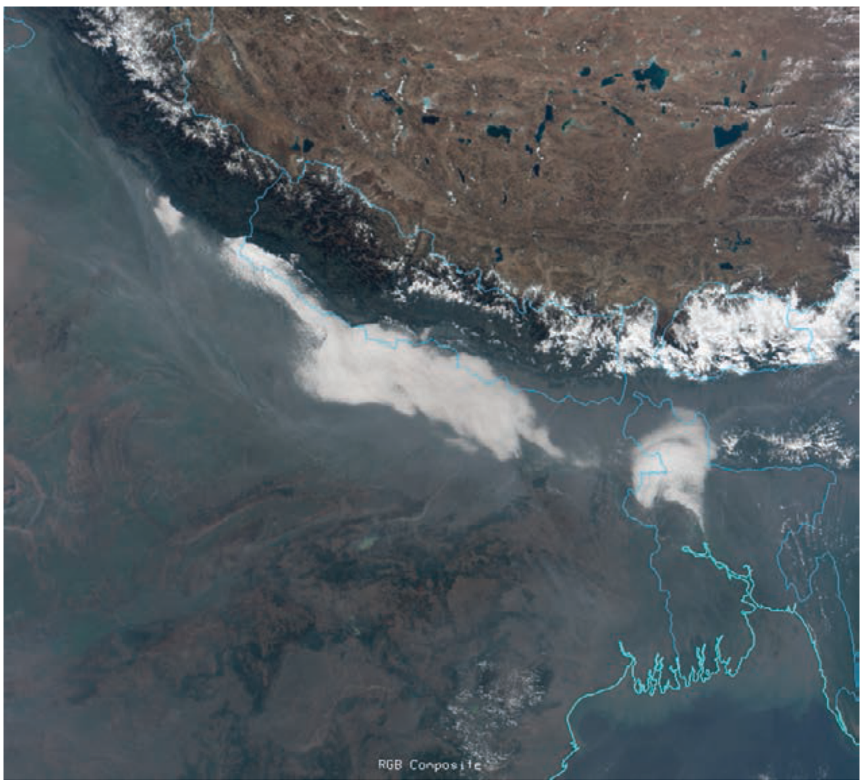

Figure 58. VIIRS true-color image generated by McIDAS-V from bands M3-M5 over northern India and Tibet at 7:25 UTC 14 Dec 2011. Note the large contrast in aerosol scattering between the cooler, drier, and shallower air mass to the north of the Himalayan chain and the warm, humid, and deeper air mass to the south.

Publications and Conference Reports

Hillger, D., T. Kopp, T. Lee, D. Lindsey, C. Seaman, S. Miller, J. Solbrig, S. Kidder, S. Bachmeier, T. Jasmin, T. Rink: First-Light Imagery From Suomi NPP VIIRS, Bulletin of the American Meteorological Society (BAMS), **94** Number 7, July 2013.

14.4 VIIRS Aerosol Product Support

CIMSS Task Leader: Robert Holz

CIMSS Support Scientist: Min Oo
NOAA Collaborators: Shobha Kondragunta and Istvan Laszlo

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

Project Overview

The goal of the this effort is to assist the JPSS aerosol product team in evaluating the global aerosol product from VIIRS (Visible Infrared Imaging Radiometer Suite) 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.

Summary of Accomplishments and Findings

As part of this effort we generate and save the collocated dataset of VIIRS (both IP (Intermediate Product) and EDR (Environmental Data Record)) MODIS aerosol product from 2012 to current. This collocated product was used extensively for the VIIRS aerosol product calibration and validation team (VIIRS Aerosol Cal/Val Team) Beta and Provisional stage aerosol product maturity declaration. VIIRS global mean AOT (Aerosol Optical Thickness) or AOD (Aerosol Optical Depth) at 550nm differs from that of MODIS by approximately -0.01 over ocean and 0.03 over land. The time period of this analysis is May 2, 2012 – September1, 2013. This analysis demonstrates that VIIRS can provide AOT with approximately about the same uncertainty that MODIS provides. However, there are some large regional biases over land (see Figure 59). The results from comparison with VIIRS and MODIS show VIIRS AOT at 550nm can provide a reliable dataset for both scientific investigation and environmental monitoring of global aerosols.

Publications and Conference Reports

Liu , H., Remer, L.A., Huang, J., Huang, H.C., Kondragunta, S., Laszlo, I., Oo, M., and Jackson, J.M. "*Preliminary Evaluation of Suomi-NPP VIIRS Aerosol Optical Thickness*" JGR-Atmospheres on Suomi-NPP Cal/Val Science Results. June 13, 2013.

Min Oo, Robert Holz, Jingfeng Huang, Christina Hsu, Istvan Laszlo, Shobha Kondragunta, Lorraine Remer and Atmospheric PEATE team: "Overview of Atmospheric PEATE evaluation Capability to VIIRS Aerosol retrieval" poster section at NPP science Team meeting.

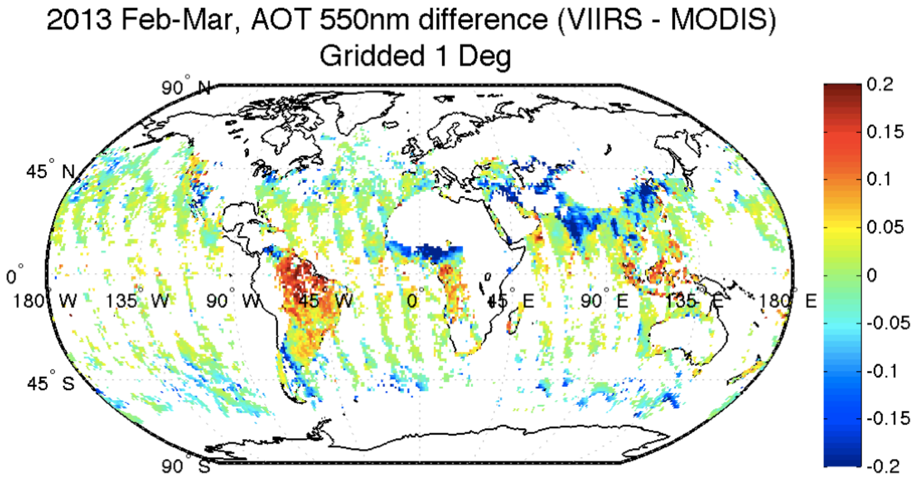

Figure 59. Aerosol Optical Difference between VIIRS (EDR) and MODIS (Aqua) for 2 months 1 degree grid.

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

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

CIMSS Task Leaders: Dave Tobin, Hank Revercomb
CIMSS Support Scientists: Joe Taylor, Robert Knuteson, Lori Borg, Dan DeSlover, Graeme Martin
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

Proposed efforts for this period of performance are divided into the following four categories:

1. Support CrIS Planning and Review Meetings/Telecons

We will support appropriate NPP, JPSS, and CrIS test related meetings, telecons, and conferences under this task. Examples include CrIS performance review and analyses meetings, JPSS cal/val meetings, weekly JPSS telecons, and conferences where CrIS and JPSS relevant topics are discussed.

2. Post-launch CrIS RDR and SDR Cal/Val Tasks

The large majority of our work during this period of performance will be to continue to perform our various cal/val tasks related to the CrIS SDRs. This covers a range of CrIS performance issues including noise performance, principle component analysis, radiometric calibration, radiometric nonlinearity, and lineshape and spectral calibration. For each task we will provide timely reporting to the project on our findings as well as written reports for each task and presentation of the analyses at appropriate project meetings and conferences. During the extended Cal/Val period we will work to assess whether the SDR products meet the performance requirements and identify SDR algorithm changes required to meet those requirements. Among others areas of investigation, this will specifically include:

1) Further diagnosis and solution to the spectral ringing artifacts
2) Further diagnosis and solution to radiometric artifacts seen in the shortwave band for very cold scene temperatures
3) Small refinements to the ILS and nonlinearity coefficients
4) Final estimates of the CrIS Radiometric Uncertainty (RU)
5) Further development and internal distribution of CCAST
6) Analysis of the full spectral resolution RDRs and internal SDRs
7) Validation of the truncated (normal) resolution SDRs following download of the full resolution RDRs
8) Contributions to the JGR special issue on Suomi-NPP Cal/Val

3. CrIS FM-2 Pre-launch Test Support and Performance Analysis

We will participate in the design and review of the CrIS FM-2 pre-launch testing and analyses of the resulting data to assess the performance of the sensor as well as associated reviews and activities, with Bench Testing currently scheduled to begin in May 2013 and Thermal Vacuum testing from November 2012 to March 2014. This effort includes a wide range of participation to support the needs of the CrIS SDR Cal/Val and anticipate potential changes to the SDR algorithm for J1.

4. Aircraft Instrument Calibration, Maintenance and Improvement

This work includes efforts relating to the calibration and maintenance of the Scanning-HIS aircraft sensor. It is anticipated that the level of effort for this task during this period of performance will be relatively small.

Summary of Accomplishments and Findings

Efforts related to the four categories are described here.

1. Support CrIS Planning and Review Meetings/Telecons

We have actively participated in the CrIS SDR team activities, including the weekly Wednesday telecons, side meetings, and relevant conferences. A major component is the work leading up to and presentation of results at the SDR Validated Review meeting held in December 2013.

2. Post-launch CrIS RDR and SDR Cal/Val Tasks

We have made significant progress on all of our cal/val tasks. These results were highlighted at the December 2013 SDR Valdiated Review meeting and in several journal article published as part of the JGR special issue on Suomi-NPP. Leading up to the validated review, we re-analysed the CrIS mission record to produce refined estimates of the nonlinearity and spectral calibration parameters which were subsequently included in the EPv36 calibration coefficients, as well as corresponding changes to the SDR algorithm, which are in use today. Along with this, we produced Radiometric Uncertainty estimates of the CrIS SDRs for use for weather, climate, and intercalibration applications of the data. Most recently, we have determined the root cause of the spectral ringing artifacts caused by the non-cyclic application of the on-board numerical filter, and have also developed a ground processing fix for the artifacts.

3. CrIS FM-2 Pre-launch Test Support and Performance Analysis

J1 CrIS underwent two phases of Bench level testing in 2013 including the RRB Bench in June and the CPT Bench in September. Our efforts have focused on analyses of some of the Bench test data and on refinement/development of analysis software. Our primary analyses to date have focussed on characterization of the J1 sensor radiometric nonlinearity. We have analyzed the Bench level Diagnostic Mode data collected in June and September 2013. Overall, the nonlinearity characterization of J1 CrIS is similar to Suomi-NPP CrIS with the SW band showing very little nonlinearity, the MW band showing quite a low level of nonlinearity for all FOV except FOV 9 that shows a high degree of nonlinearity, and with the LW band FOVs all showing a significant level of nonlinearity. This implies that the same quadratic nonlinearity correction approach and TVAC and on-orbit analysis techniques developed for Suomi-NPP will be suitable for J1 CrIS.

4. Aircraft Instrument Calibration, Maintenance and Improvement

As anticipated there has not been any efforts related to this task in the current period of performance.

Publications and Conference Reports

DeSlover, Daniel H. and Borg, Lori A., Cross-track infrared sounder (CrIS) spectral radiance calibration and evaluations, AIP Conference Proceedings, 1531, 724-727 (2013), DOI:http://dx.doi.org/10.1063/1.4804872

Han, Y. et al., Suomi NPP CrIS measurements, sensor data record algorithm, calibration and validation activities, and record data quality. Journal of Geophysical Research-Atmospheres, Volume 118, Issue 22, 2013, doi:10.1002/2013JD020344.

Knuteson, R., D. Tobin, H. Revercomb, J. Taylor, D. DeSlover, and L. Borg (2013), Assessment of CrIS/IASI Satellite Inter-Calibration, AMS/EUMETSAT Satellite Conference, 16-20 September 2013, Vienna, Austria.

Moeller, Chris, Dave Tobin, Greg Quinn, S-NPP VIIRS thermal band spectral radiance performance through 18 months of operation on-orbit. Proc. SPIE 8866, Earth Observing Systems XVIII, 88661N (September 23, 2013); doi:10.1117/12.2023389.

Revercomb, Henry and Best, Fred and Knuteson, Robert and Tobin, David and Taylor, Joe and Gero, Jon, Status of high spectral resolution IR for advancing atmospheric state characterization and climate trend benchmarking: A period of both opportunity realized and squandered, AIP Conference Proceedings, 1531, 27-30 (2013), DOI:http://dx.doi.org/10.1063/1.4804699

Revercomb, Hank, Fred, Best, Dave Tobin, Bob Knuteson, Joe Taylor, IR Calibration Breakthroughs Demonstrated by Current Advanced Sounders and by a Recent Prototype of Future Instruments for Climate and Weather, Part 1: Emphasis on the Cross-track Infrared Sounder (CrIS) on Suomi NPP, AMS/EUMETSAT Satellite Conference, 16-20 September 2013, Vienna, Austria.

Strow, L. et al., Spectral calibration and validation of the Cross-track Infrared Sounder on the Soumi NPP satellite. Journal of Geophysical Research-Atmospheres, Volume 118, Issue 22, 2013, doi:10.1002/2013JD020480.

Taylor, J. K., D. Tobin, H. Revercomb, F. Best, R. Garcia, B. Imbiriba, and M. Goldberg, 2014: Suomi NPP/JPSS Cross-track Infrared Sounder (CrIS): Calibration validation with the aircraft based Scanning High-resolution Interferometer Sounder (S-HIS). Annual Symposium on Future Operational Environmental Satellite Systems, 10th, Atlanta, GA, American Meteorological Society.

Tobin, D., H. Revercomb, J. Taylor, R. Knuteson, D. H. Deslover, and L. A. Borg, "Calibration/Validation Results for the Cross-track Infrared Sounder (CrIS) on Suomi-NPP," in Imaging and Applied Optics, OSA Technical Digest (online) (Optical Society of America, 2013), paper FTh1C.2. http://www.opticsinfobase.org/abstract.cfm?URI=FTS-2013-FTh1C.2

Tobin, David and Joe Taylor, CrIS Radiometric Uncertainty and Recent Aircraft Underflights to Establish its On-Orbit Traceability, GSICS Quarterly Newsletter, Volume 7 Number 4, 2014, doi: 10.7289/V55Q4T1S

Tobin, D. et al., Suomi-NPP CrIS radiometric calibration uncertainty. Journal of Geophysical Research-Atmospheres, Volume 118, Issue 18, 2013, doi:10.1002/jgrd.50809.
Tobin, David C. and Revercomb, Henry E. and Taylor, Joe K. and Knuteson, Robert O. and

Tobin, D. C., Suomi-NPP Infrared Sounder (CrIS) Intercalibration With AIRS, IASI, and VIIRS, Spring 2013 GSICS Quarterly Newsletter.
http://www.star.nesdis.noaa.gov/smcd/GCC/documents/newsletter/GSICS_Quarterly_Vol7No1_2013.pdf

Tobin, DC, HE Revercomb, JK Taylor, RO Knuteson, D DeSlover, LA Borg, G Martin, " CrIS Radiometric Calibration: Uncertainty Estimates and Evaluations", In International TOVS Study Conference XIX. Jeju, Korea: ITWG, 2014.

15.2 VIIRS Radiance 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 Performance and EDR Impact Assessments
    - Continued data collected under implemented Cal/Val task network assignments (RAD-01, RAD-04, RAD-12A,B), including beneficial modifications to strategy that may become evident in the SNPP post- launch era.
    - Performance analyses and reports on those Cal/Val tasks assigned to UW-Madison. These include tasks on radiometric, spectral and HAM performance.
    - On-going review of VIIRS performance through imagery inspection using McIDAS to identify, isolate and characterize anomalous performance in all VIIRS bands.
    - Monitor SNPP VIIRS spectral performance, including RTA mirror degradation anomaly impact on VIIRS RSR. Update RSR as needed.
    - Strategies for mitigating SNPP performance anomalies as revealed in post-launch era.
    - Support LUT updates as needed in coordination with the VIIRS instrument lead.
    - Direct interaction with EDR teams (land, ocean, cloud/atmosphere) to convey VIIRS SDR performance anomalies, identify VIIRS SDR performance anomalies in the context of EDR performance, and plan effective mitigation strategies when needed.
    - As government team POC for spectral, continue to manage VIIRS RSR products in coordination with STAR and to support science community use of VIIRS RSR.
    - Initial aircraft-based VIIRS SDR Cal/Val flights are anticipated in FY2013. Data collection, production, and analysis to support 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 J1 VIIRS on-orbit assessment.
    - Participate in review of performance analyses and reports for non-UW Cal/Val tasks.
2. Preparation and onset of JPSS-1 VIIRS Pre-Launch Test Program
    - Participation in joint government and industry J1 GSE working group.
    - Vetting and recommending changes to the proposed J1 VIIRS test program with an emphasis on spectral characterization. Onset of pre-launch test program.
3. Participation on VIIRS SDR and Technical teams and in all associated activities
    - Regular SDR Team and Technical Team meetings.
    - VIIRS SDR performance and data maturity status meetings.

Summary of Accomplishments and Findings

The reporting period includes and extends beyond the 2nd year of on-orbit performance by SNPP VIIRS, including the march towards validated status for the SDR product. The period also includes the preparation and completion of ambient phase testing on the JPSS-1 VIIRS as well as preparation for the TVAC phase of the JPSS-1 test program. Participation on the VIIRS SDR team was also supported.

SNPP VIIRS Relative Spectral Response (RSR) Characterization

An update to VIIRS SDR RSR LUT was completed to mitigate the impact of RTA mirror throughput degradation on the RSR (DR4971). The update used a snapshot modulated RSR valid on Feb 1, 2013. This update mitigates a small bias that was building in the SDR due to the modulation.

SNPP VIIRS On-Orbit Performance Evaluation

UW-Madison has implemented Cal/Val tasks RAD-01, RAD-04, RAD-12(A,B) and RAD-21. These tasks have contributed to the body of evidence supporting VIIRS SDR quality achieving a "Validated" status. Beyond these Cal/Val tasks, UW-Madison has taken an active role in reviewing various aspects of the SNPP VIIRS performance using its McIDAS-X satellite data visualization and analysis software tool. These tasks and data vigilance have supported investigations into the following highlighted performance aspects:

- Daily SNPP VIIRS-CrIS spectral radiance comparisons over 2+ years on-orbit continue to reveal excellent calibration performance for bands M13, M15, M16, and I5 with differences < 0.1 K for typical scenes (CrIS does not contain spectral coverage for M12, M14, and I4). Existing scene temperature dependence appears to fall within specification at all scene temperatures for these bands. Adjustment of the C0 (offset) coefficient continues to be studied as a means to correct small systematic behavior in these bands.
- 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.
- SNPP VIIRS-IASI SNO comparisons also indicate that SNPP VIIRS TEB SDR for bands M13, M15, M16, and I5 are performing within radiometric specification. In addition, VIIRS bands M12, M14 and I4 are indicated to be performing within specification with possible exception of M12 at warm scenes (caveat of limited sample size).
- NASA ER-2 aircraft underflights of SNPP have provided a warm earth scene calibration assessment based upon a NIST traceable calibration source (SHIS). The analysis shows that SNPP VIIRS SDR are within 0.2 K of the SHIS for all TEB and are compliant with radiometric requirements at the warm scene temperature (290 K). Additionally, these results agree closely with those found in VIIRS-CrIS and VIIRS-IASI comparisons (Figure 60), with exception of demonstrating that band M12 is compliant at warm scenes in contrast to the VIIRS-IASI limited sample result noted in previous bullet.
- A very small percentage (<<1%) of SNPP VIIRS SDR radiances are saturated in some RSB due to the setting of a maximum radiance (RadMax) in the SDR production code. This is being evaluated for mitigation. Phenomenological studies indicate that VIIRS RadMax thresholds can be increased to accommodate these brightest of scenes, allowing the true SDR radiance to pass through to SDR.

In addition to these performance investigations, UW-Madison has participated in the review of all other SNPP VIIRS performance aspects through regular VIIRS Technical Team and SDR Team telecon discussions.

Preparation and Onset of JPSS-1 VIIRS Pre-launch Test Program

Upgrades to the SpMA have largely been completed and final adjustments to the FP-15 and FP-16 test plans are being discussed. A recommendation has been made for concurrent measurements of RSO with RSR during FP-16 VisNIR and FP-15 DNB data collection. Concurrent RSO measurements capture any drift in the source bulb output over time as well as mitigate possible loss of RSO knowledge if/when source bulbs fail. This occurred several times during the F1 test program. An increase in the frequency of offline RSO measurements is also being considered as a satisfactory alternative.

Deployment of the NIST T-SIRCUS to Raytheon to make VisNIR band RSR measurements during the JPSS-1 test program continues to be recommended. The unpolarized T-SIRCUS source will provide measurement-based insight into the polarization influence on VisNIR bands.

The T-SIRCUS setup (flood illumination of VIIRS focal plane) also measures all spectral influences simultaneously on the RSR including in-band, out-of-band, optical and electronic cross talk, correctly scaling these influences by virtue of the integrated flight-like measurement.

The ambient phase of the JPSS-1 VIIRS pre-launch test program was underway from August 2013 – January 2014. Under this project, reviews of performance testing on polarization (FP-11) and HAM RVS (FP-10) were conducted along with reviews of functional testing.

- Polarization is non-compliant for bands M1-M4. The source of the polarization appears to be in the IFA (filters), resulting in an apparent small dependence of the RSR on polarization, primarily near the edges of the extended bandpass zone.
- FP-10 HAM RVS characterization appears to meet the 0.3% uncertainty requirement for all bands with a few minor exceptions. Band M9 is marginally compliant owing to the influence of ambient water vapor on the measurements.
- Initial attempts by Raytheon to remove the water vapor influence from M9 measurements during FP-10 P1 did not result in marked improvement.
- A review of the temperature and relative humidity data collected to characterize the ambient water vapor during FP-10 P1 (RSB) testing shows unexpected behavior for a portion of the data collection, possibly due to external influences (frequency based noise?) within the test environment. Wisconsin is working with Raytheon to effectively model and remove the water vapor influence on the FP-10 P1 M9 measurements.

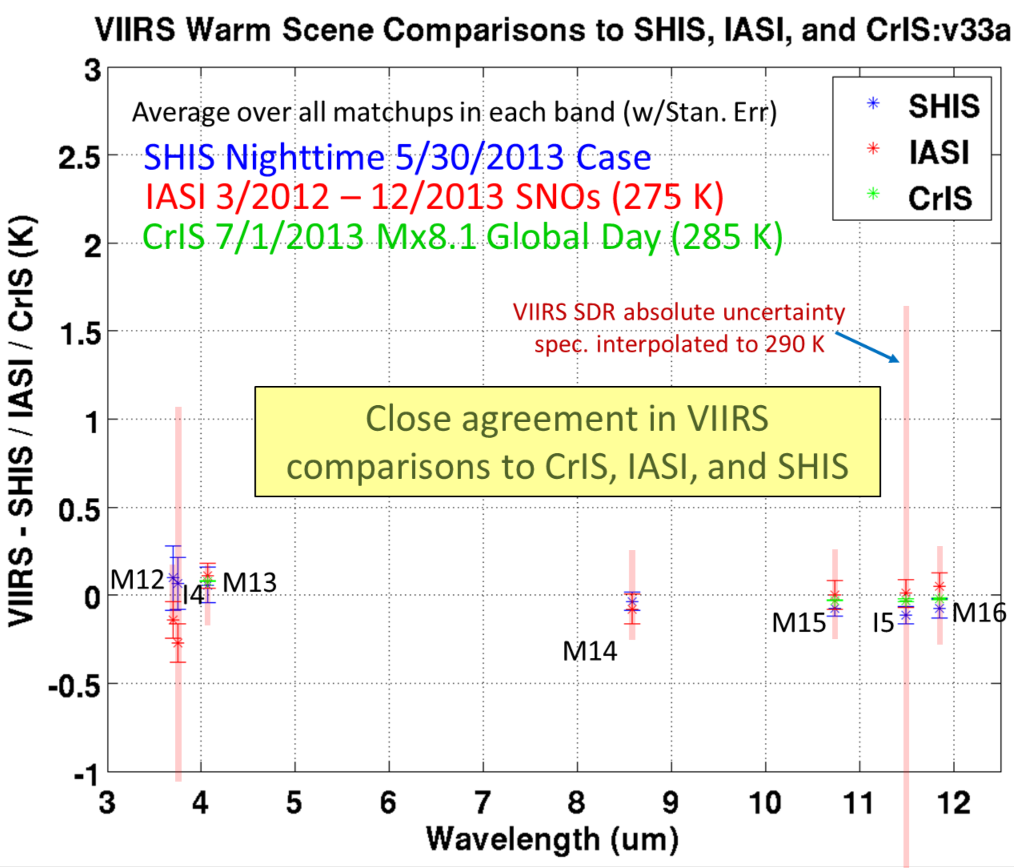

Figure 60. SNPP VIIRS-SHIS, VIIRS-IASI, and VIIRS-CrIS SDR comparisons showing close agreement between all 3 independent assessments of the VIIRS radiometric performance.

Publications, Conferences and Presentations

Moeller, C., D. Tobin, and G. Quinn, "S-NPP VIIRS Thermal Band Spectral Radiance Performance Through 18 Months of Operation On-orbit". SPIE Vol. 8866, 88661N, doi:10.1117/12.2023389, 2013.

Moyer, D., C. Moeller, and F. De Luccia "VIIRS Thermal Emissive Bands On-orbit Calibration Coefficient Performance Using Vicarious Calibration Results". SPIE Vol. 8866, 88661O, doi:10.1117/12.2023809, 2013.

Moeller, C. D. Moyer, D. Tobin, G. Quinn, C. Cao, M. Liu, F. Padula, and W. Wang "S-NPP VIIRS Thermal Emissive Band (TEB) Validation Update". Presentation at the Suomi NPP SDR Science and Product Review, December 18-20, 2013, College Park, MD.

15.3 CrIMSS Post Launch EDR Assessment

CIMSS Task Leader: Robert Knuteson
CIMSS Support Scientists: Michelle Feltz, Jacola Roman, Jessica Gartzke
NOAA Collaborators: Tony Reale, Nick Nalli

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

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

Project Overview

The CrIMSS on NPP will provide high vertical resolution and accuracy temperature and moisture profiles with global coverage. The traditional way for assessing the sounding products is to compare soundings with conventional radiosonde observations. However, radiosondes are only available at 00 UTC and 12 UTC over land, it is very important to assess the NPP sounding products with quality measurements other than conventional radiosondes. CIMSS scientists have extensive experience with the development of best quality validation dataset from the Department of Energy Atmospheric Radiation Measurement (ARM) program. In addition, new types of measurements from ground-based GPS receivers and COSMIC Radio Occultations provide accurate water vapor and temperature information for sounding assessment. We propose the use of collocated ARM site quality in-situ measurements as well as the ground-based GPS column water vapor measurements to assess the NPP water vapor sounding product, and the high quality COSMIC RO temperature profiles will be used to assess the NPP temperature sounding product.

The three sub-tasks for this project are described below. Also listed are recent publications/presentations summarizing results from previous funding periods.

Total Column Water Vapor Validation using MWR and GPS Stations

We have published detailed analyses (Bedka et al., 2010) of the accuracy of AIRS total column water vapor products using ground based microwave radiometer (MWR) validation data from the DOE ARM sites. We have extended this analysis from beyond the three ARM sites to include the NOAA SuomiNet and Wind Profiler Demonstration Network (WPDN) ground-based GPS sensors which provide much greater geographic coverage and dozens of sites around the world with similar accuracy (Roman et al., 2012, J. Climate). We have developed methods for CrIMSS validation of total water vapor using AIRS L2 products that take into account the station elevation in regional assessments. A preliminary assessment of the CrIMSS EDR PWV product has been made which shows considerable promise for use of the data in the forecasting of extreme weather events (Roman et al., 2012, AGU).

Water Vapor Profile Validation using the ARM RAMAN LIDAR

Continuously operating Raman Lidars can provide a valuable resource for the validation of satellite derived water vapor vertical profiles, particularly in regard to exact time coincidence (compared to radiosondes) and in the validation of upper tropospheric water vapor. The DOE ARM Raman lidar mixing ratio profile has been calibrated using the total column water vapor from a coincident microwave radiometer (MWR) to achieve good absolute accuracy in the vertical profile. We propose here to use the existing Raman Lidar products from the ARM Southern Great Plains site to assess the accuracy of the CrIMSS water vapor profiles. Preliminary assessment of AIRS and NOAA IASI retrievals of upper level water vapor have been used to develop the validation methodology. A Raman Lidar has been installed at the DOE ARM site in Darwin, Australia which will be incorporated into the analysis this year. These Raman Lidar profiles will be used to fill in the gaps in the seasonal coverage of the special radiosonde launches and help quantify errors in capturing the actual diurnal cycle. The profile statistics of water vapor will also be used to validate the CrIMSS upper level water vapor product stability over long time periods.

Temperature Profile Validation using GPS

This effort involves the use of temperature products derived from GPS occultation to assess the CrIMSS temperature profiles. Zonal global and regional statistics on vertical temperature deviations between the AIRS, IASI, and CrIMSS temperature soundings and the COSMIC and EPS-METOP GPS profiles are proposed. An area of emphasis will be the error assessment near the tropopause where the IR sounder temperature retrieval vertical resolution is degraded but the GPS occultation profile is considered to have excellent absolute accuracy. Methods were developed using AIRS L2 soundings for the matchup of GPS RO and IR sounding profiles which account for the horizontal and vertical geometry of the radio occultation profiles (Feltz et al., 2012, AMS). Preliminary assessment of the CrIMSS beta product where performed using this methodology to demonstrate the improvement due to a IDPS version update on October 15, 2012 (Feltz et al., 2013, AMS). During the EDR cal/val validation phase, the GPS RO data will be used to provide validation of CrIMSS products in the upper troposphere and lower stratosphere and quantify the performance of CrIMSS L2 ATVP retrievals relative to NASA AIRS L2 and NOAA-IASI L2 products for the same latitude zones and time periods.

Proposed Work

- Submit IR Sounder/COSMIC temperature validation methodology.
- Analyze CrIMSS/COSMIC temperature validation results.
- Analyze CrIMSS/SuomiNet/RamanLidar water vapor validation results.
- Present results to EDR Cal/Val in quarterly reports and regular team telecons.
- Present results at scientific conferences as appropriate.

Summary of Accomplishments and Findings

1. Graduate student Michelle Feltz submitted two papers in peer-reviewed journals on the validation of sounder products using GPS radio occultation. The citations are given below:
   Feltz, M.L., R.O. Knuteson, H.E. Revercomb, and D. C. Tobin (2014), A methodology for the validation of temperature profiles from hyperspectral infrared sounders using GPS radio occultation: Experience with AIRS and COSMIC, J. Geophys. Res. Atmos.,119, 1680–1691, doi:10.1002/2013JD020853.

   Feltz, M.L., R.O. Knuteson, S.A. Ackerman, H.E. Revercomb, and D. C. Tobin (2014), Application of GPS Radio Occultation to the Assessment of Temperature Profile Retrievals from Microwave and Infrared Sounders, Atmospheric Measurement Techniques, submitted.

2. Graduate students Michelle Feltz and Jacola Roman presented results at the EUMETSAT satellite conference:
   Feltz, M.L., R.O. Knuteson, H.E. Revercomb, and D. C. Tobin (2013), Using GPS Radio Occultation in the Validation of IR Temperature Sounding Profiles from CrIS, IASI, and AIRS. EUMETSAT Sat Met. Conf., September 2013, Vienna, Austria.

   Roman, J.A., R.O. Knuteson, S.A. Ackerman, and H.E. Revercomb (2013), Use of satellite-derived PWV to detect extreme flooding events. EUMETSAT Sat Met. Conf., September 2013, Vienna, Austria.

3. Team contribution to two NOAA STAR lead journal papers:
   Nalli, N., et al., Validation of Satellite Sounder Environmental Data Records: Application to the Cross-track Infrared Microwave Sounder Suite (CrIMSS) [Paper #2013JD020436R], submitted to Journal of Geophysical Research – Atmospheres.

   Divakarla et al. , The CRIMSS EDR Algorithm: Characterization, Optimization and Validation, [Manuscript # 2013JD020438], submitted to Journal of Geophysical Research – Atmospheres.

Publications and Conference Reports

Bedka, Sarah; Knuteson, Robert; Revercomb, Henry; Tobin, David, and Turner, David, 2010. An assessment of the absolute accuracy of the Atmospheric Infrared Sounder v5 precipitable water vapor product at tropical, midlatitude, and arctic ground-truth sites: September 2002 through August 2008. Journal of Geophysical Research v.115, no.D17, 2010, ppdoi:10.1029/2009JD013139.

Feltz, M.L., R.O. Knuteson, H.E. Revercomb, and D. C. Tobin (2014), A methodology for the validation of temperature profiles from hyperspectral infrared sounders using GPS radio occultation: Experience with AIRS and COSMIC, J. Geophys. Res. Atmos.,119, 1680–1691, doi:10.1002/2013JD020853.

Feltz, M.L., R.O. Knuteson, S.A. Ackerman, H.E. Revercomb, and D. C. Tobin (2014), Application of GPS Radio Occultation to the Assessment of Temperature Profile Retrievals from Microwave and Infrared Sounders, Atmospheric Measurement Techniques, submitted.

Feltz, M.L., R.O. Knuteson, H.E. Revercomb, and D. C. Tobin (2013), Using GPS Radio Occultation in the Validation of IR Temperature Sounding Profiles from CrIS, IASI, and AIRS. EUMETSAT Sat Met. Conf., September 2013, Vienna, Austria.

