Cooperative Agreement Annual Report
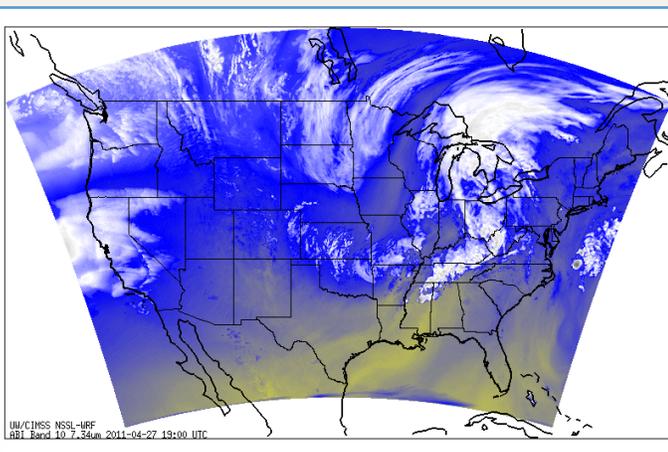
C I M S S

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Current GOES:
Wind Shear Product

Meeting our Mission's Goals

*collaborating with NOAA,
serving as a center of excellence,
training the scientists
and engineers of today
and tomorrow...*

Suomi NPP:
Global Mosaic of CrIS

900 cm⁻¹ Brightness Temperature (K)

Preparing for GOES-R:
27 April 2011 Tornado Outbreak
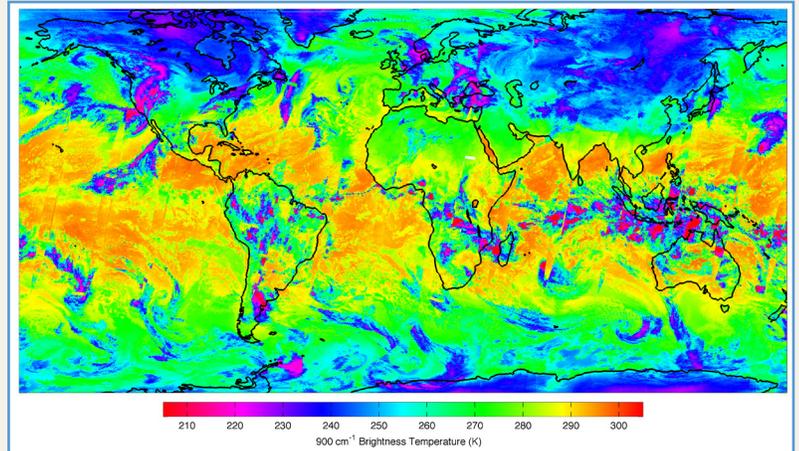
30 April 2012

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 2011 to 31 March 2012
Cooperative Agreement Number: NA10NES4400013

Submitted to:
National Oceanic and Atmospheric Administration
(NOAA)

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

1 April 2011 to 31 March 2012

Steven Ackerman   **Thomas Achtor**
Director, CIMSS   **Executive Director, Editor**

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

1 April 2011 to 31 March 2012

Steven Ackerman	Thomas Achtor
Director, CIMSS	**Executive Director, Editor**

I. Director's Executive Summary

The collaborative relationship between the National Oceanic and Atmospheric Administration (NOAA) and the University of Wisconsin-Madison (UW-Madison), as represented through the continuation of the Cooperative Institute for Meteorological Satellite Studies (CIMSS), 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 Madison. This collaboration recently expanded through the inclusion of a scientist from the National Climate Data Center (NCDC) who joined the NOAA NESDIS employees stationed at CIMSS.

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 2), indicating the strong collaborations between the two organizations. For NOAA, 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 satellite instruments. For example, GOES-15 began operational use as GOES-West on December 6, 2011, before this occurred, OSPO received updated versions of operational software packages for Clear Sky Brightness Temperature, Imager and Sounder Cloud Products, Temperature/Moisture

Retrievals, and Atmospheric Motion Vector algorithms. CIMSS was a key contributor to a majority of the figures and analysis contained in the NOAA science technical report for GOES-15; including noise analysis, image generation, and product validation

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. GIMPAP supported projects have demonstrated that quantitative GOES satellite derived cloud properties are very valuable for predicting the short-term behavior of convective storms. CIMSS/ASPB scientists are incorporating these satellite derived properties with additional data sources such as NEXRAD (and eventually dual polarization radar) and Rapid Update Cycle (RUC)/Rapid Refresh (RR) model output. This work addresses the growing need of the NWS to have access to "fused" products that are more valuable than satellite-alone, radar-alone, or NWP-alone products. To further enhance convective initiation (CI) decision support products, UW-CIMSS has teamed with the NOAA Cooperative Institute of Mesoscale Meteorological Studies (CIMMS) at the University of Oklahoma. OU-CIMMS proposed using the WDSS-II software developed for GOES imager top of troposphere cloud emissivity that has been successfully imported into the WDSS-II (software developed by CIMMS) system, and initial testing/optimization for GOES imager objective tracking has been conducted. The convective cloud object-tracking system is being used to validate the convective initiation/cloud-top cooling nowcast algorithm (UWCI-CTC) rates versus a variety of NEXRAD fields and NLDN data. As another example, there is no archive of GOES Imager cloud products available from NOAA. As part of GIMPAP, CIMSS scientists have partnered with ASPB to make a new cloud climatology for the GOES I-M series and beyond. This climatology will be hosted at CIMSS.

CIMSS scientists continue to work with NOAA on deriving GOES Atmospheric Motion Vectors (AMV). Although AMVs have had positive impacts on NWP, the representative vector heights have proven to be a relatively large source of observation uncertainty. Problems in data assimilation of AMVs can arise from the difficulty in accurately placing the height of the tracer. Thus, CIMSS is taking a fresh look at developing a specific quality indicator for AMV height assignment and validating this against collocated CALIOP observations.

CIMSS also has a strong partnership with NOAA in the GOES-R program. CIMSS is producing high quality proxy ABI data sets derived from NWP model simulations to many GOES-R activities and teams, including the GOES-R Proving Ground Program, the Algorithm Integration Team (AIT), the GRAFIIR, and the AWG Sounding, Winds, Clouds, Aviation, and Imagery/Visualization teams. Applications have included testing and evaluating AWG team algorithms, supplying data for responding to instrument waivers put forth by the GOES-R instrument vendors, and providing data to help train weather forecasters on the capabilities of ABI observations. CIMSS also assists NOAA when the respond to proposed changes in ABI instrument specifications. We help assess the potential effects on products and ABI waiver analysis when requested. The primary diagnostic tool, called Glance, was expanded and improved throughout the year, and updates are provided to the AWG's Algorithm Integration Team (AIT). This GRAFIIR team continues to consult with the Integrated Modeling Working Group (IMWG) on behalf of the AWG.

CIMSS is internationally recognized for its tropical cyclone (TC) research, with the development of the program going back to the early 1980s. The Automated Dvorak Technique (ADT) developed at CIMSS is now an established operational TC intensity estimation algorithm used by

the NWS. Working with NOAA scientists, CIMSS researchers continue to improve the ADT performance through new innovations that when successful will be transitioned to the operational version. Since the ADT is already utilized by several United States operational TC forecast centers (including the National Hurricane Center, Joint Typhoon Warning Center, and Satellite Analysis Branch), integration of an accurate tool to improve TC intensity forecasting ability would be easy to implement and highly regarded. The CIMSS derived TC products, as well as many other products, are distributed through web pages to a broad global audience of forecasts, planners and citizens. The CIMSS ADT was selected to be the operational Hurricane Intensity Estimation algorithm to operate within the GOES-R framework.

For many years GOES-East/-West were the only operational environmental geostationary platforms with fire monitoring capabilities. CIMSS scientists recently updated the Wildfire Automated Biomass Burning Algorithm (WF_ABBA to Version 6.5.006 (v65) to provide new metadata and to support the international constellation of geostationary satellites. The new version of the WF_ABBA is capable of producing fire detection and characterization for all data scanned by GOES–E/-W/-SA, Met-8/-9, and MTSAT-1R/-2, including the Rapid Scan Operation (RSO) and Super Rapid Scan Operation (SRSO) modes of GOES. CIMSS continues to support international satellite fire monitoring efforts.

Building on our strong reputation for atmospheric sounding, CIMSS scientists are developing the legacy atmospheric profile (LAP) algorithm for the next generation GOES-R ABI weather satellite. The algorithm retrieves atmospheric temperature and moisture profiles and the derived products including total precipitable water, layer precipitable water, lifted index, convective available potential energy, total totals index, Showalter index, and the K-index from the clear sky infrared radiances within a 5 by 5 ABI field-of-view box area. This project requires CIMSS scientists to develop the GOES-R LAP algorithm to process high temporal and spatial resolution ABI data efficiently. This project also 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. The latest GOES-R LAP software was delivered to Algorithm Integration Team (AIT). CIMSS sounding team has implemented the GOES-R AWG LAP algorithm for the current GOES Sounder and MODIS for validation purpose.

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

CIMSS began evaluation of one of its new satellite products: the Tropical Overshooting Top (TOT) detection algorithm. This product currently displays Atlantic TOT activity derived from GOES and Meteosat at 15-min intervals. TAFB is already finding it useful to their tropical analyses. This product will be more rigorously evaluated in the upcoming 2012 hurricane season.

CIMSS scientists are investigating quantitative relationships between TOT activity and TC genesis and rapid intensification.

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. We also collaborate with the Cooperative Institute for Research in the Atmosphere (CIRA) at the Colorado State University on using GOES-R instruments for hurricane data assimilation to improve hurricane forecasting.

In addition to supporting the next generation geostationary weather satellite, CIMSS scientists work closely with the NOAA/ASPB scientists to support the next generation polar satellite programs. The Joint Polar Satellite System (JPSS) is the successor to NOAA's Polar Orbiting Environmental Satellite series. The first JPSS satellite to be launched, the Suomi NPP (National Polar Partnership), contains the Visible/Infrared Imager and Radiometer Suite (VIIRS) instrument. CIMSS personnel are collaborating with NOAA, CIRA, Northrop Grumman, and University of Utah personnel to create a suite of high quality cloud products. NOAA, along with Northrup Grumman have created the algorithms to ingest VIIRS raw data and produce cloud products from these data, including cloud presence, cloud water phase, cloud top height, cloud base height, and cloud water optical depth.

CIMSS scientists are recognized for applying satellite observations to address aviation interests. The tropopause folding turbulence product (TFTP) resolves regions of dynamical turbulence caused by tropopause folds at air mass boundaries. Tropopause folds are located by their association with gradients in moisture, which are evident in the ABI band sensitive to upper-tropospheric water vapor. The TFTP automatically detects these gradients in moisture, imposes extra conditions for association with flow instability and presents a distribution of regions of expected turbulence. Identifying these regions of turbulence is important to the aviation community (commercial and non-commercial) for purposes of hazard awareness and safety. Volcanic ash is also an aviation hazard and ASPB/CIMSS scientists have developed an infrared-based approach for detecting the presence of ash and estimating the ash cloud height and mass loading retrieval scheme. The team is also developing infrared-based SO_2 detection algorithm.

CIMSS scientists work collaboratively with ASPB scientists to develop global data sets of cloud amount and cloud properties from the Advanced Very High Resolution Radiometer (AVHRR) processing system, this research builds off the successful Pathfinder Atmospheres Extended (PATMOS-x) project data set, which recently delivered 30 years of cloud climate records from NOAA's POES Imager (AVHRR) to NOAA's National Climatic Data Center (NCDC). ASPB/CIMSS scientists have been active participants in international efforts of GEWEX to assess the capabilities of these polar orbiting satellites to define global cloudiness. In 2010, PATMOS-x was selected as one of the first three Climate Data Records (CDR) to become operational CDRs at the NCDC. The version of PATMOS-x chosen for this delivery was the AVHRR-only version. PATMOS-x SDRs use AVHRR measurements with a spatial resolution of 0.1 degree (11 km) spanning 1978 to 2009. The SDR generation component was accomplished using the Atmospheric Product Evaluation And Test Element (PEATE) processing system at CIMSS. CIMSS/ASPB scientists have developed of an algorithm to derive cirrus optical and microphysical properties from the MODIS IR observations coupled with existing cloud heights. This approach attempts to yield day/night consistency of the IR-based method.

As a final example of cross institute collaborations, we work with colleagues at NOAA/NESDIS, the University of Colorado, and NASA Goddard Space Flight Center, CIMSS as part of a Cryosphere Product Development Team that is providing coordination for the generation, validation, and archival of fundamental and thematic snow and ice climate data records (FCDR and TCDR) that the scientific community can use to help answer the questions about a changing global climate.

CIMSS sponsored many national and international visitors during this time (Appendix 4). For example, CIMSS hosted a visiting scientist from China's National Meteorological Satellite Center (NMSC), Dr. Yong Zhang. Dr. Zhang is involved in the GSICS efforts for China and is a subject matter expert on FY-2 (China's geostationary imager series) calibration. Dr. P Van Delst from NOAA visited CIMSS to collaborate and instruct on the use of the Community Radiative Transfer Model. A. Soerensen and C Ponsard from EUMETSAT visited CIMSS scientists to discuss their use of SEVIRI imagery in weather training. Visitors from the Indian Space Research Organization and the India Meteorological Department visited to collaborate on algorithms and visualizations of satellite data.

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. NOAA and NASA grants support CIMSS graduate students in the UW-Madison Department of Atmospheric and Oceanic Sciences. The education/research center link 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 Virtual Institute for Satellite Integration Training (VISIT) program has involved research, development, and demonstration of new distance learning techniques and materials to address the utilization and integration of advanced meteorological data sources. This year we continued to create VISITview distance learning modules for a broad satellite meteorology audience, providing valuable satellite imagery interpretation materials that can be used in education and training, and also on maintenance and updates to existing satellite image lesson material. Twenty-three "live" instructor-led VISITview teletraining sessions were given to a total of 82 NWS forecasters during this period, on ten different topics.

UW-CIMSS primarily engaged in demonstrations within the NOAA spring 2011 Hazardous Weather Testbed (HWT) where University of Wisconsin Convective Initiation (UWCI), GOES overshooting-top/enhanced-V (OTTC), and WRF ARW simulated decision support products were made available and NWS end user evaluation accomplished as GOES-R proxy information. UW-CIMSS provided real-time access to University of Wisconsin Convective Initiation (UWCI) and GOES overshooting-top/enhanced-V (OTTC) decision support products via AWIPS and N-AWIPS to the Storm Prediction Center (SPC) as part of the Hazardous Weather Testbed Experimental Warning Program (HWT EWP) spring 2011 experiment as a proxy for future GOES-R future capability detection capabilities. The UWCI decision support products were provided within the HWT via N-AWIPS gridded format and the EWP in AWIPS gridded format for the 2011 Spring Experiment. 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. The presence of fully-functioning Advanced Weather Interactive Processing System (AWIPS) workstations at CIMSS allows for faster development of new educational materials that address these types of satellite interpretation topics (and also facilitates more frequent updates to pre-existing modules) as new case study examples are observed on a daily basis. This real-time AWIPS capability gives CIMSS the unique ability to present these satellite interpretation topics in a context that the National Weather Service (NWS) forecaster can more easily relate to. Members of the CIMSS SHyMet team continued to participate in monthly VISIT/SHyMet teleconference calls, which were important to help in the identification and prioritization of new satellite training topics (especially related to GOES-R Proxy data that are being used to help prepare NWS forecasters for the GOES-R era).

Building on the success of the polar products in AWIPS work at CIMSS, the JPSS High Latitude Proving Ground aims to provide NPP/JPSS products to the National Weather Service as a means to improve local forecasts. CIMSS has completed initial testing of a training tool using data overpasses from the Suomi NPP Atmospheres Product Evaluation and Test Element (PEATE) covering Alaska. The data quality is very high and displays nicely in AWIPS using the CIMSS created AWIPS menus and enhancements. Future collaborations with Alaska are planned.

CIMSS continues to demonstrate learning the value of satellite observations using real time weather analysis distributed through the CIMSS Satellite Blog [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 that can be used in future VISIT teletraining modules. During this past year, 159 new posts were added to the CIMSS Satellite blog. The CIMSS Satellite Blog also acts as an important source of "Just-In-Time" satellite training material for weather events that have recently occurred (or for important changes in operational satellites or satellite products).

CIMSS supported the expanding use of satellite-based weather products by placing a CIMSS satellite scientist at the National Weather Service Training (NWS) Center and another at the Aviation Weather Center (AWC) in Kansas City, MO. The CIMSS scientists will provide leadership, satellite expertise, and meteorological support for the GOES-R Proving Ground efforts based at the NWS Training Center (NWSTC).

CIMSS researchers also support NOAA education programs. We are very active in NOAA's Science on a Sphere education program, both locally and nationally. The Aldo Leopold Nature Center has recently acquired a SOS and we provide data and docent services to that organization to reach various public and school audiences. CIMSS launched a new blog to support the Science on a Sphere network docents on interpreting weather and climate observations from NOAA that are displayed on the sphere. 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.