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

15.4 CrIMSS EDR Cal/Val: ARM Site Support

CIMSS Task Leader: Dave Tobin
CIMSS Support Scientists: Lori Borg, Robert Knuteson
NOAA Collaborators: Nicholas Nalli, Tony Reale

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 proposed work is designed to prepare for and to conduct efforts for the critical validation of NPP CrIMSS atmospheric temperature and water vapor retrieved profiles and observed infrared radiances. The assessment of soundings on the 1K/km level and the establishment of a long term set of well-characterized sounding products, requires accurate and on-going validation data. The Atmospheric Radiation Measurement (ARM) program field sites provide such data. In this arrangement, radiosondes are launched from the ARM sites coincident with the satellite overpasses of the sites, and analysis is performed by UW-Madison personnel to compare the radiosonde and CrIMSS EDR products to assess the accuracy of the satellite products. Previously for AIRS and IASI, best estimates of the atmospheric state and surface properties at the satellite overpass times were produced via a similar collaborative effort between NASA and ARM. This work was a fundamental, integral, and cost-effective part of the EOS validation effort and provided critical accuracy assessments of the AIRS temperature and water vapor soundings. Further science justification and details of the approach for this effort are described in detail in Tobin et al., 2006. This effort is anticipated to be repeated throughout the NPP mission life into FY15.

Summary of Accomplishments and Findings
Over the last year, this effort involved the continuing coordination of sonde launches at three ARM sites; the Southern Great Plains (SGP), North Slope Alaska (NSA), and Tropical West Pacific (TWP) Manus sites, coincident with overpasses of the NPP-Suomi satellite. 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 were presented at the EUMESAT conference in Vienna in September 2013 (Borg, L., et al., 2013) and at the ARM conference in Atlanta, GA in February 2014 (Borg, L. et al., 2014) and effort was contributed to the journal publication by Nalli et al., 2013.

Phase1 of this effort began in June 2012 at all three ARM sites and was complete after 6 months at NSA and SGP, but due to launch and contract issues ran through June 2013 at TWP. Phase2 of this effort began in June 2013 and is ongoing. As of March 2014, sondes have been launched coincident with 159 overpasses at NSA, 155 at SGP, and 152 at TWP and were a combination of single- and dual-sondes at NSA and SGP and single-sondes at TWP. Phase2 of this effort has been extended through September 2014 at NSA and SGP, but will cease at TWP in May 2014 due to the closure of this site. It is unfortunate to lose the TWP site for this effort, but discussions with

ARM are ongoing to begin launches at the ARM Eastern North Atlantic (ENA) site in future phases.

Samples of results from this effort to validate CrIMSS temperature and water vapor profiles are shown below. Figure 61 shows the differences between sondes in dual-sonde pairs at NSA and SGP and represent the mean variability in the temperature and water vapor that occurs within 40 minutes. Analysis of this type is critical in understanding the errors associated with this validation method, and for temperature and (water vapor) are on the order of 0.4°K (0.1 g/kg) at NSA and 0.5°K (0.3 g/kg) at SGP. Figure 62 shows the differences between the ARM site best estimates and retrievals using the CSPP hyperspectral retrieval model. It is clear that the ARM site best estimate differs with the CSPP retrievals. For example, at TWP, there are large temperature biases, on the order of 3-4K, near 250mb and 50mb along with large water vapor biases near the surface. While large differences were not unexpected, since CSPP is an IR only retrieval model, these differences are being investigated. This retrieval model was chosen for this analysis because the operational CrIMSS EDR code is no longer being supported. For more information regarding CSPP, see http://cimss.ssec.wisc.edu/cspp/. Additional comparisons were made using retrievals from the GDAS model, which compare very well with the ARM site best estimates. Given that the GDAS model is heavily weighted by synoptic radiosondes, this was also expected.

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.

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.

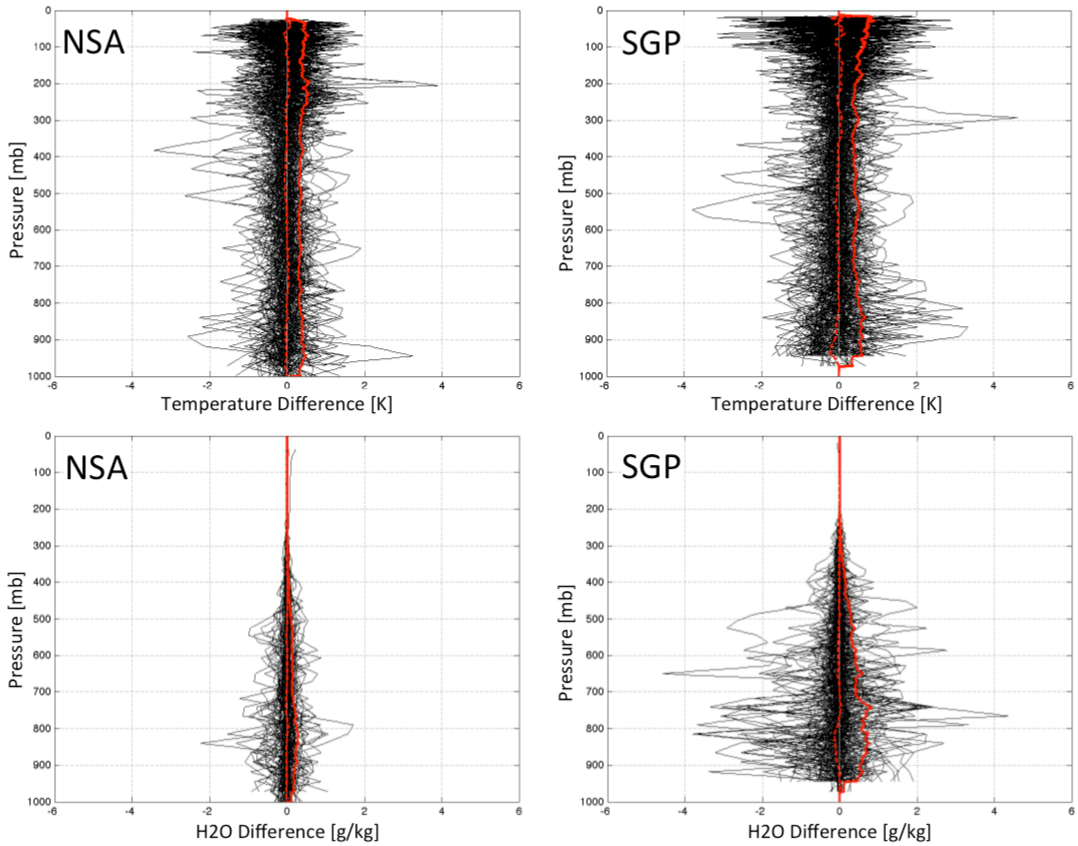

Figure 61. Difference between sondes in dual-sonde pairs at NSA (left) & SGP (right): Temperature (top) & H2O (bottom) versus pressure, with mean (dashed-red) and stdev (solid-red).

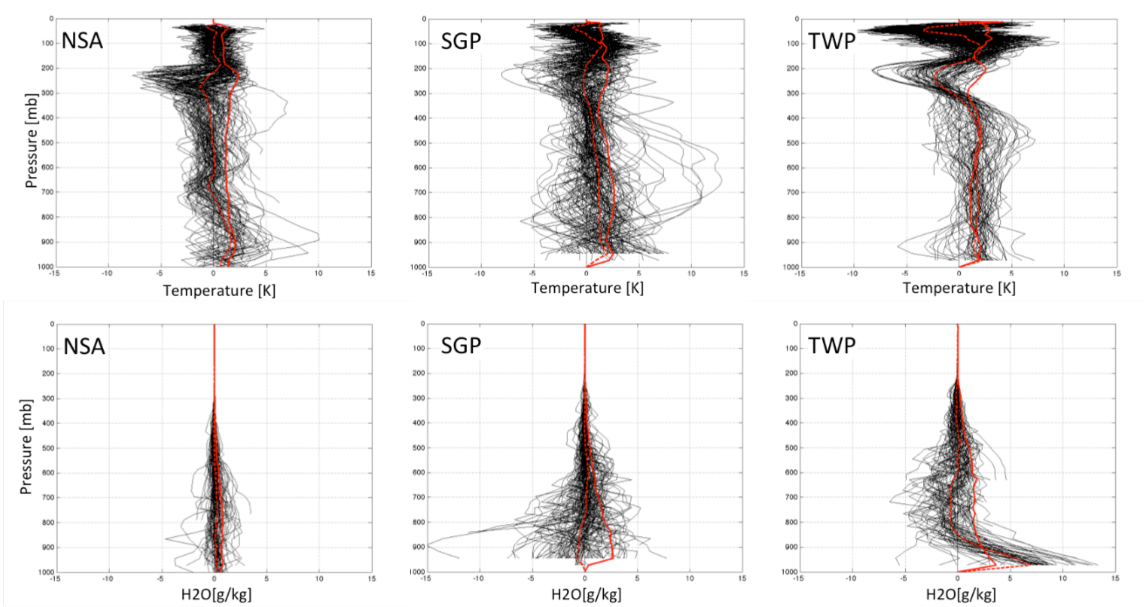

Figure 62. Difference between ARM Site Best Estimate & CSPP Temperature (top) & H2O (bottom) Profiles versus pressure, with mean (dashed-red) and stdev (solid-red). NSA (left), SGP (middle), and TWP (right).

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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.

16. CIMSS Participation in the JPSS Algorithm Continuity Risk Reduction Program for 2013

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

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

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

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

CIMSS Research Themes:
- Satellite Meteorology Research and Applications

Project Overview

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

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

Summary of Accomplishments and Findings

GOES-R algorithms have been modified to run using VIIRS data. Differences between ABI and VIIRS are taken into account, particularly the number and characteristics of the spectral bands of GOES-R ABI and VIIRS. Parameters related to the sensor characteristics have been updated in the algorithm. The latest algorithm has been transferred to the Algorithm Integration Team (AIT) with test cases. Initial test run shows identical results as the outputs here in CIMSS. Figure 63 shows examples of ice concentration, thickness, and age retrieved with VIIRS data.

More case studies have been generated, and results are being compared to operational VIIRS products and to products generated with MODIS data. Preliminary comparison shows better performance of our algorithm than that of the operational VIIRS algorithm. More validation with in-situ observations will be performed. The algorithm has been implemented locally in CIMSS, and generating near real-time VIIRS products.

The process of integrating the algorithms into the GOES-R Algorithm Integration Team's "Framework" has begun. Documents, such as the Algorithm Theoretical Basis Documents (ATBD) that were written for ABI, will be modified accordingly.

A number of design reviews are required for this project. We had the Critical Design Review (CDR) in April 2013.

Publications and Conference Reports

Liu, Y., J. Key, and X. Wang, 2013, Sea Ice Concentration with the Combined Use of Microwave and Visible/infrared Observations, 2013 AGU Fall Meeting, 9-13 December 2013, San Francisco California, USA.

Jeffrey R. Key, Robert Mahoney, Yinghui Liu, Peter Romanov, Mark Tschudi, Igor Appel, James Maslanik, Dan Baldwin, Xuanji Wang, and Paul Meade, 2013, Snow and Ice Products from Suomi NPP VIIRS, JGR-Atmospheres, 118, doi:10.1002/2013JD020459.

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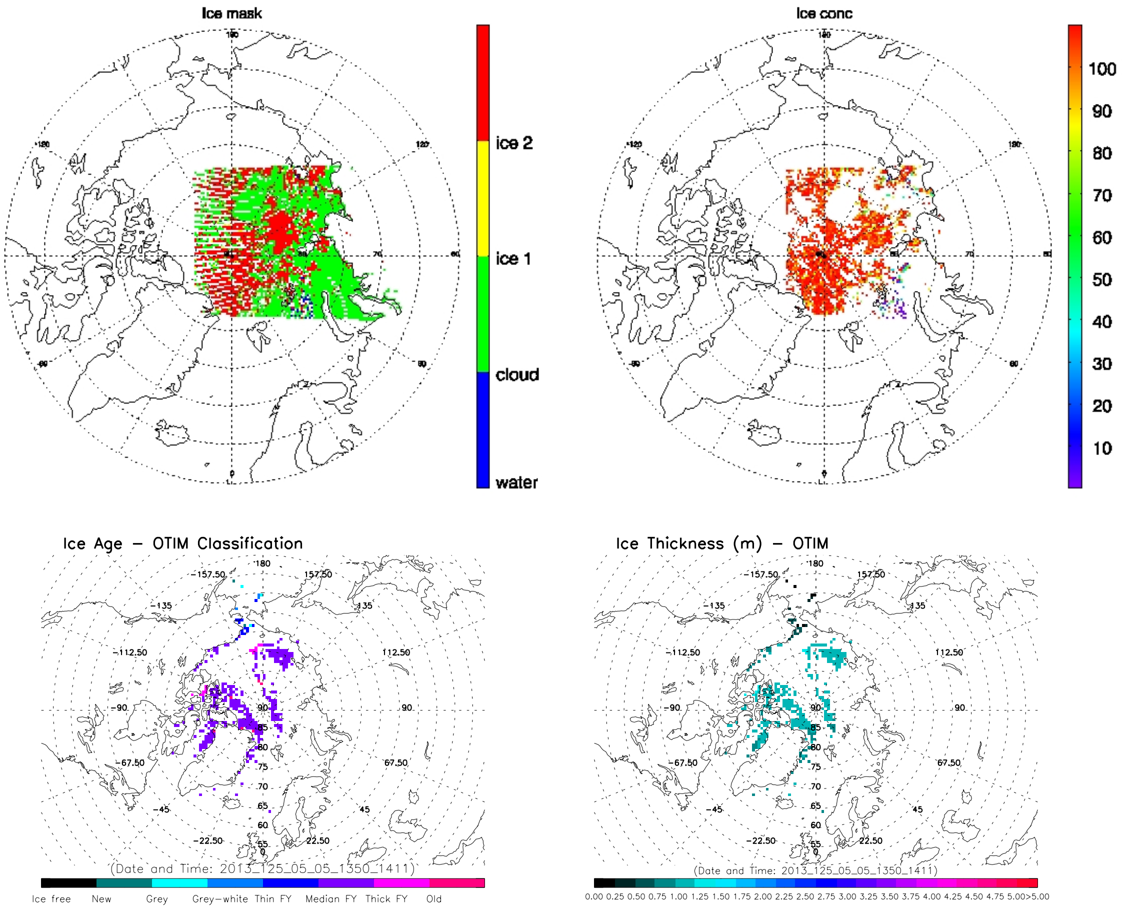

Figure 63. Sea ice mask (top-left) and ice concentration (top-right) with VIIRS data 01:17 to 01:38 UTC on October 25th, 2013, and OTIM retrieved sea ice age (bottom left) and sea ice thickness (bottom-right) at 13:50 UTC on May, 5th, 2013.

16.2 Transition of GOES-R AWG Cloud Algorithms to VIIRS

CIMSS Task Leader: Andi Walther
CIMSS Support Scientist: Denis Botambekov
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 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.univ-lille1.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 capability of the GOES-ABI cloud algorithms to run on VIIRS level-1b data. This involved the preparation of scientific software, the evaluation of the output and optimization work. This was initially done within the retrieval software package CLAVR-x, which is hosted at CIMSS.

We took special focus on the additional channels on VIIRS (in comparison to current GOES sensors), which will increase the performance of the algorithms.

Regarding DCOMP, we have been working on improved optical properties retrieval over snow and sea-ice surfaces, which will play a greater role for a polar-orbiting sensor. The outcome of this research will lead to better results in these difficult regions over the poles.

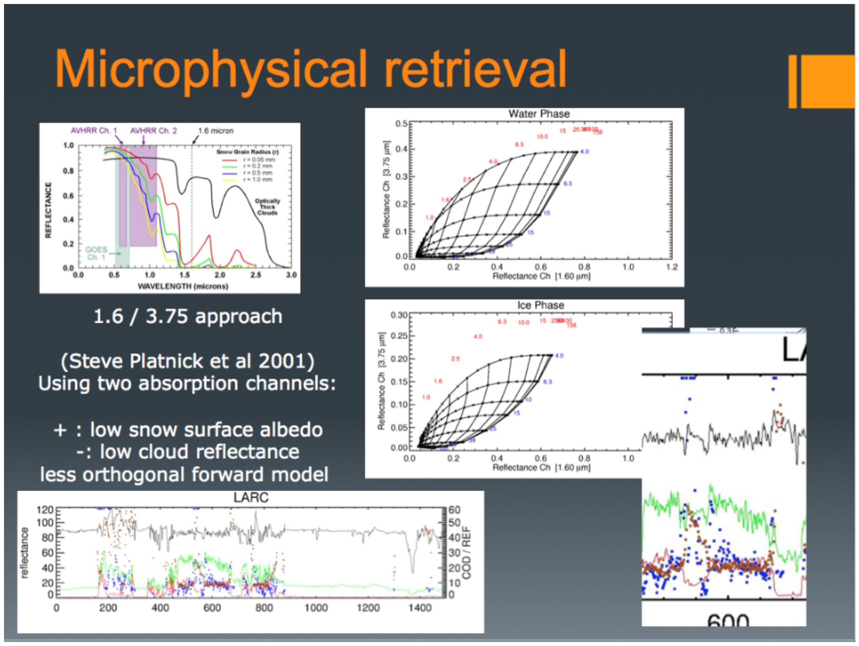

Figure 64. Part of talk at the EUMETSAT Cloud Retrieval and Evaluation Workshop in Grainau, Germany March 2014.

A further step is the preparation of these retrieval codes in the NOAA/STAR retrieval system FRAMEWORK.

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

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

NOAA Long Term Goals:
- Weather-Ready Nation

NOAA Strategic Goals:
- 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. Figure 65 shows an example of the modified GOES-R ash detection and retrievals using VIIRS. A spatially very small ash cloud from the Tungurahua volcano in Ecuador was detected, with a retrieved height between 8 and 9 km (26 and 30 kft). The early results are encouraging and continued research into modifying the GOES-R Volcanic ash algorithms for optimal use with VIIRS will continue.

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 indicates that some modifications are needed in order to improve the performance of the algorithm. These modifications include fine tuning threshold functions and values that are used to differntiate 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. The top image in Figure 66 shows a VIIRS false color image where bare land appears green, ice clouds look bright pink and water clouds are yellowish in color. The bottom left image shows the VIIRS cloud type algorithm before modifications were made to the threshold functions. The bottom right image shows the VIIRS cloud type algorithm applied using the new modified threshold functions. Note that the convective cloud tops in the red-circled area are now correctly identified as opaque ice clouds instead of mixed phase. Further evaluation and threshold tuning is needed, but 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 will be the first algorithm (before the volcanic ash algorithms) to start the transition into operations during the summer of 2014.

Tungurahua – March 06, 2013

Higher spatial resolution and additional spectral channels are critical. VIIRS IR channels have a spatial resolution of 750 m!

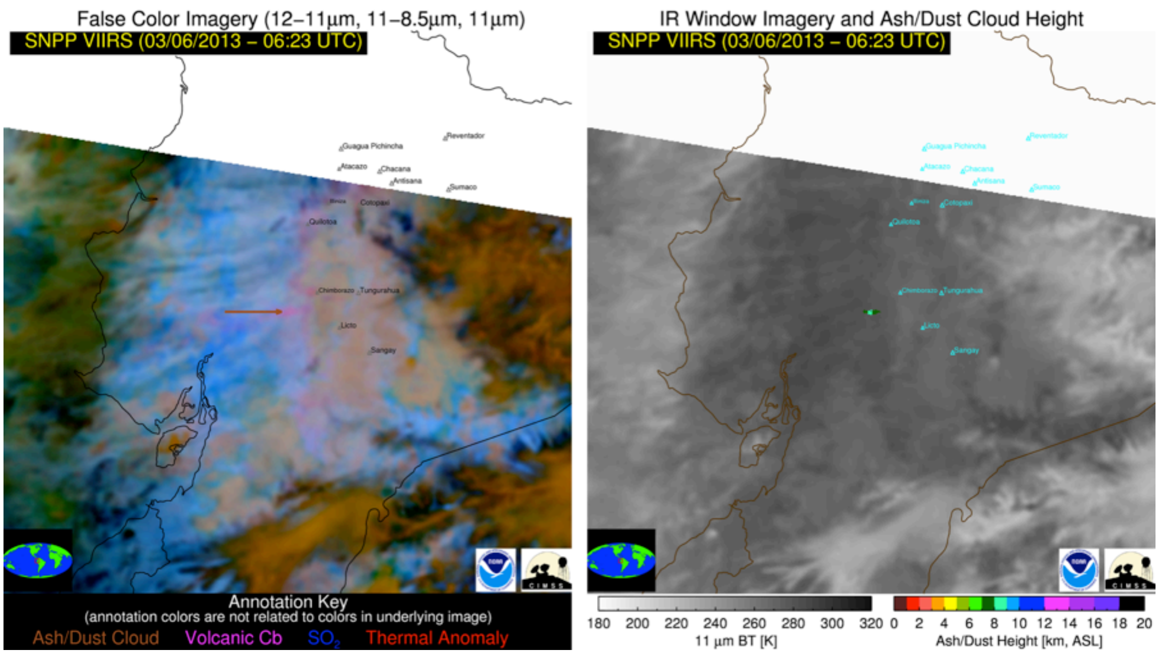

Figure 65. An example of output from modified GOES-R Volcanic algorithms for use with VIIRS from an eruption of Tungurahua volcano at 0632 UTC 06 March 2013. The left panel is a false color VIIRS imagery, with a small ash cloud denoted by the brown arrow. The right panel is the 11 µm brightness temperature imagery with retrieved ash height in the dark/light green (approximately 8-9 km).

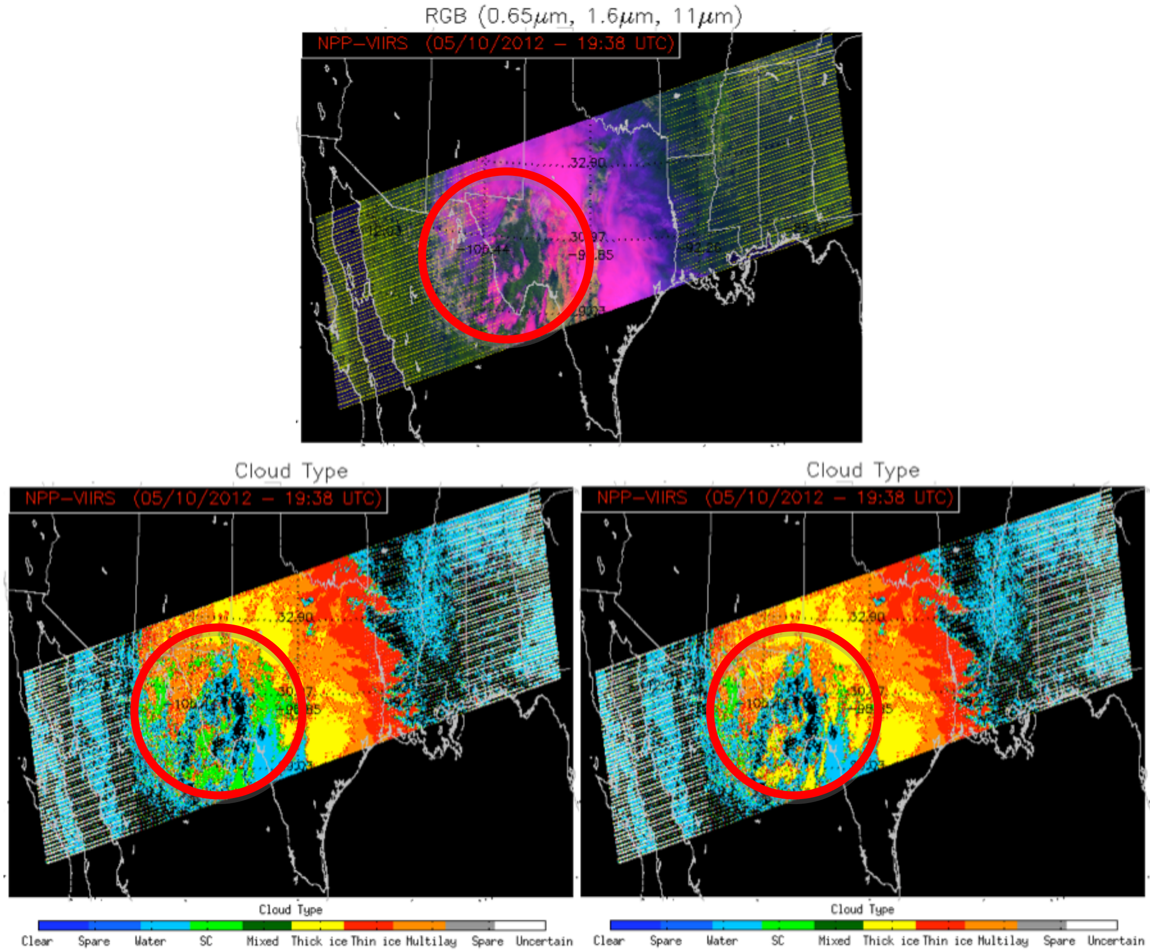

Figure 66. A daytime VIIRS scene over Texas on May 10, 2012 at 1938Z. The top panel is a false color image where ice clouds appear pink and water clouds appear yellowish. The bottom left panel is the VIIRS cloud type product with the original infrared cloud phase discrimination threshold function. The bottom right panel is the VIIRS cloud type product with the updated threshold function.

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

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.

16.4 JPSS Algorithm Integration Team

CIMSS Task Leader: R. K. Garcia
CIMSS Support Scientist : G. D. Martin, E. N. Schiffer, W. C. Straka III
NOAA Collaborator: W. Wolf

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

CIMSS Research Themes:
- Satellite Meteorology Research and Applications

Project Overview
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.

Algorithms are primarily adapted from GOES-R algorithm implementations, with necessary updates and modifications for multi-satellite and polar-orbiter use. AIT-MW will principally be supporting algorithms originating at UW-Madison CIMSS. This includes technical, implementation, and portability/compatibility concerns for development and operational target systems. It also includes management of testing, delivery, and acceptance process.

Efforts will be focused on risk-reduction for NPP / JPSS, i.e., adapting, testing and validating for NPP a subset of product algorithms researched for and initially applied to GOES-R.

Milestones for 2013
- Reviews complete for candidate algorithms and current implementations, identifying strategy for use with VIIRS input.
- Framework software interfaces reviewed and compared/contrasted among AIT Framework, GEOCAT, CLAVR-x, NPP IDPS/ADL, Harris/AER DMI for GOES-R. Preliminary software portability strategy defined.
- Algorithms divided into trailblazer, second round, final round by expected difficulty level.
- Demonstration of Cloud product algorithms on development framework using VIIRS.

Summary of Accomplishments and Findings
For the JPSS-RR effort, a number of algorithms have been ported to a revised "framework-agnostic" interface specification allowing science code modules to be improved independently of framework interface modules, given prerequisites and outputs remain largely stable. These include the CLAVR-x Cloud Type, which acts as a proxy for the Cloud Type algorithm, and ABI Cloud Height algorithms. Delivery of a Naive Bayesian Cloud Mask applicable to JPSS was included in this work; this algorithm can be applied to multiple sensors supported by CLAVR-x, GEOCAT, and the AIT Frameworks.

The GEOCAT development framework at CIMSS introduced capability to operate on VIIRS Moderate Resolution Band ("M-Band") SDR and geolocation data, as well as be able to calculate the clear sky radiance values using both the PFAAST and CRTM models.

Assistance with preparation for Critical Design Reviews of JPSS-RR revised algorithms also took place.

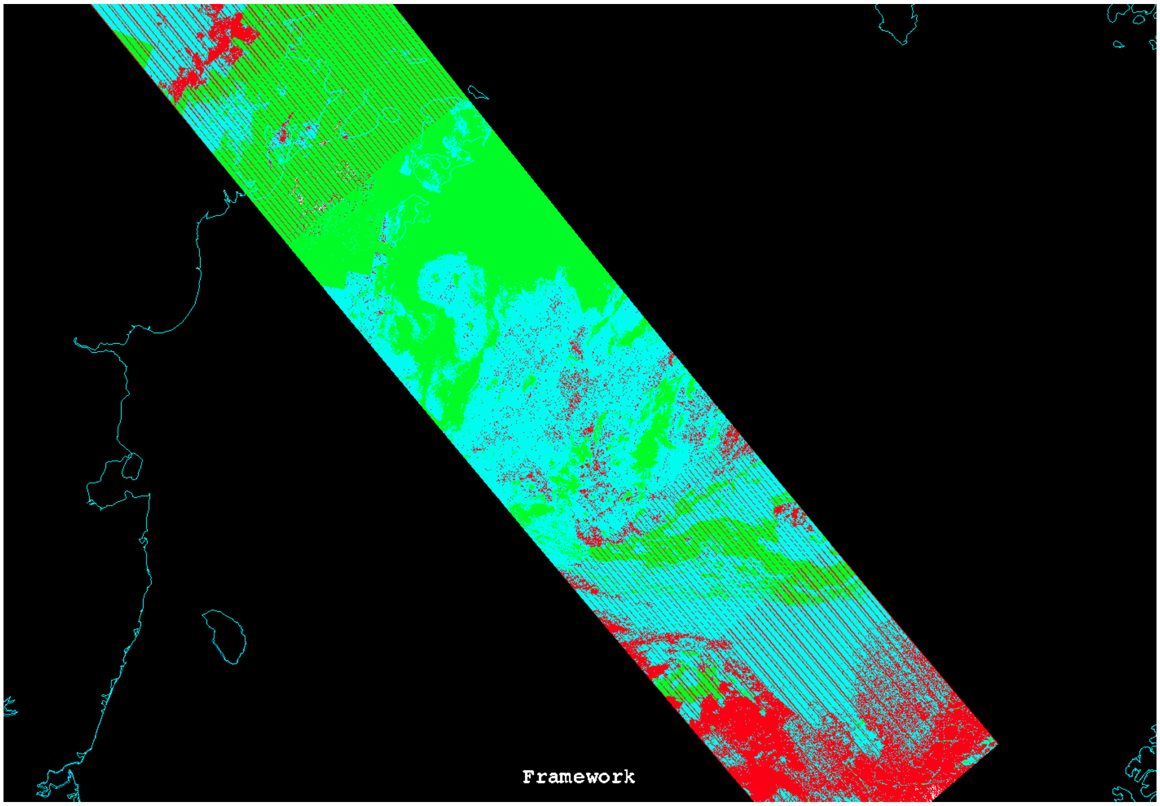

Figure 67. GOES-R AWG Cloud Mask for VIIRS in Framework.

17. 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 Sr., Nadia Smith
NOAA Collaborator: Mitch Goldberg

NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

NOAA Strategic Goals:

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

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

- Environmental Models and Data Assimilation
- Education and Outreach

Project Overview

Accurate retrievals from hyperspectral sounder radiance measurements under both clear and cloudy sky conditions are becoming indispensible sources of mesoscale information in a wide range of applications. In particular the use of hyperspectral retrieval data in complement with visible imagery and products from broadband imagers has the potential to greatly enhance regional weather prediction capabilities. To initiate the operational use of hyperspectral retrieval data in NWS (National Weather Service) forecasting offices we propose to prepare retrieval products from AIRS, IASI and CRIS 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 University of Wisconsin hyperspectral retrieval software package for direct-broadcast applications has been released in November 2012 as part of the Community Satellite Processing Package (CSPP). The last version update has been released in September 2013. This multi-instrument retrieval algorithm is based on the Dual-Regression (DR) method (Smith et al., 2012, Weisz et al., 2013) for use with CrIS (Cross-track Infrared Sounder), AIRS (Atmospheric Infrared Sounder) or IASI (Infrared Atmospheric Sounding Interferometer) radiance measurements. It retrieves a suite of surface, cloud and atmospheric parameters at single field-of-view resolution.

We have demonstrated that hyperspectral retrieval data (e.g., cloud top pressure, cloud optical thickness) adds valuable quantitative information to visible imagery. As an example a low-pressure system over the Gulf of Alaska is shown in Figure 68. The VIIRS image of the longwave infrared band centered at 11.45 µm (upper left panel in Figure 68) shows great details of the storm, whereas the CrIS retrievals increase our understanding of the atmospheric situation by adding absolute values of humidity, cloud altitude and cloud optical thickness. Close collaboration with Alaska Weather Forecast Offices (WFOs) through the Geographic Information Network of Alaska (GINA) at the University of Alaska Fairbanks (UAF) has been pursued to demonstrate the accuracy as well to ensure the relevance of the products to the forecasters.

For high latitudes, such as for the Alaskan region, Aqua/NPP and MetOp overpasses are frequent enough to allow the study of atmospheric changes. Hence, via atmospheric retrievals from different sounders on consecutive orbits at 10-60 minute intervals we were able to explore atmospheric dynamics by means of time tendencies or weather changes. These include atmospheric cloud and moisture motion, as well as thermodynamic instability tendencies. In particular, before and during storm systems the atmospheric situation changes very quickly. We found that the change in stability (e.g., lifted index) and clouds (in altitude, thickness, temperature) can be detected from subsequent orbits, thus providing valuable information on convective instability, moisture transport and atmospheric motion.

To support WFOs software to convert selected retrieval products (i.e., clout top pressure, cloud optical thickness, temperature and relative humidity at 500 hPa, lifted index) to formats apt for display and analysis in AWIPS has been developed. This provides an easy tool for forecasters to view imager and sounder products simultaneously and therefore fully utilize the sounders' information about the atmosphere. Figure 69 depicts a sample screenshot of an AWIPS display showing various parameters retrieved from CrIS radiance measurements.

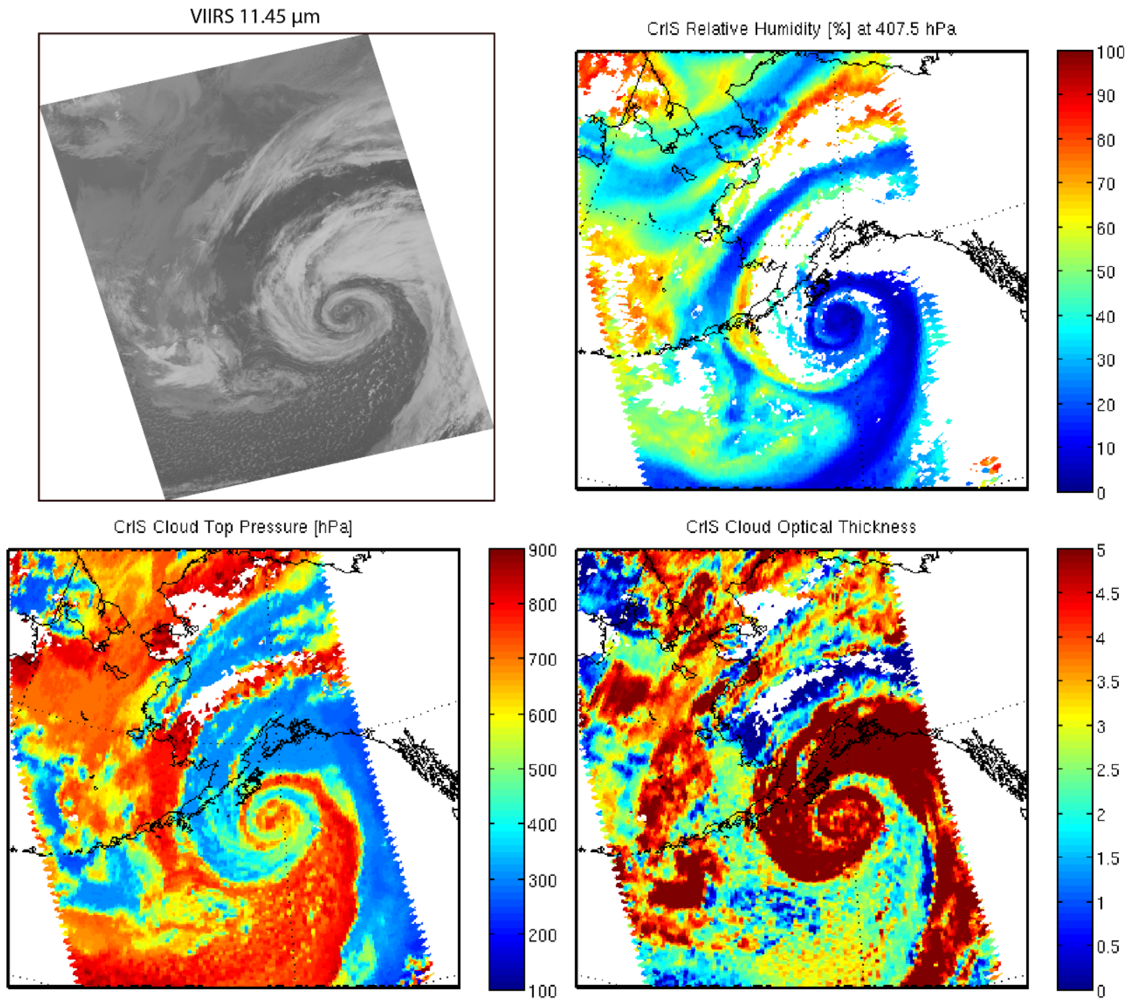

Figure 68. VIIRS I5 band, and CrIS retrievals of relative humidity (at 400 hPa), cloud top pressure and cloud optical thickness on 26 Sept 2012.

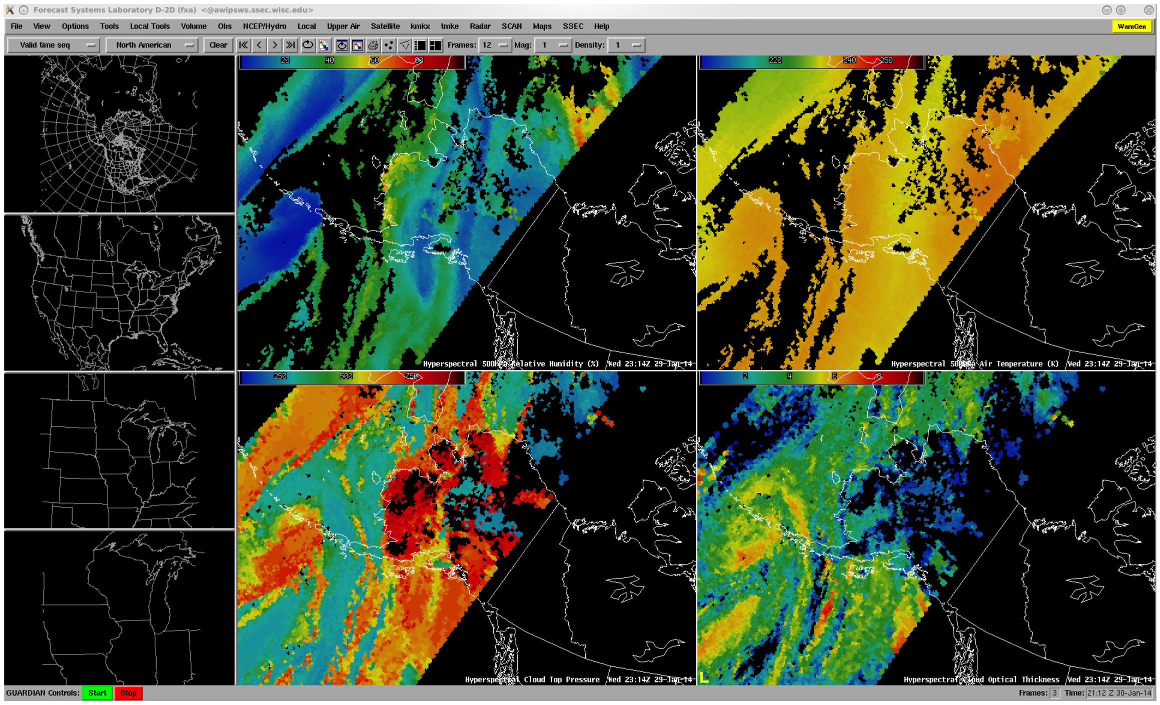

Figure 69. AWIPS screenshot showing relative humidity and temperature at 500 hPa, cloud top pressure and cloud optical thickness, retrieved from CrIS measurements on 29 Jan 2014.

Publications and Conference Reports

Weisz, E., W. L. Smith, and Nadia Smith (2013), Advances in simultaneous atmospheric profile and cloud parameter regression based retrieval from high-spectral resolution radiance measurements. Journal of Geophysical Research -Atmospheres, 118, 6433-6443.

Weisz, E., W. L. Smith, N. Smith, Community Satellite Processing Package (CSPP) Cross-track Infrared Sounder (CrIS) Dual- Regression Retrievals and Applications. NOAA 2013 Satellite Conference, 8-12 April 2013, College Park, MD.

Smith, N., E. Weisz, W. L. Smith, A Fresh Look at Hyperspectral Sounders: How 3-D Quantitative Information About the Atmosphere Can Enhance Real-Time Applications and Decision Making. CSPP/IMAPP Users' Group Meeting, 21-23 May 2013, Madison, WI.

Weisz, E., W. L. Smith, N. Smith, JPSS PG Hyperspectral Sounder Retrieval Applications. JPSS Science Seminar, 22 July 2013.

Smith, N., E. Weisz, and W.L. Smith Sr., Nowcasting applications with polar-orbiting sounders: a multi-instrument approach. Workshop on NWC applications using MTG-IRS, 25–26 July 2013, EUMETSAT HQ, Darmstadt, Germany.

Weisz, E., W. L. Smith, N. Smith, Quantitative Information Retrieved from Hyperspectral Sounders for Real-Time Applications. 2013 Joint EUMETSAT/AMS Conference, 16-20 September 2013, Vienna, Austria.

Weisz, E., W. L. Smith, N. Smith, W. Straka, R. Garcia, D. Hoese, Encouraging the Use of Hyperspectral Sounder Products in Forecasting Applications. 94th AMS Annual Meeting, 2-6 February 2014, Atlanta, Georgia.

Weisz, E., W. L. Smith, N. Smith, J. Feltz, S. Bachmeyer, J. Gerth, New Perspectives on Using Multi-Instrument Hyperspectral Sounder Information in the Analysis of Severe Local Storms. 94th AMS Annual Meeting, 2-6 February 2014, Atlanta, Georgia.

Weisz, E., W. L. Smith, N. Smith, Using Real-Time Retrievals from Multiple Hyperspectral Sounders in the Analysis of Superstorm Sandy. 94th AMS Annual Meeting, 2-6 February 2014, Atlanta, Georgia.

Smith, W. L., A. Larar, H. Revercomb, M. Yesalusky, E. Weisz, The May 2013 SNPP Cal/Val Campaign – Validation of Satellite Soundings, 19th International TOVS Study Conference (ITSC-19), 26 March - 1 April 2014, Jeju Island, South Korea.

Smith, N., E. Weisz, W. L. Smith, An overview of the UW Hyperspectral Retrieval System for AIRS, IASI and CrIS. 19th International TOVS Study Conference (ITSC-19), 26 March - 1 April 2014, Jeju Island, South Korea.

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.

18. UW Scanning-HIS Participation in the NPP/JPSS Aircraft Field Campaigns

CIMSS Task Leaders: Dave Tobin, Joe Taylor, Hank Revercomb
CIMSS Support Scientists: Ray Garcia, Dan DeSlover, Elisabeth Weisz, William Smith
NOAA Collaborator: Mitch Goldberg

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

JAVEx13 (JPSS Airborne Validation Experiment 2013) is an aircraft field campaign conducted in May 2013 for calibration/validation of the JPSS/NPP platform SDRs of CrIS, VIIRS, and ATMS. Including integration and de-integration activities, the University of Wisconsin Scanning-HIS instrument and team are participating in this campaign for five weeks, with ER-2 activities conducted out of Palmdale, CA. Currently, an aircraft campaign is not scheduled for 2014 or 2015, but a campaign is anticipated for the following year.

Related to the JAVEx13, this proposed work includes the following tasks:

1) Post-campaign assessment of Scanning-HIS calibration accuracy.
2) Calibration/validation analysis of the aircraft and satellite observations with emphasis on assessing the radiometric calibration uncertainty of CrIS and VIIRS.
3) Temperature and water vapor retrieval studies, with focus on the impact of FOV size on the impact of cloud contamination, yield, and profile accuracy.

The corresponding proposed milestones were:

- 01 August 2013: Post-campaign assessment of Scanning-HIS calibration accuracy.
  We will perform post-JAVEx13 laboratory calibration tests to assess the spectral and radiometric performance of the Scanning-HIS. This will be combined with pre-launch tests to ensure and document the uncertainty and traceability of the JAVEx13 Scanning-HIS datasets. A report of the results will be provided.
- 30 June 2014: Calibration/validation analysis of the JAVEx13 aircraft and satellite observations with emphasis on assessing the radiometric calibration uncertainty of CrIS and VIIRS.
  This task involves analysis of the JAVEx13 dataset to determine conditions for which the aircraft and satellite data are suitable for intercomparison, followed by spatial, temporal, and spectral processing to create radiometric comparisons of the Scanning-HIS and satellite data. This will include assessments of the CrIS and VIIRS infrared observations, as well as AIRS and IASI if suitable underflights are obtained. These results will be provided in a report, presented at conferences, and pending outcome submitted as a journal paper.
- 30 June 2014: Temperature and water vapor retrieval studies, with focus on the impact of FOV size on the impact of cloud contamination, yield, and profile accuracy.
  Future versions of CrIS and other hyperspectral infrared sounders may have smaller footprints. Cloud contamination is a major source of uncertainty in atmospheric profile retrievals as well as a limiting factor in NWP radiance assimilation. In this work, we will use the JAVEx13 Scanning-HIS 2-km footprint observations to study the impact of footprint size on the ability to detect clear sky footprints and on the accuracy of temperature and water vapor profiles for footprint sizes from 2km to 14 km. The results will be provided in a report.

Summary of Accomplishments and Findings

Tasks (1) and (2) have been completed and task (3) is being currently being worked on.

Our efforts related to tasks (1) and (2) have been very successful, and the full results are summarized in a GSICS newsletter and in an AMS extended abstract (see Publications and Conference Reports). Figure 70 shows example CrIS and Scanning-HIS brightness temperature maps for four of the underflights obtained during JAVEx13. A comprehensive detailed report of the analysis is being finalized and provided to the project, and a journal paper is being prepared. Summarizing the results, we have established very good traceability and low uncertainty of the

Scanning-HIS filed campaign data and have validated the CrIS observations with uncertainty of approximately 0.2 K 3-sigma.

Our efforts related to task 3 (FOV size study) are underway and we expect to have results by the end of the proposed period of performance. The current study is examining the Dual Regression retrievals from the JAVEx13 Scanning-HIS data to study the impact of footprint size on the ability to detect clear sky footprints and on the accuracy of temperature and water vapor profiles for footprint sizes from 2km to 14 km.

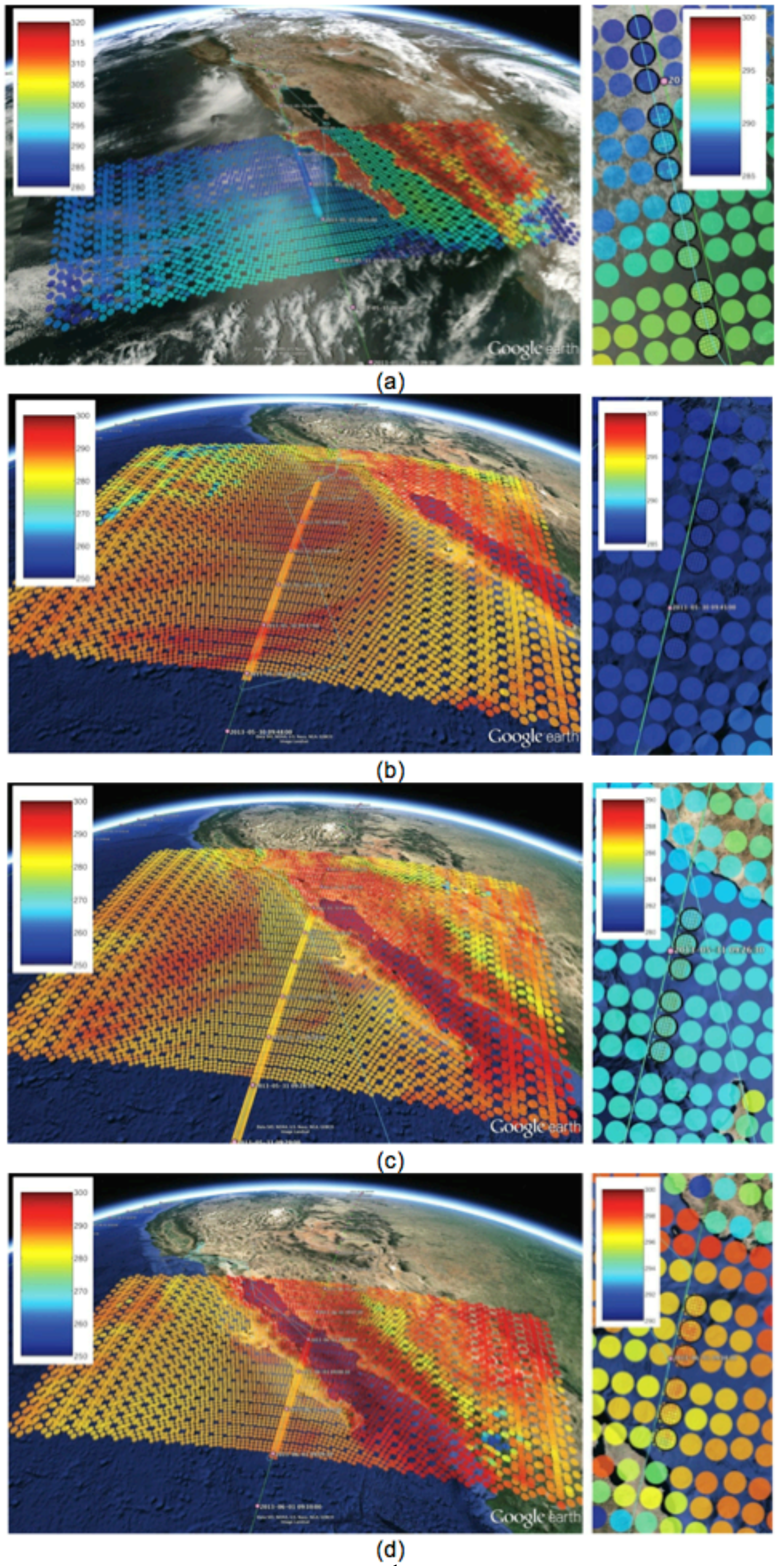

Figure 70. Brightness temperature images (895 – 900 cm^{-1} mean) for (a) 2013-05-15, (b) 2013-05-30, (c) 2013-05-31, and (d) 2013-06-01 SNPP under-flights. The images in the left column show the CrIS and S-HIS footprints over a large region surrounding each underpass, while the images on the right provide a closer view of the overpass region. FOVs used in the intercalibration for each underflight are outlined in black.

Publications and Conference Reports

Taylor, Joe K, DC Tobin, HE Revercomb, FA Best, RO Knuteson, DA Adler, C Pettersen and RK Garcia. "Suomi NPP/JPSS Cross-Track Infrared Sounder (CrIS): Calibration Validation with the Aircraft Based Scanning High-Resolution Interferometer Sounder (S-HIS)." In AGU Fall Meeting. San Francisco, CA: American Geophysical Union, 2013.

Tobin, David and Joe Taylor, CrIS Radiometric Uncertainty and Recent Aircraft Underflights to Establish its On-Orbit Traceability, GSICS Quarterly Newsletter, Volume 7 Number 4, 2014, doi: 10.7289/V55Q4T1S

Taylor, J. K., D. Tobin, H. Revercomb, F. Best, R. Garcia, B. Imbiriba, and M. Goldberg, 2014: Suomi NPP/JPSS Cross-track Infrared Sounder (CrIS): Calibration validation with the aircraft based Scanning High-resolution Interferometer Sounder (S-HIS). Annual Symposium on Future Operational Environmental Satellite Systems, 10th, Atlanta, GA, American Meteorological Society.

Taylor, Joe K, DC Tobin, HE Revercomb, FA Best, RK Garcia, H Motteler and M Goldberg. "Suomi NPP/JPSS Cross-Track Infrared Sounder (CrIS): Calibration Validation with the Aircraft Based Scanning High-Resolution Interferometer Sounder (S-HIS)." In International TOVS Study Conference XIX. Jeju, Korea: ITWG, 2014.

19. 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

HIRS and IASI cloud top pressures (CTPs) were processed for several granules for data from 15 January 2009 using the Dual Regression algorithm (Smith et al., 2012; Weisz et al., 2013). Figure 71 shows the radiances for IASI (at 910 cm-1) and HIRS (at 11 microns using IASI high spectral resolution data convolved with the HIRS IRW spectral response function). The associated CTPs are shown in Figure 72.

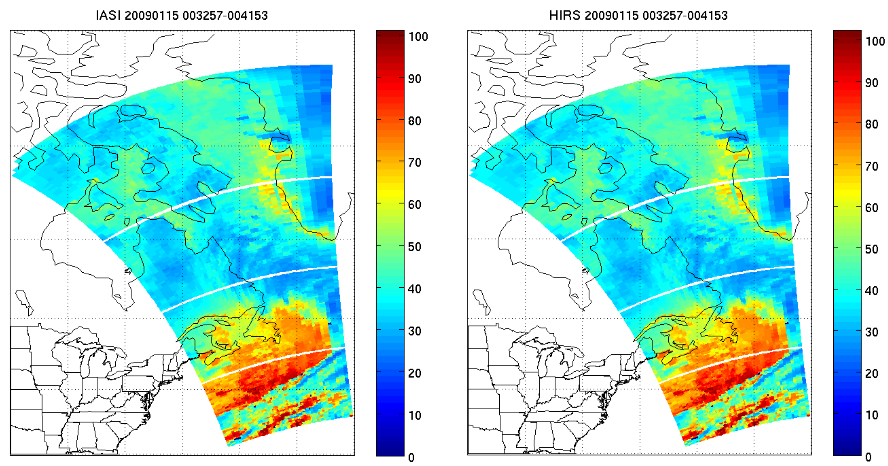

Figure 71. IASI radiances observed on 15 Jan 2009 at 910 cm-1 (left) along with HIRS channel 8 broad band radiances centered at 900 cm-1 simulated by convolving the IASI high spectral resolution radiances with the HIRS IR window spectral response function (right). Good agreement between the two is seen.

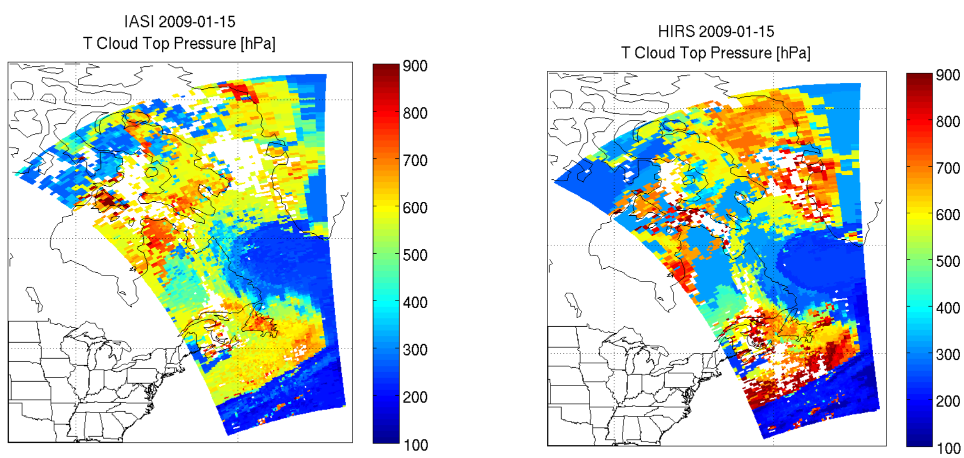

Figure 72. Cloud top pressures determined with the Dual Regression algorithm (Weisz et al., 2013) using IASI radiances (left) and HIRS radiances simulated from IASI (right). IASI captures more mid-level (CTP > 440 hPa) clouds than HIRS but there is good agreement for high level clouds (CTP < 440 hPa).

Table 1 provides a stratification into high-, mid-, and low-level clouds and thin, thick, and opaque clouds. IASI finds more mid-level clouds and fewer low clouds than HIRS. IASI also finds more thin clouds. There is reasonable agreement on total cloud cover and opaque cloud cover.

Table 1. Comparison of IASI (black) and HIRS (red) high-, mid-, and low- level clouds sorted by thin (cloud optical thickness (COT) <1), thick (1<COT<3.5), and opaque (COT>3.5) categories. COT is determined from the Dual Regression algorithm application to IASI data.

	all clouds	COT<1	1<=COT<3.5	COT>=3.5
High (<440)	40% 49%	7% 4%	12% 18%	21% 27%
Mid (440-680)	45% 26%	10% 2%	24% 22%	11% 2%
Low(>680)	5% 16%	3% 3%	2% 13%	0% 1%
Total	90% 91%	20% 9%	38% 53%	32% 30%

Publications and Conference Reports
Abstract has been submitted to Boston AMS Cloud Conference in July 2014

References
Smith, W. L., E. Weisz, S. Kirev, D. K. Zhou, Z. Li, and E. E. Borbas, 2012: Dual-regression retrieval algorithm for realtime processing of satellite ultraspectral radiances. *J. Appl. Meteor. Climatol.*, **51**, 1455–1476.

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.

20. 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 will be developed that uses thermal channels and radiance data from ATMS in the near storm environment to estimate TC intensity. This new information will be incorporated into existing intensity estimation techniques previously developed at CIMSS that already employ similar radiance data from AMSU and SSMIS. Once the ATMS algorithm is mature, the products will be made available through the JPSS Proving Ground to operational forecasters at the National Hurricane Center (NHC) and Joint Typhoon Warning Center (JTWC) for evaluation and feedback. If the evaluation is positive, the products can be transitioned to NHC and JTWC operations.

Summary of Accomplishments and Findings

Work this period has focused on evaluating the CIMSS ATMS MSLP intensity algorithm and developing a scan angle bias correction to produce bias-corrected brightness temperatures. 120 ATMS passes have been processed for the period 2012-2014. MSLP estimates from the ATMS algorithm for these 120 passes have been compared to Best Track (BT) MSLP estimates for validation. Best Track MSLP estimates were derived using all available data and include storms for all ocean basins. Validation represents a mix of ground truth observations of MSLP from aircraft reconnaissance in the Atlantic (40 cases) and satellite-based estimates from both objective (SATCON) and subjective (Dvorak IR-based) estimates along with a few surface observations for the remaining cases. Figure 73 shows a comparison of the ATMS-derived MSLP estimates to the BT estimates. For this sample, the bias = 0.3 hPa, Average Error = 7 hPa and RMSE = 9.4 hPa.

Up until now, ATMS Tb anomalies were calculated using uncorrected data. This is possible by producing the anomalies in the along-track direction where there is no change in scan angle. This approach, however, limits the number of environmental Tbs that can be used in the algorithm. Also, it is desirable to display the Tb anomaly cross sections in both the horizontal and vertical direction for direct comparisons to AMSU and SSMIS-derived Tb anomalies. Therefore, a scan angle correction has been developed to account for the scan angle bias. The 120 cases will be re-processed using the corrected data and the regressions re-derived. In addition a Vmax algorithm will be added to the MSLP algorithm.

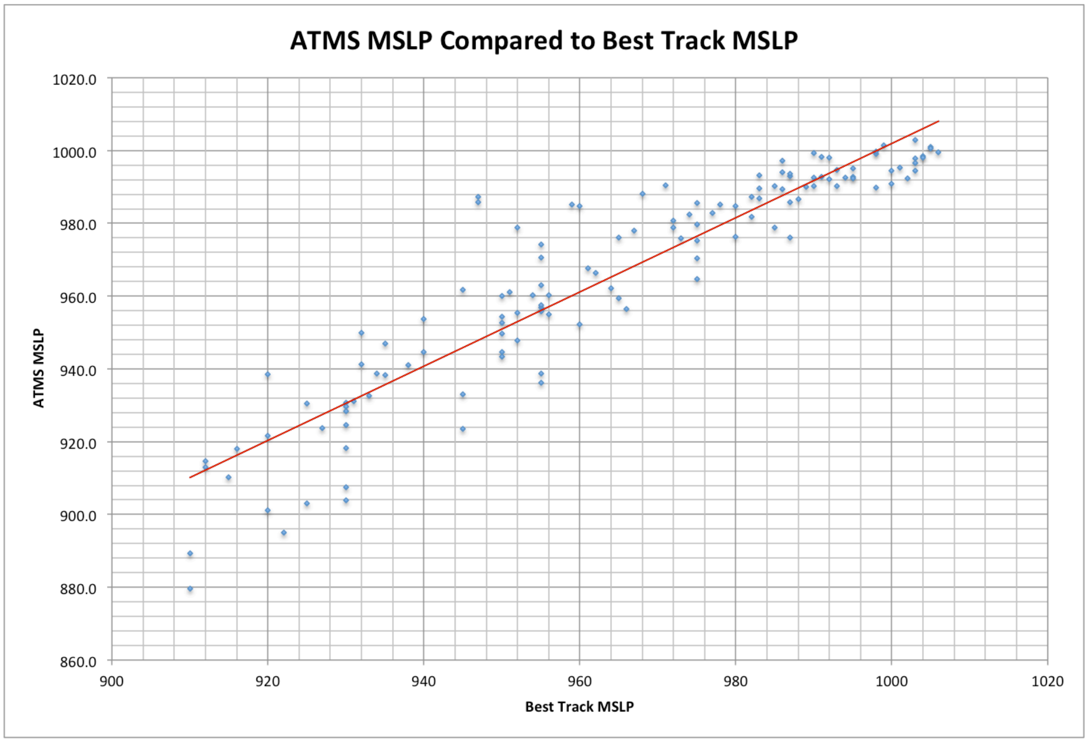

Figure 73. ATMS MSLP estimates compared to Best Track MSLP estimates for 2012-2014 (N=120).

Publications and Conference Reports

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.

21. 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

OTIM was initially developed for ice thickness estimation using GOES-R Advanced Baseline Imager (ABI) data. It has been modified to run using VIIRS data products of ice surface temperature and ice surface albedo. Recent improvements of the OTIM include the regression estimation of residual heat flux with surface atmospheric conditions and the daily interpolation of climatological snow depth data.

Several case studies have been generated with VIIRS data products from 2013, particularly in May when the cloud mask was significantly improved. The results are being compared to the current VIIRS ice age product and will be compared with ice thickness products from MODIS, ICESat, IceBridge, CyroSat-2, SMOS and numerical model simulations from PIOMAS. Validation with in situ data will be performed as appropriate. An example is shown in Figure 74.

The sea ice concentration retrieval algorithm, which was initially developed for GOES-R ABI, has been modified and implemented to run on the near real-time VIIRS data. Sun glint and cloud shadow flags in the cloud mask products have been utilized. All Landsat scenes without cloud contamination over the Beaufort Seas in the year 2013 have been downloaded from a USGS data server. An algorithm developed to derive sea ice concentration VIIRS has been adapted to calculate sea ice concentration for Landsat scene. Collocation of these Landsat data and derived sea ice concentration with corresponding VIIRS sea ice concentration has also developed for case studies. Sea ice concentration from VIIRS (and/or MODIS) will be combined with ice concentration from passive microwave sensors such as AMSR-E for historical work, SSMIS, or AMSR2. Uncertainties in VIIRS/SSMIS are being evaluated through comparison to Landsat derived sea ice concentration in case studies.

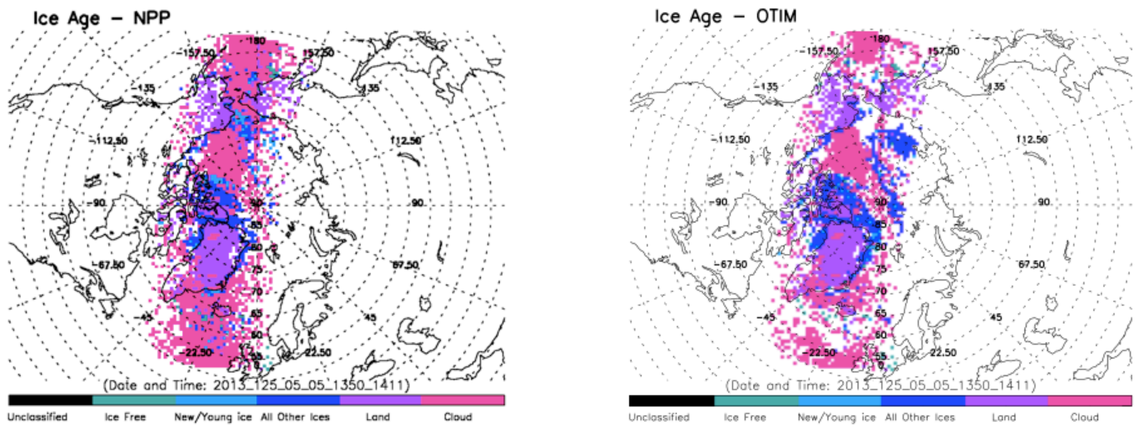

Figure 74. Sea ice age categories from VIIRS sea ice age classification (left) and OTIM ice thickness converted to the same categories (right) at 13:50 UTC on May 5, 2013 in the Arctic Ocean. The day/night terminator (90 degree solar zenith) passes approximately through the center of the image from lower left to upper right.

Publications and Conference Reports

Liu, Y., J. Key, and X. Wang, 2013, Sea Ice Concentration with the Combined Use of Microwave and Visible/infrared Observations, 2013 AGU Fall Meeting, 9-13 December 2013, San Francisco California, USA.

Jeffrey R. Key, Robert Mahoney, Yinghui Liu, Peter Romanov, Mark Tschudi, Igor Appel, James Maslanik, Dan Baldwin, Xuanji Wang, and Paul Meade, 2013, Snow and Ice Products from Suomi NPP VIIRS, JGR-Atmospheres, 118, doi:10.1002/2013JD020459.