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

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

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

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) was formed through a Memorandum of Understanding between the University of Wisconsin–Madison (UW–Madison) and the National Oceanic and Atmospheric Administration (NOAA). The CIMSS formal agreement with NOAA began in 1980 and was continued through a competitive review process in 2010. 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 six CIMSS themes, five science research themes and one outreach theme:

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

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 figure below. Algorithms are developed and applied to observations (data) to yield information about Earth. We apply this information to gain knowledge about the Earth system, knowledge that can be utilized in decision-making processes. As we rely on this knowledge to take action we demonstrate the need for better observations, and work with our partners, particularly those in SSEC, in designing and testing improved instrumentation. At the center of this research process is education - the training of students, professionals and ourselves.

Information

Data   **Education**   **Knowledge**
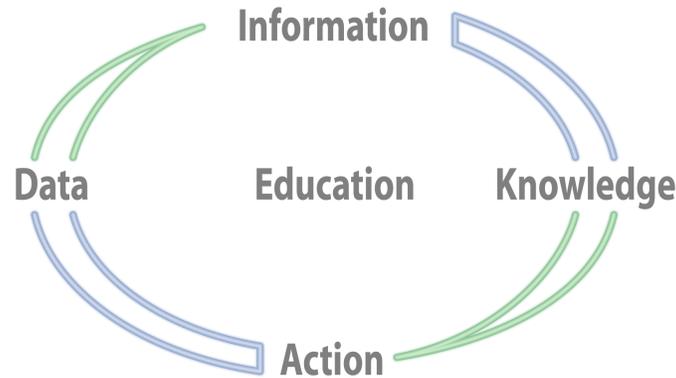
Action

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 forthcoming CrIS (Cross-track Infrared Sounder) hyperspectral sounder on Joint Polar Satellite System (JPSS). In addition to bringing "corporate memory" to these new GOES and JPSS programs, the senior staff help to train the next generation of CIMSS scientists who will support future partnerships between CIMSS and NOAA.

CIMSS scientists work side-by-side with the NESDIS/STAR/ASPB (Advanced Satellite Products Branch) scientists who are stationed in Madison. Being collocated in the same building and having similar research interests fosters powerful ties and collaborations. In addition to working with CIMSS scientists, ASPB scientists often mentor graduate students on research projects. These research projects address NOAA needs while helping to satisfy UW-Madison degree requirements. Based on this positive experience, some of these students go on to work with NOAA and supporting contractors. The National Climate Data Center (NCDC) has stationed a research scientist at CIMSS to further build collaborations. CIMSS plans to leverage this collaboration by providing expertise in using satellite data sets for climate studies. CIMSS and ASPB scientists have developed satellite data sets for climate studies including, a HIRS/2 cloud climatology data set, the PATMOS-X AVHRR data set, an AVHRR polar applications data set, and a GOES cloud properties data set. The polar orbiting satellite data sets extend back more than 20 years.

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. Nearly 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 Thomas Achtor 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 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 14 full-time staff and several students providing services that include human relations, proposal processing and publishing, grant and contract management, accounting, financial programming, purchasing and travel.
- **Technical Computing**
  The technical computing support team includes 6 full-time staff and several students providing consultation and implementation on system design, networking infrastructure, and full support for Unix and pc computing.
- **Data Center**
  The SSEC Data Center provides access, maintenance, and distribution of real-time and archive weather and weather satellite data. The Data Center currently receives data from 8 geostationary and 7 polar orbiting weather satellites in real time and provides a critical resource to SSEC/CIMSS researchers.
- **Library and Media**
  SSEC maintains an atmospheric science library as part of the UW–Madison library system. A full time librarian is on staff and two part time assistants. SSEC also employs a full time media specialist to support the dissemination of information on scientist activities and research results and to develop in-house publications.

- **Visualization Tools**
  SSEC is a leader in developing visualization tools for analyzing geophysical data. The Man-computer Interactive Data Access System (McIDAS), Vis5D and VisAD software are used worldwide in a variety of research and operational environments. The VISITView software is used extensively as a tele-training tool by the NWS and others. To further support NOAA NWS forecast offices, CIMSS is developing satellite products for AWIPS and AWIPS2, maintaining both systems within our facilities.

3. NOAA funding to CIMSS Cooperative Agreement NA10NES4400013 in FY2012 - summarized by Research Task, NOAA Strategic Goal and CIMSS Research and Education Themes

In FY2012, funding to CIMSS through Cooperative Agreement NA10NES4400013 totaled $9,276,561 at the time this report was submitted. 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 FY2012 funds provided to CIMSS under the Cooperative Agreement that began on 1 July 2010 and covers the 12 month period from 1 April 2011 to 31 March 2012.

Funding by NOAA Task

CIMSS Task	Funding in dollars	Percentage
Task 1: Administration	$ 290,000	3%
Task 2: Research primarily with NESDIS Scientists	$ 8,986,561	97%
Task 3: Research with other NOAA Programs	$ 0	0%
	$9,276,561	

Funding by NOAA Task

Task 1: Administration $290,000 3%

Task 3: Research with other NOAA Programs $0 0%

Task 2: Research primarily with NESDIS Scientists $8,986,561 97%
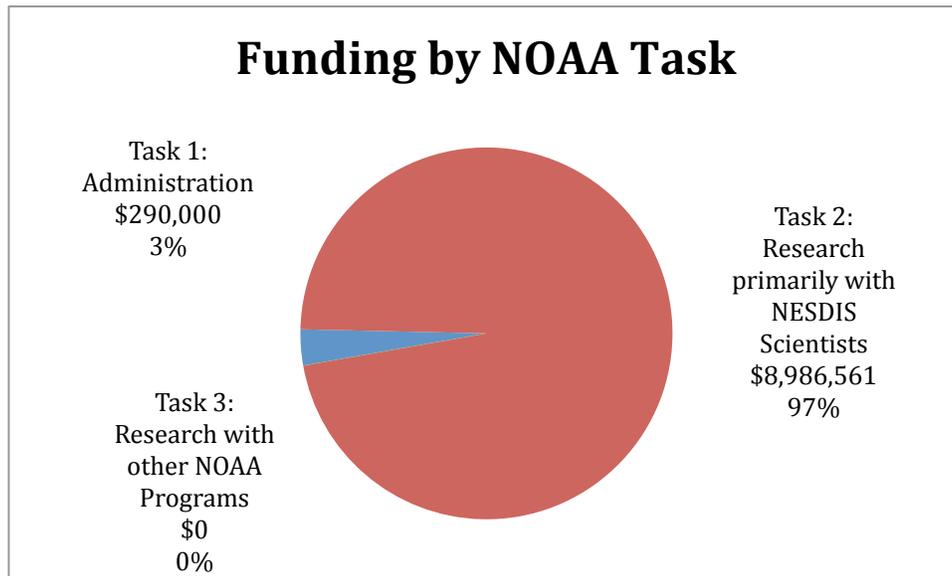
Funding by NOAA Strategic Goal

NOAA Strategic Goal	Funding in dollars	Percentage
Weather and Water	$ 6,800,107	73%
Climate	$ 546,723	6%
Coasts and Oceans	$ 0	0%
Commerce and Transportation	$ 165,930	2%
Critical NOAA Support	$1,763,801	19%
	$9,276,561	

Funding by NOAA Strategic Goal
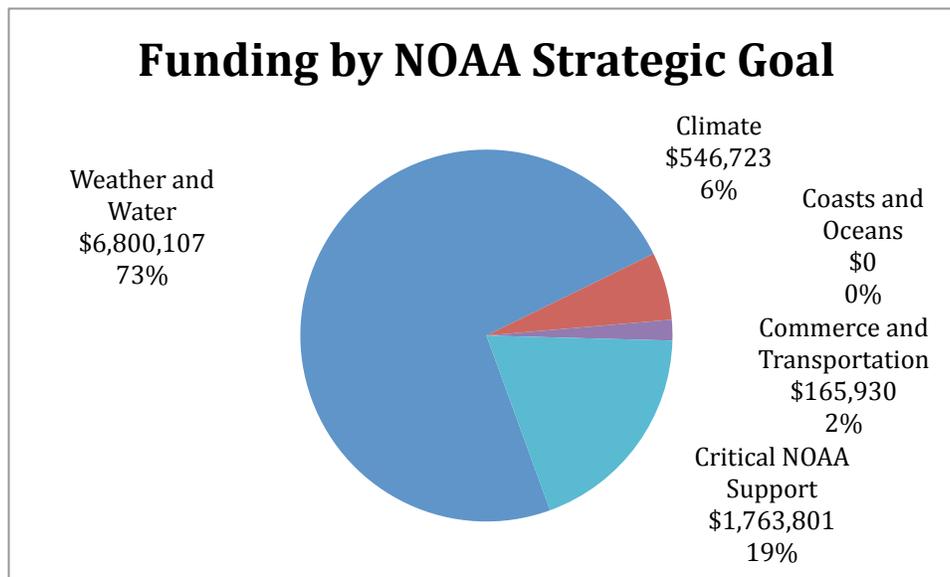
Funding by CIMSS Research and Outreach Themes

CIMSS Theme	Funding in dollars	Percentage
Satellite Meteorology Research and Applications	$ 5,919,482	66%
Satellite Sensors and Techniques	$ 1,645,851	18%
Environmental Models and Data Assimilation	$ 1,311,741	15%
Education and Outreach	$ 109,487	1%
	$8,986,561*	

* - does not include the Task 1 funding

Funding by CIMSS Research and Outreach Themes
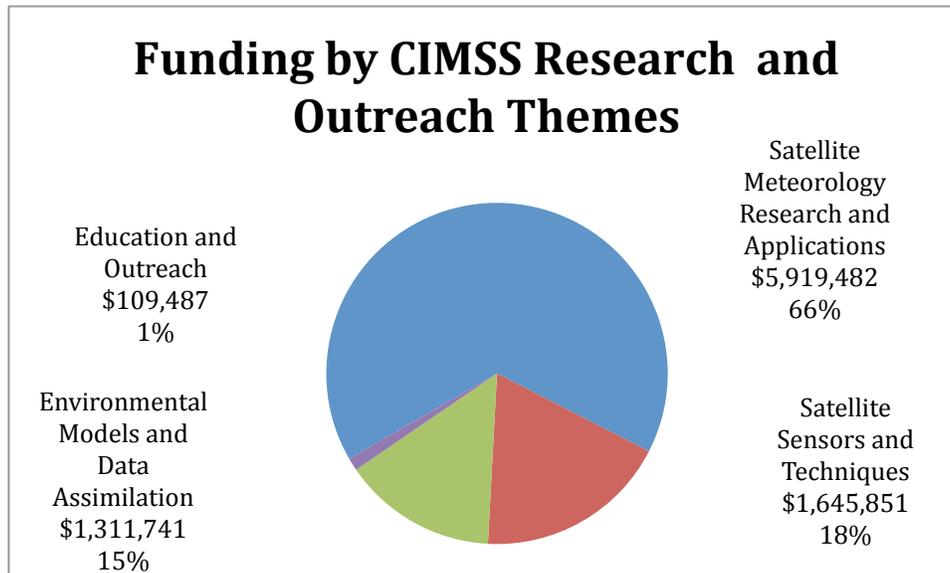
4. Board and Council Membership

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
Jonathan Martin	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,
Ralf Bennartz	Professor, Department of Atmospheric and Oceanic Sciences, UW-Madison
Christopher Kummerow	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

III. Project Reports

1. CIMSS Task 1A Support

CIMSS Task Leaders: Steve Ackerman, Tom Achtor
CIMSS Support: Maria Vasys, Leanne Avila, Wenhua Wu, Jenny Hackel
NOAA Strategic Goals
  • Provide critical support for the NOAA mission
CIMSS Research Themes
  • Education and Outreach

Proposed Work
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 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.

Task I funding supports the development and updates of the CIMSS Web page (see http://cimss.ssec.wisc.edu/). The home page provides an innovative approach to the research pages by allowing users to access CIMSS research projects via three paths: alphabetically, by observing platform and by CIMSS research theme.

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

CIMSS Task I funding also provided support for two graduate students, Mark Smalley and Caitlin Hart, as they fulfilled their academic course obligations and decided on their research thesis topics. Funding is also used to support short term visitors who collaborate with CIMSS scientists on NOAA-related issues and provide seminars on pertinent topics.

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

CIMSS Task Leaders: Margaret Mooney and Steve Ackerman
CIMSS Support Scientists: Patrick Rowley, Jordan Gerth, Tommy Jasmin and Tom Whittaker
NOAA Collaborators: Nina Jackson, Gary Wade, Patricia Huff, LuAnn Dahlman, Frank Niepold and Bruce Moravchik

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

Proposed Work

The Cooperative Institute for Meteorological Satellite Studies 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 maintains several Web-based weather and climate curriculums for teachers and students.

Summary of Accomplishments and Findings

In April 2011 CIMSS played an organizational role in an open house at the Atmospheric, Oceanic and Space Sciences (AOSS) building as part of a campus-wide informal science event. Visitors to AOSS were able to view real-time satellite imagery on our 3D globe and interact with weather and climate applets on touch screen monitors set up in the lobby.

In May CIMSS Director Steve Ackerman conducted a Web seminar specifically for National Weather Service (NWS) storm spotters on the topics of climate change, climate mitigation and emerging applications to access weather and climate data with mobile devices. Nineteen storm spotters participated in this event and eleven provided feedback via a follow-up survey. One attendee commented, "Thank-you for putting together this Web seminar. As a weather spotter, I found the information helpful, even humbling, to know climate change is already happening. Great job!"

June featured the 19th annual CIMSS student workshop. Ten future scientists from Wisconsin, Minnesota, Illinois and as far away as Connecticut visited the UW-Madison campus for this popular "weather camp." Most events took place at AOSS with presentations and activities led by grad students, academic staff, senior scientists, faculty and NOAA researchers. In addition, participating students enjoyed field trips to the UW-Madison Observatory, Planetarium and Geology museum as well as a local TV broadcast station, the Milwaukee/Sullivan National Weather Service office, a State Park, and a limnology dredging expedition on Lake Mendota. Workshop graduates, who paid tuition to attend, left significantly smarter and infinitely wiser about future college and career choices.

Margaret Mooney from CIMSS organized a teacher workshop at the Federation of Earth Science Information Partners (ESIP) summer meeting in July 2011 with funding channeled through ESIP. The workshop's overall theme was Earth science education with an integral strand dedicated to climate literacy. Twenty-seven educators registered for the event and twenty-three attended. Breakout sessions were led by ESIP members from NOAA, NASA, CIMSS, EPA and several Universities from around the country. In the evaluations, eighteen participants gave the workshop an "excellent" rating overall and five teachers checked the next best box of "very good."

Figure 2.1. 2011 ESIP Teacher Workshop.

In August 2011 CIMSS shipped over a hundred CDs featuring the revised Satellite Applications for Geoscience Education course (http://cimss.ssec.wisc.edu/sage/) for distribution at the Satellite Educators conference in southern California.

CIMSS launched a new blog (http://sphere.ssec.wisc.edu/) for the Science on a Sphere network supported by a NOAA OED Environmental Literacy Grant in October 2011. CIMSS also accepted an invitation to present in the NOAA NPOESS Preparatory Project (NPP) Educator's Launch in October. The conference was held in conjunction with the NPP satellite launch at Vandenberg Air Force Base in California. With approximately 100 teachers from across the country at the workshop, Patrick Rowley from CIMSS led sessions showcasing online courses for teachers (Satellite Applications in Geoscience Education), college students (Satellite Observations in Science Education) and middle and high school students (Satellite Meteorology for Grades 7-12).

For the American Geophysical Union (AGU) meeting in December, Margaret Mooney organized a session on "Mobile Apps for Education and Environmental Monitoring" which she co-chaired with CIMSS Director Steve Ackerman. Several NOAA OED projects were featured in this session, as well as a presentation on NOAA's Climate Dashboard from the climate.gov site.

Finally, CIMSS participated in WeatherFest at the annual American Meteorological Society meeting in January 2012 featuring the ever-popular weather and climate applets (http://cimss.ssec.wisc.edu/wxfest/) and animations of satellite imagery on our 3D globe.

3. GIMPAP

3.1 Improvement and Validation of Convective Initiation/Cloud Top Cooling Rate Using WDSS-II Object Tracking

CIMSS Task Leader: Wayne Feltz
CIMSS Support Scientists: Justin Sieglaff, Dan Hartung, Lee Cronce
NOAA Collaborators: Mike Pavolonis, Bob Rabin
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

Proposed Work
The UW-CIMSS Satellite Nowcasting Aviation Applications (SNAAP) team proposed via 2010-2011 GIMPAP resources to:
1) Support further refinement of an experimental cloud-top cooling/convective initiation nowcast algorithm (UWCI-CTC, Sieglaff et al., 2011) developed with GIMPAP funding resources, and
2) Integrate object tracking using the Warning Decision Support System Integrated Information (WDSS-II, http://www.wdssii.org/) software developed by the NOAA Cooperative Institute of Mesoscale Meteorological Studies (CIMMS) at the University of Oklahoma to allow robust radar to satellite validation and improvement in convective initiation/cloud-top cooling detection and identify potential operational utility of cloud-top cooling rates.