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

22. Improving Very Short Range Forecasts for the NWS Alaska Region using Objective Tools Designed to Optimize the Retention of Hyperspectral Infrared and Microwave Moisture LEO Soundings

CIMSS Task Leader: Ralph A. Petersen
CIMSS Support Scientists: Lee Cronce, Richard Dworak, Nadia Smith, Elisabeth Weisz
NOAA Collaborator: Robert Aune

NOAA Long Term Goals:

- Weather-Ready Nation

NOAA Strategic Goals:

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

CIMSS Research Themes:

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

Project Overview

This work was proposed in coordination with the National Weather Service (NWS) Alaska Region (AR) to provide initial support for a longer-term project intended to increase the operational utility of low earth orbit (LEO) soundings to forecasters and to help fill the large data gaps that exist between the sparse conventional and radar sites. The long-term project objectives are: 1) to assess and validate the 'best' LEO sounder moisture products for very-short-range forecast guidance for products specifically designed for the Alaska Region (AR) forecasting needs, 2) to test the impact of LEO-retrieval based NearCasts on improving a variety of AR operational very-short-range forecasting problems, and 3) to determine the optimal information contained in both hyperspectral and microwave LEO moisture retrievals using a variety of algorithms. Initial seed funding was received in mid-2013, with full project activity scheduled for mid-2014.

Summary of Accomplishments and Findings

NWS Alaska Region wishes to establish a technical framework and develop a more efficient and scientifically sound forecast process that facilitates improving the use of satellite observations in Impact Decision Support Services (IDSS) in Alaska. Given the limited number of traditional observation systems in the Arctic (e.g., ASOS, upper air, buoys, etc.), NWS AR relies heavily on satellite observations to maintain situational awareness and aid in the forecast process. AR is unique within the NWS in that Low Earth Orbiting (LEO) observations form the dominant satellite data source. And given the latitude, the LEO systems provide sufficient temporal and spatial coverage to play a significant role in that process by providing frequently updated observation (with a 90-180 minutes observation repeat cycles – less when using multiple satellites). Thus most any science and/or technological advances will need to integrate satellite information, especially from LEO satellites, as part of the solution. The high repeat cycle allows the data to be used in a similar ways that used with GOES sounder data (with its standard 1 hour repeat cycle) over the CONUS.

Several of the forecast challenges that are especially challenging in AR given the aforementioned observational limitations and that would benefit from improved short-range forecast tools include:

- Convective location, timing and sustainment:
  - Convection over lower terrain.
  - Wildfires and resulting smoke past decade.
  - Mesoscale heavy snow events.
- Evolution of Turnagain Arm wind events:
  - Impact air traffic operations.
  - The forecast problem is thus characterizing factors that control the mountain wave response (e.g., Stability, wind, moisture content, etc.) to help forecast the phenomena.
- Heavy Rain events in the Warm Season:
  - Heavy rain events are difficult to accurately pinpoint spatially with the integration of larger scale vertical motion fields, complex terrain, and moisture plumes.

The long-term goal of this effort focuses on improving very-short-range moisture, stability and precipitation forecasts by identifying the 'best' JPSS products and procedures to use in improving forecast guidance for the AR. As the prerequisite step to this effort, we are providing an independent assessment of the accuracy and test the applicability of JPSS moisture data over land at high latitudes based on existing GPS TPW observation using the system is already being developed at CIMSS that compares GEO/LEO Total Precipitable Water (TPW) data to surface GPS data, as well as surface-based microwave radiometer and Raman Lidar data from the ARM CART site and moisture profiles from AMDAR equipped aircraft. This effort will extend the CIMSS GOES-based system to assess the results from a variety of other AIRS/IASI/CrIS retrieval systems and include microwave retrievals over oceans where possible. The results of this effort will be important to both subjective (forecaster) and objective (NWP) use of future JPSS observations.

The second part of this new effort builds upon investments already made by the GOES-R program toward the goal of expanding the utility of satellite soundings to forecasters by adding a reliable prediction tool. Although the time between successive LEO soundings over AR is greater than that for GOES data over the CONUS, the quality of the LEO produces will make up for much of the different. Instead of restricting forecasters to use the detailed time/space-frequency LEO soundings only as observations, a major benefit in using the new tools is likely to come through applying proven objective systems that assist forecasters in predicting rapidly developing, extreme weather events. This will be done by adapting the data-driven CIMSS "NearCasting" system developed under the GOES-R program to use LEO observations. The system has proven useful in filling the 1-12 hour information-gap which exists between Nowcasts (based primarily on extrapolation of limited AR radar data) and longer-range NWP guidance. The NearCasting system is unique in that it can detect and retain extreme horizontal and vertical variations in the atmosphere (especially moisture fields) and incorporate large volumes of high-resolution asynoptic data, while also being extremely computationally efficient, with analysis and forecast refreshes becoming available immediately after every satellite product update. The systems has been especially useful in expanding the usefulness of current and future GOES-DPI products in NWS WFOs, expanding their use from only offering observations of past conditions to providing predictions of pre-storm conditions in the near future. An example of initial tests of a LEO NearCast analysis is shown in Figure 75.

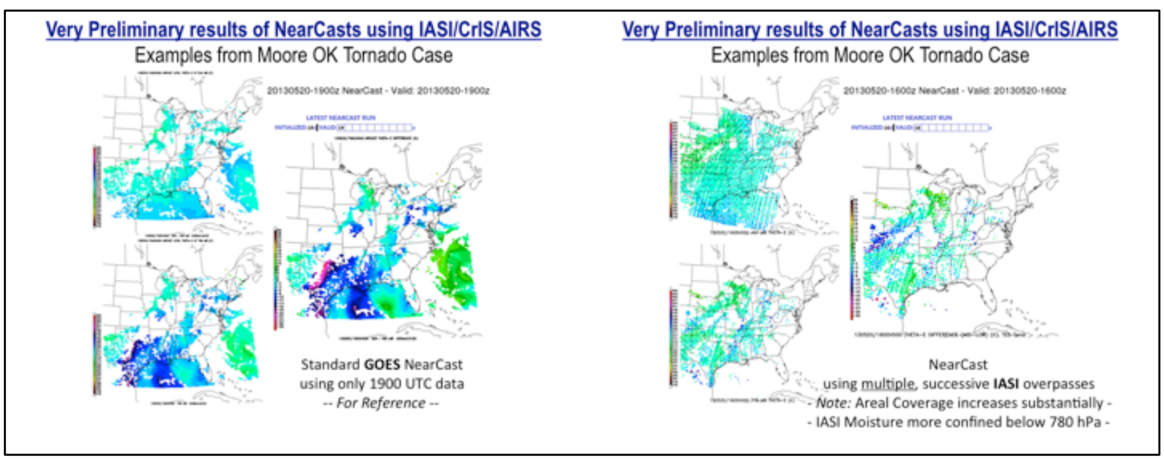


Figure 75. Sample comparison of NearCast analysis of lower-level Theta-E for the Moore Tornado event using deep-layer GEO (left) and finer-vertical-resolution LEO (right, IASI) retrievals at the same vertical levels.

Publications and Conference Reports

Presentations

- Petersen et al. at EUMETSAT Users Conference and Conf. Report (Sept. 2013)
- Petersen et al. at NOAA Science Weeks in Madison, WI (March 2014)
- Petersen et al. at EUMETSAT Convection Working Group Workshop (April. 2014)

23. CIMSS Participation in the JPSS Risk Reduction Program for 2013

23.1 Near Real-time Assimilation System Development for Improving Tropical Cyclone Forecasts with NPP/JPSS Sounder Data

CIMSS Task Leader: Jun Li
CIMSS Support Scientists: Jinlong Li, Pei Wang, Kevin Baggett, Wenguang Bai
NOAA Collaborators: Tim Schmit (STAR/NESDIS), John (Jack) L. Beven (NHC/NWS), Mark DeMaria (NHC/NWS)

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
- Environmental Models and Data Assimilation

Project Overview

The objective is to use the NPP/JPSS sounder measurements for improving the prediction of tropical cyclone (TC) genesis and evolution. The work will use the regional numerical weather prediction (NWP) models (WRF - Weather Research and Forecasting, and/or HWRF – Hurricane WRF) and the advanced data assimilation methodologies (GSI, and/or EnKF). CIMSS scientists will develop a near real time assimilation system (SDAT – Satellite sounder data assimilation for Tropical storm forecasts) based on the combination of GSI 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 sounding measurements for TC forecasting.

SDAT system mainly consists of data preparation and data assimilation/forecast parts. The major components of system include:

- The acquisition of real time GDAS/GFS, conventional and satellite observations;
- The preparation and conversion of off-line satellite derived products such as soundings (temperature and moisture profiles), total precipitable water (TPW) and AMVs into Bufr format needed by GSI;
- WRF preprocessing system (WPS) to prepare WRF/GSI initial conditions and WRF boundary conditions;
- WRF system to do short-range forecast (6 hours) to provide the backgrounds for GSI cycling run and to do a final 72 hours forecast after GSI cycling final analysis;

- GSI system to assimilate both conventional and satellite observations to update WRF model's initial conditions;
- Interfaces from GSI to WRF and from WRF to GSI systems;
- WRF forecast post processing: diagnostics, plotting, and data archive; and
- Online Web page so that researchers/users can access the forecasts for references and feedback.

Summary of Accomplishments and Findings

The FY13 accomplishments are summarized below:

- Making SDAT running in near real time for tropical cyclone (TC) forecast improvement at CIMSS;
- Life cyclone of Sandy forecast experiments conducted with SDAT;
- SDAT forecasts on 2013 TC events evaluated; and
- Standard tracker program implemented for SDAT post-processing.

Making WRF/GSI running in near real time for tropical cyclone (TC) forecast improvement

SDAT (http://cimss.ssec.wisc.edu/sdat) has been running in real time since August 2013 at CIMSS. Experiments have been done to see how long of GSI cycling run is better for tropical cyclone forecast with SDAT. At the initial design, only one-step concurrent GSI/WRF run was allowed, meaning no cycling assimilation. Now by changing a few parameters, any length of cycling assimilation can be executed. Experiments have also been done to see how long of GSI cycling run is better for tropical cyclone forecast (See Figure 76). Another important improvement is the radiance bias coefficients update. At first assimilation step, the real time global radiance bias coefficients are used. At each of the following cycling steps both air-mass and scan angle bias coefficients are then updated. Getting good bias coefficients is very important for radiance assimilation, especially for regional NWP model. There is still a lot of work need to be done on bias adjustment. The impact of model horizontal resolution (e.g., 36 km versus 15 km) is also tested, in general the higher resolution improves the hurricane track and maximum wind forecasts (see Figure 77).

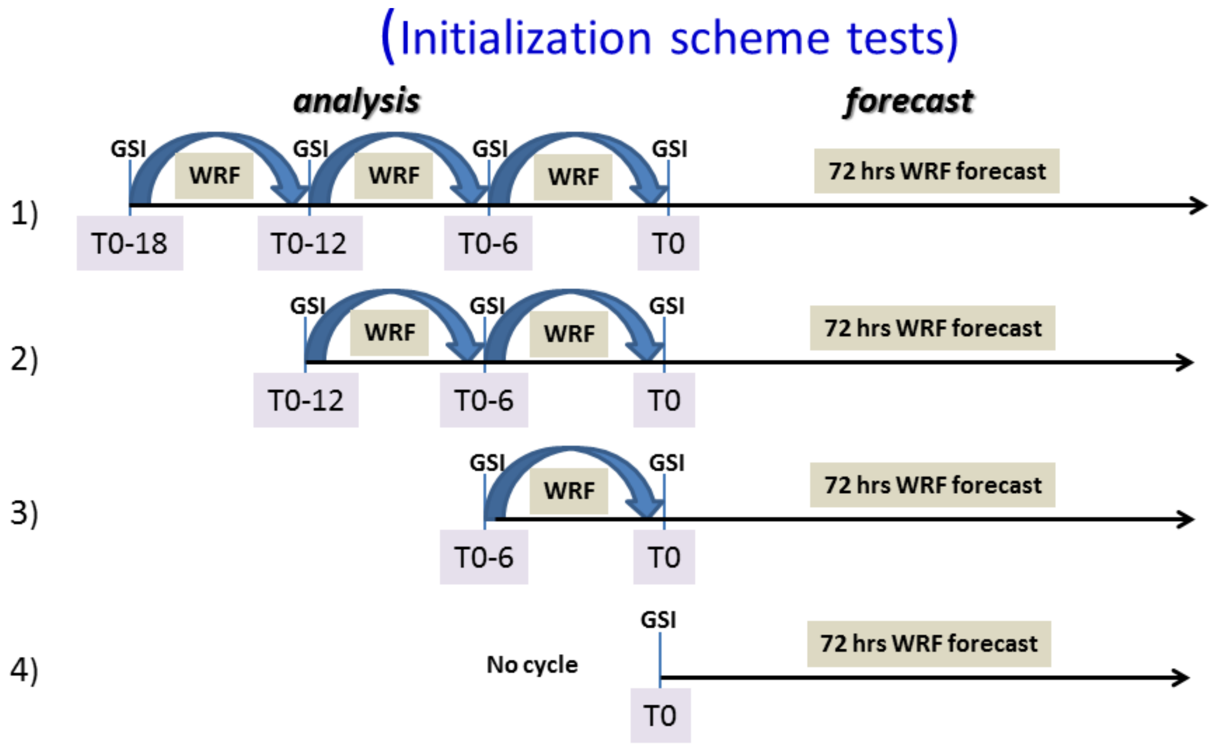


Figure 76. WRF/GSI set up experiments and initialization scheme tests.

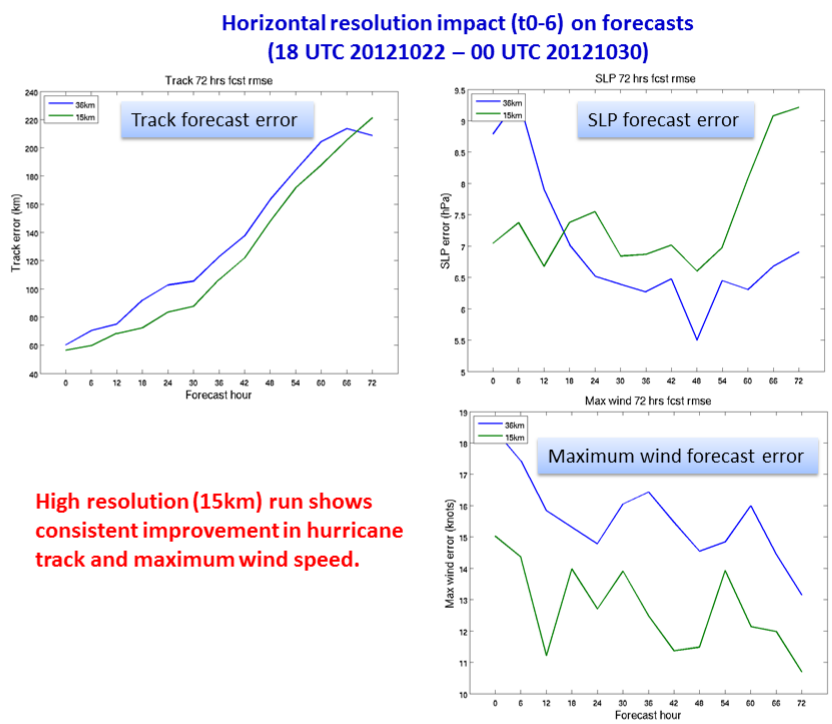


Figure 77. Hurricane Sandy life cycle forecast experiments with WRF/GSI for the impact of model horizontal resolution. The track, central sea level pressure and maximum wind forecast errors from 15 km (green) and 36 km (blue) are shown.

Table 2 lists the experiments and comparisons on hurricane Sandy (2012) life cycle forecasts with different assimilation schemes. Assimilated data include conventional data and satellite observations from AMSUA/AMSUB, HIRS, MHS, ATMS, AIRS and IASI radiances.

Table 2. GSI/WRF set up experiments on Sandy (2012) life cycle forecasts.

Experiments	Hurricane track	Sea level pressure (SLP)	Maximum wind speed
Initialization scheme (T0-18, T0-12, T0-6, T0)	For weak storm, the earlier, the worse; For strong storm, comparable;	Moderate improvement in earlier start;	Comparable;
Background error (NAM vs Global)	Slight improvement in first 6 hrs forecast by using NAM;	Comparable;	Comparable;
Initial NCEP data (GDAS vs GFS)	Slight improvement in first 12 hrs forecast by using GFS;	Slight improvement using GFS;	Slight improvement using GFS;
Horizontal resolution (36km vs 15km)	Moderate improvement in 15km;	Moderate improvement in first 12 hrs forecast in 15km;	Moderate improvement in 15km;

Life cyclone of Sandy forecast experiments with SDAT

The SDAT has been tested for Sandy life cycle forecasts. The data assimilated include conventional data and satellite observations from GOES Sounder, AMSUA/AMSUB, HIRS, MHS, ATMS, AIRS and IASI radiances. The experiments show that the GFS has best track, but worst SLP and maximum wind most of time. HWRF has a very good analysis results. SDAT has the best SLP and maximum wind most of time.

2013 TC Events forecasted by SDAT - examples

The SDAT (http://cimss.ssec.wisc.edu/sdat) has been tested offline for Hurricane Sandy (2012) life cycle forecasts successfully (Li et al., 2013; Wang et al., 2014). Since August 2013, SDAT has been running in near real time, all the storms over CONUS and tropical cyclones over Atlantic Ocean are forecasted by SDAT within it spatial coverage. In 2013, there were no many hurricanes over Atlantic Ocean, the two storms over Atlantic Ocean: Gabrielle and Humberto, were also well reflected by SDAT. Figure 78 shows the 72 hour 6-hour cumulative precipitation forecasts started at 00 UTC on 18 September 2013. The position of tropical storm Humberto was reflected by our near real time SDAT. Figure 79 shows the life-cycle track forecasts from SDAT (left pane), GFS (middle) and HWRF (right). It indicates that SDAT has the similar track forecasts capability of GFS, while better intensity forecasts than GFS. HWRF has the best intensity forecasts but the track forecasts are not as good as GFS and SDAT in this case.

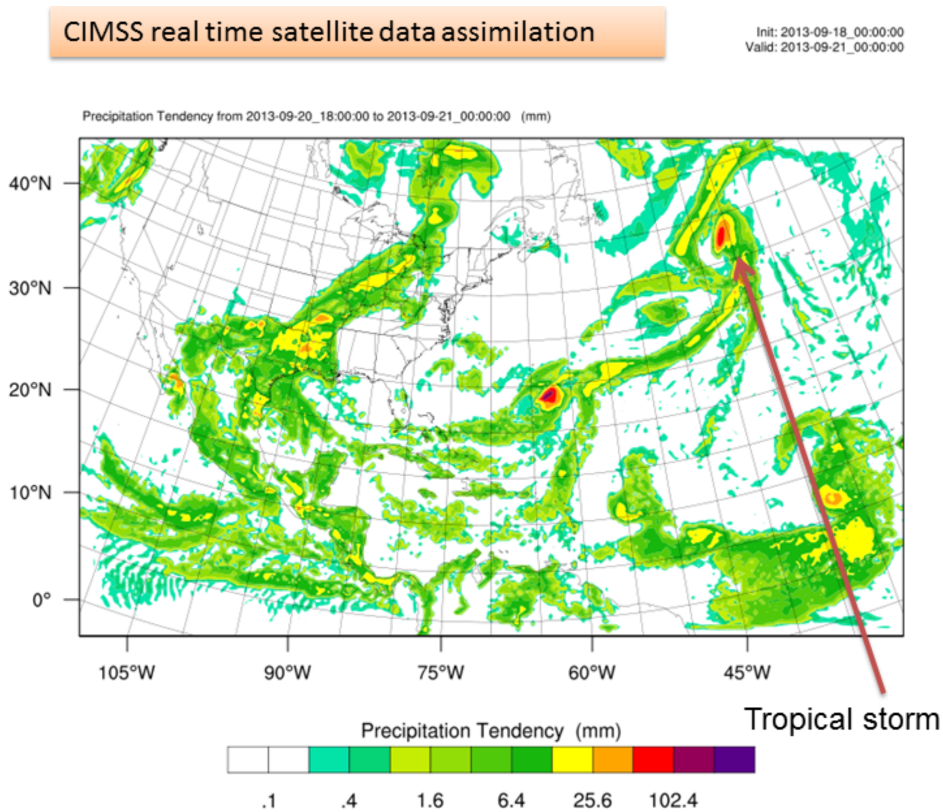


Figure 78. The 72 hour 6-hour cumulative precipitation forecasts started at 00 UTC on 18 September 2013.

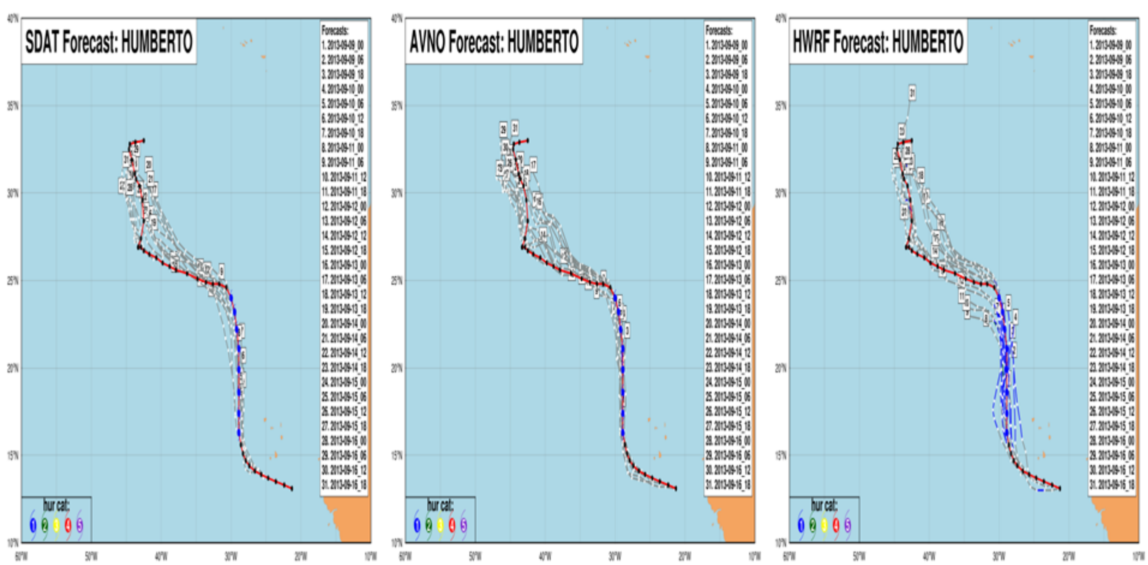


Figure 79. The life cycle track forecasts for Hurricane Humberto (2013090900 - 2013091618) from SDAT (left pane), GFS (middle), and HWRF (right).

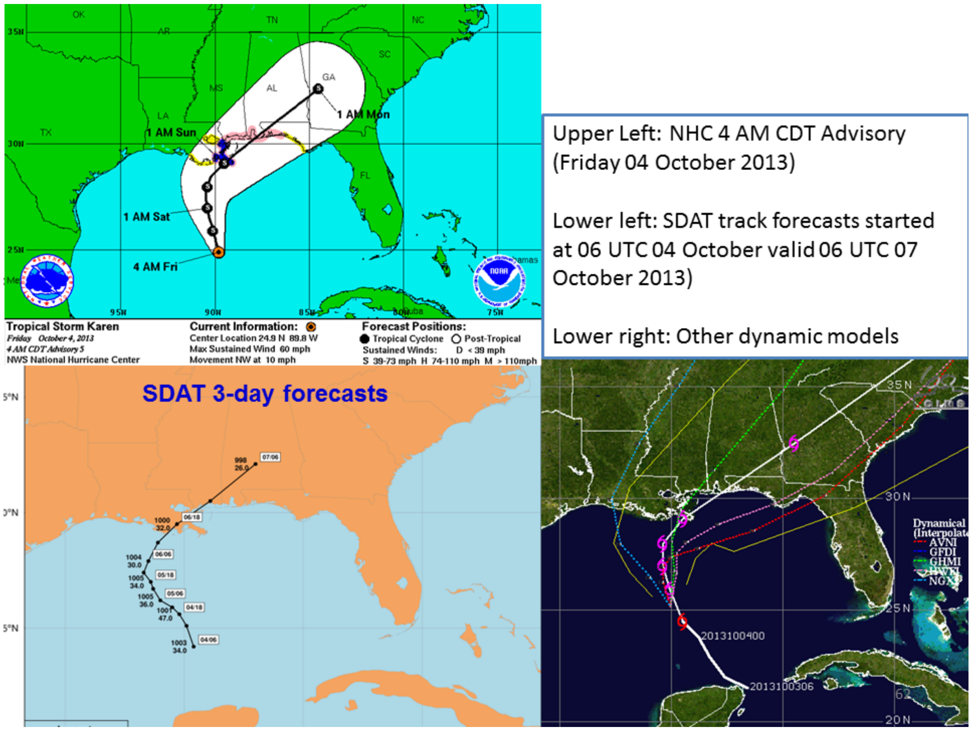


Figure 80. NHC 4 AM CDT advisory (upper left) and SDAT forecasts (lower left), results from other dynamic models are shown in lower right panel.

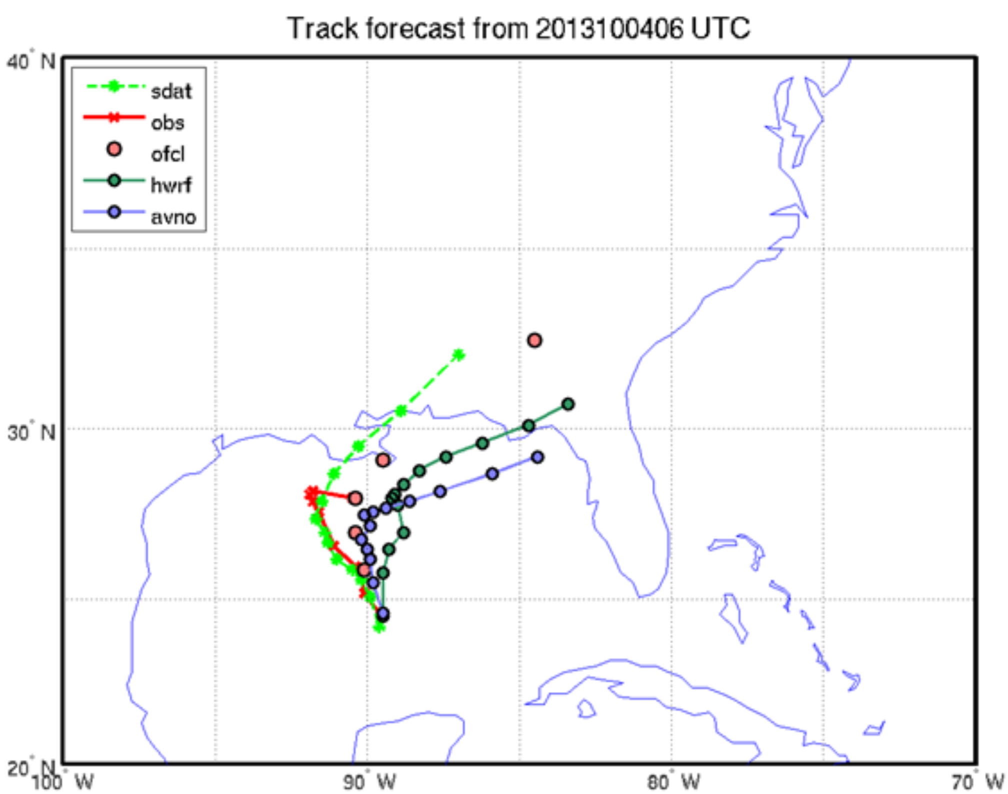


Figure 81. SDAT track forecasts and NCH official guidance, along with operational HWRF and GFS forecasts. The observations are available at only limited time period.

Hurricane Karen is the only weak hurricane landed onto U.S. It is found that SDAT forecasts are closer to the observations than other dynamic models, and are very close to the official guidance (see Figure 80 and Figure 81).

Standard vortex tracking program has been implemented in Oct 2013 in SDAT
GFDL vortex tracker v3.5b (released Sept. 16, 2013) was implemented in SDAT. With "tracker program" running in near real time, we are able to derive the tropical cyclone (TC) forecast products such as track, central sea level pressure (SLP), maximum wind speed (SPD) in the same way as other dynamic models use. With SDAT and "tracker" running sequentially, the applications of SDAT will be greatly enhanced, for example, through collaboration with CIRA and NHC (Mark DeMaria), we are going to provide SDAT products for proving ground next hurricane season to get the track/intensity information in the Automated Tropical Cyclone Forecast (ATCF) system that NHC uses. In addition, the SDAT product can be used in CIRA's statistical model for improving track and intensity forecasts.

Publications and Conference Reports

Li, Jinlong et al., 2013: A near real-time regional satellite data assimilation system for tropical cyclone forecast improvement studies, The 11th JCSDA Science Workshop on Satellite Data Assimilation, 05 – 07 June 2013, NOAA Center for Weather and Climate Prediction.

Li, Jun, Tim Schmit, Mitch Goldberg, Jinlong Li, Pei Wang, and John L. Beven, A Near Real-Time Assimilation and Forecasting System for Tropical Cyclone Application of NPP/JPSS Sounding Measurements, NOAA Satellite Conference, April 8-12, 2013, College Park, MD

Li, Jun et al., 2013: Improving tropical cyclone forecasts by assimilating microwave and advanced IR sounder measurements, 2013 EUMETSAT Meteorological Satellite Conference/19th AMS Satellite Meteorology, Oceanography, and Climatology Conference, 16 – 20 September 2013, Vienna, Austria.

Li, J., Jinlong Li, Pei Wang, Tim Schmit, Zhenglong Li , and Chris Velden, 2013; A near real time JPSS/GOESR data assimilation system, GOES-R/JPSS Web Seminar, 18 November 2013.

Zheng, J., Jun Li, T. J. Schmit, Jinlong Li, 2013: Study on the assimilation of atmospheric temperature and moisture profiles from Atmospheric InfraRed Sounder (AIRS) measurements for improving hurricane forecasts, Advances in Atmospheric Sciences (conditionally accepted).

Wang, P., Jun Li, Jinlong Li, T. J. Schmit, 2014: Advanced infrared sounder sub-pixel cloud detection with imagers and its impact on radiance assimilation in NWP, Geophysical Research Letters, 41, doi:10.1002/ 2013GL059067.

DeMaria, Mark, Fuzhong Weng, Jun Li, Christopher Velden, and Tomislava Vukicevic, 2014: Tropical Cyclone Satellite Data Assimilation Using JPSS and GOES-R Datasets, featured article on JPSS science.

23.2 Advancing Nighttime VIIRS Cloud Products with the Day/Night Band

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} μm^{-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 the development work of the new cloud optical properties retrieval for nighttime observations by use of lunar reflection (NLCOMP).

A version of NLCOMP was developed as a stand-alone FORTRAN95 retrieval tool, and has been implemented as a release 1.0 into CLAVR-x in the reported period. We have processed several weeks of NLCOMP results. We have been working on comparison studies between daytime and nighttime results. The results look promising, especially for cloud optical thickness. This will help to close the nighttime observation gap of microphysical cloud properties.

The development and performance of the algorithm was published in a JGR paper [Walther et al., 2013].

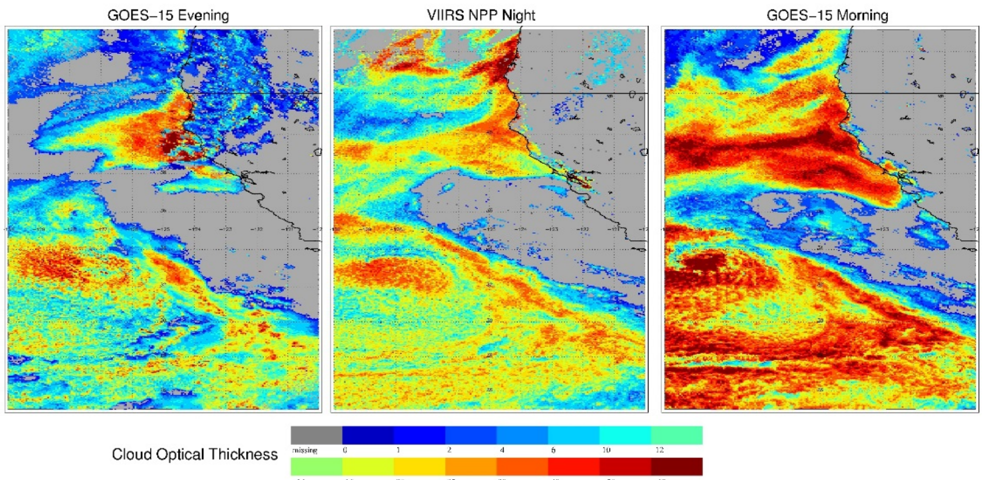


Figure 82. Comparison of the cloud optical depth evolution from VIIRS and GOES-15. All data is from April 26, 2013. Image on the right is NOAA/DCOMP applied to GOES-15 Evening data is observed 6:30 PM local, the GOES-15 Morning is observed at 9:30 AM local, the VIIRS Night are observed at 1:30 AM local during full moon condition.

Publications and Conference Reports

Walther, A., A. K. Heidinger, and S. Miller (2013), The expected performance of cloud optical and microphysical properties derived from Suomi NPP VIIRS day/night band lunar reflectance, J. Geophys. Res. Atmos., 118, 13,230–13,240, doi:10.1002/2013JD020478.

Walther, A., A. K. Heidinger, and S. Miller: NIGHTTIME CLOUD PRODUCTS WITH THE VIIRS DAY/NIGHT BAND, Talk held at EUMETSAT Conference Wien, Austria, Sept 2013.

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

CIMSS Task Leader: Mathew Gunshor
CIMSS Support Scientist: Hong Zhang

NOAA Long Term Goals:

- Weather-Ready Nation

NOAA Strategic Goals:

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

CIMSS Research Themes:

- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques

Project Overview

CIMSS proposed to design, implement, and operate an analysis facility in support of JPSS. Initially the system will be designed to conduct sensor modeling, measurement simulation, EDR algorithm adaptation, and VIIRS instrument impact assessment on system requirements. This proposed work follows the successful GOES-R Analysis Facility for Instrument Impacts on Requirements project (GOES-R AWG GRAFIIR). CIMSS proposed to continue expanding the JAFIIR framework and capabilities to grow with the development of the Community Satellite Processing Package (CSPP) algorithm development activities. The Glance program will continue to develop with JPSS products (EDR and SDR) and capabilities.

Proposed tasks:

- Continue to expand features of JAFIIR to model VIIRS instrument effects.
- Improve analysis function of JAFIIR to include more VIIRS products to extend the study of sensor impacts on products not already analyzed. This will require continued expansion of CSPP capabilities.
- Provide support and datasets to JPSS program elements to assist in evaluating and testing of product algorithms.
- Respond to proposed changes in VIIRS instrument specifications to assess potential effects on products.
- Continue to interface with visualization teams to better utilize visualization software and tools.
- Continue to expand and improve Glance.
- Respond to JPSS program requests to meet specific programmatic needs.

Summary of Accomplishments and Findings

The JAFIIR project has demonstrated with VIIRS that an instrument effect altering calibration of a band can be simulated and that the impact on products can be determined. The capability to run more products examples with different instrument effects will continue to be grown. JAFIIR relies on the development of the CSPP project for access to JPSS VIIRS algorithms.

- Glance expanded capabilities to read AWIPS files.
- VIIRS radiance perturbation code being developed.
  - o Can currently add a 'calibration offset' of a specified amount.
- CSPP Cloud Mask Example
  - o VIIRS 10.8um band M15 altered with 1K and 3K offsets for 3 time periods.
  - o Cloud Mask and Cloud Phase generated for original, 1K and 3K cases.
  - o Glance used to compare results of 1K and 3K cases to original, unaltered.

The following milestones were developed in anticipation of possible and planned CSPP updates which trigger testing events for JAFIIR. CSPP EDR version 1.1 was installed on our test machine. The new version has more output products: Cloud Mask, Active Fires, Aerosol Optical Thickness, Atmosphere Suspended Matter and Sea Surface Temperatures. The following milestones were completed:

1. CSPP VIIRS bow tie effect fix implemented in JAFIIR Matlab code.
   a. Additionally, the SDR reader utilizes the quality flag QF1_VIIRSMBANDSDR to mask out values which will include the bow-tie pixels. This will be used when altering VIIRS radiances for impact studies such that bow-tie values aren't

changed. This could also be used in the future on proxy VIIRS data to mimic the bow-tie effect.

2. CSPP VIIRS Active Fires algorithm testing
   a. The active fires algorithm is different from most other algorithms. The files only contain a list of fire locations (not pixel-to-pixel match of imagery). In the sensitivity studies performed, nothing changed because the number of fire pixels or their locations were not altered. These types of files will not work in Glance and the types of statistics that Glance provides would be relatively meaningless even if some pixel's fire mask were changed. In the event of a waiver situation that may affect this product, we would use a simple analysis that did not require Glance. Parameters that might change with subtle instrument effects, such as Fire Radiative Power, are not included in this product at this time. This product is not meant to be imaged alone, it would need to be combined with another product or on top of a single band or RGB image. We are still looking into whether this could be accomplished in standard viewing tools McIDAS-V or AWIPS, or if a new file must be generated to be viewed in those packages.
3. CSPP CLAVR-X VIIRS Clouds v1.0 testing
   a. Not Yet
4. CSPP SDR v1.5 testing.
   a. CSPP SDR v1.5 has been released and tested.
5. CSPP EDR v1.1 testing.
   a. Cloud Mask and Cloud Phase sensitivity studies were done http://www.ssec.wisc.edu/grafiir/JAFIIR/VIIRS_CloudMask/
   b. CSPP EDR v1.2.1 has also been released and tested.
      i. VIIRS Cloud Mask
      ii. VIIRS Active Fires
      iii. VIIRS Aerosol Optical Thickness
      iv. VIIRS Suspended Matter
      v. VIIRS Sea Surface Temperatures
      vi. VIIRS Surface Reflectance
      vii. VIIRS Enhanced Vegetation Index
      viii. VIIRS Normalized Difference Vegetation Index
6. CSPP VIIRS Aerosols and SST testing.
   a. Sensitivity studies with Aerosol Optical Thickness (AOT) and Sea Surface Temperature (SST) have been performed. Sensitivity studies were done with a calibration offset of 1K and 3K for Band 15 to exercise instrument effect impacts on these products.
   b. AOT: http://www.ssec.wisc.edu/grafiir/JAFIIR/VIIRS_AOT/
   c. SST: http://www.ssec.wisc.edu/grafiir/JAFIIR/VIIRS_CloudMask_EDR1.1/
   d. SST required changes to the glance filter due to Glance needing to read SST output factors (scale and offset).
7. CSPP VIIRS Vegetative Index testing
   a. Completed as part of the CSPP SDR v1.5 test.

Publications and Conference Reports

Oral presentation at the 2013 EUMETSAT Meteorological Satellite Conference (Joint with the 19th AMS Satellite Meteorology, Oceanography, and Climatology Conference) in Vienna, Austria: "GRAFIIR and JAFIIR - Efficient end-to-end semi automated GEO and LEO sensor performance analysis and verification systems" presented by Hong Zhang, 20 September 2013.

25. 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; and
- Provide value-added products for end users that are not part of the JPSS operational suite, such as images in KML format for Google Earth; Night Fog Detection; Volcanic Ash; and Aviation Safety products.

Summary of Accomplishments and Findings

As of March 2014, the CSPP suite includes software for generating the following products:

- Suomi NPP CrIS, VIIRS and ATMS SDR (geolocation and calibration),
- Suomi NPP VIIRS EDR (cloud mask, active fires, surface reflectance, NDVI, SST, aerosol optical thickness),
- CrIS, IASI, and AIRS Dual Regression Retrieval,
- VIIRS SDR and MODIS L1B GeoTIFF and AWIPS Reprojected Imagery,
- Microwave Integrated Retrieval System (MIRS),
- HYDRA2 Multispectral Data Analysis Toolkit,
- Suomi NPP Imagery EDR (projected imagery for AWIPS).

New products in testing for release as part of CSPP in the next 6 months include:

- VIIRS, AVHRR, and MODIS Cloud Top Parameters from the 'Clouds from AVHRR Extended' (CLAVR-X) software,
- CrIS/ATMS, IASI/AMSU, and AIRS AMSU retrievals from the 'NOAA Unique CrIS/ ATMS Processing System' (NUCAPS) software,
- VIIRS, AVHRR, and MODIS sea surface temperatures from the 'Advanced Clear-Sky Processor for Oceans' (ACSPO) software,
- CSPP SDR calibration and geolocation software based on IDPS release Mx8.3,
- CSPP EDR software based on IDPS release Mx8.3, including Land Surface Temperature,
- CrIS full spectral resolution (FSR) calibration software.

New features added to the CSPP SDR and VIIRS EDR software packages during the reporting period included multi-core processing; improved EDR granule yield, updated lookup tables; and the first release of the VIIRS surface reflectance, NDVI, SST, AOT, and Imagery EDR algorithms.

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, but we have not changed the underlying processing software, algorithms, or data formats. The output files from the CSPP SDR processing software are identical in naming, format, and structure to the corresponding files from NOAA/NESDIS. The native format for NPP SDR products is HDF5, and descriptions of the NPP file formats are available in the "Common Data Format Control Books."

CSPP 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 during the reporting period.

March 21, 2014 (CSPP Suomi NPP Imagery EDR Software Versions 1.1)

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.

March 20, 2014 (CSPP Microwave Integrated Retrieval System (MIRS) Software Version 1.0)
First CSPP release of the NOAA NESDIS Center for Satellite Applications and Research (STAR) Microwave Integrated Retrieval System (MIRS) software in support of the ATMS instrument onboard S-NPP, and the AMSU-A and MHS instruments onboard NOAA-18, NOAA-19, MetOp-A and MetOp-B satellites.

March 19, 2014 (CSPP Suomi NPP HYDRA2 Multispectral Data Analysis Toolkit v1.0)
First release of a visualization and analysis toolkit for interrogating JPSS S-NPP and NASA EOS Aqua and Terra instrument data. This toolkit was developed to assist research and development of remote sensing applications as well as education and training of remote sensing scientists.

February 14, 2014 (CSPP Suomi NPP VIIRS EDR Software v1.2.1)
Updated algorithm Look-Up-Tables (LUTs), and improved Land/Sea boundary designation are included in this release of software that supports creation of Visible Infrared Imaging Radiometer Suite (VIIRS) instrument Environmental Data Record (EDR) Cloud Mask, Active Fires, Aerosol Optical Thickness, Sea Surface Temperatures, Surface Reflectance and Vegetation Indices. Also included in this release is the ability to process data using multiple cores. This software is designed to work with the CSPP VIIRS SDR V1.5 algorithms.

December 18, 2013 (CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software v1.5)
New version of the calibration and geolocation Science 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 the option to process all three instruments on multiple processor cores, and is compatible with the CSPP VIIRS EDR version 1.2 release. This version also includes the use of LUTs to correct for VIIRS Day/Night Band stray light contamination.

December 18, 2013 (CSPP Suomi NPP VIIRS EDR Software v1.2)
Software package that supports creation of Visible Infrared Imaging Radiometer Suite (VIIRS) instrument Environmental Data Record (EDR) Cloud Mask, Active Fires, Aerosol Optical Thickness, Sea Surface Temperatures, Surface Reflectance and Vegetation Indices. Also included in this release is the ability to process data using multiple cores. This software is designed to work with the CSPP VIIRS SDR V1.5 algorithms.

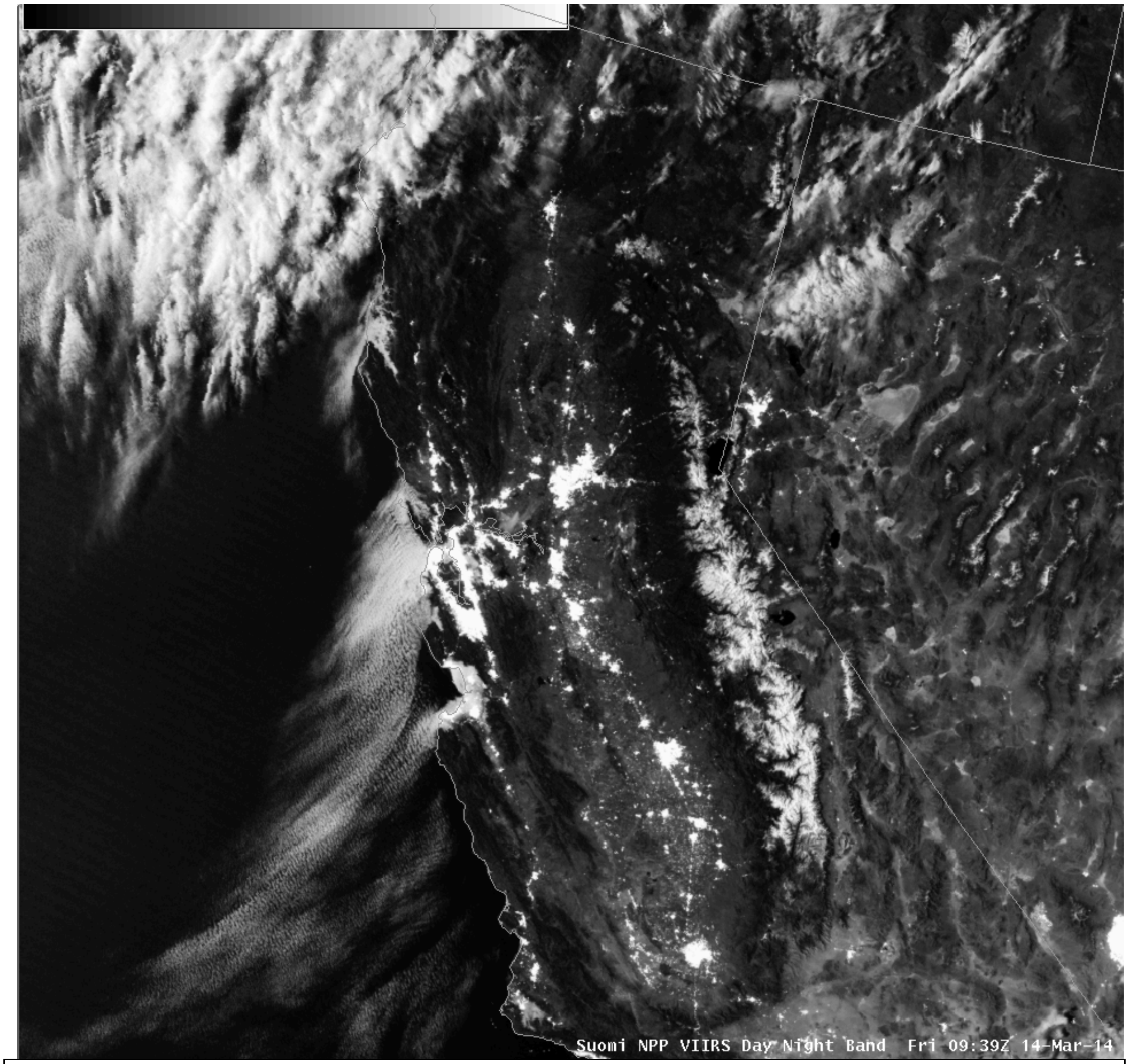
October 18, 2013 (CSPP VIIRS SDR GeoTIFF and AWIPS Reprojection Software v1.1)
Update to the software that creates reprojected GeoTIFFS and/or AWIPS NetCDF-3 files from Visible Infrared Imaging Radiometer Suite (VIIRS) Science Data Record (SDR) HDF5 files. AWIPS stands for the Advanced Weather Interactive Processing System, the visualization and analysis tool used by the US National Weather Service. This update includes the capability to create True Color 24 bit GeoTIFF files, as well as allowing users to specify their own local grids.

September 24, 2013 (CSPP CrIS, AIRS and IASI Dual Regression Retrieval Software v1.2)
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 update includes new instrument coefficient files, as well as a bug fix for surface emissivity over the oceans.

July 8, 2013 (CSPP Suomi NPP CrIS, VIIRS and ATMS SDR Software v1.4)
New version of the calibration and geolocation Science 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 the option to run on multiple processor cores, and is compatible with the CSPP VIIRS EDR version 1.1 release.

July 8, 2013 (CSPP Suomi NPP VIIRS EDR Software v1.1)
Software package that supports creation of Visible Infrared Imaging Radiometer Suite (VIIRS) instrument Environmental Data Record (EDR) Cloud Mask, Active Fires, Aerosol Optical Thickness and Sea Surface Temperatures. This software is designed to work with the CSPP VIIRS SDR V1.4 algorithms.

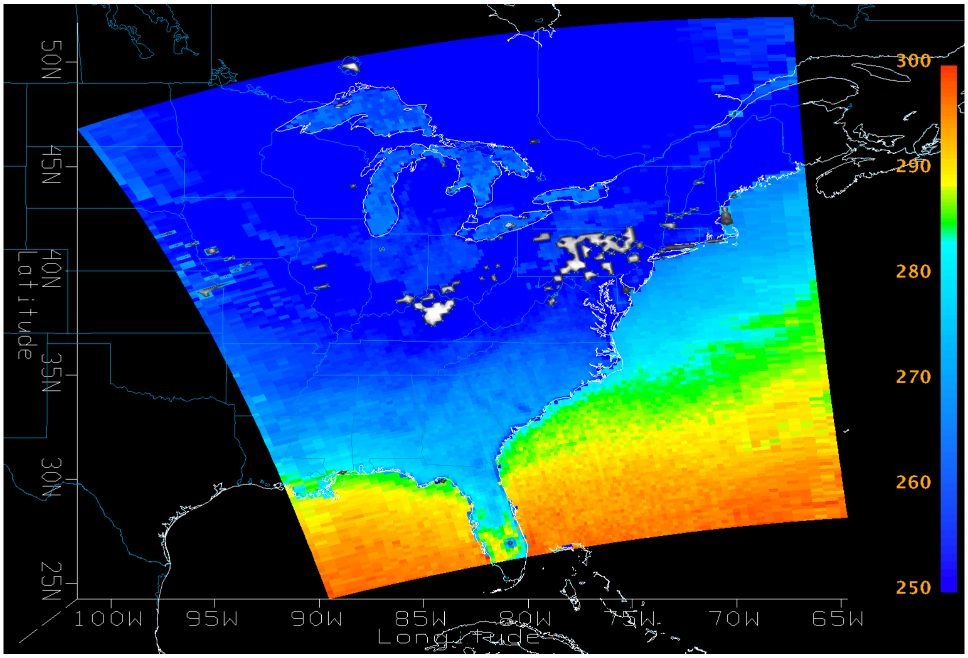
April 29, 2013 (CSPP CrIS, AIRS and IASI Dual Regression Retrieval Software v1.1)
New version of the multi-instrument hyperspectral retrieval software package that uses Suomi NPP CrIS, Aqua AIRS or MetOp IASI radiances as inputs and produces vertical profiles of temperature, moisture, ozone as well as cloud and surface properties at single field-of-view resolution.



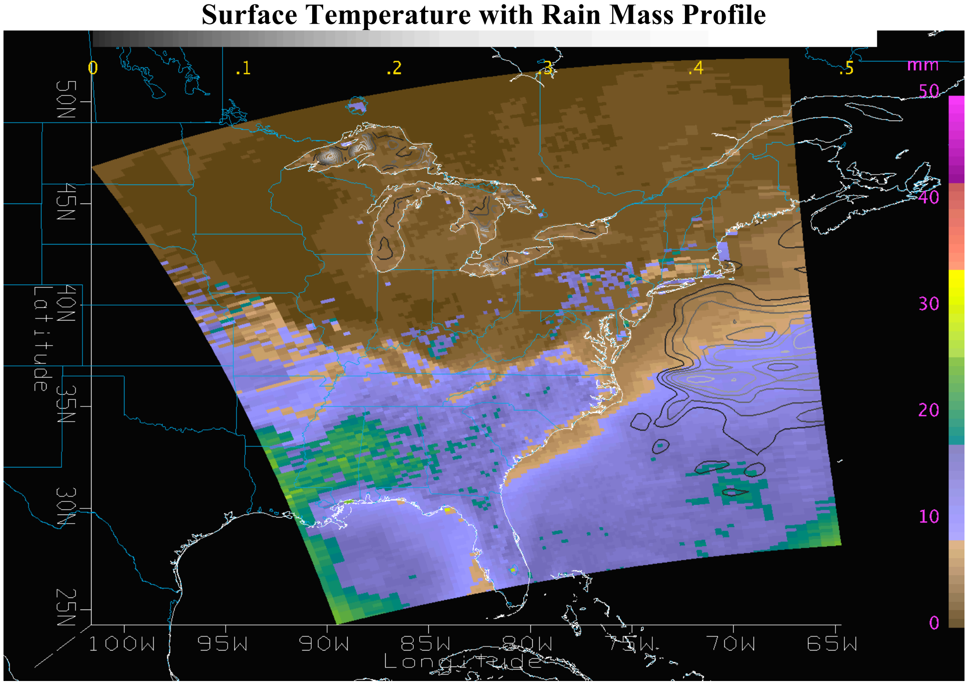
AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE SAN FRANCISCO BAY AREA
443 AM PDT FRI MAR 14 2014

.DISCUSSION...AS OF 4:10 AM PDT FRIDAY...THE DRY TAIL END OF A WEATHER SYSTEM MOVING IN TO THE PACIFIC NORTHWEST IS APPROACHING OUR DISTRICT...AND RESULTING IN ENHANCEMENT OF THE MARINE LAYER AND *A RETURN OF THE MARINE STRATUS. LATEST GOES FOG PRODUCT IMAGERY...AND IN RATHER SPECTACULAR DETAIL* ***JUST REC'D SUOMI VIIRS NIGHTTIME HIGH RES VISUAL IMAGE****...SHOW COVERAGE ALONG MUCH OF THE COAST FROM PT REYES SOUTH TO THE VICINITY OF THE MONTEREY PENINSULA...AND A BROAD SWATH EXTENDING INLAND ACROSS SAN FRANCISCO AND THROUGH THE GOLDEN GATE TO THE EAST BAY.* LATEST BODEGA BAY AND FT ORD PROFILER DATA INDICATE A MARINE LAYER DEPTH OF ABOUT 1300 FT. SOME THIN HIGH CLOUDS ARE ALSO PASSING THROUGH ABOVE.

Figure 83. VIIRS DNB image in AWIPS processed by CSPP showing low cloud and fog over San Francisco Region and mentioned in NWS forecast discussion on 14 March 2014.



Surface Temperature with Rain Mass Profile



Total Precipitable Water with contours of Cloud Liquid Water

Figure 84. Suomi NPP ATMS products created from direct broadcast data on 2014/01/23 by the CSPP release of the Microwave Integrated Retrievals System (MIRS).

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

CIMSS Task Leader: Liam Gumley

CIMSS Support Scientists: Scott Mindock, Ray Garcia, Graeme Martin, Geoff Cureton, Kathy Strabala, Jim Davies
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 proposes continue 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 Web site and User Forum;
- Providing user support for installing and operating ADL;
- Providing training material and courses for end users of ADL;
- Developing and enhancing the Virtual Appliance distribution of ADL;
- Developing an ingest and pre-processing capability for dynamic ancillary data in ADL;
- Verify compatibility with RDRs from Direct Broadcast sources;
- Check compatibility of Direct Broadcast produced SDRs with the corresponding IDPS SDRs; and
- Verify robustness of ADL distributions before public release.

SSEC 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 supported several ADL releases in 2013. In August an update to ADL 4.1 was received, built, tested, and posted for the public. This was followed by ADL 4.2 in September, and an update to ADL 4.2 in December. Each ADL release or update initiates several activities at SSEC. These activities include but are not limited to:
- Staging of ADL release DVD contents, including generation of checksums,
- Updates of installation scripts,
- Testing of installation scripts on several platforms,
- Updates to download page of ADL wiki,
- Updates to ADL installation instructions, and
- Building and testing ADL using a variety of compiler versions on supported platforms.

The ADL Virtual Appliance (VA), built on 64-bit Ubuntu Linux, continued to be a popular method for end users to download, install and run ADL. The ADL VA allows end users who may not have access to a configurable Linux system (e.g., users in the NOAA security zone) a way to get started with ADL using a Windows host computer. The ADL Virtual Appliance functions identically to a native Linux install of ADL, and provides all the functionality of the ADL build and run environment. 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 ADL 4.2 release included the addition of an Eclipse based XML/LUT editor, which precipitated the inclusion of Eclipse in the VA. SSEC supplied and maintained instructions for updating the virtual appliance to leverage Raytheon patches made available in the Common CM environment. Support for Perl was enhanced to simplify this process.

During the testing of the ADL 4.1 release a defect was discovered in the redirection of XML configurations. A fix for this defect was developed and reported to the Raytheon ADL team in time for inclusion in the ADL 4.2 release.

The SSEC ADL team also worked with CSPP developers to incorporate the use of compiler optimizations and configuration redirection into the CSPP release based on ADL 4.1.

SSEC continued to support, develop, and refine the ADL Web site for documentation and user instructions, and the ADL Forum for user interaction. The ADL Web site (Figure 85) is available at
https://jpss-adl-wiki.ssec.wisc.edu/

The ADL Web site includes information on ADL Software and Downloads, Installation Instructions, Scripts and Helper Applications, ADL Virtual Appliance, HOWTOs, Add-Ons, and a link to the ADL help desk email address. The Web site also contains links to the ADL ancillary data Web site.

The ADL User Forum (Figure 86) is available at
https://forums.ssec.wisc.edu/viewforum.php?f=23

and provides a place where ADL users can interact directly with 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. In 2013 changes to format of the VIIRS-SDR-RADIOMETRIC-PARAM- LUT and VIIRS-SDR-DNB-STRAY-LIGHT-CORRECTION-LUT required special attention by SSEC to ensure that correctly formats LUTS were available for ADL users. The Web site 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

Publications and Conference Reports

SSEC attended and presented at the ADL Workshop in January 2014. The presentation highlighted real world uses of ADL, and the services SSEC provides to support ADL users.

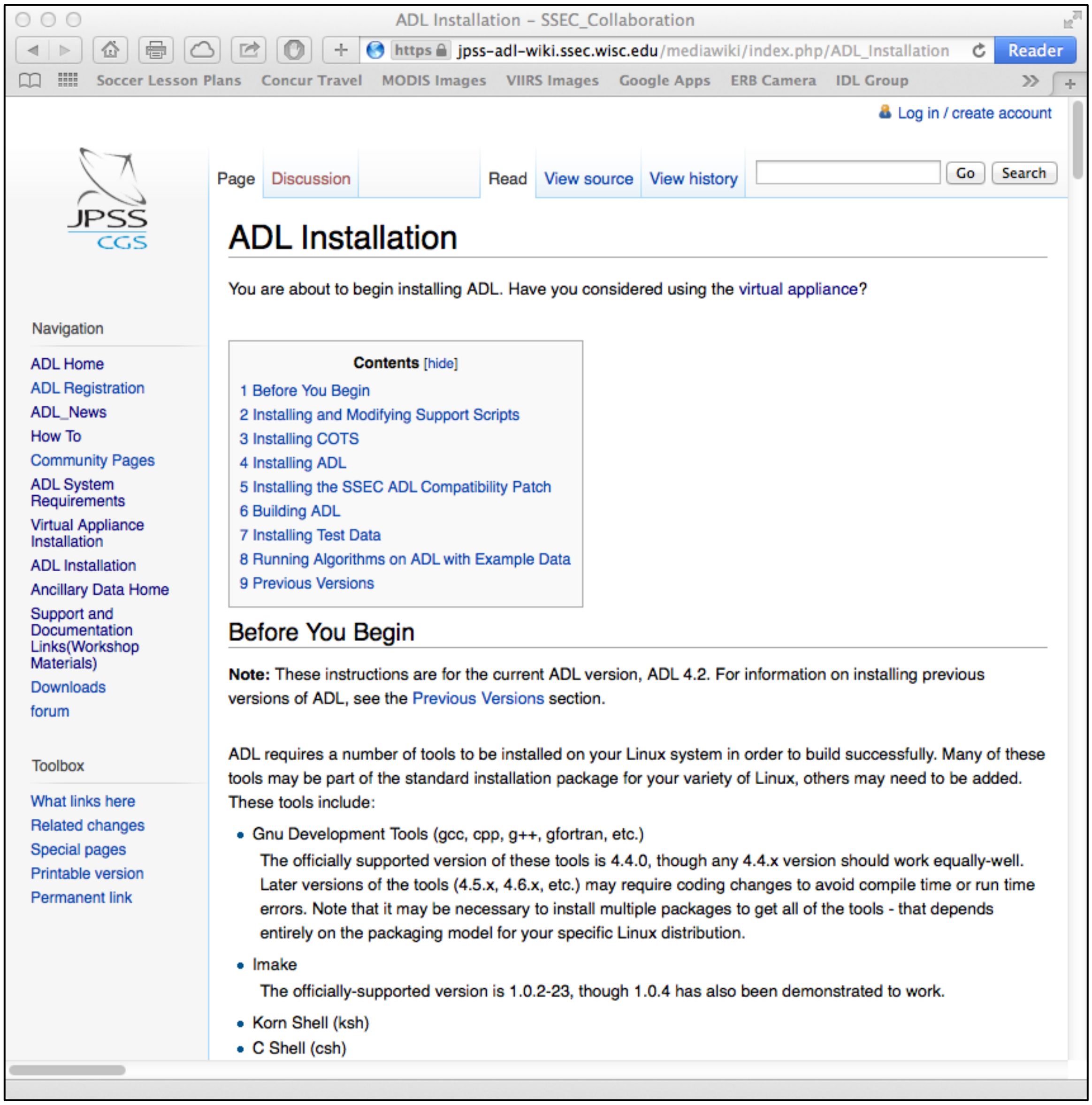


Figure 85. SSEC ADL Web site showing ADL installation instructions.

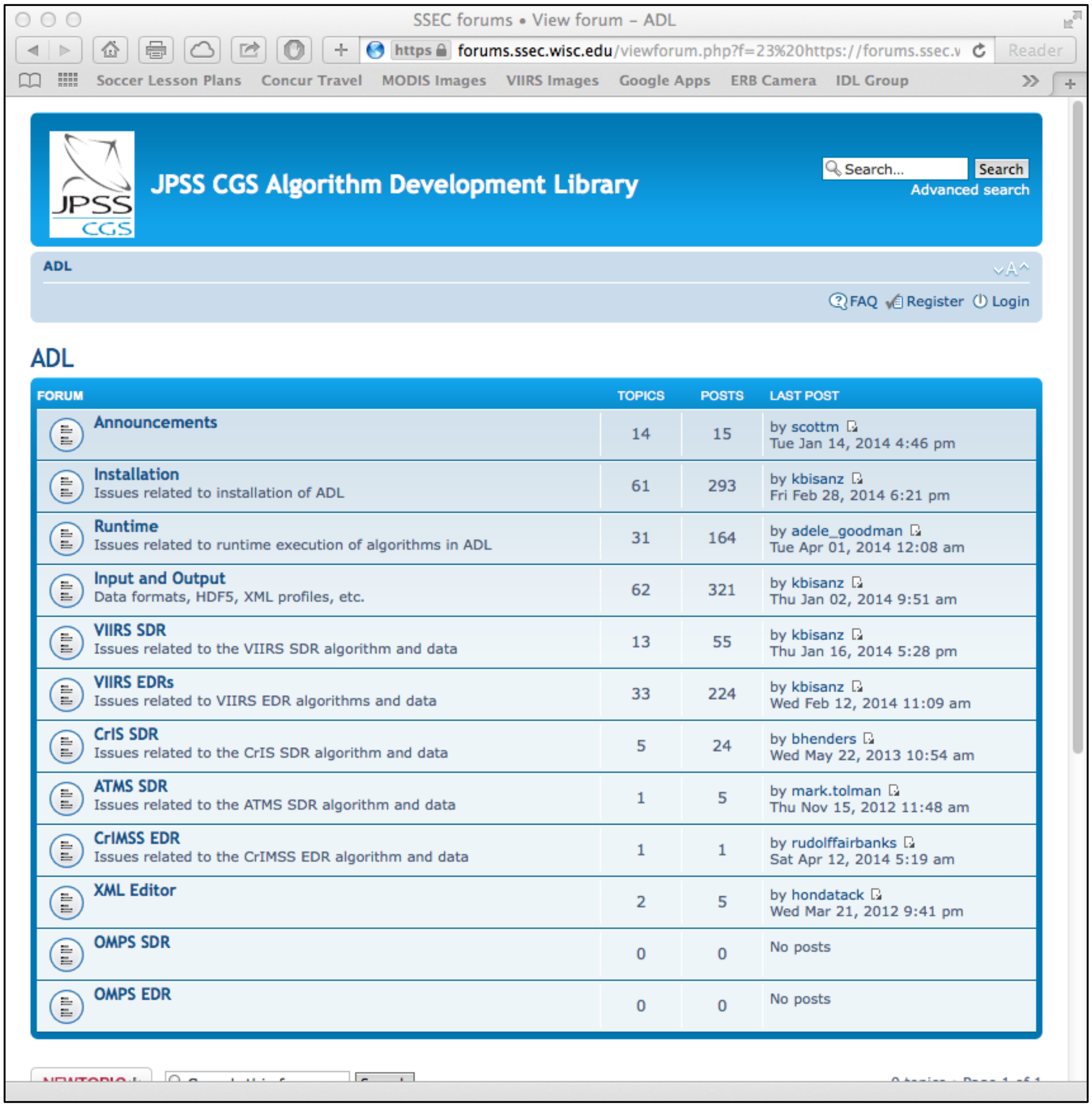


Figure 86. SSEC Forum Web site for ADL.

27. Science and Management Support for NPP VIIRS Snow and Ice EDRs in 2013

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

Work at CIMSS focused on obtaining 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. Our accomplishments and findings include:

- Ice surface temperature EDR passed the Stage 1 Maturity Evaluation;
- Visualizations and quantitative comparisons of daily global gridded VIIRS IST, have been made with MODIS IST and NCEP surface air temperature, Ice Bridge flight IST, as shown in Figure 87. The product meets accuracy requirements under some, but not all, conditions. The product has known flaws but these products are of sufficient quality to justify use by a broader community;

- Some false ice retrieved by the VIIRS Sea Ice Concentration IP has been linked to cloud leakage from a VIIRS Cloud Mask (VCM). IST EDR performance is expected to benefit from improvements to resolve the current VCM bias toward over-prediction of confidently clear regions at night in polar regions;
- Uncertainties for primary sample sets are 0.6-1.0K (requirement is 1K). Uncertainties when compared to MODIS IST are larger than requirement at higher temperatures; and
- There are larger uncertainties at high ice surface temperature.