Summary of Accomplishments and Findings
The first year of the project included refinement of the UWCI-CTC algorithm and initial work on a WDSS-II based object-tracking methodology. This report is focused on the final year of this project in which a convective cloud object-tracking system was completed for use in validating UWCI-CTC rates versus a variety of NEXRAD fields and NLDN data. The convective cloud object tracking system was used for validating and exploring relationships between UWCI-CTC rates and 7 NEXRAD fields (composite reflectivity, reflectivity at -10°C isotherm, Vertically Integrated Liquid, Maximum Expected Hail Size, and Echo Top heights at 18, 30, and 50 dBZ) and NLDN data. An overview of the object tracking system and key findings of the UWCI-CTC rates vs. NEXRAD study are presented.

The convective cloud object-tracking system utilizes the 11 µm top of troposphere cloud emissivity (ε_{tot}) (Pavolonis, 2010) as input into WDSS-II for creating cloud objects and tracking

those cloud objects through space and time, while maintaining consistent, unique IDs for each cloud object. A cloud object is a collection of adjacent satellite pixels that are treated as a single entity, much like how a human interprets satellite data. The ε_{tot} is used because it maintains the spatial gradients observed in the 11 µm brightness temperature field, but values range from 0 to 1 (clouds at the surface to clouds at the tropopause, respectively) and is nearly seasonally and latitudinally independent (11 µm brightness temperatures of convective clouds can vary substantially depending on the height of the tropopause, by using NWP tropopause height, the ε_{tot} removes this variance and a single cloud object creation configuration can be used). The WDSS-II cloud objects are then post-processed by a UW-CIMSS developed methodology that combines various spatial scale output from WDSS-II into a final set of cloud objects and performs additional tests to maintain cloud object IDs when WDSS-II undesirably changes object ID between two satellite observations. The convective cloud object-tracking system performance was quantified and it was determined that the object tracking performance increases as cloud object size increases and as satellite temporal resolution increases. Full details of the system can be found in Sieglaff et al. (2012).

The cloud object tracking system was used to fuse UWCI-CTC rates, a variety of NEXRAD fields, and NLDN to perform the study to validate and determine relationships between a given storm's maximum UWCI-CTC rate and future NEXRAD/NLDN observations. The study consisted of 34 convective events over the Central United States during 2008 and 2009. The key findings are summarized below; full detail can be found in Hartung et al. (2012).
- UWCI-CTC rates were found to be most skillful in detecting convective clouds that achieved intense radar signatures (e.g., POD for 35 dBZ reflectivity at -10°C: 0.25; POD increases to 0.65 for 60+ dBZ).
- UWCI-CTC rates grouped into weak, moderate, and strong bins were found (to the 95% confidence level) to be related to increasingly more intense precipitation cores as determined by composite reflectivity (median values: 45, 50, and 55 dBZ, respectively).
- The false alarm ratio was shown to decrease substantially as the magnitude of UWCI-CTC rates increased for all radar fields. (A forecaster should have increased confidence a developing storm with a larger cooling rate will more likely produce a more intense precipitation core than a developing storm with a small cooling rate.)
- For developing storms that achieve a non-zero radar estimated Maximum Expected Hail Size (MESH) and exhibit weak, moderate, and strong UWCI-CTC rates will achieve 0.50", 0.75", and 1.0" (severe) median MESH values at some point in their life, respectively. Additionally, POD for storms that achieve severe hail (1.00" or larger) is 0.71 (Figure 3.1.1 shows the distribution of MESH size as a function of UWCI-CTC rate).

It was also necessary to determine the prognostic value (e.g., lead time) the UWCI-CTC rate provides ahead of each NEXRAD threshold/field. For example, the median lead-time of maximum UWCI-CTC rates was 10 minutes for 35 dBZ composite reflectivity, 25 minutes for 60 dBZ and 60+ minutes for 65 dBZ; 28 minutes for 0.25" MESH, 45 minutes for 1.00" MESH, and 60+ minutes for 1.25"+ MESH. These lead times associated with the UWCI-CTC rates can by used by operational forecasters to identify thunderstorms that will produce significant precipitation and severe hail; which could be used to increase lead time of QPF related products and severe thunderstorm warning lead time than by using NEXRAD alone.
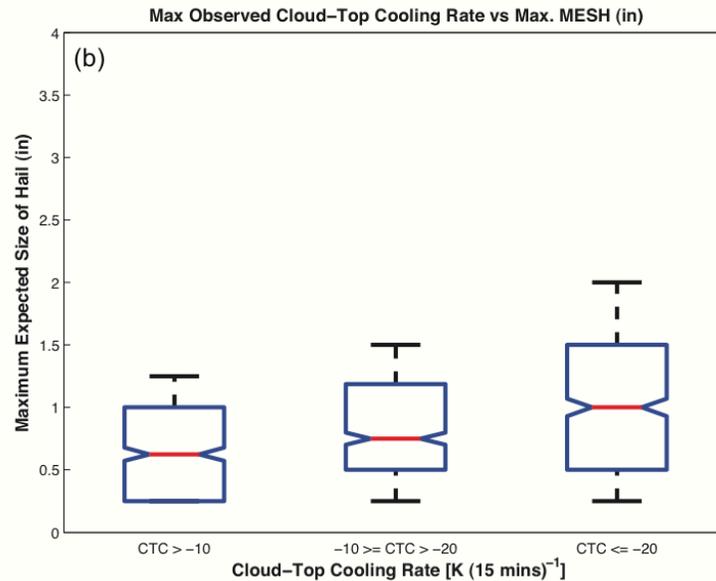
Figure 3.1.1. Comparison of maximum UWCI-CTC rates to maximum Maximum Expected Hail Size (MESH) for cloud objects that had both an UWCI-CTC rate and valid MESH at some point in their lifetime. UW-CTC rates are binned by intensity [K (15 min)$^{-1}$] with weak, moderate, and strong convective growth defined as UW-CTC > -10, -10 ≥ UW-CTC > -20, and UW-CTC ≤ -20, respectively. For each boxplot, the median (red line), 25th and 75th percentiles (lower and upper bounds of blue box), and one standard deviation (whiskers) are shown. The medians of different intensity bins are significantly different at the 95% confidence level if the widths of the notches centered on the medians do not overlap.

Publications and Conference Reports

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. *Submitted to Wea. Forecasting.*

Sieglaff, J. M., D. C. Hartung, W. F. Feltz, L. M. Cronce, and V. Lakshmanan, 2012: Development and application of a satellite-based convective cloud object-tracking methodology: A multipurpose data fusion tool. *Submitted to J. Appl. Meteor. Climatol.*

References

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., 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.

3.2 GOES I-M Cloud Climate Products

CIMSS Task Leader: Mike Foster
CIMSS Support Scientist: Christine Molling
NOAA Collaborator: Andrew Heidinger
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
- Protect, restore and manage the use of coastal and ocean resources through an ecosystem approach to management
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

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

Proposed Work

The AVHRR version of the PATMOS-x data set demonstrated that there is great interest in the climate research community for accurate long-term cloud climate records that are made publicly available. Currently, there is no archive of GOES Imager cloud products available from NOAA. Just recently CLASS has begun to archive the real-time products from GOES Surface and Insolation Project (GSIP) but there is no plan to go back in time. While GOES Imager data are used by the International Satellite Cloud Climatology Project (ISCCP), only two channels sampled at a very coarse resolution are used. In this effort, we proposed to make new cloud product climatology starting with the GOES I-M series. This climatology will be hosted at CIMSS. Technically, the generation of cloud climate records from GOES is not challenging because we can leverage off the 2007 GIMPAP project that funded the implementation of the GOES-R AWG cloud algorithms on the current GOES data. Figure 3.2.1 demonstrates our chosen domains for these data. Domain A is for the GOES/WEST data, Domain B is for the GOES/East data and Domain C is for the GOES/South data. For reference, the existing global domain used for the AVHRR PATMOS-x data is labeled Domain D. The spatial resolution for all data is 0.1 degrees. One of the goals of this work is to bring consistent POES/GOES products to the community. Figure 3.2.2 demonstrates that the cloud fraction for the Chilean Stratus Deck resolved by GOES many times a day is in close agreement with the 4 times per day observations from the POES/AVHRR sensor.

Our specific tasks are as follows:
- Generate a cloud climatology using GOES-11 (2006-2010) Northern Hemisphere domains (every 30 minutes), and
- Generate a cloud climatology using GOES-10/12 (2007-2010) Southern Hemisphere domains (every 30 minutes).

Once the methodology of data production and the Web-interface are mature, we will move on to the entire GOES-I-M record and then GOES-NOP. This effort will require an additional proposal and approval from the appropriate NESDIS boards.

Summary of Accomplishments and Findings

Accomplishments and findings thus far include:

- GOES-11 (Domain A) generated and hosted on the PATMOS-x ftp site (ftp.ssec.wisc.edu/pub/patmosx);
- GOES-10/12 (Domain B) data generated for 2008/9 and hosted on PATMOS-x ftp site;
- GOES-13 (Domain C) data have also been generated for 2011 (though outside original scope);
- Paper submitted (Foster and Heidinger) to the Journal of Climatology. This paper explores the diurnal cycle of cloudiness in the long-term AVHRR PATMOS-x data using the shorter-term GOES PATMOS-x data generated here;
- A validation report is being generated where the GOES PATMOS-x is compared to other data sets including the SURFRAD network in the USA; and
- The data set has been provided to several researchers for initial evaluation including Simone Placidi of the University of Delft in the Netherlands and to a group of astronomers studying cloudiness patterns for the siting of telescopes.
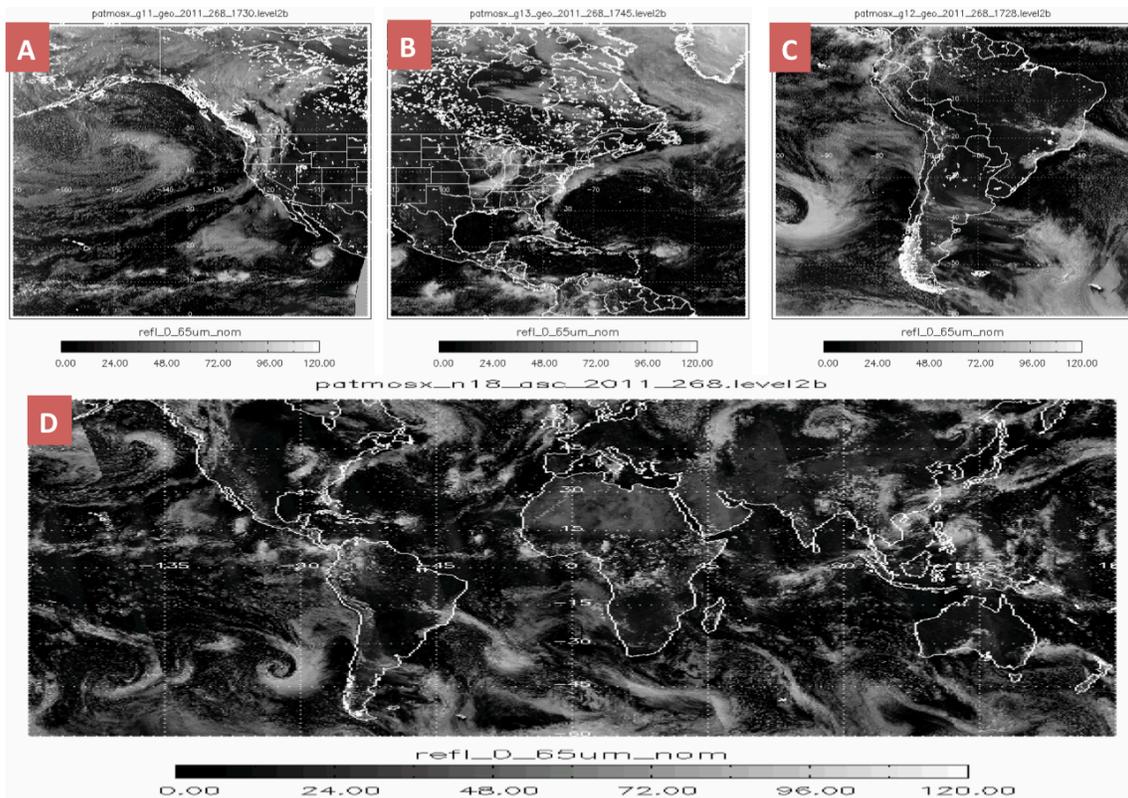
Figure 3.2.1. Illustration of the data domains used for GOES/West (A), GOES/EAST(B) and GOES/South(C). Global domain used for AVHRR PATMOS-x given by (D).
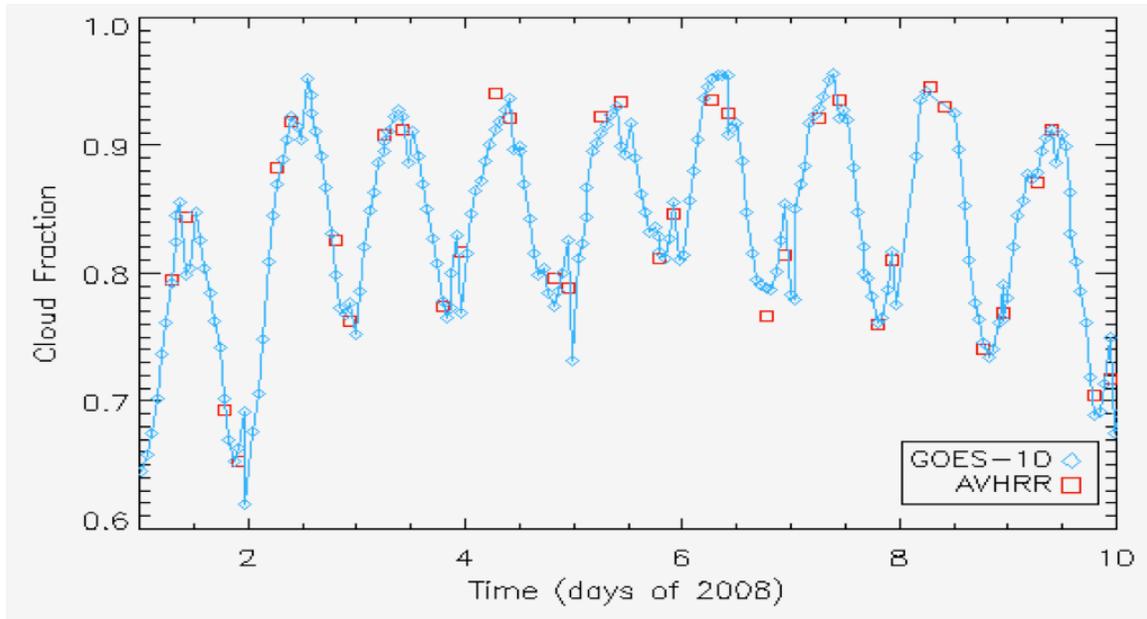
Figure 3.2.2. Comparison of the cloud fraction from the AVHRR and GOES versions of PATMOS-x over the Chilean Stratus Deck for one month of data.

Publications and Conference Reports

Heidinger, Andrew K.; Foster, M. J.; Molling, C.; Straka, W. and Walther, A. Advances in long-term high spatial and temporal resolution cloud climate records from PATMOS-x using NOAA's LEO and GEO imagers. Conference on Satellite Meteorology, Oceanography and Climatology, 18th, and Joint AMS-Asia Satellite Meteorology Conference, 1st, New Orleans, LA, 22-26 January 2012. American Meteorological Society, Boston, MA, 2012.

References

Foster, M. J and A. K. Heidinger, 2012: PATMOS-x: Results from a Diurnally-Corrected Thirty-Year Satellite Cloud Climatology. In review to *Journal of Climate*.

3.3 GOES Biomass Burning Research and Applications

CIMSS Task Leader: Chris Schmidt
CIMSS Support Scientists: Jason Brunner, Jay Hoffman, Elaine Prins (UW-Madison/CIMSS-Consultant)
NOAA Collaborators: Robert Rabin (NOAA/NSSL), Phillip Bothwell (NOAA/NWS/SPC), Ivan Csiszar (NOAA/NESDIS/STAR), Shobha Kondragunta (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

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

Proposed Work

For many years GOES-E/-W were the only operational environmental geostationary platforms with fire monitoring capabilities. With the launch of Met-8/-9, MTSAT-1R/-2, and future instruments (INSAT-3D, COMS, etc.) this capability is now global. The Wildfire Automated Biomass Burning Algorithm (WF_ABBA) has been recently upgraded to Version 6.5.006 (v65) to provide new metadata and to support the international constellation of geostationary satellites that can provide fire detection and characterization, including but not limited to current GOES–E/-W/-SA, Met-8/-9, and MTSAT-1R/-2. The new version of the WF_ABBA is capable of producing output for all data scanned by those satellites, including the Rapid Scan Operation (RSO) and Super Rapid Scan Operation (SRSO) modes of GOES. In order to successfully use these global satellite data products for real-time fire monitoring, trend analyses and applications in data assimilation and long-range transport, new techniques are being developed to characterize and integrate the data.