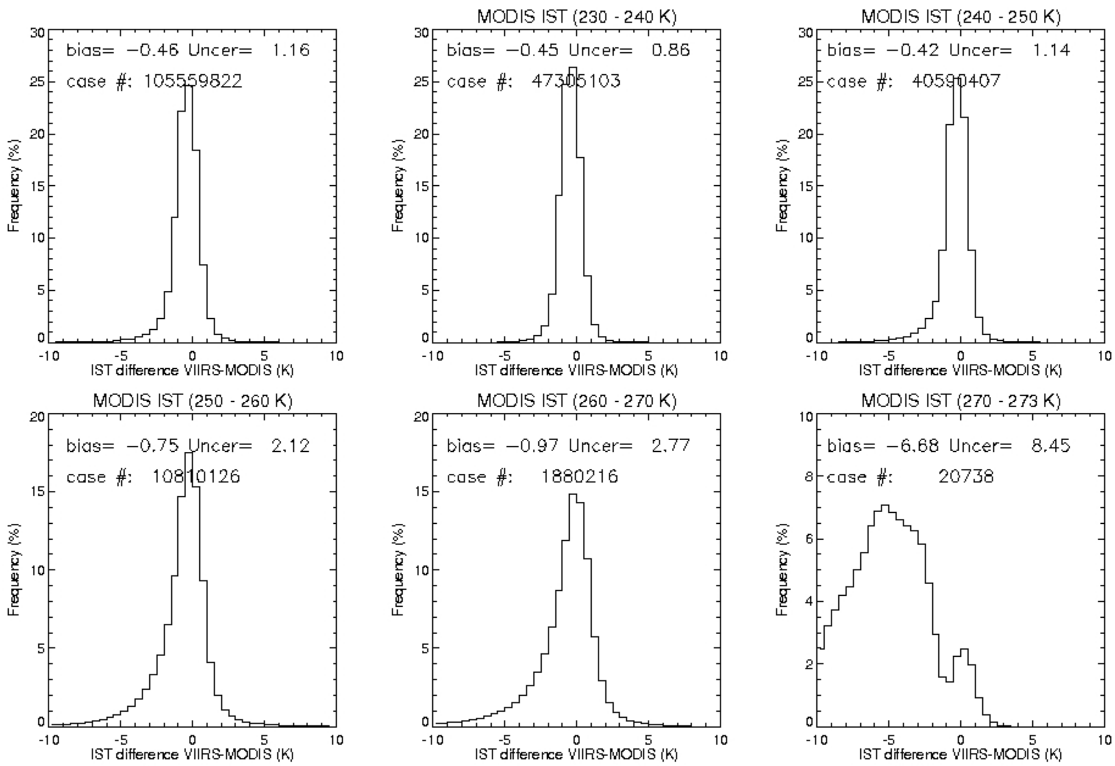


Figure 87. Histogram of ice surface temperature differences of NPP VIIRS and MODIS (Aqua and Terra) in February 2013 in the Arctic for all cases (upper left), and for cases with MODIS ice surface temperature in the ranges 230-240 K, 240-250 K, 250-260 K, 260-270 K, and 270-273 K. Measurement bias (bias) and measurement uncertainty (Prec) are indicated for each bin.

The cryosphere team in CIMSS continues to participate in the evaluation of the snow/ice product gridding process and its impact on downstream products. A summary of recommendations on the gridding process has been provided.

- Improvement in VIIRS gridded Snow/Ice was seen with the MX 7.2 VCM update and with the application of our additional quality control criteria.
- Sea Ice probability of detection and false alarm rate relative to NOAA Auto Snow and Ice for VIIRS gridded Sea Ice are approximately 87% (94%) and 7% (5%) respectively for Arctic Summer (Antarctic Winter) after testing with the proposed quality control criteria.
- Significant regions were not updated by VIIRS Snow/Ice even after a 7 day gridding test period.
- Cloud shadows result in missing snow/ice in the Snow/Ice Rolling Tile grid. A solar zenith angle threshold of 80° used in the gridding tests appeared to mitigate cloud shadow errors.

- Further reduction in Snow/Ice gridding errors will require significant effort to implement climatology-based quality control criteria, such as that used in the production of the NOAA Auto Snow and Ice, and additional quality control criteria.

Publications and Conference Reports

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, J. Geophys. Res. Atmos., 118, doi:10.1002/2013JD020459.

Liu, Y., J. Key, and X. Wang, 2013, Sea Ice Concentration with the Combined Use of Microwave and Visible/infrared Observations, 2013 AGU Fall Meeting, 9-13 December 2013, San Francisco California, USA.

28 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.

Summary of Accomplishments and Findings

This report covers the period from 1 March 2013 to 30 March 2014. During this period, specific tasks included:

- OTIM for use with MODIS Terra & Aqua composite data has been further improved with residual heat flux being estimated for accurate estimation of sea ice thickness for both day and night times;
- Sea ice thickness data from MODIS over 2003~2013 were processed for the Arctic and the Antarctic under not only clear sky condition but also cloudy sky condition as well; and
- Sea ice thickness data from MODIS, APP-x, ICESat, CrySat-2, SMOS, IceBridge, and PIOMAS have been all regridded to the 25 km EASE grid for the evaluation study, and the inter-comparisons between them.

Figure 88 shows an example of sea ice thickness data from different sea ice thickness data sets, namely, MODIS, APP-x, PIOMAS, ICESat, CrySat-2, SMOS, and IceBridge. Note that the dates are different for different sea ice thickness data sets as shown here.

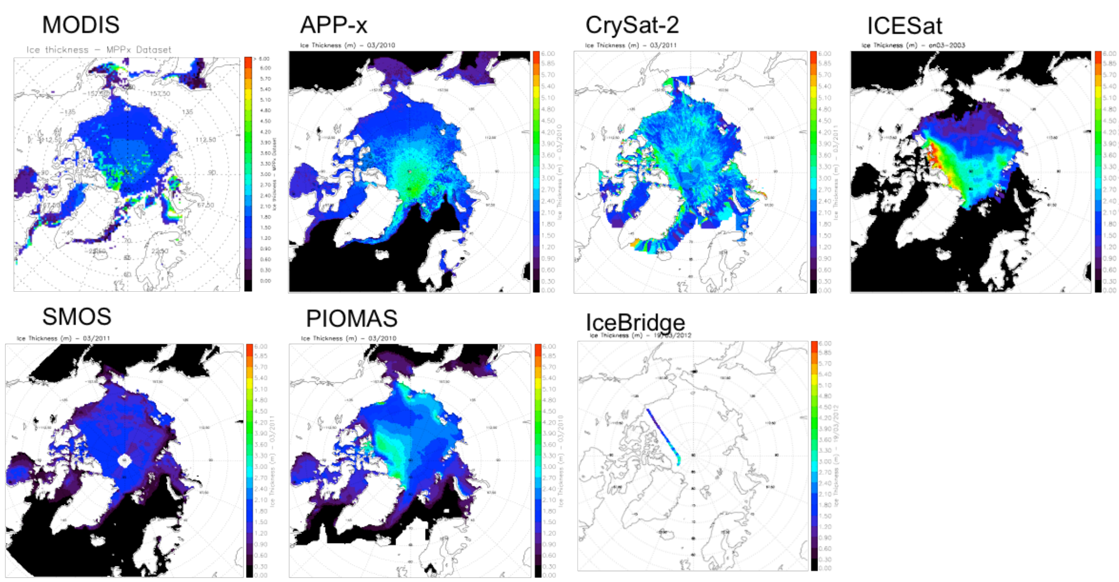


Figure 88. Sea ice thickness from MODIS, APP-x, CrySat-2, ICESat, SMOS, PIOMAS, and IceBridge.

Figure 89 lists the sea ice thickness data sets that have been generated and/or collected, and their corresponding time period for future evaluation, validation, and comparison work.

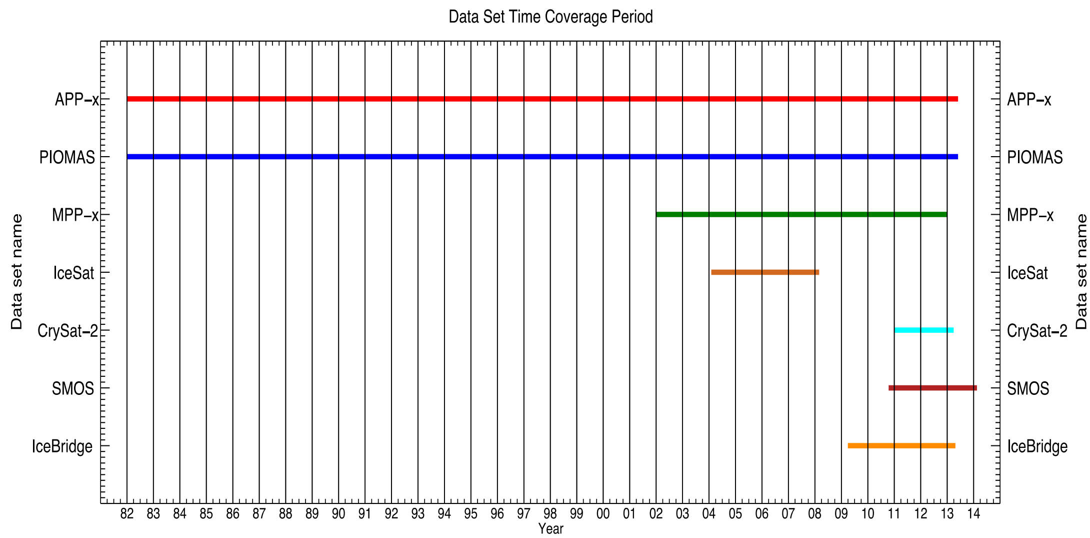


Figure 89. Sea ice thickness data set names and their time periods.

Publications and Conference Reports

Jeffrey R. Key, Robert Mahoney, Yinghui Liu, Peter Romanov, Mark Tschudi, Igor Appel, James Maslanik, Dan Baldwin, Xuanji Wang, and Paul Meade, 2013, Snow and Ice Products from Suomi NPP VIIRS, JGR-Atmospheres, 118, doi:10.1002/2013JD020459.

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.

29. 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

The Advanced Microwave Scanning Radiometer 2 (AMSR2) is the next generation of the AMSR-E instrument that is currently on NASA's Aqua satellite. AMSR2 is on the Japan Aerospace Exploration Agency (JAXA) Global Change Observation Mission 1st – Water (GCOM-W1) satellite. GCOM-W1 was launched in May 2012. NOAA is supporting work with AMSR2 as part of the Joint Polar Satellite System (JPSS) program.

Monitoring of cryosphere, and in particular of the Earth's snow cover, is among primary applications of the AMSR2 instrument. AMSR2 cryosphere environmental data records (EDRs) are Ice Characterization, Snow Cover/Depth, and Snow Water Equivalent (SWE). 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 will be modified as necessary. The assessment of the algorithm performance as well as the development of the data processing and product generation system will be conducted using observations from AMSR-E onboard Aqua as a proxy for GCOM AMSR2.

Summary of Accomplishments and Findings

Snow cover is one of the most dynamic hydrological variables on the Earth's surface and it plays a key role in the global energy and water budget. The ability to detect global snow cover and measure snow depth in nearly all weather conditions has been shown using satellite passive microwave measurements such as the Scanning Multi-channel Microwave Radiometer (SMMR), the Special Sensor Microwave Imager (SSM/I), and the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E). Unfortunately, AMSR-E on NASA's Aqua satellite stopped functioning on October 4, 2011. The Advanced Microwave Scanning Radiometer 2 (AMSR2) instrument launched on May 18, 2012 onboard the Global Change Observation Mission 1st - Water "SHIZUKU" (GCOM-W1) satellite. From an operational and functional perspective, it will replace the AMSR-E instrument.

The suite of AMSR2 algorithms that is being developed for the retrieval of snow cover and snow depth 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 application of the developed snow detection, snow depth, and snow equivalent algorithms to AMSR2 measurements. Preliminary validation results are encouraging. Figure 90 shows the accuracy of the snow detection algorithm applied to AMSR2 data when compared to the Interactive Multisensor Snow and Ice Mapping System (IMS) as the reference. The overall accuracy is generally above 80%. Based on this result, the product will meet the system requirements. Figure 91 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 are used. Spatial patterns in the two products are similar.

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

Publications and Conference Reports

Lee, Y.-K., C. Kongoli, and J. R. Key, 2013, “Snow property (snow cover, depth, and SWE) retrieval from the Global Change Observation Mission (GCOM) AMSR2 measurement”, 2013 Fall meeting, AGU, 9-13, Dec. San Francisco, CA.

References

Grody, N. C. (1991), Classification of snow cover and precipitation using the special sensor microwave imager, J. Geophys. Res., 96 (D4), pp 7423-7435.

Grody, N. C., and A. N. Basist, (1996), Global identification of snowcover using SSM/I measurements, IEEE Trans. Geosci. Remote Sens., 34 (1), pp 237-249.

Kelly, R. (2009), The AMSR-E snow depth algorithm: description and initial results, J. Remote Sensing Soc. Japan, 29 (1), pp 307-317.

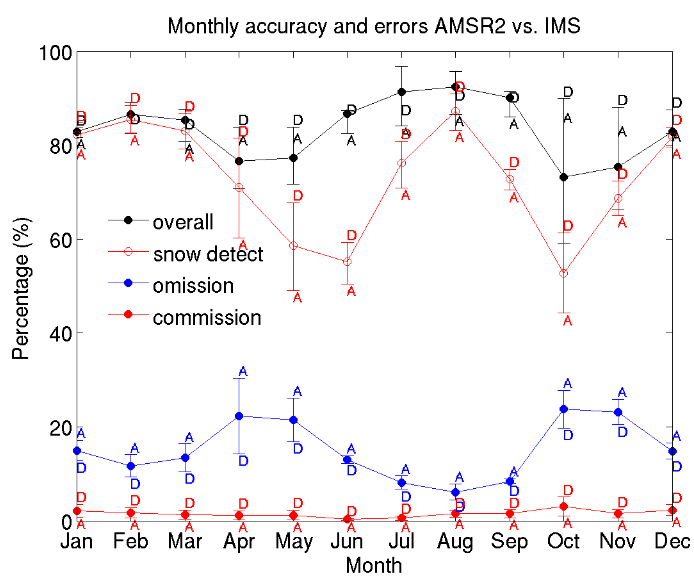


Figure 90. Snow detection/false alarm rate of AMSR2 with Grody's algorithm compared to IMS snowcover for every 5 day (13-17) of each month between August 2012 and July 2013. The bars above and below each point indicate descending ("D") and ascending ("A") orbits.

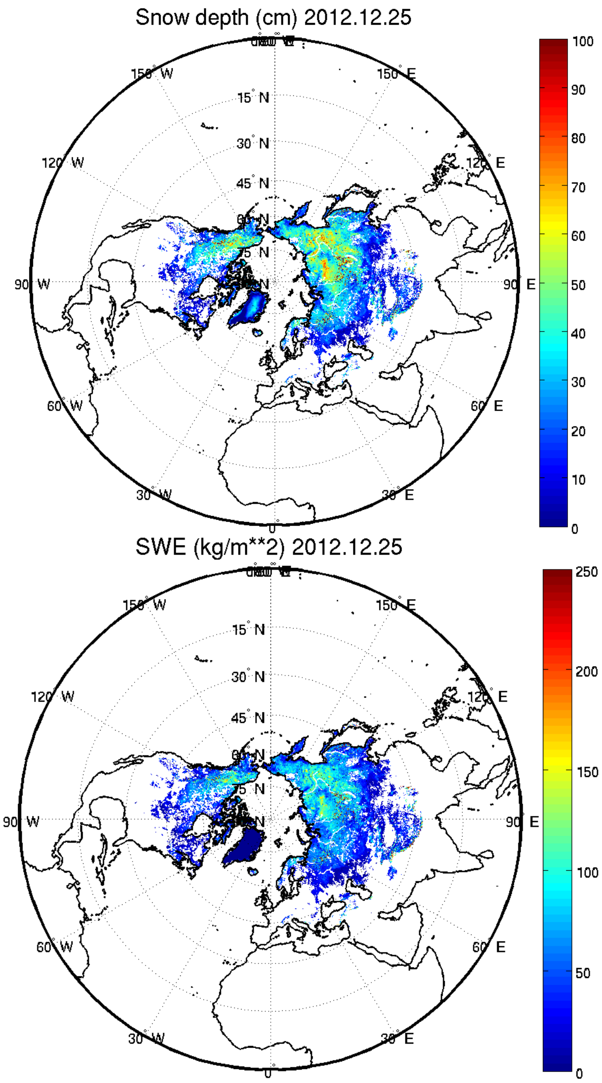


Figure 91. Snow depth from AMSR-E (Kelly's algorithm, left) and snow water equivalent product (right) on 25 December 2012. The two products show similar spatial patterns and variability.

30. Identification of Severe PyroConvection Events in GOES-R and S-NPP Data

CIMSS Task Leader(s): Bryan A. Baum (PI), Scott Bachmeier (Co-I)
NOAA Collaborator(s): Andrew Heidinger (NOAA/NESDIS/STAR), Dan Lindsey (NOAA/NESDIS/STAR)

NOAA Long Term Goals:

- Climate Adaptation and Mitigation
- Weather-Ready Nation

NOAA Strategic Goals:

- Serve society's needs for weather and water
- 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 goal of this proposal is to use geostationary data to investigate the impact of wildfire events that become pyroconvective, meaning that plumes quickly grow to incredible heights over the course of hours and become pyroCumulonimbus, or pyroCb (Fromm et al., 2010). The pyroCb events inject huge amounts of 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 is a training ground for undergraduate students to discuss a severe pyroCb event as it unfolds, provides information to the general public, and will also support scientific research that will eventually makes its way into the peer-review literature.

Summary of Accomplishments and Findings

We initiated a blog in 2013 to track the occurrence of new events: http://pyrocb.ssec.wisc.edu. The original focus 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. As it turns out, there were numerous pyroCbs in 2013, and fortunately we were able to obtain GOES-14 super rapid scan (1 minute) data for several of them. The pyroCb blog continues to evolve as we gain experience to make it easier for viewers to understand what is in the geostationary animations of reflectance and infrared (IR) brightness temperature. Additionally, 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. The pyroCb blog currently enlists five undergraduate (UG) atmospheric science students. The UG students are proficient at preparing geostationary data animations and organizing 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 UG students to provide analysis and discussion of pyroCb events as they occur. In this project, we intend to focus on the more practical, operational aspects of pyroCbs, such as the plume affect on cloud properties, the role of lightning in the plumes, determination of smoke injection height, and the use of HYSPLIT to gain a sense of the plume dispersion.

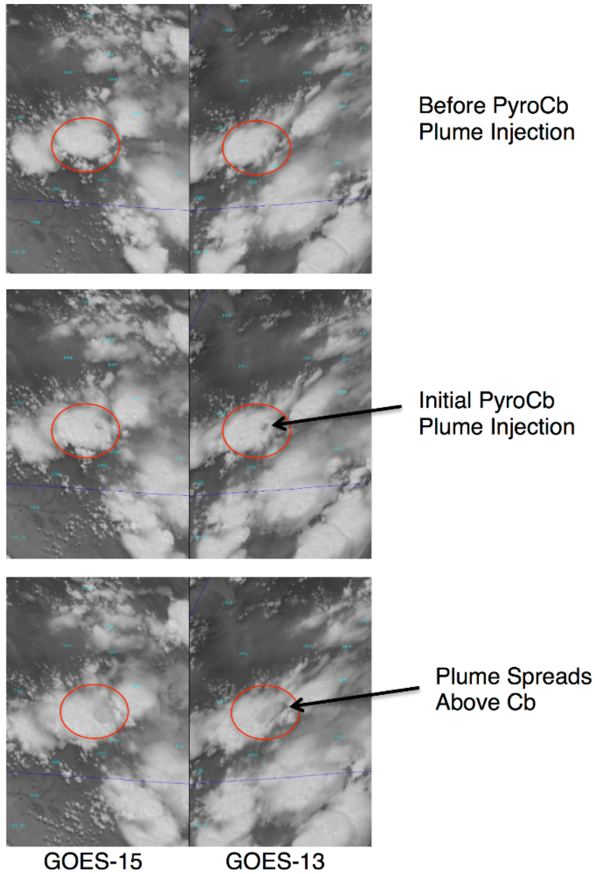


Figure 92. GOES-15 (left) and GOES-13 (right) 0.63 µm visible channel images of the West Fork, Colorado PyroCb event on June 28, 2013 at 15-min intervals showing the penetration of an existing cumulonimbus cloud by a pyroCb plume. The top panels show the initial state of the Cb before the plume interacts with it – the region of interest is within the red circle on each panel. The middle panels show the initial penetration of the Cb by the smoke plume rising from the pyroCb. The bottom panels show the dispersion of the smoke plume over the Cb. Further information may be found on the blog post for this event at http://pyrocb.ssec.wisc.edu/archives/95.

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

CIMSS Task Leader: James Jung
NOAA Collaborators: John Derber, Daryl Kleist, Sid Boukabara

NOAA Long Term Goals:
- Weather-Ready Nation

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

CIMSS Research Themes:

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

Project Overview

This project proposes to develop and evaluate several advanced data assimilation techniques, including but not limited, to assimilate infrared and microwave water vapor channels in NOAA operational forecast models, with a goal to improve the model fields within the analysis (i.e., moisture), with a focus on the 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 National Oceanic and Atmospheric Administration (NOAA) operational weather forecast models.

Other responsibilities of this project are to maintain a credible Operations-to-Research (O2R) environment of the NOAA operational weather forecast models. The focus here will be the National Centers for Environmental Prediction (NCEP) Global Data Assimilation System/Global Forecast System (GDAS/GFS) and validation/verification software.

Summary of Accomplishments and Findings

Changes to how supersaturation is controlled in the GDAS/GFS was developed and incorporated into the Gridpoint Statistical Interpolation (GSI) portion of the GDAS. This technique consists of reducing points which are supersaturated to saturation during each outer loop and penalizing the minimization for producing supersaturation. A two month, during two seasons experiment was then conducted to determine the effects of these changes. We used the 2012 hybrid version of the GDAS/GFS on the Joint Center for Satellite Data Assimilation (JCSDA) computer JIBB.

Removing the supersaturation made significant changes to the moisture field within the analysis. Two common verification parameters are relative humidity and cloud water mass. Both parameters were reduced in the mid- and upper-troposphere as shown in Figure 93 and Figure 94. Changes were also noted in the temperature field as the cold bias/drift in the stratosphere was also reduced.

The next phase of this experiment was to modify the GSI to use specific humidity perturbations, instead of relative humidity, from the ensemble members to determine the moisture background errors. The hypothesis was that using relative humidity, containing both temperature and moisture perturbations was actually using the temperature perturbations twice. Daryl Kleist (NOAA/NCEP) modified my supersaturation removal version of the GSI to use the specific humidity perturbations. A two month, during two seasons experiment was conducted to determine the effects of these changes.

The results of this test showed little change in the moisture field of the model but did have a positive impact on most of the forecast skill parameters used by NCEP. There were day to day variations in the moisture and cloud fields but the overall statistics showed little change over the reduction in relative humidity and cloud water mass compared to removing the supersaturation. There were general improvements in the global temperature fields and the tropical winds. There were also improvements in the anomaly correlation scores as shown in Figure 95.

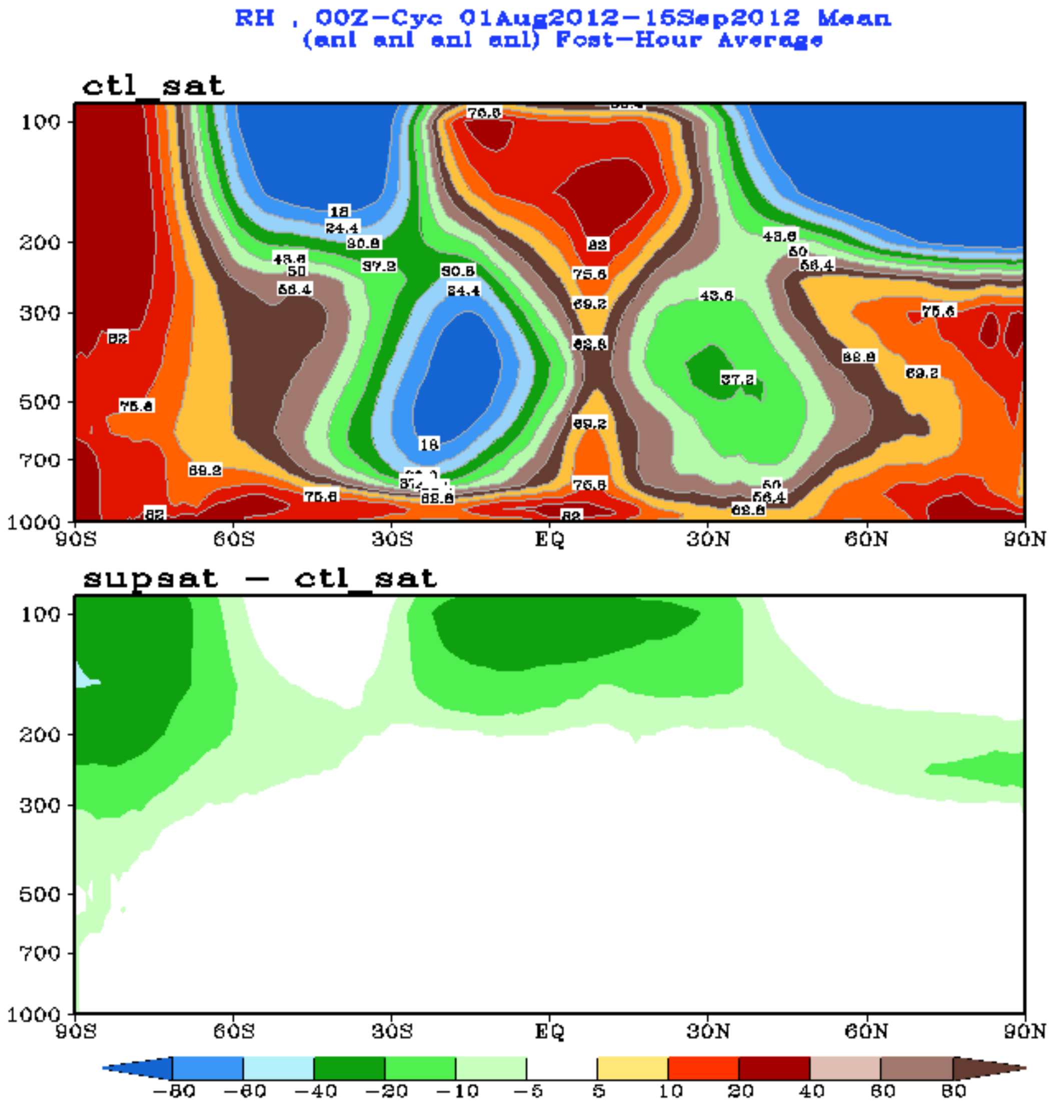


Figure 93. Difference in relative humidity from removing supersaturation from the analysis. Top panel is the average humidity field from the control. Bottom panel is the difference between the removal of supersaturation (supersat) and the control (ctl_sat). Green indicates the mid and upper troposphere is drier when the supersaturation is removed from the analysis.

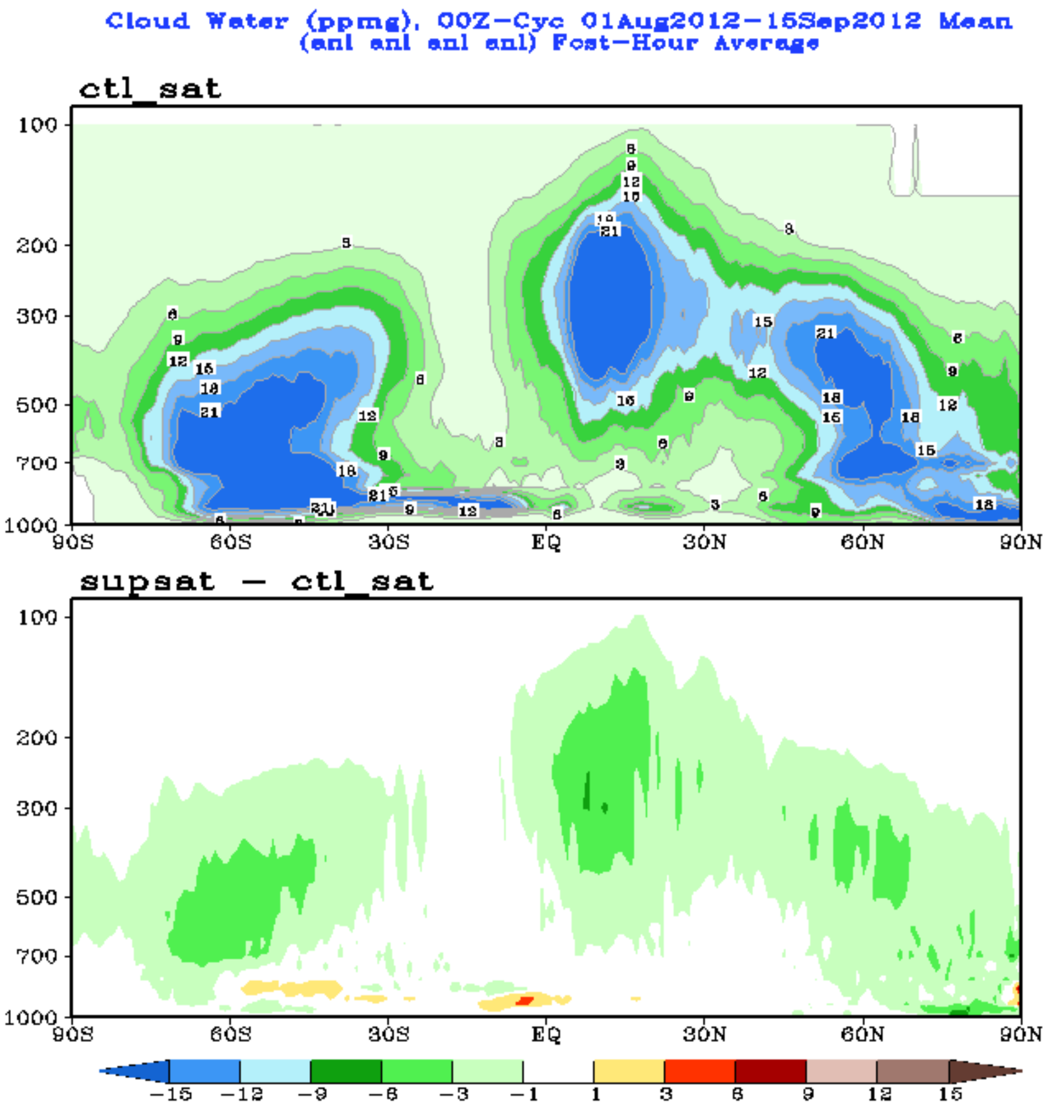


Figure 94. Difference in cloud water mass from removing the supersaturation from the analysis. Top panel is the average cloud water mass field from the control. Bottom panel is the difference between the removal of supersaturation (supersat) and the control (ctl_sat). Green indicates there are less/thinner clouds in the mid and upper troposphere when the supersaturation is removed from the analysis.

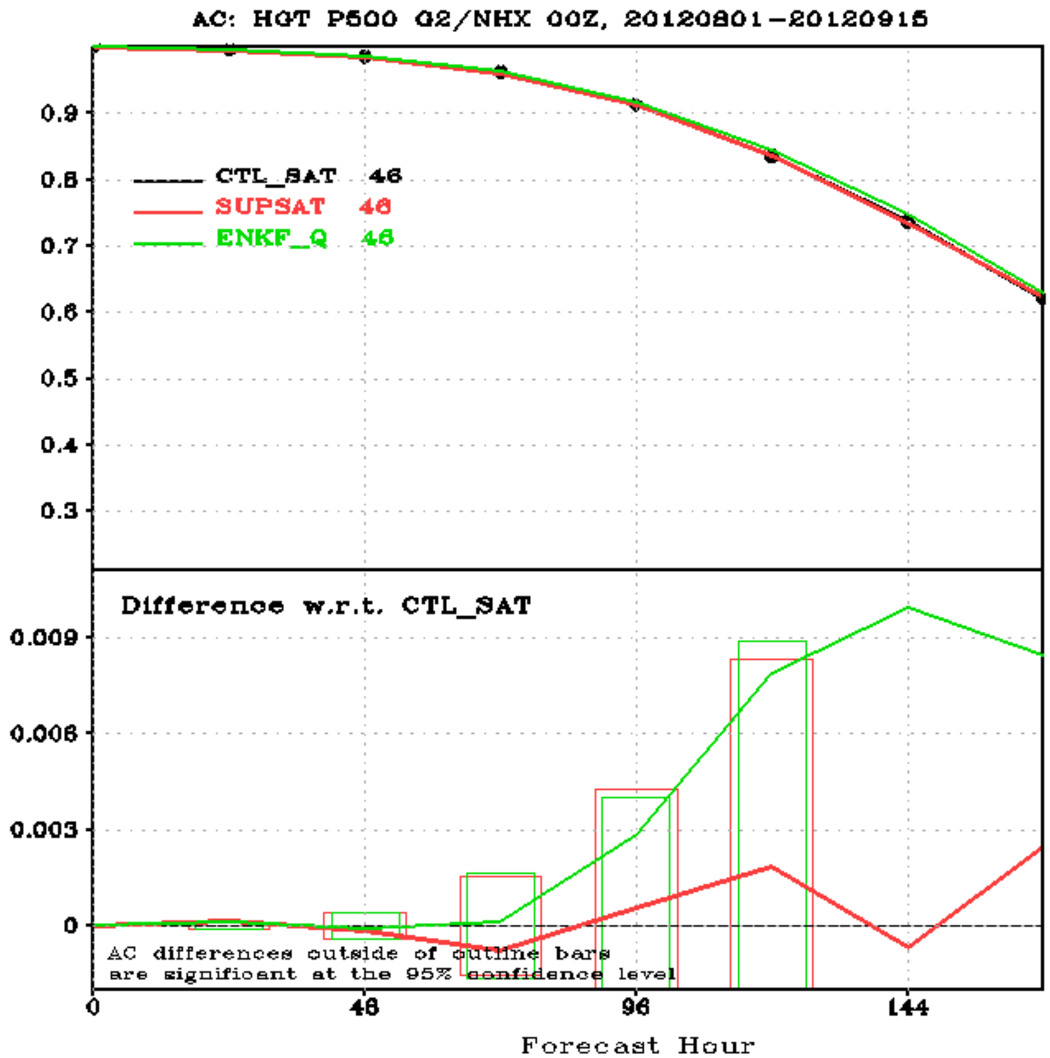


Figure 95. 500 hPa Northern Hemisphere anomaly correlation die-off curves for the supersaturation removal (supsat, red) and using specific humidity instead of relative humidity when generating the background error (enkf_q, green). The top panel is the actual scores. The bottom panel is the difference between the two experiments and the control. Positive differences indicate improvements in forecast skill over the control.

The modifications necessary to the GSI from both of these experiments have passed NCEP's science and code reviews. They are now part of the GSI. All of the groups currently using the GSI to initialize their forecast models are now able to use/implement these techniques.

Three OSEs were conducted this year. As outlined in the proposal, these experiments started with a minimum number of observations (all conventional data and the Global Positioning System – Radio Occultation (GPS-RO)) and added 1) the NOAA-19 Advanced Microwave Sounding Unit / Microwave Humidity Sounder (AMSUA/MHS) and 2) the JPSS Advanced Technology Microwave Sounder (ATMS) and 3) the NASA Aqua (Atmospheric InfraRed Sounder (AIRS). These experiments used the May 2012 version of the NCEP GDAS at the NCEP operations resolution and were conducted during two seasons.

In general the results illustrated that the three instruments (AMSUA/MHS, ATMS, and AIRS) produce almost equivalent forecast improvements, as measured by anomaly correlations, with respect to the minimum observations as shown in Figure 96.

The Operations to Research (O2R) activities are continuous. The various operational forecast models and verification software are updated on an irregular but continuous basis. In order to be capable of transitioning any new assimilation techniques back to the operational NWP centers, these updates must be part of the research test environment. We have been focused primarily on maintaining the NCEP GDAS/GFS and its verification packages. The JCSDA computers are not identical to the NCEP operational computers, so several porting issues must be addressed with each upgrade. Since the JCSDA computers are not bit-reproducible with the NCEP operations computers, extensive testing must be conducted to ensure the answers are consistent and the differences statistically insignificant.

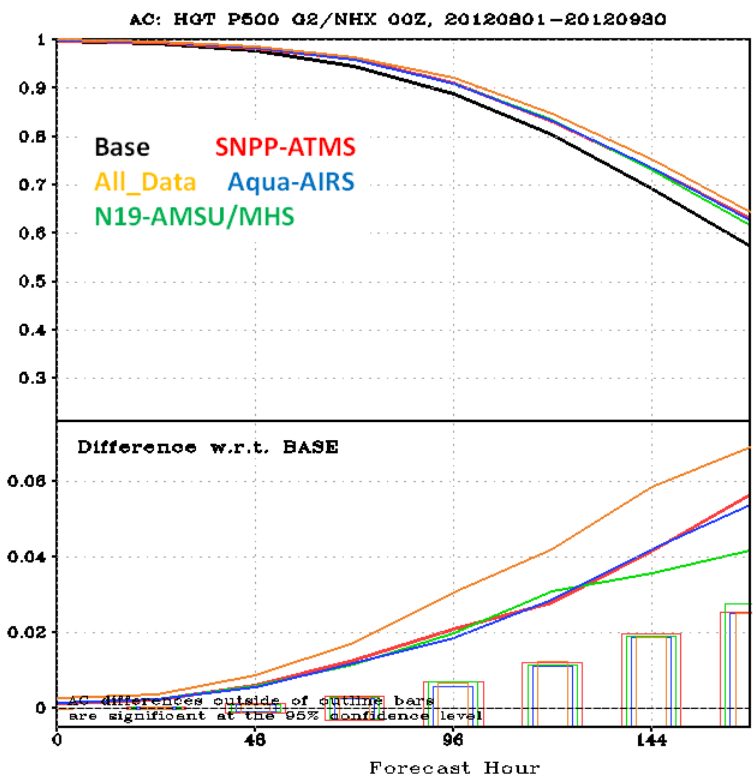


Figure 96. 500 hPa Northern Hemisphere anomaly correlation die-off curves for the baseline experiment (Base, black), adding ATMS (SNPP-ATMS, red), adding AMSU/MHS (N19-AMSU/MHS, green), and using all available data (All_data, yellow). The top panel is the actual scores. The bottom panel is the difference between the baseline experiment and the various data addition experiments. Positive values indicate improvements in forecast skill over the baseline experiments.

Publications and Conference Reports

Bi. L., J. Jung, and S. Boukabara, 2013: Assimilating OSCAT Surface Wind Retrievals in the NCEP GDAS/GFS., JCSDA 11th Annual Workshop, 5-7 June 2013.

Jung, J. A., 2013: JCSDA O2R / R2O Maintenance, OSEs and Water Vapor Data Assimilation Techniques, JPSS Proving Ground Seminar, 29 May 2013.

Jung, J. A., 2013: Water Vapor Assimilation, Preliminary Results of Correcting for Supersaturation., JCSDA 11th Annual Workshop, 5-7 June 2013.

Santek, D., B. Hoover, S. Nabuda, and J. Jung, 2013: Status of improving the use of MODIS, AVHRR, and VIIRS polar winds in the GDAS/GFS., JCSDA 11th Annual Workshop, 5-7 June 2013.

Shontz, K., J. Jung, M. Goldberg, S. Lord, J. Derber, and A. Maples, 2013: Satellite Data Assimilation Impacts on Simulated Weather Forecasts: An overview of the Joint Polar Satellite System (JPSS) Program Science Impact Studies. 2013 EUMETSAT Meteorological Satellite Conference, Vienna Austria, 16-20 September 2013.

Jung, J., 2013: Impacts on Global Forecasts: Conventional vs Satellite Data, JCSDA Quarterly Newsletter, March 2013.

Le Marshall, J., J. Lee, J. Jung, P. Gregory, and B. Roux, 2013: The considerable Impact of Earth Observations from Space on Numerical Weather Prediction. Submitted to Aust. Meteor. Ocean. Journal.

Le Marshall, J., J. A. Jung, J. Lee, C. Barnett and E. S. Maddy 2013: Improving Tropospheric and Stratospheric Moisture Analysis with Hyperspectral Infrared Radiances, Accepted for publication by Aust. Meteor. Ocean. Journal.

Le Marshall, J., R. Seecamp, Y. Xiao, P. Gregory, J. Jung, P. Stienle, T. Skinner, C. Tingwell, and T. Le, 2013: The Operational Generation of Continuous Winds in the Australian Region and their Assimilation with 4DVAR., Wea Forecasting, 28, 504-514.

32. 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 (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. 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

During the previous six months, we began working on an idealized OSSE experiment that will investigate the impact of assimilating different types of satellite data with and without radar data using a storm-scale model. A 1-km nature run, or "truth" simulation, was performed using the Advanced Regional Prediction System (ARPS) for 04 June 2005, with data output at 5-minute intervals. The environment for the idealized case was defined using a modified sounding from Topeka, KS at 0000 UTC to capture the overall environment present for this event. Convection within the truth run was initiated using a surface warm bubble placed in the southwest portion of the domain at the beginning of the experiment. In this environment, convection rapidly develops, taking on supercell characteristics before growing upscale and taking on more linear features by the end of the simulation. Synthetic WSR-88D Doppler radar reflectivity and radial velocity observations along with GOES-R ABI infrared brightness temperatures were generated using output from the truth simulation, and are used during the assimilation experiments.

Assimilation experiments were performed using the ensemble Kalman filter (EnKF) algorithm 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. The code was also updated so that the University of Wisconsin Global Infrared Land Surface Emissivity database could be used instead of the default CRTM surface emissivity dataset. Scripts were set up to run the assimilation experiments and initial conditions for the idealized experiments were created. Radar reflectivity and radial velocity observations have been successfully assimilated and several covariance localization thresholds were tested. Forecasts were run for those experiments and some post-processing scripts were set up for computing statistics from the data resulting from the assimilation and forecast periods.

Current efforts are focused on assimilating synthetic GOES-R satellite observations from bands 8 and 9, which have central wavelengths of 6.19 and 6.95 microns, respectively, and are sensitive to atmospheric water vapor and clouds. Different horizontal localizations were tested for the spatial resolution and domain being used, with results indicating that a much smaller localization radius than had been used for previous mesoscale OSSE experiments was required to eliminate instabilities in the assimilation system. It was originally assumed that perturbing the initial sounding and then using the perturbed soundings to create an ensemble of horizontally homogeneous initial conditions similar to prior experiments would be sufficient to allow the assimilation and production of a storm to occur.

Publications and Conference Reports

Cintineo, R., J. A. Otkin, T. A. Jones, S. Koch, L. Wicker, and D. J. Stensrud., 2014: Assimilation of satellite and radar observations in a convection-resolving Observing System Simulation Experiment. *22nd Conference on Numerical Weather Prediction*, Atlanta, GA.

33. CIMSS Cal/Val Activities in Support of the Calibration Working Group

CIMSS Task Leader: Mathew Gunshor
CIMSS Support Scientists: James P. Nelson III, Anthony J. 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
CIMSS has been heavily involved in GOES calibration as well as product generation since its inception. The experience developed at CIMSS on current GOES has been extended to include the GOES-R ABI. Over half of the ABI product algorithms were developed at CIMSS.

There are five sub-tasks proposed to meet the objective of this project. The first is to assist the CWG on matters of ABI calibration by consulting (through the monthly CWG telecons) with the group and, when appropriate, offering a tie-in to products to help quantify and understand calibration issues. This will help ensure ABI L1b calibration and data quality. The capability of generating products, comparing product outputs, and product analysis has been developed at CIMSS already under the GOES-R Algorithm Working Group (AWG). The second objective is to assist the CWG with JMA's AHI in understanding the calibration and navigation, which allows us to leverage any knowledge gained at JMA and will help the CWG prepare for the ABI. In addition to this we propose to continue the monitoring of current GOES Sounder calibration using the "calc versus obs" method begun in the prior year, as practice for the GOES-R ABI. Finally, we propose to report to the CWG any issues that CIMSS assists with that affect current GOES radiance quality which arise periodically, but unpredictably.

Proposed Activities
1) Attend monthly CWG telecons
2) Assist CWG in analysis of calibration issues as pertaining to their effects on products, supporting L1b calibration and ensuring ABI data quality.
3) Assist CWG in analysis of calibration and navigation on JMA's AHI.
4) Continue GOES Sounder "calc versus obs" on-line Web tool.
5) Report on issues addressed by CIMSS that affect current GOES radiance quality.

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

how to handle future situations. One of the topics discussed by CIMSS was an issue of co-registration affecting the GOES-13 Imager. Co-registration is a problem where data from two or more satellite bands from the same instrument are not aligned properly on the Earth coordinate system. Slides were presented illustrating the process of how the issue was discovered (fictitious fog and clouds in river valleys and along other land/water boundaries) and highlighting the effect of the co-registration problem on products such as cloud top pressure and the cloud mask. Before implementing a possible Co-registration correction technique additional testing by the bio mass burning group using GOES-13 Imager data revealed new insights. Rather than alter the 3.9 um band and alter our ability to detect and characterize fires, it was decided to alter the other bands instead to reduce the co-registration errors.

On 22 May 2013, GOES-13 experienced a serious anomaly, now believed to be caused by a micro-meteorite striking the spacecraft, which caused the satellite to place itself in storage mode. CIMSS, SSEC, and ASPB colleagues provided support to the Office of Satellite and Product Operations (OSPO) during the outage. On 30 May 2013 GOES-13 was sending data again. These data were received in real-time by the SSEC Data Center. The Sounder was put through outgassing at the request of T. Schmit (NOAA/NESDIS/STAR) for approximately 4 days in order to improve signal-to-noise before returning to operations. The operational Sounder data were monitored for noise and showed an improvement in the shortwave bands, especially band 15 (4.5 um). This was presented to the CWG in June 2013.

In addition to this, CIMSS continues to maintain a Web page for monitoring GOES Sounder calibration. The method utilized for this is primarily comparing calculations from a forward model using forecast model atmospheric profile data to actual Sounder observations. This is often referred to as “calc vs obs,” and is used by EUMETSAT and others as well. The GOES Sounder monitoring Web site has gone through many upgrades, and is now capable of generating custom plots and saving the plots to the user’s local computer. This is an improvement over previous versions of the page which had static plots generated automatically. Allowing the user to generate their own plots provides the ability to choose custom dates and overlay multiple variables on one plot.

CIMSS provided high resolution NWP data to the CWG so that a smarter resampler could be tested and will work with the CWG to quantify those results, possibly in level 2 product space.

The latest Spectral Response Functions (SRFs) for the AHI were downloaded from the JMA Web site and compared to the version 1 and version 2 ABI flight model 1 SRFs. Figure 97 and Figure 98 show the visible/near-InfraRed and IR, respectively, SRFs for ABI Flight Model 1 version 1, version 2, and the AHI. Collaborations with JMA will continue where possible. Table 3 contains the brightness temperatures calculated by convolving the SRFs of ABI (versions 1 and 2 of Flight Model 1) and AHI with the US Standard Atmosphere radiance spectrum (at 0.1 cm-1 spectral resolution). The last two columns are the brightness temperature differences, by band, comparing ABI version 1 to version 2 and AHI to ABI version 2. In the comparisons of version 1 to version 2, the bands are very similar, as seen in Figure 98, with differences typically very small except in bands 11 and 16. The difference in band 16 is remarkably large (over 1.5 K). The differences between the ABI and AHI are on the order of several tenths of a degree (K) for most bands. In Table 4 the Planck Function Coefficients for converting radiance to brightness temperature are shown. These are calculated from the ABI version 2 SRFs and follow the formula outlined in the GOES-R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document (ATBD) for Cloud and Moisture Imagery Product (CMIP).

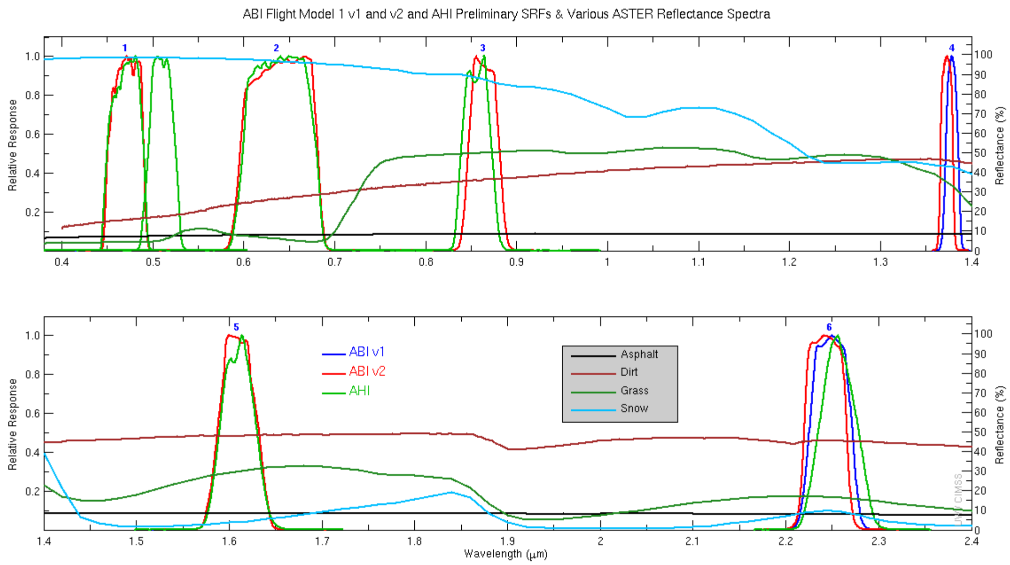


Figure 97. ABI Flight Model 1 version 1(blue), version 2 (red), and AHI (green) visible/near-IR spectral response functions plotted together with various ASTER reflectance spectra for different surface types.

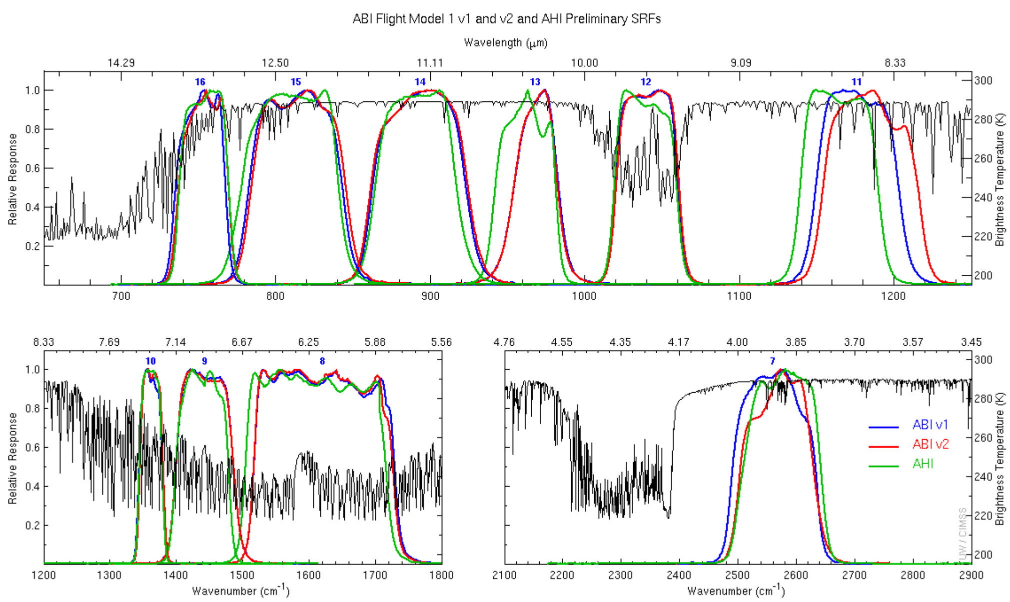


Figure 98. ABI Flight Model 1 version 1(blue), version 2 (red), and AHI (green) IR spectral response functions plotted together with the US Standard Atmosphere brightness temperature spectrum.

Table 3. Brightness Temperatures (and differences) calculated for the ABI version 1, version 2, and AHI spectral response functions convolved with the US Standard Atmosphere Spectrum. Column one contains the ABI band number and the nominal central wavelength.

IR Band	ABIv1 Tbb (K)	ABIv2 Tbb (K)	AHI Tbb (K)	ABIv1-v2 (K)	AHI-ABIv2 (K)
07 (3.9µm)	288.24	288.27	288.30	-0.03	0.03
08 (6.19µm)	236.23	236.18	235.74	0.04	-0.44
09 (6.95µm)	244.21	244.24	244.54	-0.03	0.30
10 (7.34µm)	255.07	254.98	255.01	0.09	0.03
11 (8.5µm)	286.11	285.85	286.19	0.26	0.34
12 (9.61µm)	260.52	260.46	260.70	0.05	0.24
13 (10.35µm)	288.34	288.36	288.47	-0.02	0.11
14 (11.2µm)	288.67	288.67	288.66	0.00	-0.01
15 (12.3µm)	286.42	286.50	286.22	-0.08	-0.28
16 (13.3µm)	271.00	272.62	272.87	-1.61	0.25

Table 4. Similar to Table 8 in the GOES-R AWG Cloud and Moisture Imagery Product (CMIP) Algorithm Theoretical Basis Document (ATBD), the Planck Function Coefficients (to convert between radiance and brightness temperature) for the ABI version 2 spectral response.

IR Band	Central Wavelength (µm)	Central Wavenumber (cm^{-1})	FK1	FK2	BC1	BC2
07 (3.9µm)	3.89	2570.33	202252.01	3698.12	0.43892	0.99939
08 (6.19µm)	6.17	1620.46	50680.37	2331.47	1.56423	0.99664
09 (6.95µm)	6.93	1443.60	35831.67	2077.01	0.35423	0.99916
10 (7.34µm)	7.34	1363.22	30173.46	1961.37	0.05680	0.99986
11 (8.5µm)	8.44	1184.24	19780.75	1703.85	0.19178	0.99947
12 (9.61µm)	9.61	1040.89	13432.02	1497.61	0.09115	0.99971
13 (10.35µm)	10.33	968.03	10804.19	1392.78	0.07804	0.99974
14 (11.2µm)	11.19	894.01	8510.42	1286.28	0.22588	0.99919
15 (12.3µm)	12.27	815.32	6455.25	1173.06	0.22117	0.99914
16 (13.3µm)	13.27	753.79	5101.27	1084.53	0.06272	0.99974

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

CIMSS Task Leader: Michael J. Foster
NOAA Collaborator: Andrew Heidinger

NOAA Long Term Goals:
- Climate Adaptation and Mitigation

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 Pathfinder Atmospheres Extended (PATMOS-x) is a NOAA/NESDIS climate dataset generated in partnership with CIMSS. Until recently, PATMOS-x dealt exclusively with data from the Advanced Very High Resolution Radiometer (AVHRR) with instruments on the POES and METOP series of polar orbiting spacecraft. PATMOS-x has been modified to generate products from MODIS, GOES and the VIIRS sensor.

In 2010, PATMOS-x was selected as one of the first three Climate Data Records (CDR) to become operational CDRs at the National Climatic Data Center (NCDC). The version of PATMOS-x chosen for this delivery was the AVHRR-only version. NCDC's main goal was to host the PATMOS-x solar reflectance sensor data records (SDRs), which included the 0.63-, 0.86- and 1.63-micron reflectance (Heidinger et al., 2010).

This project extends that initial delivery to present day, incorporates a continuing near real-time delivery of data, and expands the Fundamental CDR (FCDR) to include the brightness temperature from the AVHRR infrared channels. Figure 99 shows an example of AVHRR Channel 4 plotted as a part of quality assurance during processing. The delivery also includes a subset of cloud properties identified as Thematic CDRs (TCDRs). Finally, this project includes development of a new PATMOS-x climate record derived from merged AVHRR/HIRS measurements.

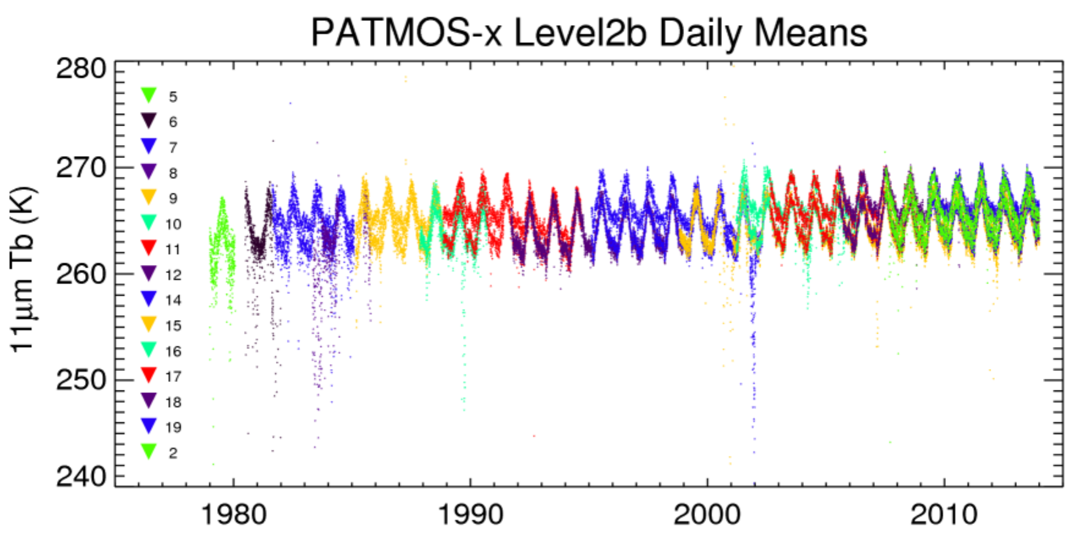


Figure 99. Record of 11-micron brightness temperature comprised of AVHRR sensors flown on the NOAA and MetOp polar orbiters. Numbers correspond with satellite number (e.g., 10 = NOAA-10 and 2 = MetOp-02).

Summary of Accomplishments and Findings

During this reporting year, the milestones necessary to maintain and augment the PATMOS-x operational CDRs at NCDC are as follows:

- Bulk delivery of the PATMOS-x FCDR spanning from 1979 - present. This is an update to the existing PATMOS-x calibrated reflectance FCDR, and will include the beginning of the daily generation and delivery of the FCDR to maintain a near real-time record;

- Bulk delivery of the Cloud TCDR spanning from 1981 – present. This will be a new delivery and thus include the transition to Initial Operational Capability as well as subsequent daily updates;
- Creation and delivery of Quality Assurance and Annual Reports;
- Creation and delivery of a C-ATBD, Maturity Matrix and Data Flow Diagram for the Cloud TCDR;
- Creation and delivery of the source code for the Cloud TCDR; and
- Development of a combined AVHRR + HIRS Cloud TCDR derived from the PATMOS-x AVHRR FCDR and the Menzel HIRS FCDR.

A major task for this year involved modifing the PATMOS-x processing system, called CLAVR-x, to generate output files that meet NCDC CDR program formatting and metadata requirements. This has been completed, and as of the writing of this report the entire FCDR and TCDR records have been processed. The other major task involved creating the documentation necessary for proper usage of the data set. This includes a Quality Assurance report, C-ATBDs for the cloud TCDRs, and Maturity Matrices and Data Flow Diagrams for the FCDRs and TCDRs. This documentation has been created and delivered to NCDC. The source code and ancillary data have been packed up and are being staged along with the processed data sets on the CIMSS FTP server for delivery.

The second part of the data delivery will be in the form of near real-time processing. The scripting required for this has been completed, and it is expected that delivery will commence after bulk delivery of the FCDR and TCDR record (1979 through present) is complete.

The AVHRR/HIRS combined PATMOS-x data set is in initial stages of development. Progress for this year includes creating tools for generating co-located, coincident spectral measurements from AVHRR and HIRS in a single file. Specifically we have leveraged the 'Intermediate File Format' (IFF) used for VIIRS/CrIS projects. The CLAVR-x processing system has been modified to ingest the IFF file format.

The other milestones set for this period are providing support for the NCDC team for the proper usage of the CDR in operations and collecting usage statistics of PATMOS-x. These are ongoing services that we have maintained throughout this year.

Publications and Conference Reports

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

Foster, M. J. and A. K. Heidinger, 2014: Entering the Era of 30+ Year Satellite Cloud Climatologies: A North American Case Study. *Accepted with minor revisions in Journal of Climate.*

References

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

35. 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.

This project is an extension of the original three-year project, focusing only on the transition of the APP and APP-x products to NCDC.

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;
- Algorithm Theoretical Basis Document (C-ATBD), Data Flow Diagram and Maturity Matrix have been drafted and sent to NCDC for evaluation;
- 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 100; and
- 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.

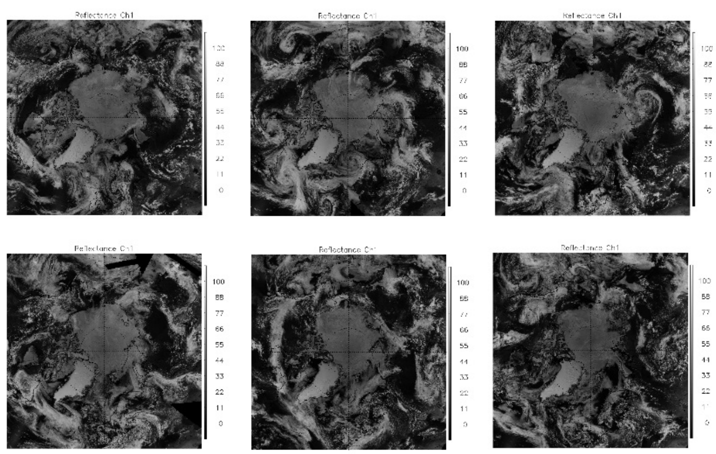


Figure 100. APP channel 1 reflectance (%) at 1400 SLT of north pole on July 1st of the year 1982, 1986, 1989, 1996, 2002, and 2007.

Publications and Conference Reports

Liu, Y. and J. Key, 2014, Less Winter Cloud Aids Summer 2013 Arctic Sea Ice Return from 2012 Minimum, Environ. Res. Lett. 9 044002 doi:10.1088/1748-9326/9/4/044002.

References

Xuanji Wang, Jeffrey Key, Yinghui Liu, Charles Fowler, James Maslanik, and Mark Tschudi, 2012, Arctic Climate Variability and Trends from Satellite Observations, Advances in Meteorology, Vol. 2012, Article ID 505613, 22 pages, doi:10.1155/2012/505613.

36. EOY: A CIMSS Satellite Climate Data Server

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

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 Meteorology Research and Applications

Project Overview

Within CIMSS, several cloud climate data sets are generated. These include the AVHRR Polar Pathfinder Extended (APP-x), the UW-Madison HIRS data set and the Pathfinder Atmospheres Extended (PATMOS-x). All of these data sets span over 3 decades and the size of data sets are large. For example, PATMOS-x exceeds 10Tb. Downloading the entire data sets requires the user community to expend significant effort and investment in data storage. The goal of this work is to develop within CIMSS, a Climate Data Portal that would allow users to subset the data by time, space and parameter to allow for efficient access to the data. PATMOS-x is serving as the initial data set for development of the CIMSS Climate Data Portal but the goal is to extend this to all other CIMSS cloud climate data sets. Another goal of the Climate Data Portal is to allow for CIMSS scientists to serve experimental climate records to users and allow for user feedback to help steer the development of the cloud climate records before they are transferred to the official NOAA archive.

Summary of Accomplishments and Findings

To date, Mike Hiley (CIMSS) has developed a tool written in Java to perform time, space and parameter sub-setting on the PATMOS-x Level-2b data. The goal is to marry this tool with a graphical user interface (GUI) to be accessed from the CIMSS Web site. Tommy Jasmin (CIMSS) is currently developing this interface, which will consist of both a new Web-based data ordering system and an extension of the SSEC-RealEarth Web Map Server that allows users to visualize products selected from the ordering system. The goal is to allow users to visually browse the products available in the dataset, and then specify a desired time range, spatial subset, and parameter subset before receiving an order confirmation email with information on where the data can be accessed (after the CIMSS server has finished the sub-setting operation). Figure 101 shows a subset of the global PATMOS-x data over the USA for 4 important climate parameters, demonstrating the type of spatial sub-setting and parameter sub-setting being developed.

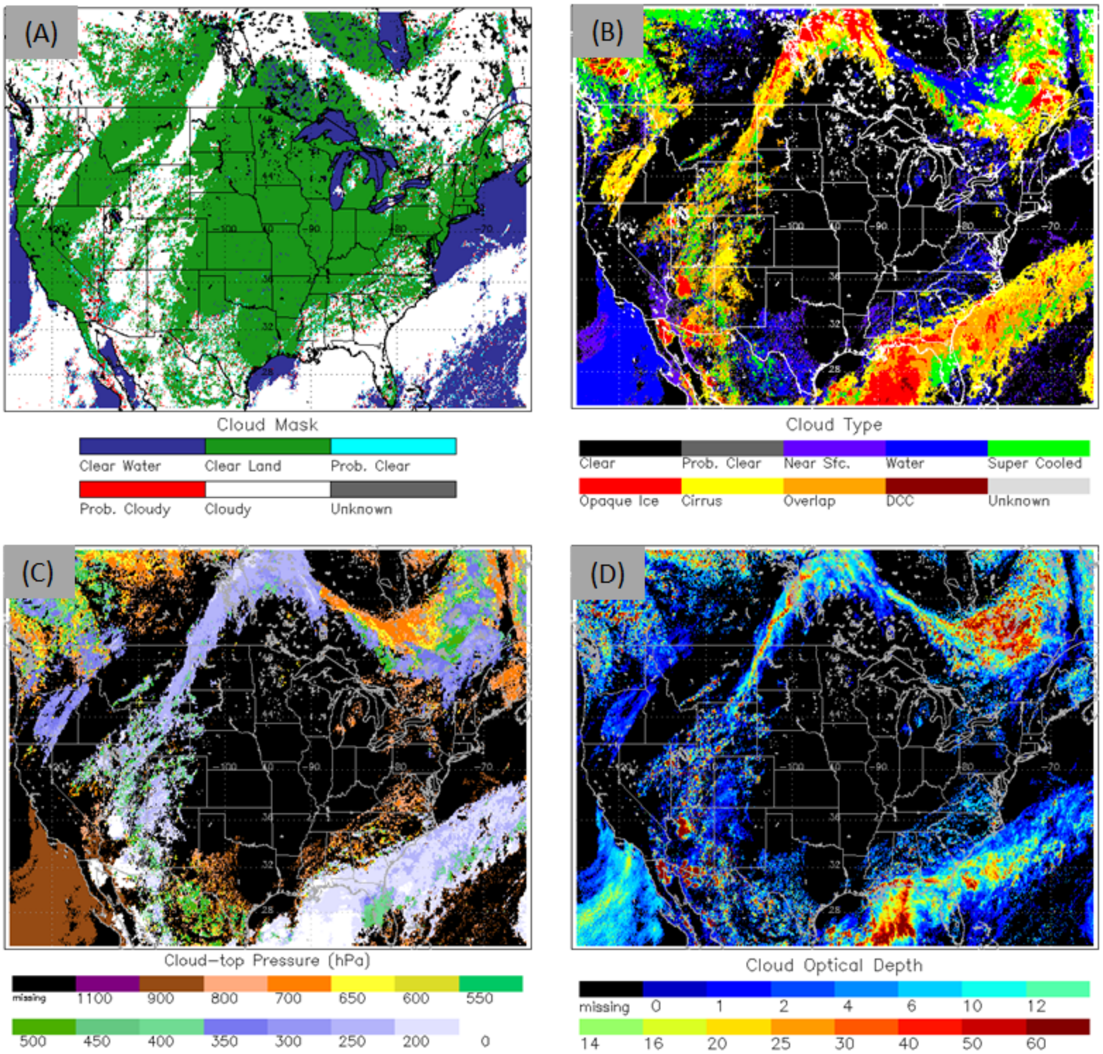


Figure 101. Example of PATMOS-x Level-2b data sub-setted over the USA. Panel (A) shows the cloud mask. Panel (B) shows the cloud type. Panel (C) shows the cloud-top pressure. Panel (D) shows the cloud optical depth. Data is from PATMOS-x AVHRR for NOAA-18.