This project utilizes the new WF_ABBA 17-year and growing fire database and supports to add fire coverage for new geostationary satellites in the global constellation. A key component of this work is collaboration with NSSL via Bob Rabin and Phillip Bothwell to create a climatology of wildfires from the WF_ABBA v65 data and to examine whether the WF_ABBA data can be used in conjunction with other ancillary information to create a "fire potential" product. The fire potential product aims to improve predictions of fire potential for a 24-48 hour time frame. The climatology and, if proven successful, the fire potential product, will be of use to NOAA's Storm Prediction Center (SPC) forecasters and others. The creation of the climatology leverages techniques developed for fire studies over South America under the NASA LBA program.

Summary of Accomplishments and Findings

The global WF_ABBA v65 includes the addition of FRP and a fire/metadata mask that provides information on processing regions, fire locations, fire confidence, cloud cover, block-out zones, and saturated areas. The GOES WF_ABBA v65 trend analysis is being expanded to extend around the globe and now includes Met-8/-9 over Africa and Europe and also MTSAT-1R/-2 over Asia and Australia. The combination of Met-8/-9, MTSAT-1R/-2 and GOES-E/-W provides nearly complete global coverage by the WF_ABBA.

Now that the processing of the GOES-East WF_ABBA v65 fire/metadata mask for the climatology of fires is complete, a peer-reviewed publication will be submitted in the near future. With the fire/metadata mask, analysis of fires can take into account coverage by opaque clouds and other regions where fire detection was not possible. Figure 3.3.1 shows GOES East WF_ABBA v65 satellite coverage corrected 0.25 degree binned total number of fires (all fire categories included but low possibility) for 2007 over the Western Hemisphere. Fires were most prevalent over the Amazon and Arc of Deforestation in South America. Figure 3.3.2 shows GOES East WF_ABBA v65 satellite coverage corrected total number of fires for each fire category for 1995-2010 over North America. The most active fire years were 1998, 2000 and 2005 while the least active fire years were 2004 and 2010. In general there seems to be a downward trend in the number of total fires over North America since 2005. In North America the low confidence category is often indicative of false alarms but can also represent an initial detect along cloud edges. A segment of the user community is interested in monitoring low confidence to observe if they develop into active fires over time.

The time period of focus for the fire potential product is April – October 2010 over the United States. Daily ancillary data sets over the United States were created along with daily fire totals over the same data grid domain. The main ancillary data sets include the Fosberg Fire Weather Index and a Cloud to Ground Lightning database. Analyses include investigating relationships between fire totals and these products. For example, are there differences in Cloud to Ground Lightning counts and/or Fosberg values in bins with fires verses without fires? CIMSS will continue to participate in conference calls with Bob Rabin and Phillip Bothwell to determine what type of analysis might be most useful as it relates to the possible development of a fire potential product.

The GOES East/West fire products continue to be used in aerosol transport models (e.g., Navy NAAPS, INPE CPTEC, WRAP, FLEXPART, IDEA, and others), emissions assessment and modeling, air quality applications, and climate change analyses. CIMSS actively collaborates with users in a variety of ongoing and new applications. As the CIMSS geostationary fire program expands to monitor burning around the globe, applications are expanding as well. NRL is currently testing integration of global geostationary fire products (GOES, MTSAT, Met-9) into the NAAPS model. CIMSS collaborated with Ed Hyer at NRL-Monterey on an analysis of fire activity detected in Indonesia and Malaysia from polar and geostationary satellites. A summary of this effort was recently accepted for publication in Atmospheric Research. At U.C. Irvine, M. Mu and J. T. Randerson have incorporated emissions derived from multi-year GOES WF_ABBA fire products into the Global Fire Emissions Database version 3 (GFED3). As part of this effort CIMSS collaborated with U.C. Irvine on a publication titled "Daily and 3-hourly variability in global fire emissions and consequences for atmospheric model predictions of carbon monoxide," which was published in JGR – Atmospheres.

CIMSS has also collaborated with scientists at UC Davis who are developing and testing new techniques for early wildfire detection in the western U.S. using GOES-West. As part of this effort the GOES-West WF_ABBA fire product for the summer of 2006 was evaluated for California. The results indicated reliable performance of the temporally filtered WF_ABBA fire product with about 75% of fire pixels corresponding to actual recorded active wildfires. Many of the unsubstantiated fire detects may be associated with agricultural burning. A significant number of the wildfires were detected during their first hour of activity, and some before the initial reports from conventional sources. The manuscript titled "On timeliness and accuracy of wildfire detection by the GOES WF-ABBA algorithm over California during the 2006 fire season" summarizes this effort and was submitted for publication in Remote Sensing of Environment.

The Met-9 WF_ABBA was evaluated for the 2008 fire season in Italy by CIMSS graduate student, Giuseppe Baldassarre, who submitted his findings for publication in Remote Sensing of Environment. Results indicated that the WF_ABBA was able to detect 40% of the fires that eventually grew into the most damaging fire events. The WF_ABBA also detected many agricultural fires which are not recorded in the conventional government databases. Approximately 10-15% of the WF_ABBA fire detections were recorded up to 3 hours before the first ground report.

CIMSS continues to support international satellite fire monitoring efforts by being actively involved in GEOSS, GTOS GOFC/GOLD, CEOS, and CGMS activities. This involvement includes international planning committees, workshops and technology transfer to global partners in Europe, Africa, Asia, Australia, etc. One of the primary goals is to foster closer connections to international working groups and inter-agency efforts to gain better insight into the needs of the

global user community, to enable better coordination of data sources and products, and to provide input for future missions. Currently, global geostationary fire monitoring is being considered as a CEOS Constellation Concept.
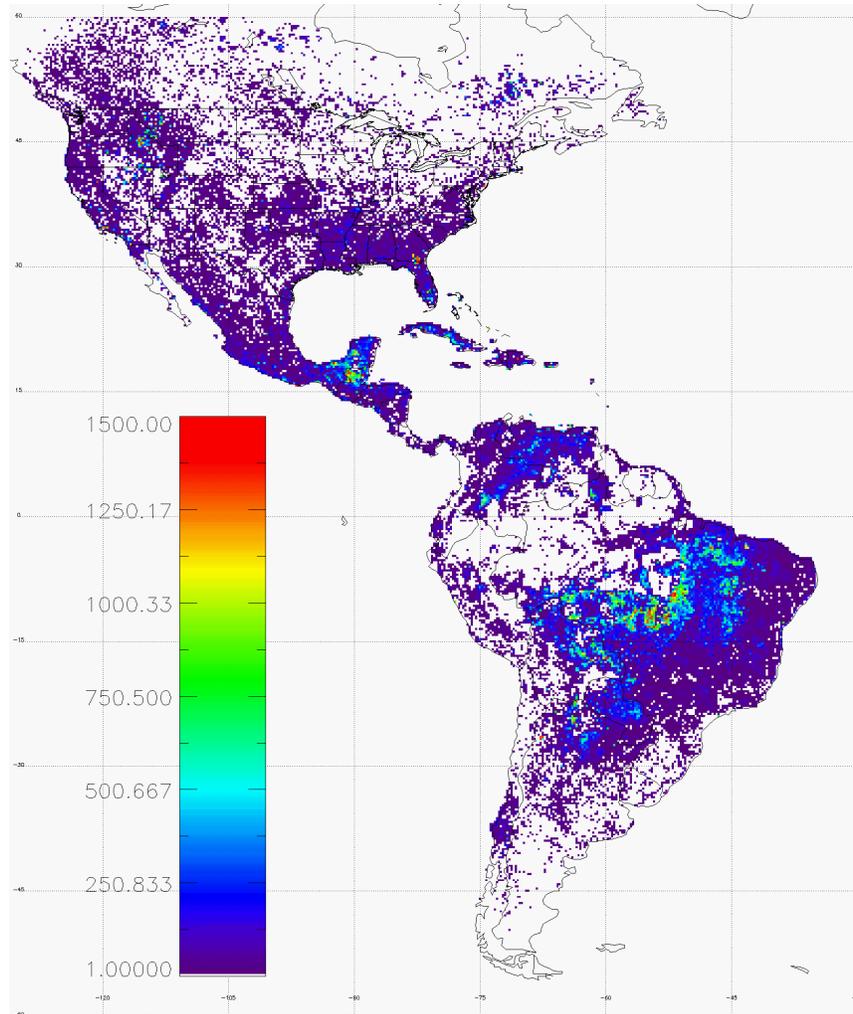
Figure 3.3.1. GOES East WF_ABBA v65 satellite coverage corrected 0.25 degree binned total number of fires (all fire categories included but low possibility) for 2007 over the Western Hemisphere.
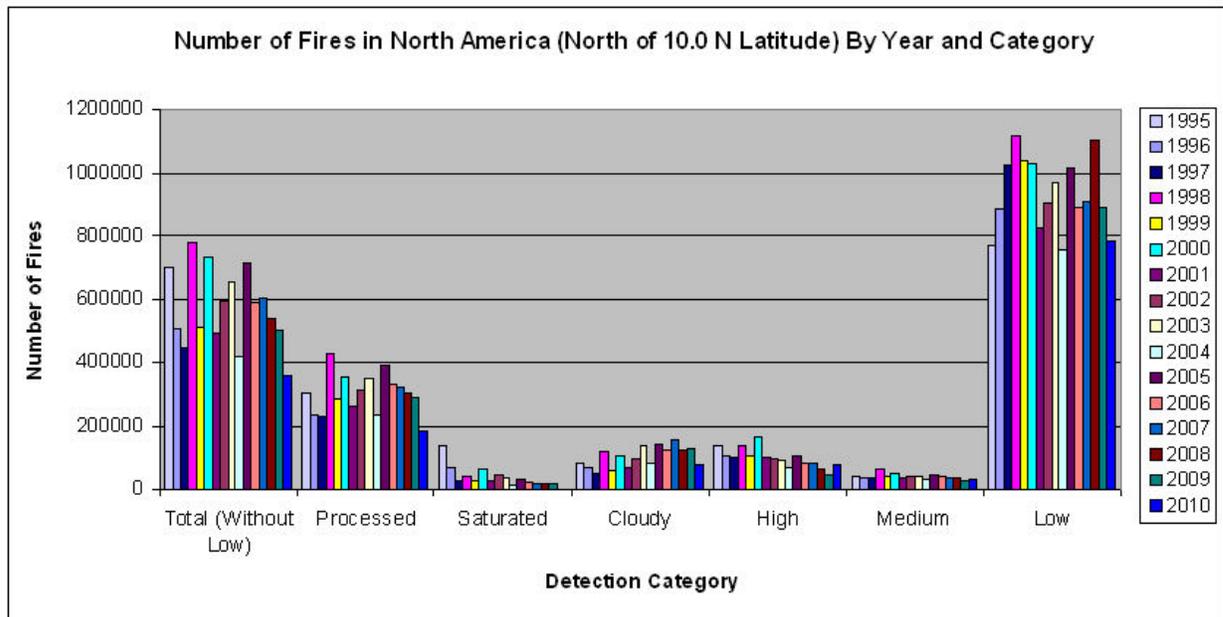
Figure 3.3.2. GOES East WF_ABBA v65 satellite coverage corrected total number of fires for each fire category for 1995-2010 over North America.

Publications and Conference Reports

Baldassarre, G., W. P. Menzel, J. M. Phillips, C. C. Schmidt, J. C. Brunner, J. P. Hoffman, E. M. Prins, 2011: A performance analysis of WF_ABBA (MSG-SEVIRI based) fire detection products over Italy. Submitted to *Remote Sensing of Environment*.

Brunner, J. C., C. C. Schmidt, E. M. Prins, J. P. Hoffman, W. Schroeder, and I. Csiszar, 2012: Western Hemisphere Diurnal Fire Activity 1995-2011: Description and Initial Fire Trend Analysis of the GOES-East Version 6.5 WF_ABBA Data Archive. 18th Conference on Satellite Meteorology and Oceanography. New Orleans, LA. January 2012, Amer. Meteor. Soc., P476.

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Koltunov, A., S. L. Ustin, E. Prins, 2011: On timeliness and accuracy of wildfire detection by the GOES WF-ABBA algorithm over California during the 2006 fire season. Submitted to *Remote Sensing of Environment*.

Mu, M, J.T. Randerson, G.R. van der Werf, L. Giglio, P. Kasibhatla, D. Morton, G.J. Collatz, R.S. DeFries, E.J. Hyer, E.M. Prins, D.W.T. Griffith, D. Wunch, G.C. Toon, V. Sherlock, and P.O. Wennberg, 2011: Daily and 3-hourly variability in global fire emissions and consequences for atmospheric model predictions of carbon monoxide. *J. Geophys. Res.*, **116**, D24303, doi:10.1029/2011JD016245.

Schmidt, C. C., E. M. Prins, E. Hyer, J. P. Hoffman, J. Brunner and J. S. Reid, 2012: The Global Geostationary Wildfire ABBA: Current Implementation and Future Plans. 18th Conference on Satellite Meteorology and Oceanography. New Orleans, LA. January 2012, Amer. Meteor. Soc., P165.

3.4 Improvements to the Advanced Dvorak Technique (ADT)

CIMSS Project Leads: Tim Olander and Chris Velden
CIMSS Support Scientist: John Sears
NOAA Collaborators: Mike Turk (SAB), Jack Beven (NHC)
NOAA Strategic Goals
- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

CIMSS Research Themes
- Weather Nowcasting and Forecasting

Proposed Work

The Advanced Dvorak Technique (ADT) was designed to objectively estimate tropical cyclone (TC) intensity from satellite imagery (Olander and Velden 2007). The algorithm compliments the use of the more subjective and time-consuming Dvorak Technique (DT), which has been in use operationally since the 1970's. Investigation of a new concept to utilize multispectral geostationary satellite data has been conducted with results presented in a recent publication (Olander and Velden, 2009). These results showed considerable promise, with certain aspects of the investigation being directly applicable to possible use within the ADT to augment analysis techniques currently employed in the algorithm and expansion into new areas of application and functionality.

One area of particular interest is the possible use of the information to improve tropical cyclone (TC) forecast intensity analysis, a high-priority research goal set forth by the NOAA/NWS. Since the ADT is already utilized by several United States operational TC forecast centers (including the National Hurricane Center, Joint Typhoon Warning Center, and Satellite Analysis Branch), integration of an accurate tool to improve TC intensity forecasting ability would be easy to implement and highly regarded.

Summary of Accomplishments and Findings

The technique employed is centered on the spectral response differences between the geostationary infrared (IR) and water vapor (WV) channels of the GOES (and other) satellites   In typical clear sky conditions, the IR-WV difference will be positive since the WV brightness temperature values are cooler than the IR values. However, in regions of intense TC convective activity, water vapor is pushed into the upper-tropopause/lower-stratosphere (UTLS), resulting in a change of sign in the IR-WV signal where the UTLS WV absorbs and reemits radiation from the cloud below. An example is shown in Figure 3.4.1 for Hurricane Wilma (2005).

A preliminary assessment of how the utilization of the IR-WV differencing could improve correlations between current ADT intensity estimates and observed TC intensities was presented in Olander and Velden (2009). More recent research is showing an even stronger correlation between IR-WV information and Rapid Intensification (RI) at time periods 18-24 prior to the onset of such events. Further research is needed to fine tune the IR-WV signals for integration into the ADT rules schemes, but the initial results are encouraging.

Figure 3.4.2 presents the IR-WV counts versus the NHC Best Track intensity for four individual storms. It must be noted that several of the storms which were labeled false alarms may have actually been very close to reaching the official wind speed criteria (e.g., Bonnie in 1998) or may have been hindered from reaching RI due to environmental factors such as the TC moving over land, interaction with other TCs, or encountering significant atmospheric shear. Such cases may

be inflating the false alarm rate misleadingly since the storm may have undergone an RI event if not for the extenuating circumstance. Further research is needed to closely examine all cases and continue to modify the RI identification criteria; however initial results are quite promising.
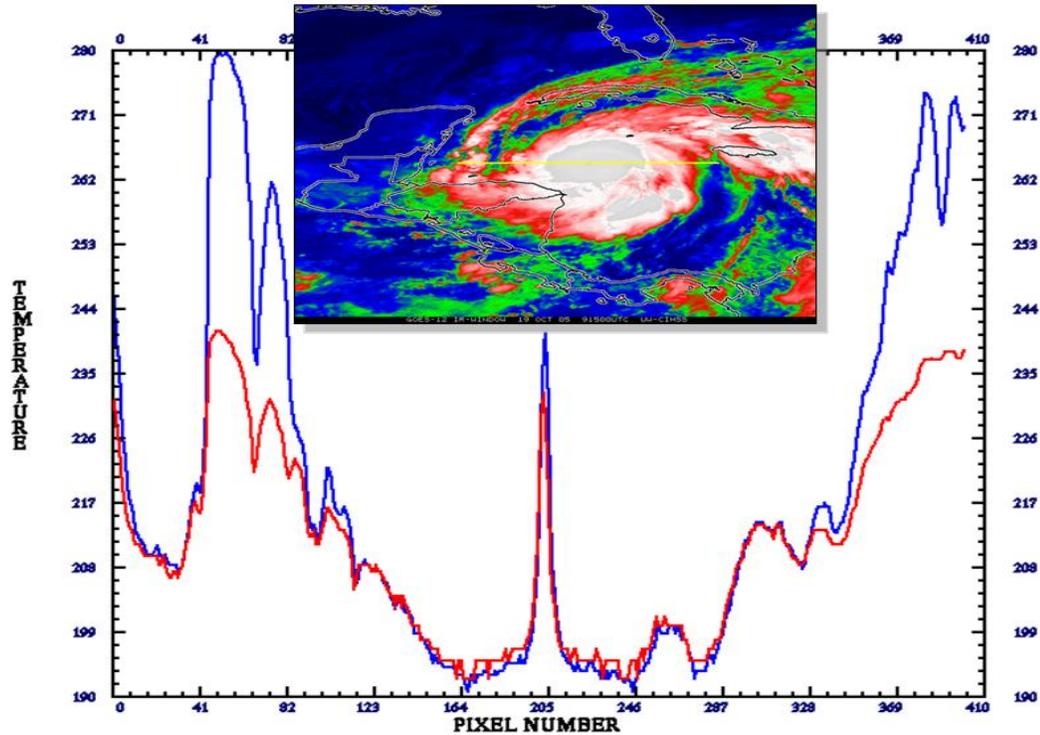
Figure 3.4.1. Cross section of GOES-12 brightness temperatures (Tb) during Hurricane Wilma (2005) near the time of its maximum intensity on 19 October/09:15UTC. The west to east cross section transverses the eyewall as well as the outer rainbands of the storm. In the outer regions of the TC, the clouds are typically less opaque or missing entirely, resulting in brightness temperature measurements in line with those expected; WV Tbs (red) are colder than the corresponding IRW values (blue). In the inner eyewall region, however, this relationship reverses as water vapor above the convection is forced through the tropopause and into the stratosphere where it re-emits in the WV emission bands at higher temperatures. Here, the IRW minus WV (IRWV) difference values are near zero or negative, indicating the presence of vigorous convection "overshooting" into the stratosphere.
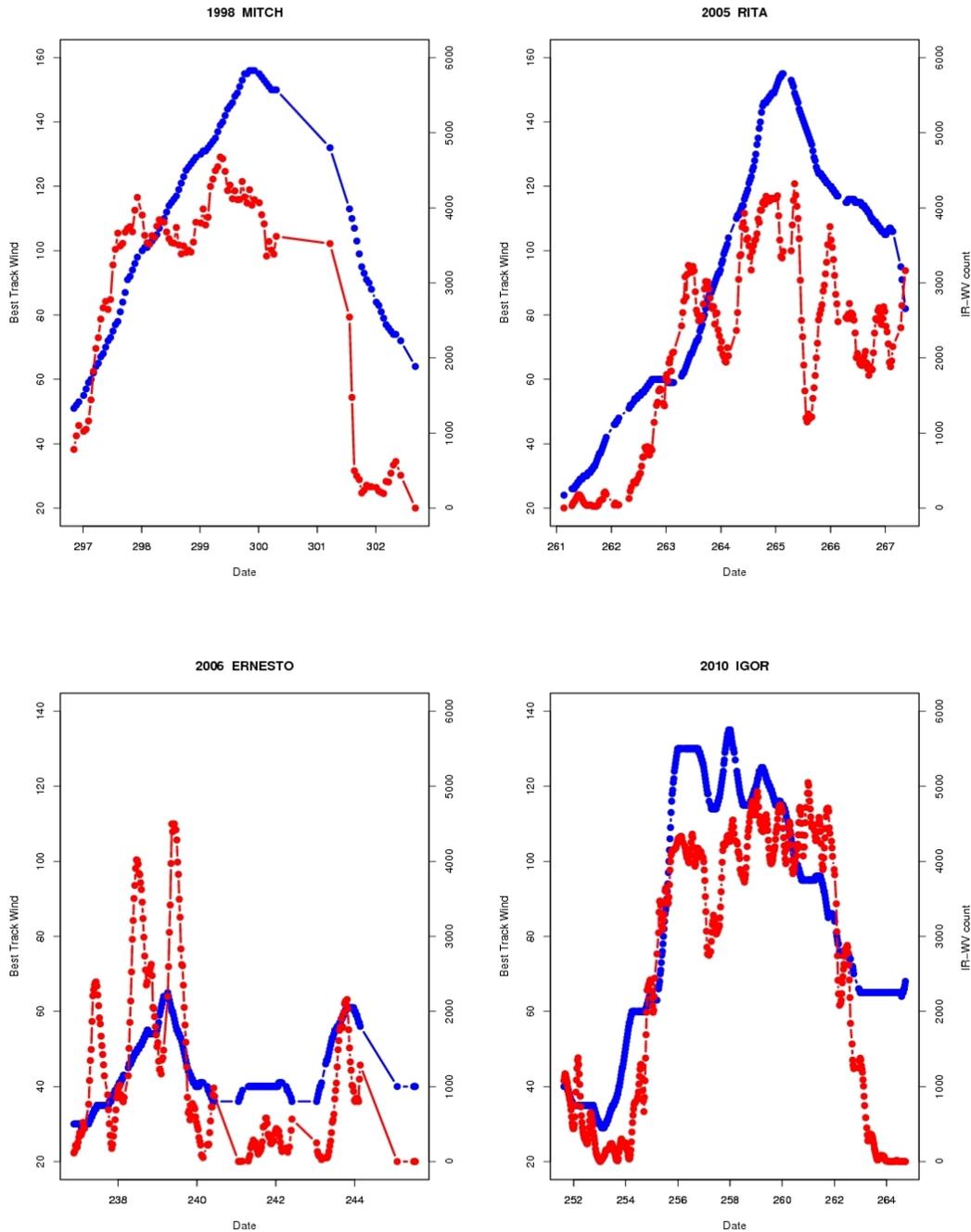
Figure 3.4.2. IR-WV pixel count values less than zero (Y-axis/right side; red lines/dots) versus NHC Best Track wind speed estimates (Y-axis/left side) blue lines/dots) for four storms in rapid intensification (RI) study sample. Hurricanes Mitch, Rita and Igor all exceeded the NHC criteria for RI and were correctly identified by the IR-WV RI identification scheme prior to the onset of RI in the NHC Best Track. Hurricane Ernesto was falsely identified as a potential RI storm with the IR-WV methodology, but did not meet the NHC criteria during its lifecycle possibly due to land interaction after reaching its maximum intensity of 65 knots on August 29 (Julian day 239).

Publications and Conference Reports

Olander, T. and C. Velden, 2012: The Advanced Dvorak Technique (ADT) – Current Status and Latest Advancements, 92nd AMS Annual Meeting, New Orleans, LA, January 22-26.

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

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.

Olander, T.L. and C.S. Velden, 2009: Tropical Cyclone Convection and Intensity Analysis Using Differenced Infrared and Water Vapor Imagery. *Wea. & Forecasting*, **24**, 1558-1572.

3.5 Testing of New Height Assignment Methodology for GOES Atmospheric Motion Vectors (AMVs)

CIMSS Task Leaders: Chris Velden, Steve Wanzong
NOAA Collaborators: Jaime Daniels (STAR), Andrew Heidinger (ASPB)
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

Proposed Work

Although AMVs (Atmospheric Motion Vectors) have had positive impacts on NWP, the representative vector heights have proven to be a relatively large source of observation uncertainty, because in most cases the satellite imagers actually sense radiation emitted from a finite layer of the troposphere rather than just one specific level. Problems in data assimilation of AMVs can arise from the difficulty in accurately placing the height of the tracer. Thus, we have proposed to take a fresh look at developing a specific quality indicator for AMV height assignment. To this end, we are working with cloud height experts. Once developed, we will work with data assimilation colleagues to address the issue of exploiting this new AMV height assignment information in numerical model simulations to determine the potential forecast impact.

The AMV processing algorithm uses upstream cloud team algorithms for AMV height assignment. Included in the pixel-level cloud height output structure are estimated pressure and temperature errors. It is still hoped that this will eventually be a way to estimate AMV tracer cloud height uncertainty for use in NWP. Also included in the cloud team output structure are quality flags with respect to the cloud height retrieval for each pixel. We will look at cloud retrieval quality estimates and 11-micron emissivity values compared against AMV-CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) cloud height comparisons. Software modifications will need to be introduced to read this information from the upstream

cloud height algorithm and include the quality flags and emissivity values that make up the height assignment set of pixels.

Summary of Accomplishments and Findings

During this reporting period AMVs derived from Meteosat-9 SEVIRI are compared to the CALIPSO 5km cloud top height product. To ensure high quality matches, the AMVs must have an internal quality indicator (QI) of 60 or greater, with a maximum of 100. The AMV 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 requirement filters out 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. Future LIDAR missions such as ADM-Aeolus will have the ability to retrieve profiles of wind information. Two cases will be discussed. The first is a low-level AMV case from 15 September 2011, at 00 UTC. The second is an upper-level AMV data set from 22 September 2011, at 00 UTC.

Figure 3.5.1 is a typical example of the global Meteosat-9 AMV coverage from 15 September 2011, at 00 UTC. In this figure, only the Longwave IR (LWIR) AMVs have been plotted over water. Upper-level AMVs are plotted in pink (100-400 hPa), mid-level in blue (400-700 hPa) and low-level in yellow (700-1000 hPa). The white line represents the CALIPSO transect locations nearest the time of the AMVs.
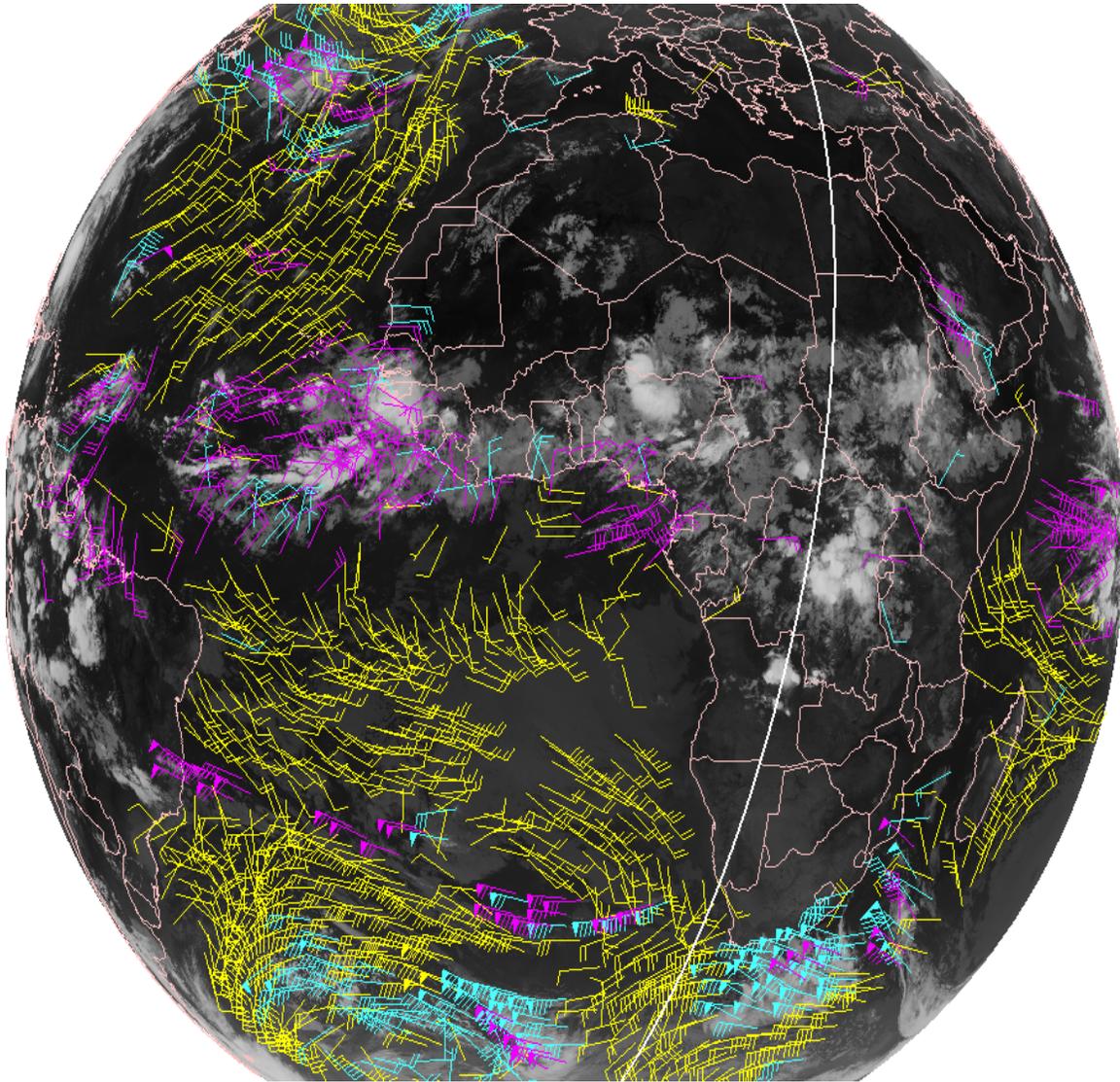
Figure 3.5.1. LWIR AMVs from Meteosat-9 for 15 September 2011 at 00 UTC plotted with the CALIPSO transect locations in white.

Figure 3.5.2 shows the AMV CALIPSO match locations as yellow "plus signs." There were approximately 10,000 LWIR AMVs in this example. If we apply the collocation filtering described above, we find 29 matches between the AMVs and the CALIPSO profiles.
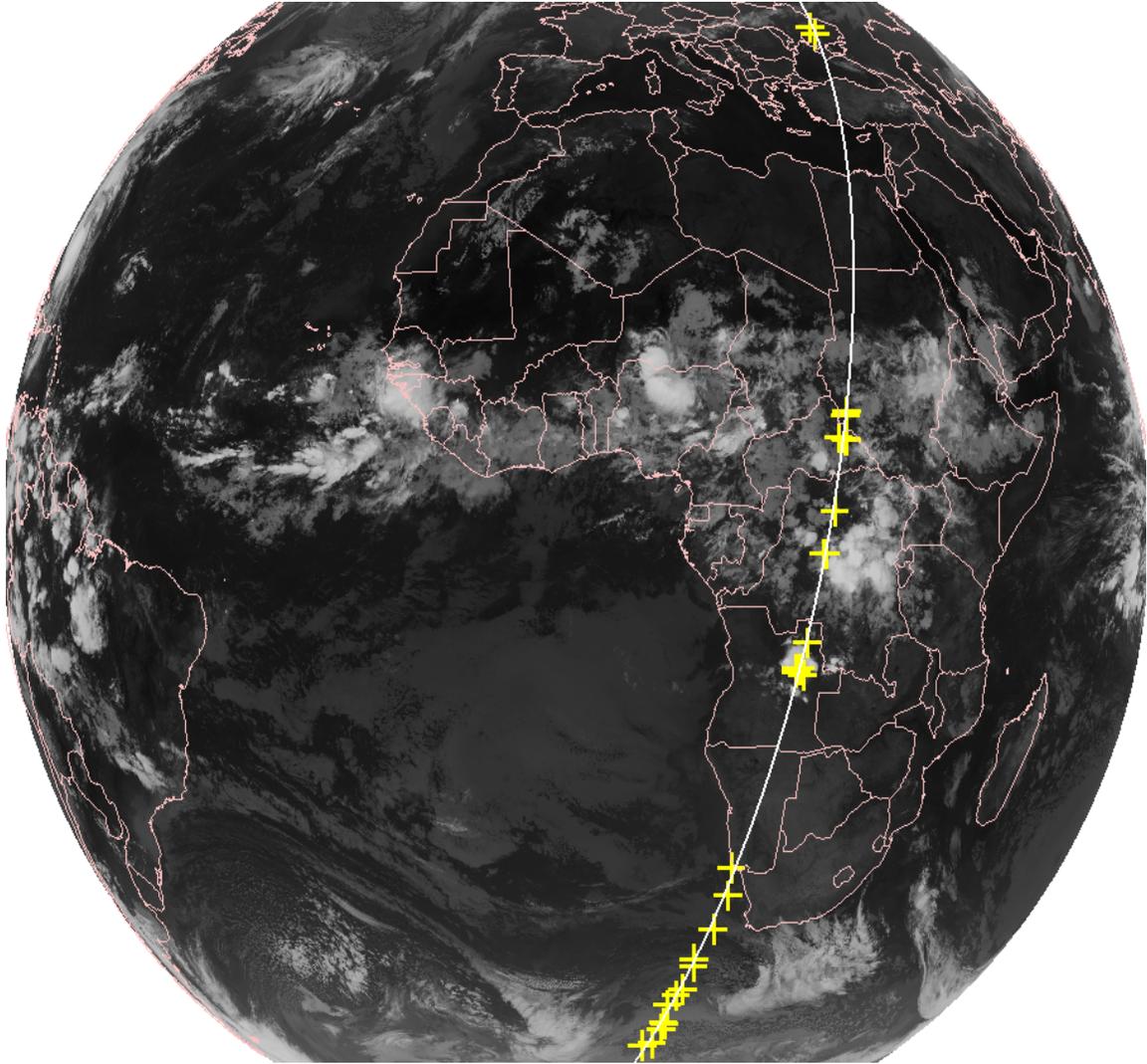
Figure 3.5.2. AMV CALIPSO match locations for 15 September 2011 at 00 UTC.