References

Heidinger, A. K., Foster, M.F, Walther A., and X. Zhao, 2013: The Pathfinder Atmospheres Extended (PATMOS-x) AVHRR Climate Data Set. Bulletin of the American Meteorological Society; e-View doi: http://dx.doi.org/10.1175/BAMS-D-12-00246.1

37. CIMSS Participation in SHyMet for 2013

CIMSS Task Leader: Steve Ackerman
CIMSS Support Scientists: Scott Bachmeier, Scott Lindstrom
NOAA Collaborators: Gary Wade, 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 courses for the Intern Course, the Tropical Course, the Forecaster Course, the Severe Course and the pending GOES-R Course and Winter Weather Course. Preliminary planning for an Aviation Course is continuing. Data for case studies/training modules has been placed on CIMSS Satellite Blog (http://cimss.ssec.wisc.edu/goes/blog); entries include data from MODIS and Suomi NPP VIIRS that can serve as a proxy for GOES-R and JPSS. See, for example, http://cimss.ssec.wisc.edu/goes/blog/archives/15086 for Winter Weather and http://cimss.ssec.wisc.edu/goes/blog/archives/14795 for Aviation training. Training material more appropriate for the Fused Fog/Low Stratus GOES-R products is at http://fusedfog.ssec.wisc.edu/ . These case studies can easily be mined for relevant examples.

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.

Publications and Conference Reports
Bachmeier, A. S. and S. S. Lindstrom, 2014: Blogging as a Training Tool for new Forecast Algorithms, Presented at 30th Conference on Environmental Information Processing Technologies at the Annual Meeting of the American Meteorological Society, 2-6 February 2014, Atlanta GA.

38. 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 proposes to support the training for satellite-based decision support products by placing a CIMSS research scientist at the National Weather Service (NWS) Training Center in Kansas City, MO. The CIMSS scientist is providing leadership, satellite expertise, and meteorological support for the GOES-R Proving Ground efforts at the Training Center.

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 NWSTC. The position is with the University of Wisconsin-Madison and the position's duty station is in Kansas City, MO.

The position is embedded within the NOAA/NWS Operations Proving Ground (OPG) at the NWSTC. The OPG provides the infrastructure and facilities to effectively transfer new and emerging scientific techniques, products, and services into NWS forecast office operations. The OPG actively engages in the research-to-operations process by supporting applied research, verifying the quality and scientific validity of new techniques and products, and providing a common venue for both forecasters and researchers to engage in developing and testing state-of-the-art 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 NWSTC, 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 NWSTC;
- 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; and
- Perform related duties as assigned.

39. 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; and
- Perform related duties as assigned.

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

CIMSS Task Leaders: Margaret Mooney and Steve Ackerman
CIMSS Support Scientists: Mike Foster, Rick Kohrs and Patrick Rowley

NOAA Collaborators: Michael Goodman, Tim Schmit and 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
Formal education efforts related to the GOES-R Education Proving Ground involve the design and development of pre-and post-launch activities for G6-12 teachers and students. Currently six teachers from three states are developing lessons plans for middle and high school science classes which will be classroom tested in the spring of the 2014 school year and presented at the 2014 Satellites and Education Conference. Informal education efforts related to this initiative involve animations of GOES-14 Super Rapid Scan visible channel images at 1-minute intervals for display on NOAA's Science on a Sphere (SOS) exhibits. SOS data sets currently under development will be refined and disseminated through the SOS Network and the CIMSS EarthNow Blog (http://sphere.ssec.wisc.edu/).

Summary of Accomplishments and Findings
The **GOES-R Education Proving Ground** involves three teams of two teachers from three different states: Wisconsin, New Jersey and Florida. Each team is developing a GOES-R related lesson plan for middle school and high school students during the 2013-14 school year. The Wisconsin team is focusing on advantages of ABI and Florida will highlight the Global Lightning Mapper. New Jersey is emphasizing STEM connections to GOES-R. All lesson plans will link content to the Next Generation Science Standards. These six GOES-R educators will share lesson plans with their peers via a workshop or webinar presentation. Most are planning to attend the 2014 Satellites and Education Conference in Madison.

Our team members are:

WISCONSIN - working with Margaret Mooney, CIMSS
- Craig Phillips – 8th grade Earth science teacher, Baraboo (cphillips@baraboo.k12.wi.us)
- Brian Witthun – 8th grade science and math Baraboo (bwitthun@baraboo.k12.wi.us)

NEW JERSEY - working John Moore, Palmyra Cove Environmental Discovery Center
- Staci Greathouse – middle school math teacher, & SEA educator (sgreathouse@bcit.cc)
- Peter Dorofy - Palmyra Cove Environmental Discovery Center (pdq72@optimum.net.)

FLORIDA – working with Paul Ruscher, Oregon Community College
- Charlotte Besse - New Smyrna Beach high school science teacher (dpbesse@aol.com)
- Amy Monahan - STEM Teacher, Volusia County Schools (ammonaha@volusia.k12.fl.us)

Informal education efforts around **Super Rapid Scan Animations for SOS** include the development of an animation with observations from the North Alabama Lightning Mapping

Array (NALMA) to test methods of displaying lightning observations to be ready for the launch of GLM on GOES-R. Additionally, a picture-in-a-picture (PIP) style animation of SRSO imagery from the June 2013 derecho was included in an SOS video developed at CIMSS entitled Extreme Weather and Climate Change which was released to the SOS Network during Severe Weather Preparedness week. This video (http://sphere.ssec.wisc.edu/20140305/) and other SRSO animations will be featured at the 2014 Satellite Educators Conference scheduled to take place in Madison July 30th through August 1st.

Figure 102. Screen Shot depicting SRSO "picture-in-a-picture" for SOS exhibits.

Publications and Conference Reports

Mooney, Margaret; Ackerman, S.; Rowley, P.; Pisut, D. P. and Uz, S. Schollaert. Advancing weather and climate literacy via museum exhibits and mobile devices. Symposium on Education, 23rd, Atlanta, GA, 2-6 February 2014. American Meteorological Society, Boston, MA, 2014

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

Rowley, Patrick; Ackerman, S.; Arkin, P.; Pisut, D. P.; Kohrs, R. A.; Mooney, M. and Uz, S. Schollaert . Communicating climate forecasts via NOAA's Science on a Sphere: The EarthNow Project. Conference on Applied Climatology, Austin, TX, January 2013. American Meteorological Society, Boston, MA, 2013.

Appendix 1: List of Awards to Staff Members

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)

2013

John Cintineo: 2013 NOAA Technology Award for the development of the Warning Decision Support System - Integrated Information on Demand (WDSSII: On Demand)

Bormin Huang: SPIE Fellow

Pei Wang: Best Graduate Student Poster, Third Annual AOSS Community Poster Reception, University of Wisconsin.

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 2012-2014. 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 2014 is incomplete.

During the period 2012-2014, 47% 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, 2012-2014.*

	Inst Lead			ASPB Lead			NOAA Lead			Other Lead		
	2012	**2013**	**2014**	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**	**2012**	**2013**	**2014***
Peer Reviewed	25	26	6	1	1	1	6	8	2	36	41	12
Non Peer Reviewed	1	2	2	0	1	0	0	0	0	0	1	0

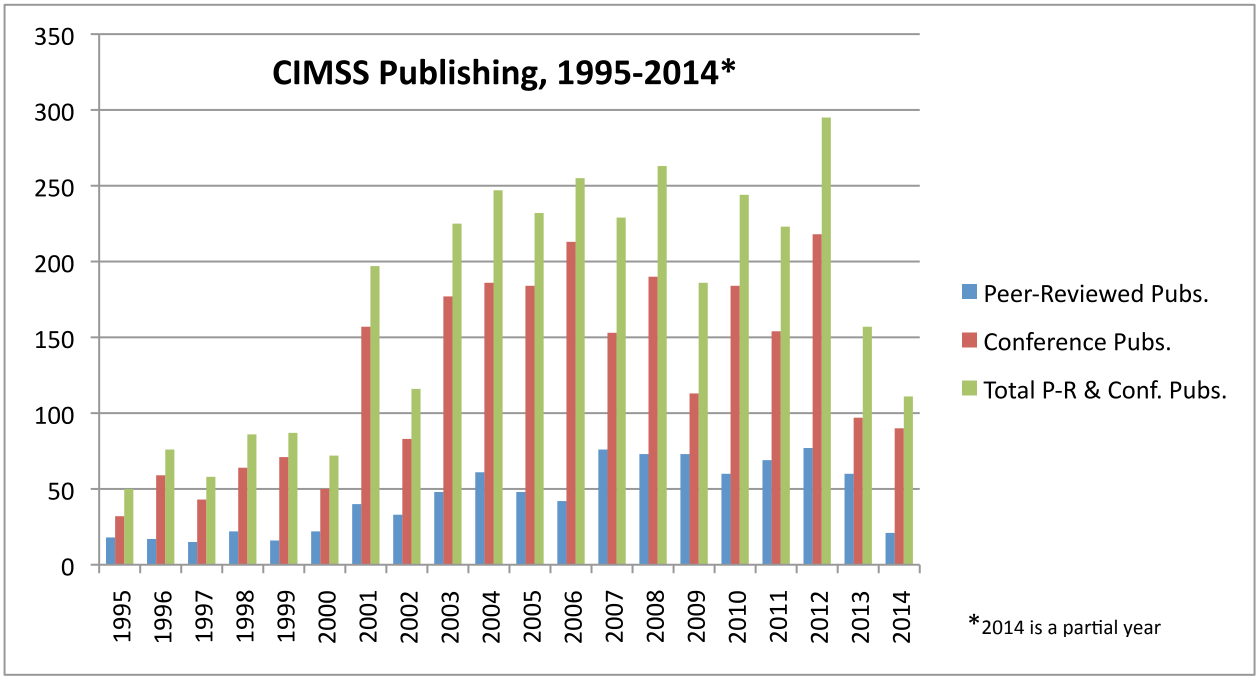
*2014 incomplete: does not include forthcoming papers or papers submitted for publication.

Table 2. Peer Reviewed and Non Peer Reviewed journal articles having one or more CIMSS, ASPB, or NOAA co-authors, 2012-2014.*

	Institute Co-Author			ASPB Co-Author			NOAA Co-Author		
	2012	**2013**	**2014***	**2012**	**2013**	**2014**	**2012**	**2013**	**2014***
Peer Reviewed	85	120	43	21	22	8	49	47	9
Non Peer Reviewed	2	5	3	1	2	2	0	0	1

*2014 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 1995-2014.



*2013 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: Apr13 - Mar14			
Name	Category	Total **Hrs**	FTE %
Bachmeier, Anthony	Researcher II	1,764.0	100%
Terborg, Amanda	Researcher I	1,764.0	100%
Schaack, Todd	Researcher III	1,764.0	100%
Jung, James	Scientist I	1,764.0	100%
Bah, Momodou	Researcher I	1,764.0	100%
Walther, Andi	Researcher I	1,764.0	100%
Li, Yue	Scientist, PostDoc	1,764.0	100%
Mindock, Scott	Computer Scientist II	1,764.0	100%
Plokhenko, Youri	Researcher III	1,764.0	100%
Straka, William	Researcher I	1,764.0	100%
Calvert, Corey	Researcher I	1,764.0	100%
Gravelle, Chad	Researcher II	1,764.0	100%
Monette, Sarah	Researcher I	1,764.0	100%
Liu, Yinghui	Researcher I	1,760.0	100%
Lee, Yong-Keun	Researcher I	1,756.0	100%
Rogal, Marek	Researcher I	1,756.0	100%
Gunshor, Mathew	Researcher II	1,745.0	99%
Botambekov, Denis	Researcher I	1,744.0	99%
Nelson, James III	Researcher III	1,737.2	98%
Cureton, Geoffrey	Manager I	1,680.0	95%
Dworak, Richard	Manager III	1,641.0	93%
Martin, Graeme	Computer Scientist II	1,641.0	93%
Knuteson, Robert	Scientist I	1,585.0	90%
DeSlover, Daniel	Researcher II	1,574.0	89%
Cintineo, John	Researcher I	1,564.0	89%
Cronce, Lee	Researcher I	1,552.0	88%
Zhang, Hong	Researcher II	1,536.0	87%
Gerth, Jordan	Scientist, PostDoc	1,500.5	85%
Sieglaff, Justin	Researcher II	1,466.0	83%
Li, Jinlong	Researcher II	1,424.4	81%
Schiffer, Eva	Computer Programmer I	1,408.0	80%
Wanzong, Steven	Researcher II	1,387.0	79%
Moeller, SzuChia	Researcher II	1,369.0	78%
Wang, Pei	Student, Graduate	1,350.0	77%
Lenzen, Allen	Researcher III	1,303.0	74%
Wang, Xuanji	Scientist, PostDoc	1,298.0	74%
Borg, Lori	Researcher I	1,282.4	73%
Davies, James	Computer Programmer II	1,275.0	72%
Oo, Min Min	Scientist, PostDoc	1,260.0	71%

Hoffman, Jay	Researcher I	1,186.0	67%
Nebuda, Sharon	Researcher I	1,168.4	66%
Lim, Agnes	Researcher I	1,144.0	65%
Antonelli, Paolo	Researcher II	1,129.6	64%
Li, Zhenglong	Researcher I	1,128.0	64%
Feltz, Michelle	Student, Graduate	1,124.5	64%
Lindstrom, Scott	Researcher II	1,077.0	61%
Schreiner, Anthony	Researcher III	1,068.0	61%
Gumley, Liam	Scientist I	1,064.0	60%
Garcia, Raymond	Computer Scientist III	1,038.0	59%
Strabala, Kathleen	Researcher III	988.0	56%
Feltz, Wayne	Scientist I	982.0	56%
Smith, Nadia	Researcher I	976.0	55%
Weisz, Elisabeth	Researcher II	972.0	55%
Li, Jun	Scientist II	967.8	55%
Nelson, Kyle	Student, Graduate	967.5	55%
Roman, Jacola	Student, Graduate	956.7	54%
Herndon, Derrick	Researcher I	928.0	53%
Vasys, Egle	Outreach Specialist I	928.0	53%
Wimmers, Anthony	Scientist I	928.0	53%
Olander, Timothy	Researcher II	924.0	52%
Hiley, Michael	Researcher I	912.0	52%
Avila, Leanne	Documentation Specialist II	904.1	51%
Sears, John	Researcher I	904.0	51%
Brunner, Jason	Researcher I	884.0	50%
Schmidt, Christopher	Researcher III	883.0	50%
Moeller, Christopher	Scientist I	881.0	50%
Tobin, David	Scientist I	852.0	48%
Feltz, Joleen	Researcher II	777.5	44%
Cintineo, Rebecca	Researcher I	755.0	43%
Hoese, Dave	Computer Programmer III	748.0	42%
Huang, Hung-Lung	Scientist III	740.0	42%
Bearson, Nicholas	Researcher I	717.0	41%
Greenwald, Thomas	Scientist I	692.0	39%
Foster, Mike	Researcher I	640.0	36%
Jasmin, Tommy	Computer Scientist II	634.0	36%
Frey, Richard	Computer Programmer III	630.0	36%
Taylor, Joseph	Engineer II	624.0	35%
Rozoff, Christopher	Researcher I	615.0	35%
Stettner, David	Researcher I	611.0	35%
Huang, Bormin	Scientist II	608.0	34%
Schiff, Louis	Student, Undergrad	608.0	34%
Otkin, Jason	Scientist I	575.0	33%
Rink, Thomas	Computer Scientist I	548.0	31%
Lewis, William	Researcher I	520.0	29%
Roubert, Lisha	Scientist, PostDoc	484.0	27%

Gjermo, Britta	Student, Undergrad	472.7	27%
Mooney, Margaret	Outreach Specialist II	416.5	24%
Price, Erik	Student, Undergrad	414.9	24%
Mielikainen, Jarno	Engineer I	412.0	23%
Hoover, Brett	Researcher I	406.0	23%
Dengel, Russell	Computer Programmer III	402.0	23%
Razenkov, Ilya	Electronics Technician I	395.0	22%
Letterly, Aaron	Student, Graduate	375.0	21%
Santek, David	Scientist I	369.0	21%
Velden, Christopher	Scientist III	354.0	20%
Molling, Christine	Researcher III	351.8	20%
Burgess, Genevieve	Student, Undergrad	305.6	17%
Heck, Patrick	Researcher II	304.4	17%
Quinn, Greg	Computer Programmer I	292.0	17%
Menzel, Wolfgang	Scientist III	286.0	16%
Revercomb, Henry	Scientist III	276.0	16%
Huang, Melin	Computer Programmer III	256.0	15%
Smith, William, Sr	Scientist III	247.0	14%
Eloranta, Edwin	Scientist III	240.0	14%
Holz, Robert	Researcher II	240.0	14%
Flynn, Bruce	Computer Scientist I	230.0	13%
Petersen, Ralph	Scientist III	230.0	13%
Yan, Yu	Student, Graduate	223.5	13%
Ziesemer, Mitchell	Student, Undergrad	210.9	12%
Olson, Erik	Computer Scientist I	210.0	12%
Bellon, Willard	Data Manager II	208.0	12%
Hubbard, Shane	Scientist, PostDoc	208.0	12%
Ackerman, Steven	Scientist III	186.1	11%
Whittaker, Thomas	Computer Scientist III	181.4	10%
Line, William	Student, Graduate	180.0	10%
Han, Hyo-Jin	Scientist, PostDoc	168.0	10%
Kulie, Mark	Researcher I	153.9	9%
Ciganovich, Nikola	Engineer, Assistant/Technician	143.4	8%
Lazzara, Mathew	Researcher III	142.2	8%
Pandey, Abhishek	Student, Graduate	142.0	8%
Hackel, Denny	Computer Programmer II	127.0	7%
Merrelli, Aronne	Researcher I	120.0	7%
Mindock, Maxwell	Undergraduate Student	117.0	7%
Nagle, Frederick	Post Retirement Rehire	112.0	6%
LaPorte, Daniel	Researcher III	107.0	6%
Kuehn, Ralph	Researcher I	100.0	6%
Gero, Jonathan	Scientist, PostDoc	88.0	5%
Stroik, Jesse	Technical Computing Specialist II	83.5	5%
Pettersen, Claire	Researcher I	73.0	4%
Chang, Yang-Lang	Researcher I	72.0	4%
Kohrs, Richard	Researcher II	69.0	4%
Hallock, Kevin	Computer Programmer I	64.0	4%
Best, Fred	Manager III	58.0	3%

Gartzke, Jessica	Student, Undergrad	57.0	3%
Smith, Eric	Student, Undergrad	56.3	3%
Borbas, Eva	Researcher II	56.0	3%
Robus, William	Manager I	51.5	3%
Han, Yi	Student, Undergrad	51.0	3%
Mulligan, Mark	Manager III	51.0	3%
Melnik, Katerina	Researcher I	48.0	3%
Drumond Lages de Oli, Mario	Student, Undergrad	36.5	2%
Achtor, Thomas	Scientist III	34.0	2%
Batzli, Samuel	Scientist I	33.0	2%
Mikolajczyk, David	Researcher I	32.5	2%
Ratcliff, Douglas	Data Center Specialist	20.0	1%
Tripoli, Gregory	Professor	19.5	1%
Weber, Nicholas	Student, Undergrad	17.0	1%
Loeb, Nathaniel	Student, Undergrad	15.6	1%
Spangler, Roseann	Data Center Specialist	13.8	1%
Baum, Bryan	Scientist II	10.0	1%
Mateling, Marian	Student, Undergrad	9.0	1%

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. Topic: The Combination of GPS Radio Occultation and Hyperspectral Infrared Sounder Data
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 validation of the sounder temperature profiles using GPS RO as a reference. This validation methodology is applied to products from multiple sensors and platforms, including the NASA AIRS, NPP CrIMSS, and NOAA IASI L2 products. Additionally, COSMIC RO and AIRS data are being used to explore the current and recent past temperature structures and trends of the stratosphere.

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 timeseries of global MODIS data from both Aqua and Terra, areas will be identified as being susceptible to the influence of internal and external cloud inhomogeneity based on using a spatial heterogeneity index based on the 0.65 mm reflectance, solar zenith angle, and viewing zenith angle. After identifying these regions, perform 3D radiative transfer calculations using a Monte Carlo model and compare the results against plane-parallel calculations for the Independent Column Approximation(ICA) and non-ICA. From this, estimate the magnitude of retrieval bias of the optical properties and the horizontal movement of photons. With those results, identify the magnitude of the visible reflectance measurements that can be attributed to the internal and external inhomogeneity of clouds. Another part of the research is helping produce a MODIS maritime water cloud record which will account for the influence of external and internal cloud inhomogeneity and calculated statistics of in-cloud distributions of cloud properties that conserve solar reflectance.

Kyle Hosley
Research focuses on examining the trajectories of high aerosol optical depth (AOD) signals, as seen by the MODIS satellite, using the Infusing satellite Data into Environmental Applications - International (IDEA-I) software. So far, the Rim Fire from August of 2013 has been analyzed using the forecast trajectories to determine the sphere of influence of trajectories from each day and to determine the cumulative influence on each day from trajectories initiated up to 2 days prior. Future research will include looking at other fires to determine their sphere of influence and looking at similar trajectories for ozone to diagnose stratospheric intrusion events.

Aaron Letterly
Research focuses on using AVHRR sea ice concentrations and ERA-Interim reanalysis output to assess factors contributing to winter sea ice growth. Particularly interested in creating a climatology of winter cloud anomaly and determining its lagged correlation with fluctuations in sea ice area anomaly. The absence of arctic sunlight throughout the winter months doesn't "turn off" the melting of sea ice, but rather sets the stage for longwave re-emission by clouds to dominate the surface energy budget in marginal ice areas (i.e., the Beaufort Sea). Comparing the 32 years of AVHRR-sensed sea ice concentration records in conjunction with anomalously clear or cloudy years allows the determination of just when winter clouds were a major contributor to changes in the sea ice record. Through extensive analysis, would like to determine seasonal cloud amount's role as a predictor on future sea ice area anomaly.

Yue Li
Post Doc Research: We studied the diurnal variations of land surface emissivities (LSE) using geostationary satellite data observations. Better understanding of LSE change can improve the retrieval accuracy from satellite observations and reduce uncertainties in number weather predictions. So the aim of this study is to investigate the magnitude and factors resulting variations of the LSE change.
b. We assessed the quality of CrIMSS post-launch EDR product. This assessment is important to report possible biases and deficiencies prior to the official release of CrIMSS product.

Agnes Lim *(Graduated)*
Post Doc Research Topic : Impact assessment of the geostationary hyperspectral data on regional NWP using Observing System Simulation Experiments (OSSE), which is used to assess the impact of geostationary hyperspectral data on a forecast system. In an OSSE, simulated observations are used as inputs into data assimilation systems. These simulated observations are

drawn from a Nature Run (NR), which serves as a proxy to the real atmosphere. The NR is a long, uninterrupted forecast generated by ECMWF. Existing observations both conventional and satellite observations, are simulated at the same spatial and temporal resolution as the current observing network. Observations from future sensors are simulated at their proposed locations. Two separate assimilation experiments are conducted; a control run and a perturbation run. All observation types used by the operational NWP centers are included in the control run. In the perturbation run, the observation type under evaluation is included in addition to the data used in the control run. Both analyses and forecasts are evaluated to assess the data impact by comparing the results between the control and perturbation as well as the truth.

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 *(Graduated, started on Ph.D.)*
M.S. Thesis title: "Climatological Analysis and Assessment in Global Climate Models and Observations of Precipitable Water Vapor (PWV) and Sea Surface Temperature (SST)". This study examines regional monthly mean and seasonal trends in PWV using ground-based GPS measurements as well as satellite (AIRS and AMSR-E) observations and reanalysis (NARR). Additionally, the study examines the simulations of the GCMs of SST for two different scenarios (decadal run 1980 and decadal run 2000). A comparison to observations will be done, in an attempt to show which scenario best stimulates the observations from 2000-2010. Once a

scenario is distinguished, the assessment of GCMs at simulating the PWV observations will be examined and evaluated, similar to the analysis done on the observations.

Gary Wade
Extending work of Ralph Petersen and Richard J. Dworak (CIMSS), research analyzes the accuracy of the moisture gradients in the GOES (Geostationary Operational Environmental Satellite) Sounder retrieved moisture fields, primarily employing comparison with independent, remotely sensed GPS (Global Positioning System) moisture data. With spatial and temporal scales comparable with GOES, GPS affords a measure of comparison that can be examined for gradients. Although retrieved moisture data from the GOES Sounder, with its limited spectral resolution, have traditionally had small impact and have been underutilized, gradient information avoids the issue of simple biases in the data. As low spectral resolution moisture data from geostationary orbit will continue in the near future with GOES-R, this study remains relevant in attempting to exploit the current and future GOES moisture measurements. As forecasters currently examine and assess the CIMSS GOES Nearcast system, where in one approach GOES layered moisture fields are advected ahead to estimate atmospheric stability, this study may help legitimize how unique and accurate one might consider the Nearcast products.

Pei Wang
Ph.D. 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.

<u>Students Funded on other projects than NOAA</u>

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.

Aronne Merrelli *(Graduated)*
Ph.D. Thesis title: "Far Infrared Remote Sensing of Cirrus Clouds and Upper Troposphere Thermodynamic Properties." This research investigates the potential of high spectral resolution far infrared (FIR) radiance measurements (100 - 600 1/cm) for ice particle property retrievals and upper troposphere temperature and water vapor profiles. Line by line and discrete ordinates

radiative transfer codes are used to model far infrared radiance spectra, for atmospheric columns including various amounts of water vapor and ice clouds. An optimal estimation algorithm is used to evaluate the retrieval and the information content of the radiance spectra. The FIR spectra show significant information in the upper troposphere, especially in the water vapor profile, and show a potential advantage over the state of the art mid infrared (MIR) measurements from satellites. In addition, the FIR spectra show increased sensitivity to ice cloud properties, especially for cases involving thick clouds where the ice spectral signature saturates in the MIR.

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. Research Topic: "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.

Alexa Ross
Research involves understanding the relationship between cloud ice orientation and precipitation over maritime regions. By examining CloudSat reflectivities and CALIOP depolarization ratios side by side, I hope to confirm whether or not signatures of horizontally oriented ice crystals in

low clouds increase the chances of precipitation. The experiment will also look into whether or not there are seasonal and/or geographic dependencies on the correlation of ice orientation and precipitation.

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 2012-2013 (visits of 3 days or more and key visitors)

8th Antarctic Meteorological Observations, Modeling and Forecasting Workshop – 50 attendees

AIT/GOES-R Meeting – 13 attendees

Cha, Eun-Jeong – Satellite Analysis Division of the National Meteorological Satellite Center (NMSC), Korea Meteorological Administration (KMA)

Chung, Sung-Rae – Satellite Analysis Division of the National Meteorological Satellite Center (NMSC), Korea Meteorological Administration (KMA)

CoRP Symposium – 55 attendees

CSPP Workshop – 55 attendees

Dunion, Jason – Rosenstiel School of Marine and Atmospheric Science

Fahney, Tom – Delta Airlines

Folmer, Michael – GOES-R/JPSS Satellite Liaisons

Fryer, Kathy – Cooperative Institute for Research in the Atmosphere (CIRA)

GeoSpacial Semantics Workshop – 55 attendees

Gravelle, Chad – GOES-R/JPSS Satellite Liaisons

Holl, Gerrit – Division of Space Technology, Lulea University of Technology, Kiruna, Sweden

Hong, Sungwook – Korean Meteorological Agency (KMA)

Iacovazzi, Robert – Geostationary Operational Environmental Satellite (GOES)-R Program Office (GPO)

Leinonen, Jussi – Radar and Space Technology, Finnish Meteorological Institute

Line, William - GOES-R/JPSS Satellite Liaisons

Mouri, Kouki – Japanese Meteorological Agency (JMA) Meteorological Satellite Center (MSC)

Musial, Jan – University of Bern, Switzerland

Narisma, Gemma – Manila Observatory/Physics Department, Ateneo de Manila University, Philippines

NOAA Satellite Science Week – 54 attendees

Setvak, Martin – Czech Hydrometeorological Institute

Stevens, Eric – GOES-R/JPSS Satellite Liaisons

Terborg, Amanda – GOES-R/JPSS Satellite Liaisons

Tushaus, Samantha – University of Michigan

Vanden Boogart, Lance – GOES-R/JPSS Satellite Liaisons

Xie, Yuanfu – NOAA Earth System Research Laboratory (ESRL)

You, Yalei – Florida State University

Appendix 6: List of Staff/Students hired by NOAA in the past years

William Line – Cooperative Institute for Mesoscale Meteorological Studies and Storm Prediction Center

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 June 2011. Current Board of Directors members include:

Martin Cadwallader, Chair	Dean, Graduate School, 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
Mary Kicza	Assistant Administrator for Satellite & 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 Kaye	Associate Director for Research, NASA
Peter Hildebrand	Director, Earth-Sun Exploration Division of the Sciences and Exploration Directorate, NASA Goddard Space Flight Center
Lelia Vann	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
Chris Velden	Senior Scientist, CIMSS
Trina McMahon	Professor, College of Engineering, UW-Madison
Annemarie Schneider	Professor, SAGE, UW-Madison,
Tristan L'Ecuyer	Professor, Department of Atmospheric and Oceanic Sciences, UW-Madison
Christopher Kummerow	Director, Cooperative Institute for Research in the Atmosphere, and Professor, Department of Atmospheric Science, Colorado State University
Bob Ellingson	Professor, Department of Earth, Ocean, and Atmospheric Science, Florida State University
Steve Goodman	GOES-R Senior Scientist, GOES-R Program Office
Ingrid Guch	Chief, Atmospheric Research and Applications Division, NOAA/NESDIS/ORA
Pat Minnis	Senior Research Scientist, NASA Langley Research Center
Steve Platnick	Acting EOS Senior Project Scientist, NASA Goddard Space Flight Center

Appendix 8: CIMSS Publications, 2013-2014

CIMSS Peer-Reviewed Publications, 2013-14

2014 Accepted for Publication

Banholzer, S., Kossin, J., and Donner, S. The Impact of Climate Change on Natural Disasters. In: Preventing Disaster: Early Warning Systems for Climate Change. [A. Singh and Z. Zommers (Eds)]. Springer Netherlands, 2014.

Baum, B. A., Yang, P.; Heymsfield, A.J.; Bansemer, A.; Merrelli, A.; Schmitt, C., and Wang, C. Ice cloud bulk single-scattering property models with the full phase matrix at wavelengths from 0.2 to 100 µm. J. Quant. Spectrosc. Radiat. Transfer, Special Issue ELS-XIV. http://dx.doi.org/10.1016/j.jqsrt.2014.02.029.

Bi, L., Yang, P.; Liu, C.; Yi, B.; Baum, B.A.; van Diedenhoven, B., and Iwabuchi, H. Assessment of the accuracy of the conventional ray-tracing technique: Implications in remote sensing and radiative transfer involving ice clouds. Journal of Quantitiative Spectroscopy and Radiative Transfer, Special Issue, ELS-XIV, 2014.

Cintineo, J.L.; Pavolonis, M.J.; Sieglaff, J.M., and Lindsey, D.T. An empirical model for assessing the severe weather potential of developing convection. Weather and Forecasting: http://journals.ametsoc.org/doi/abs/10.1175/WAF-D-13-00113.1

Cureton, Geoffrey. Retrieval of higher order ocean spectral information from sunglint. IEEE Transactions on Geoscience and Remote Sensing, doi:10.1109/TGRS.2014.2317477.

Deb, S.K.; Wanzong, S.; Velden, C.S.; Kaur, I.; Kishtawal, C.M.; Pal, P.K., and Menzel, W.P. Height assignment improvement in Kalpana-1 atmospheric motion vectors. Journal of the Indian Society of Remote Sensing, http://link.springer.com/article/10.1007/s12524-013-0278-z

Kohrs, R.A.; Lazzara, M.A.; Robaidek, J.O.; Santek, D.A., and Knuth, S.L. Global satellite composites – 20 years of evolution. Atmospheric Research, doi:10.1016/j.atmosres.2013.07.023.

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