Figure 3.5.3 shows the altitude-time 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 heights in yellow. Only the AMVs at the southern edge of Figure 3.5.2 are considered in this figure.

Total Attenuated Backscatter 532 nm
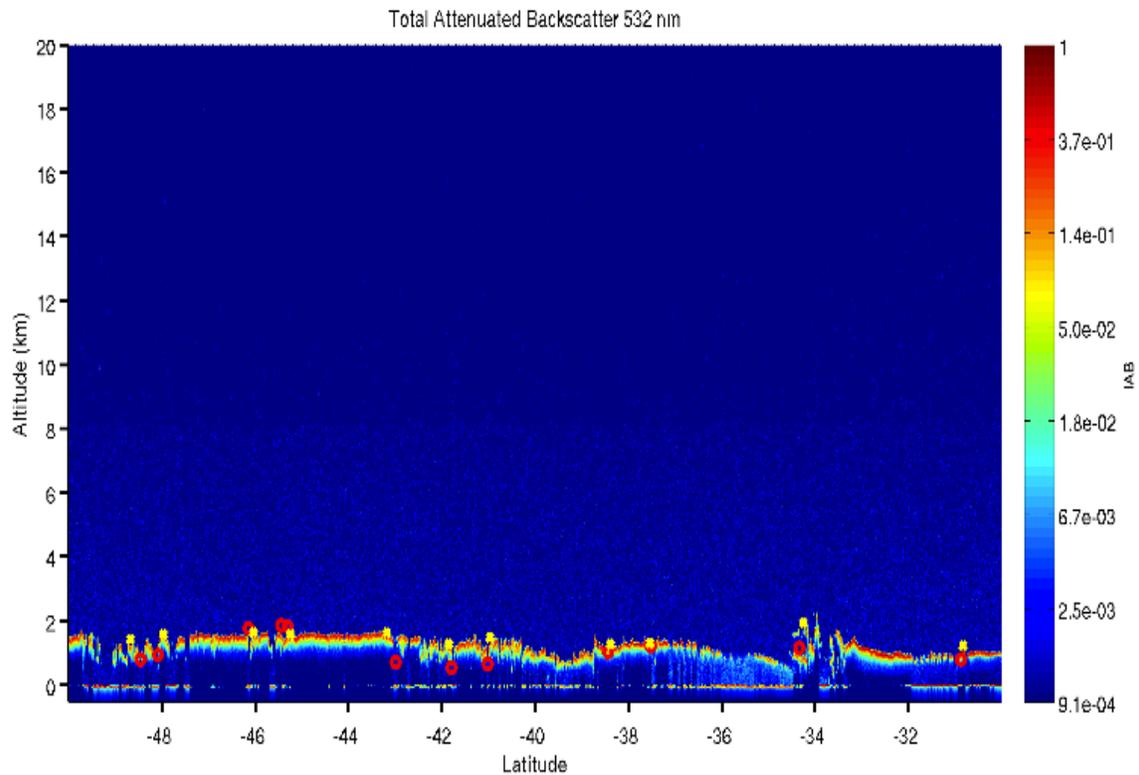
Figure 3.5.3. CALIPSO total attenuated backscatter with collocated AMV locations plotted in red and CALIPSO clouds in yellow.

For this case we concentrated on low-level water cloud heights. In general there is very good agreement between the AMV height assignment and CALIPSO cloud top heights. This result is not unexpected as low-level AMVs have traditionally been a layer that has always verified well against rawinsondes.

Figure 3.5.4 is a second example of the global Meteosat-9 AMV coverage from 22 September 2011, at 00 UTC. This figure again shows only LWIR AMVs plotted over the SEVIRI image. The white line represents the CALIPSO transect locations nearest the time of the AMVs.
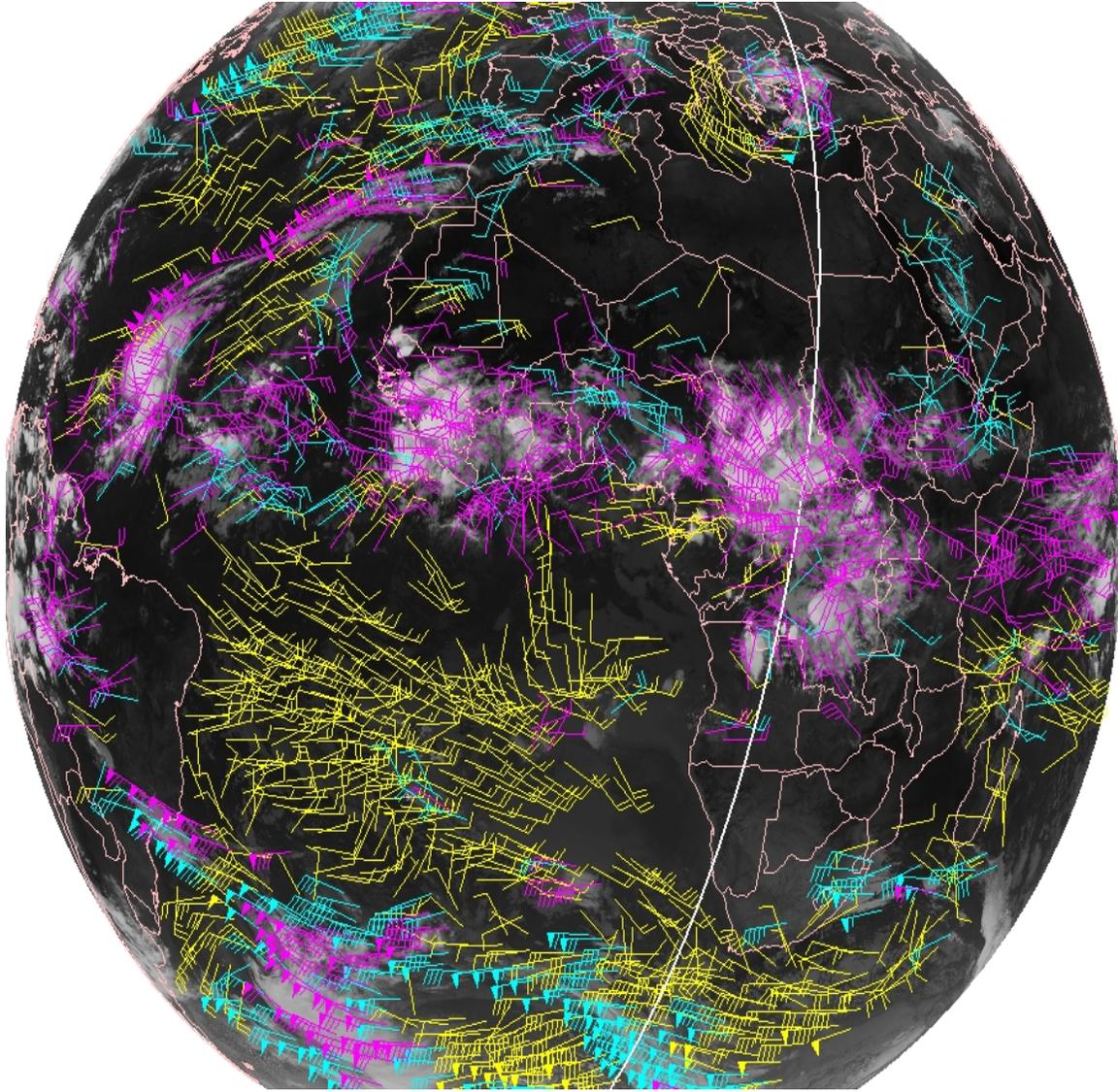
Figure 3.5.4. LWIR AMVs from Meteosat-9 for 22 September 2011 at 00 UTC plotted with the CALIPSO transect locations in white.

Figure 3.5.5 shows the AMV CALIPSO match locations as yellow "plus signs." As in the first case, more than 10,000 LWIR AMVs are present in this data set. If we apply the collocation filtering described above, we find 30 matches between the AMVs and the CALIPSO profiles.
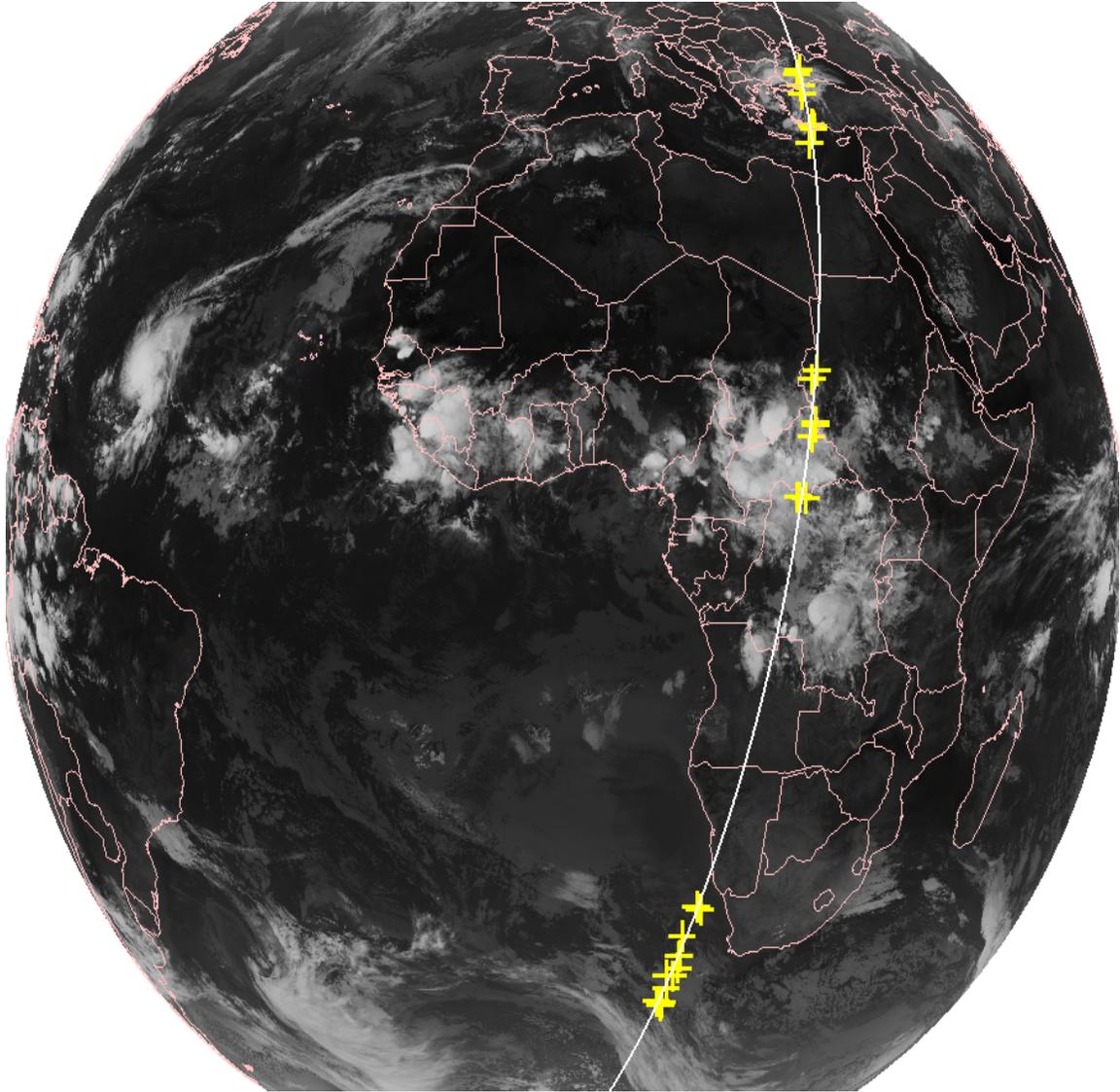
Figure 3.5.5. AMV CALIPSO match locations for 22 September 2011 at 00 UTC.

Figure 3.5.6 shows the altitude-time 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 heights in yellow. Only the AMVs in central Africa of Figure 3.5.5 are considered in this figure.
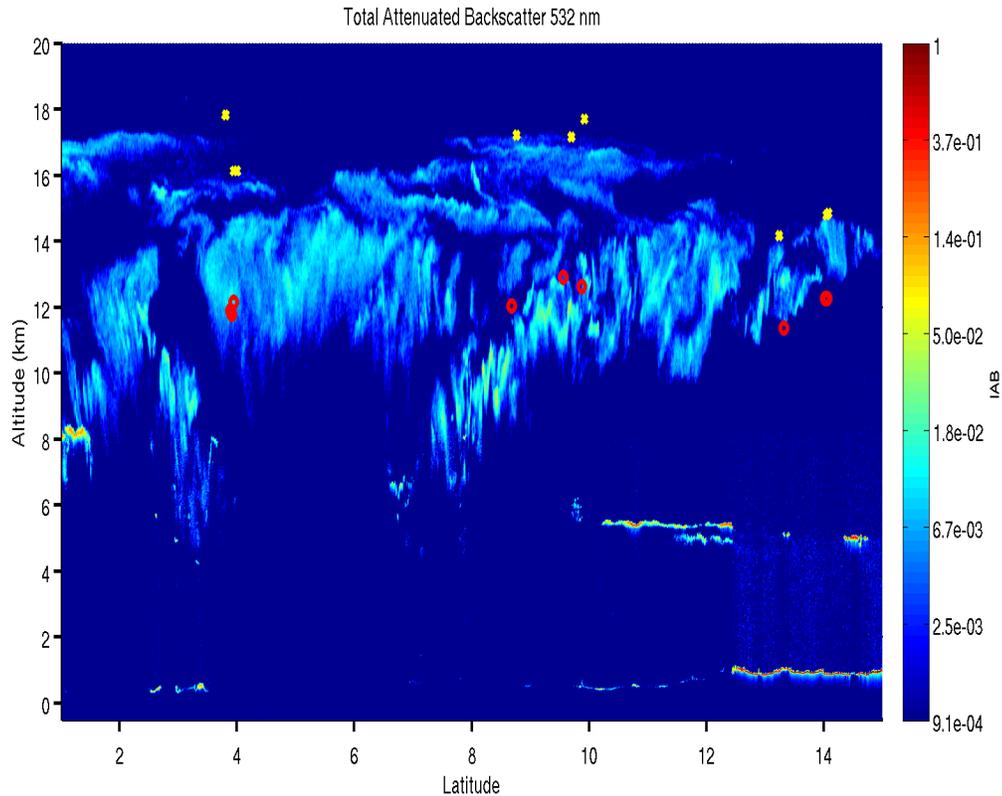
Figure 3.5.6. CALIPSO total attenuated backscatter with collocated AMV locations plotted in red and CALIPSO clouds in yellow.

Here we see large differences in the AMV heights (in red) compared to the CALIPSO cloud top height product (in yellow). This result is not necessarily a height assignment issue as it is not possible for the Meteosat-9 imager to sense the top of the observed CALIPSO cloud. For a more reasonable comparison, we need to adjust the height of the CALIPSO cloud down to a height within the Meteosat-9 sensor range. A proposed method is to use the midpoint of the CALIPSO cloud layer.

Figure 3.5.7 shows the results of this method. The two white lines are the CALIPSO cloud top height and cloud base height for what it considers a single layer feature. The yellow line is the midpoint of the cloud layer. Plotted in red are the AMV heights. Using this simple utility now shows a much better fit between the AMVs and CALIPSO.
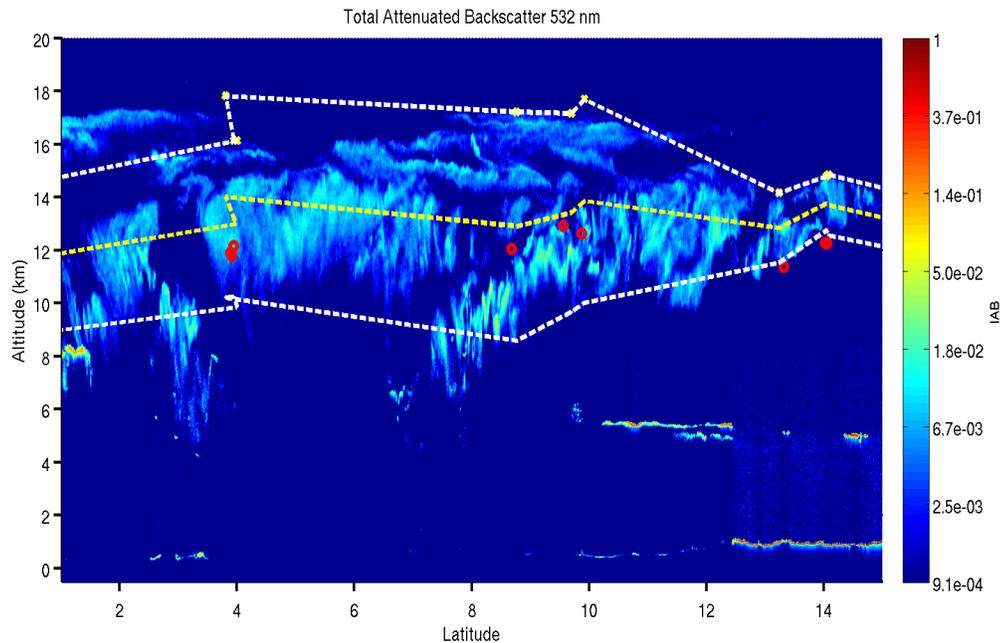
Figure 3.5.7. CALIPSO total attenuated backscatter with collocated AMV locations plotted in red. The white lines are the CALIPSO cloud top altitude and cloud base altitude. The yellow line represents the midpoint of the cloud layer.

Comparisons to date have been only qualitative. We hope to expand the software in a way that allows multiple data sets to be combined so that some statistical parameters may be reported.

Publications and Conference Reports

Wanzong, Steve; Bresky, W.; Velden, C.; Daniels, J. and Bailey, A. GOES-R Readiness: Atmospheric Motion Vectors (AMVs) Validation Activities. International Winds Workshop, 11th, Auckland, New Zealand, 29-24 February 2012.

Wanzong, Steve; Bresky, W.; Velden, C. S.; Daniels, J. M. and Rink, T. D. GOES-R AWG Atmospheric Motion Vectors: Validation activities. Conference on Satellite Meteorology, Oceanography and Climatology, 18th, and Joint AMS-Asia Satellite Meteorology Conference, 1st, New Orleans, LA, 22-26 January 2012.

Zhang, Hong; Gunshor, M.; Straka, W.; Martin, G.; Wanzong, S.; Schiffer, E.; Garcia, R. and Huang, A.GRAFIIR - An efficient end-to-end semi automated GOES-R ABI algorithm performance analysis and implementation verification system. Annual Symposium on Future Operational Environmental Satellite Systems, 8th, New Orleans, LA, 22-26 January 2012.

Daniels, Jaime M.; Bresky, W.; Wanzong, S. and Velden, C. S. Atmospheric motion vectors derived via a new nested tracking algorithm developed for the GOES-R Advanced Baseline Imager (ABI). Annual Symposium on Future Operational Environmental Satellite Systems, 8th, New Orleans, LA, 22-26 January 2012.

3.6 GOES-15 Post-Launch Test Support

CIMSS Task Leader: Mat Gunshor
CIMSS Support Scientists: Scott Bachmeier, Jun Li, James P. Nelson III,
Christopher Schmidt, Tony Schreiner, Dave Stettner, William Straka, Chris
Velden, Steve Wanzong
NOAA Collaborators: Tim Schmit, Gary Wade, Don Hillger
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

Proposed Work

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

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

The first major step is the data collection phase, which has been completed. The remaining tasks are select product generation and the generation of the NOAA technical report. A number of tasks will be completed for the GOES-15 checkout, including:

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

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

3. This final year of GOES-15 funding will incorporate the completion of the GOES-15 NOAA Technical Report. Similar to previous instrument checkouts, these results are being added to previous outcomes on the Web.

Summary of Accomplishments and Findings

On December 6, 2011, GOES-15 began operational use as GOES-West, replacing GOES-11. Before this transition occurred, all operational software production issues were resolved. OSPO received updated versions of operational software packages for Clear Sky Brightness Temperature, Imager and Sounder Cloud Products, Temperature/Moisture Retrievals, and Atmospheric Motion Vector algorithms. The NOAA science technical report for GOES-15 was completed on December 7, 2011. CIMSS was a key contributor to a majority of the figures and analysis contained in the report. These contributions included noise analysis, image generation, and product validation.
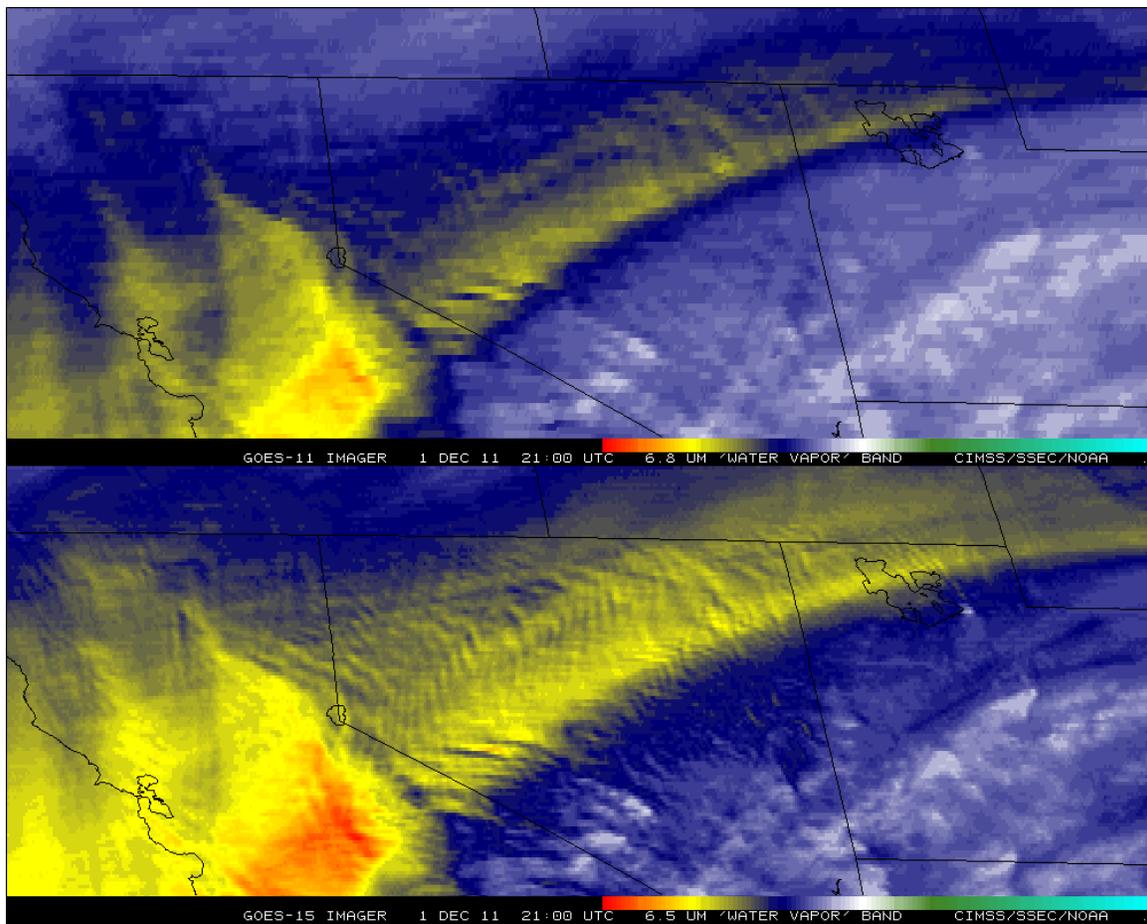
Figure 3.6.1. This two-paneled figure highlights the improved spatial resolution of the GOES-15 Imager water vapor band (bottom) compared to GOES-West predecessor GOES-11 (top), due to the increased number of detectors on this band.

Publications and Conference Reports

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

References

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

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

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

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

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

3.7 Using Quantitative GOES Imager Cloud Products to Improve Short-Term Severe Weather Forecasts

CIMSS Task Leaders: John Cintineo, Justin Sieglaff
NOAA Collaborator: Mike Pavolonis
NOAA Long Term Goals
- Weather-Ready Nation

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

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

Proposed Work

As demonstrated with previous GIMPAP funding, individual clouds can be treated as objects and tracked over time. By tracking cloud objects over time, we are able to capture and study the unique temporal trends in satellite-derived cloud properties of individual objects. Upon compiling a database of severe and non-severe storms, it was discovered that the temporal trend in several satellite-derived cloud object macro and microphysical properties differed considerably between the two classes (severe, non-severe). Based on these differences, a naïve Bayes probabilistic model was developed to predict whether it was likely or unlikely that a given storm would meet severe criteria in the future. Analysis of the probabilistic model indicates that it is capable of providing at least 20-60 minutes of lead-time *ahead of* radar-indicated severe weather metrics (e.g., rotation, large hail signatures, etc.). These results provide strong motivation to continue to develop this approach so that it can eventually be used in operations.

While previous GIMPAP projects have demonstrated quantitative GOES satellite derived cloud properties are very valuable for predicting the short-term behavior of convective storms, the probabilistic model would benefit significantly from incorporating additional data sources such as NEXRAD (and eventually dual polarization radar) and Rapid Update Cycle (RUC)/Rapid Refresh (RR) model output. Thus, we propose to continue to develop our probabilistic model by incorporating NEXRAD and NWP predictors. The addition of NEXRAD and NWP data will improve the skill of the Bayesian model (and cloud object tracking) and potentially allow for more specific predictions (e.g., probability of tornado, large hail, etc.). The proposed research addresses the growing need of the NWS to have access to "fused" products that are more valuable than satellite-alone, radar-alone, or NWP-alone products.

Summary of Accomplishments and Findings

The focus during the past year was demonstrating the lead-time of the Bayesian model *ahead* of NWS Severe Weather Warnings/NEXRAD severe signatures as well as incorporating NWP (RUC) model fields into the Bayesian model. Figure 3.7.1 shows an example of a developing thunderstorm over the panhandle of Texas with an enhanced severe probability from the Bayesian model. The enhanced probability was from 1945 UTC 15 May 2009, which is 21 minutes prior to issuance of a severe thunderstorm warning. This example demonstrates the potential advantage of using satellite-derived growth metrics in improving severe weather warning capabilities.

Additionally, temporally composited and spatially smoothed 13-km RUC most unstable CAPE and Effective Bulk Shear (Thompson et al., 2006) are being added as predictors to the Bayesian model to improve skill. The temporal compositing and spatial smoothing will mitigate any spatial/temporal errors in NWP data that may adversely affect the Bayesian model. Specifically, we are temporally compositing the fields by selecting the maximum value at each pixel in a given time window (e.g., +/- 2 hours) and then applying a Gaussian spatial filter.

Publications and Conference Reports

Sieglaff, J. M., D. C. Hartung, W. F. Feltz, L. M. Cronce, and V. Lakshmanan, 2012: Development and application of a satellite-based convective cloud object-tracking methodology: A multipurpose data fusion tool. Submitted to *J. Appl. Meteor. Climatol.*

Sieglaff, J. M., M. Pavolonis, D. Hartung, and J. Cintineo, 2012: Probabilistic Nowcasting of Severe Convection using the Temporal Evolution of Satellite-derived Deep Convective Cloud Properties, presented at Annual AMS Meeting, New Orleans, LA.

Hartung, D. C., M. Pavolonis, and J. Sieglaff, 2011: Probabilistic Forecasting of Severe Convection using the Temporal Evolution of Satellite-derived Deep Convective Cloud Properties, presented at AMS Mesoscale Conference, Los Angeles, CA.

Pavolonis, M. J., D. Hartung, and J. Sieglaff, 2011: The temporal evolution of satellite-derived deep convective cloud properties, presented at EGU Annual Meeting, Vienna, Austria.

GOES-12 Severe Storm Probability_20090515_1945_UTC
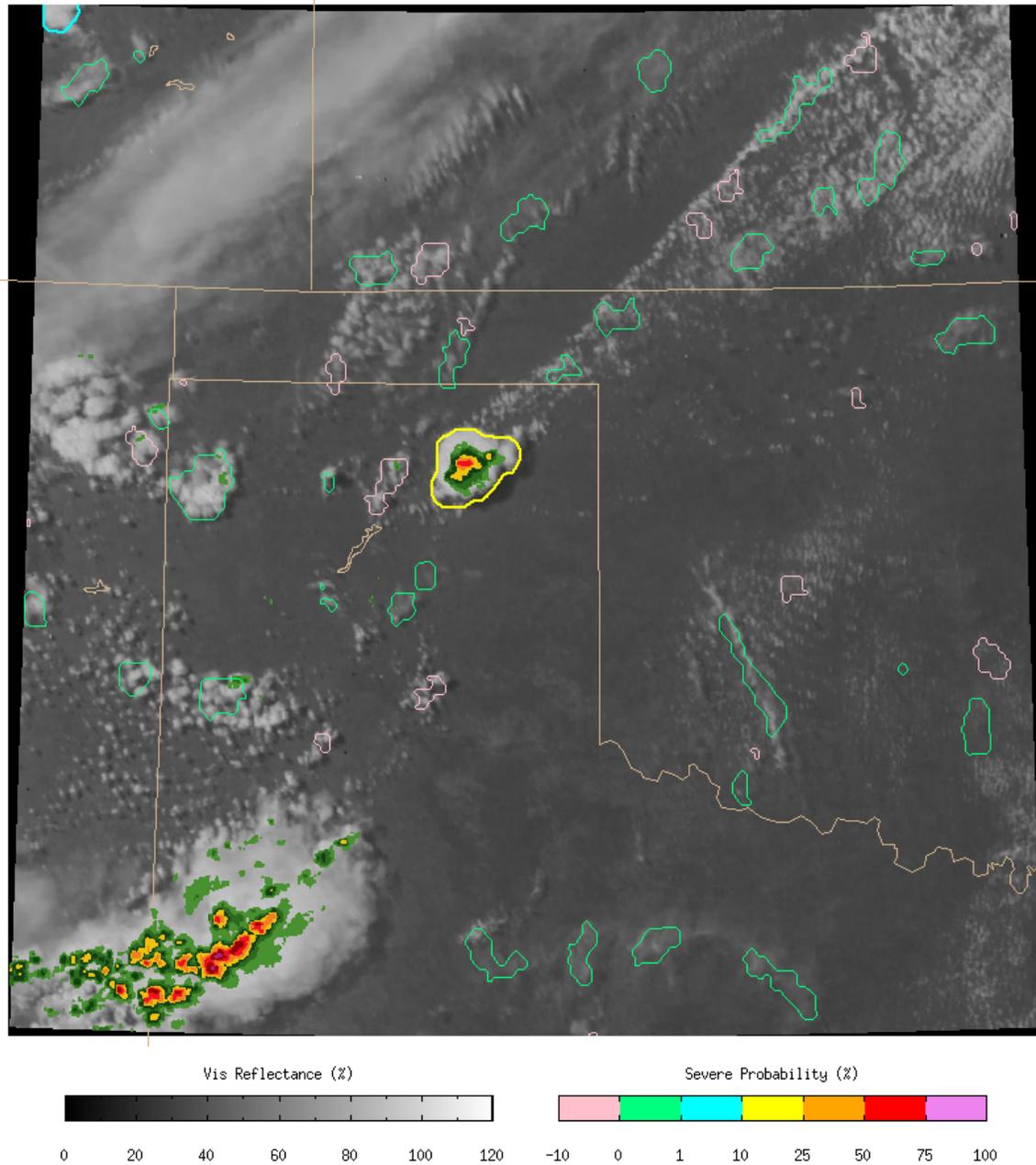
Figure 3.7.1. GOES-12 visible satellite imagery (grayscale shading), NEXRAD composite reflectivity (colored shading), and Bayesian model output for cloud objects (colored contours around various cloud objects) all valid 1945 UTC 15 May 2009. The developing supercell thunderstorm over the northeastern Texas panhandle has an enhanced probability (the only cloud object with an enhanced probability at this time). The enhanced probability occurs 21 minutes prior to the issuance of a severe thunderstorm warning.

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Lakshmanan, Valliappa, Travis Smith, Gregory Stumpf, and Kurt Hondl, 2007: The Warning Decision Support System-Integrated Information. *Wea. Forecasting,* **25**, 596-612.

Thompson, R. L., C. M. Mead, and R. Edwards, 2006: Effective Storm-Relative Helicity and Bulk Shear in Supercell Thunderstorm Environments. *Wea. and Forecasting*, **22**, 102-115.

4. PSDI

4.1 Improving the GOES Cloud Product Processing System

CIMSS Task Leader: William Straka III
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

Proposed Work

National Environmental Satellite, Data, and Information Service, Center for Applications and Research (NESDIS/STAR) and the Cooperative Institute for Meteorological Studies (CIMSS) have been developing a suite of products that will offer advanced cloud detection and retrievals of cloud properties utilizing the GOES-R ABI instrument. This work is to transition the algorithms from the GOES-R Cloud AWG to work on the current set of GOES sensors (GOES-11/12/13/14/15) for usage. These include the ABI Cloud Mask (ACM) and ABI Cloud Height Algorithm (ACHA).

Summary of Accomplishments and Findings

The ABI Cloud Mask was originally developed with multiple sensors in mind. Further testing has been done on the ACM over the previous year. This testing was done in conjunction with the validation effort for ACHA.

The ABI Cloud Height algorithm (ACHA) built on the improvements from previous years. In addition to the improvements that are being done, a validation effort was undertaken comparing the cloud top height derived from ACHA to those derived from CALIOP. An example from GOES-EAST (GOES-13) is shown below in Figure 4.1.1.
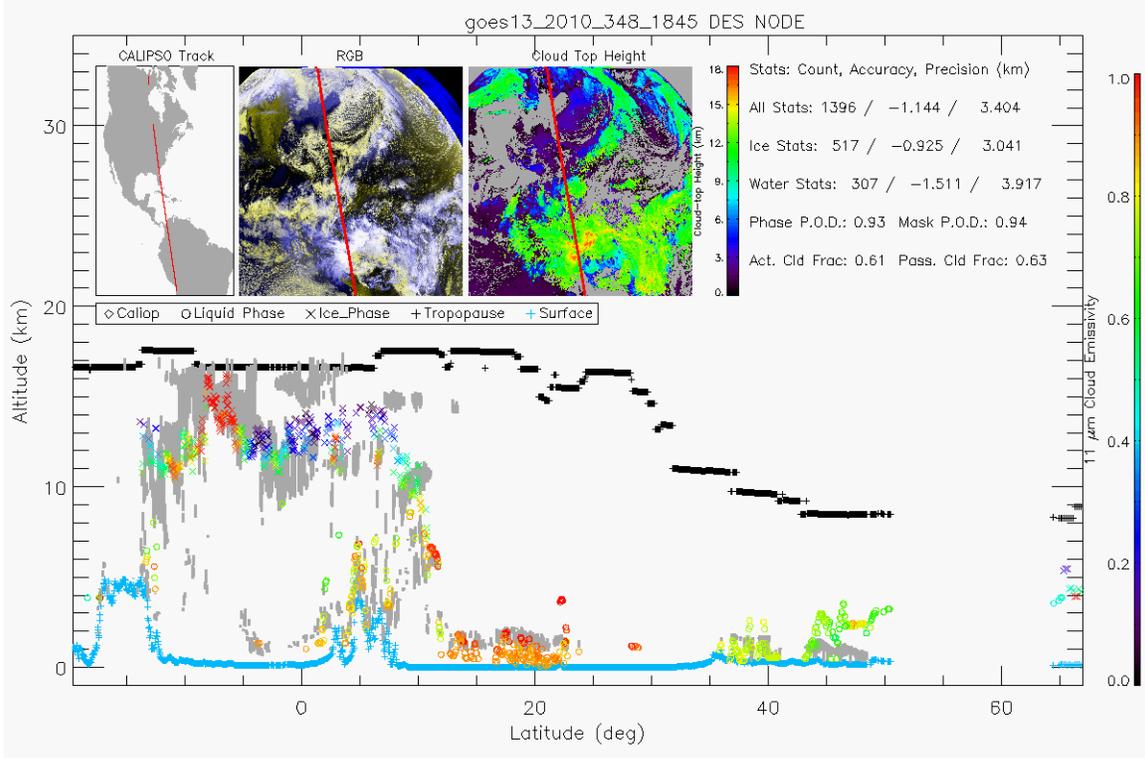
Figure 4.1.1. Comparison of cloud top height derived from ACHA to those derived from CALIOP as part of a validation effort. Figure above is an example from GOES-13.

In addition to validating the cloud height, this tool can be used to validate the performance of the cloud mask for any GEO scene collocated with CALIPSO. In addition to the validation effort shown above, a training module for forecasters was developed and is also being injected into AWIPS.

Collaboration with the GOES-R Derived motion Winds team has continued, as they are one of the primary users of the cloud height.

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

4.2 VIIRS Polar Winds

CIMSS Task Leaders: Dave Santek, Chris Velden
CIMSS Support Scientists: Steve Wanzong, Nick Bearson
NOAA Collaborator: Jeff Key
NOAA Long Term Goals
  • Climate Adaptation and Mitigation
  • Weather-Ready Nation
NOAA Strategic Goal
  • Serve society's needs for weather and water

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

Proposed Work

Fully automated cloud-drift wind production from GOES became operational in 1996, and wind vectors are routinely used in operational numerical models of the National Centers for Environmental Prediction (NCEP) and other numerical weather prediction (NWP) centers. Winds over the polar regions have been generated with Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on NASA's Terra and Aqua satellites and the Advanced Very High Resolution Radiometer (AVHRR) on NOAA satellites at CIMSS since 2001, and by NESDIS operations since 2005 (MODIS) and later (AVHRR). A timeline of polar wind product development is shown in Figure 4.2.1.
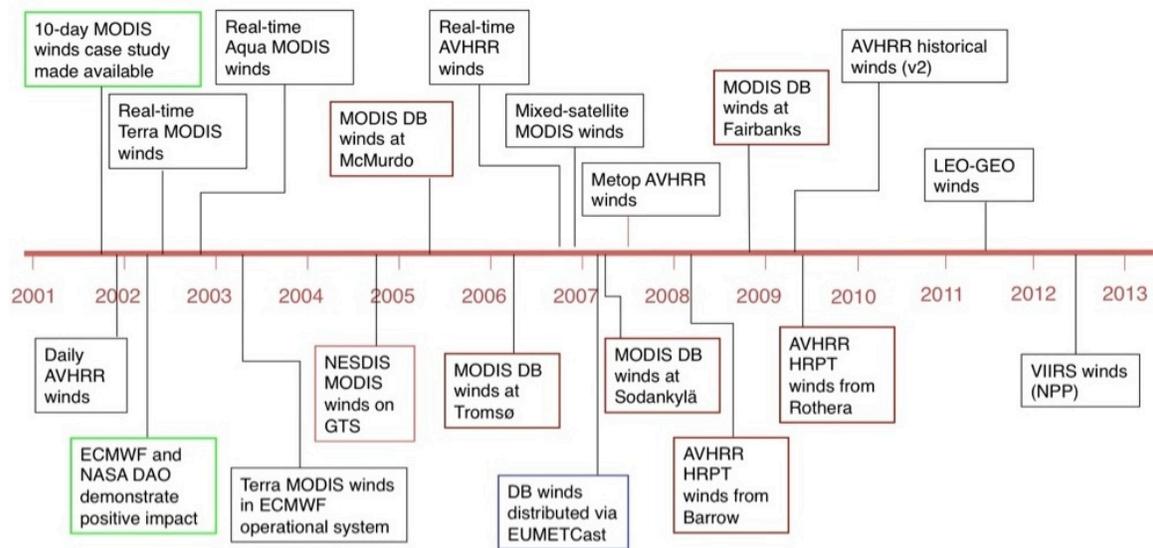
Figure 4.2.1. The polar winds product history, from 2001 to the present.

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

Summary of Accomplishments and Findings

Over the past year we have continued the real-time generation of polar winds products from Terra and Aqua MODIS and AVHRR on NOAA-15 through -19 and Metop-A. The focus of the project, however, is the development of a method to generate winds from VIIRS. VIIRS is a 22-band imaging radiometer that is a cross between MODIS and AVHRR, with some characteristics of the Operational Linescan System (OLS) on Defense Meteorological Satellite Program (DMSP) satellites. It has several unique characteristics that will have an impact on a VIIRS polar winds product. These include:
- Wider swath,

- Higher resolution (750 m for most bands; 375 m for some),
- Constrained pixel growth: better resolution at edge of swath, and
- Day-night band (DNB).

One disadvantage of VIIRS is that, unlike MODIS but similar to AVHRR, it does not have a thermal water vapor band. Therefore, no clear-sky winds can be retrieved.

VIIRS has a wider swath (3000 km) than MODIS (2320 km), so the coverage will be better. AVHRR swath width is somewhere between that of VIIRS and MODIS (2600 km). A wider swath means more winds with each orbit triplet. Figure 4.2.2 shows the overlap of three orbits, which are needed for wind derivation, for MODIS and VIIRS. The figure illustrates the improved coverage of VIIRS.
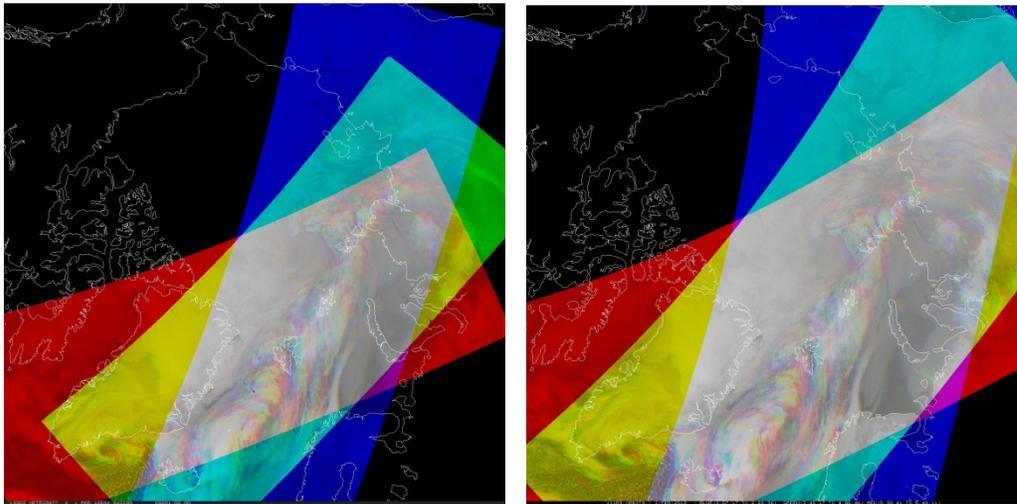
Figure 4.2.2. The gray region represents the overlap in three orbits where the polar winds are derived for MODIS (left) and VIIRS (right).

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

VIIRS polar winds processing will utilize the new GOES-R Advanced Baseline Imager (ABI) atmospheric motion vector (AMV) algorithm. A significant effort is being devoted to changing the wind retrieval code base. There are some fundamental differences from our traditional procedure. Most importantly, cloud-drift wind heights are determined by using an externally generated cloud height product rather than internal routines. We must therefore incorporate code to compute cloud properties.

Many changes to the processing have been made, including tools to convert VIIRS data to a polar stereographic projection, conversion to AREA files, and integration into GEOCAT, all without McIDAS. One case study using the new processing system with MODIS data and cloud

properties has been performed (Figure 4.2.3). The VIIRS polar winds product is scheduled to be operational in NESDIS this coming October (2012).
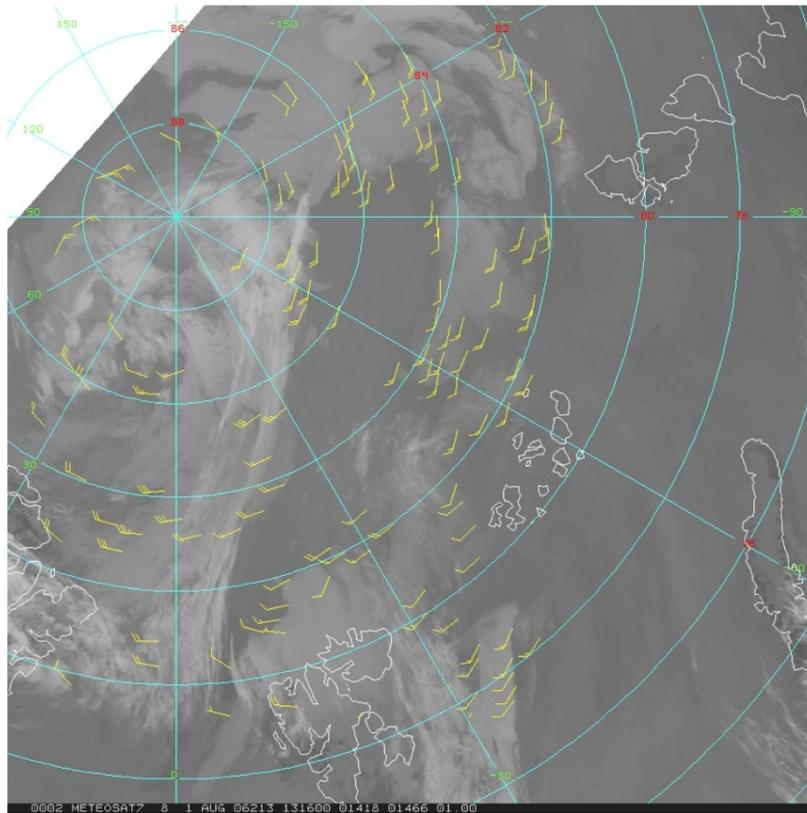
Figure 4.2.3. Polar winds based on MODIS data using the VIIRS/ABI processing system.

We continue to work with numerical weather prediction (NWP) centers regarding product quality, use, and future enhancements. At present, MODIS and AVHRR polar wind products are used operationally by 13 NWP centers in nine countries:

- European Centre for Medium-Range Weather Forecasts (ECMWF);
- NASA Global Modeling and Assimilation Office (GMAO);
- Japan Meteorological Agency (JMA), Arctic only;
- Canadian Meteorological Centre (CMC);
- US Navy, Fleet Numerical Meteorology and Oceanography Center (FNMOC);
- (UK) Met Office;
- Deutscher Wetterdienst (DWD);
- National Centers for Environmental Prediction (NCEP/EMC);
- Meteo France;
- Australian Bureau of Meteorology (BoM);
- National Center for Atmospheric Research (NCAR, USA);
- China Meteorological Administration (CMA); and
- Hydrological and Meteorological Centre of Russia (Hydrometcenter).

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

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

Publications and Conference Reports

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

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

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

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

5. JCSDA

5.1 Data Denial Experiments using the NCEP Global Forecast System

CIMSS Task Leader: James Jung
NOAA Collaborators: John Derber, Lars Peter Riishojgaard, Sid Boukabara, John Le Marshall
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

Proposed Work

S4 and JIBB Software Integration
Two of the Joint Center for Satellite Data Assimilation (JCSDA) partners, The National Environmental Satellite, Data and Information Service (NESDIS) and the National Aeronautical and Space Administration (NASA) have purchased computers dedicated to satellite data assimilation. Various National Oceanic and Atmospheric Administration (NOAA) weather forecast models and data assimilation systems developed by NCEP are currently being ported to them. CIMSS has been involved with the Software Integration Team and have aided in the transition of these data assimilation systems, forecast models and verification packages. We are currently involved in ensuring the Global Data Assimilation System / Global Forecast System

(GDAS/GFS) is setup and running properly on both NASA's Joint Center In a Big Box (JIBB) and the NESDIS Supercomputer for Satellite Simulations and data assimilation Studies (S4) computers.

Data Impact Studies

Observing System Experiments (OSEs) are used to quantify the contributions to the forecast made by conventional in-situ and remotely sensed satellite data. Two types of OSEs are typically used, those which use a limited subset of observing systems in which new ones are added and those which use the full complement of data and deny specific observing systems. We propose to use the latter. The primary goal of these experiments is to identify the contribution of these "well established" data sources in the GDAS/GFS. Understanding the impact of each observing system will aid in identifying underutilized observing systems and planning for new ones.

Summary of Accomplishments and Findings

S4 and JIBB Software Integration

The initial validation consisted of two months during two seasons. The cycled experiment comparisons were between Vapor (NOAA/NCEP), S4 (NESDIS) and JIBB (NASA). All three computers used the May 2011 operational version of the GDAS/GFS and were run at T382L64. A one month spin up was used before each season to allow the bias corrections to adjust. S4 and JIBB do not meet the initial requirements to use various restricted distribution observations (Aircraft Communications Addressing and Reporting System (ACARS), Aircraft Meteorological Data Relay (AMDAR) and Mesonet data). The prepbufr file generated from the NCEP operational prep step was used by all 3 computers, thereby allowing all 3 computers to use the same observations for the inter-comparison.

The design of this experiment was to mimic NCEP operations as much as possible. However, differences with NCEP operations were necessary. Due to computational time on VAPOR, the 7 day forecast was run only at 00Z. Also, a lower T382L64 resolution was required compared to the operational T574L64. All of the data files used were from the NCEP operations database. This database was developed in real time and has the real time data cutoff requirements incorporated. All data used by the operational system, except the restricted data, were used. The GDAS/GFS was started with the same initial files on each machine. The GDAS/GFS then used its previous forecast as the background field for the next cycle's analysis on each machine, allowing compiler and machine round off differences to influence each step of the GDAS cycles. At each 00Z cycle, the 7-day forecast was spawned and was consistent with the NCEP Central Operations (NCO) early data cutoff times, which is commonly referred to as the GFS portion of the GDAS/GFS. The case studies chosen consist of ~45-day periods during December 2010 – January 2011 and August – September 2011.

The main verification package used for this inter-comparison is the Verification Statistics Data Base (VSDB) developed by NCEP. The VSDB generates and plots time series, 1D and 2D fields, and long term average statistics for various parameters. The most common weather forecast model performance benchmarks are the mid-latitude (20-80° N/S) anomaly correlations. The day-to-day variation in the anomaly correlation time series plots between the three computers (not shown) is minimal. Obtaining almost the same value each day on the Vapor, JIBB and S4 computers suggests the day-to-day forecast skill is very similar. The 500 and 1000 hPa die-off curves for both Hemispheres in Figure 5.1.1 confirms that these forecast skill trends are consistent through all seven forecast days. Most of the forecast differences are not significant at the 95% level, suggesting the three computers are generating similar forecasts.
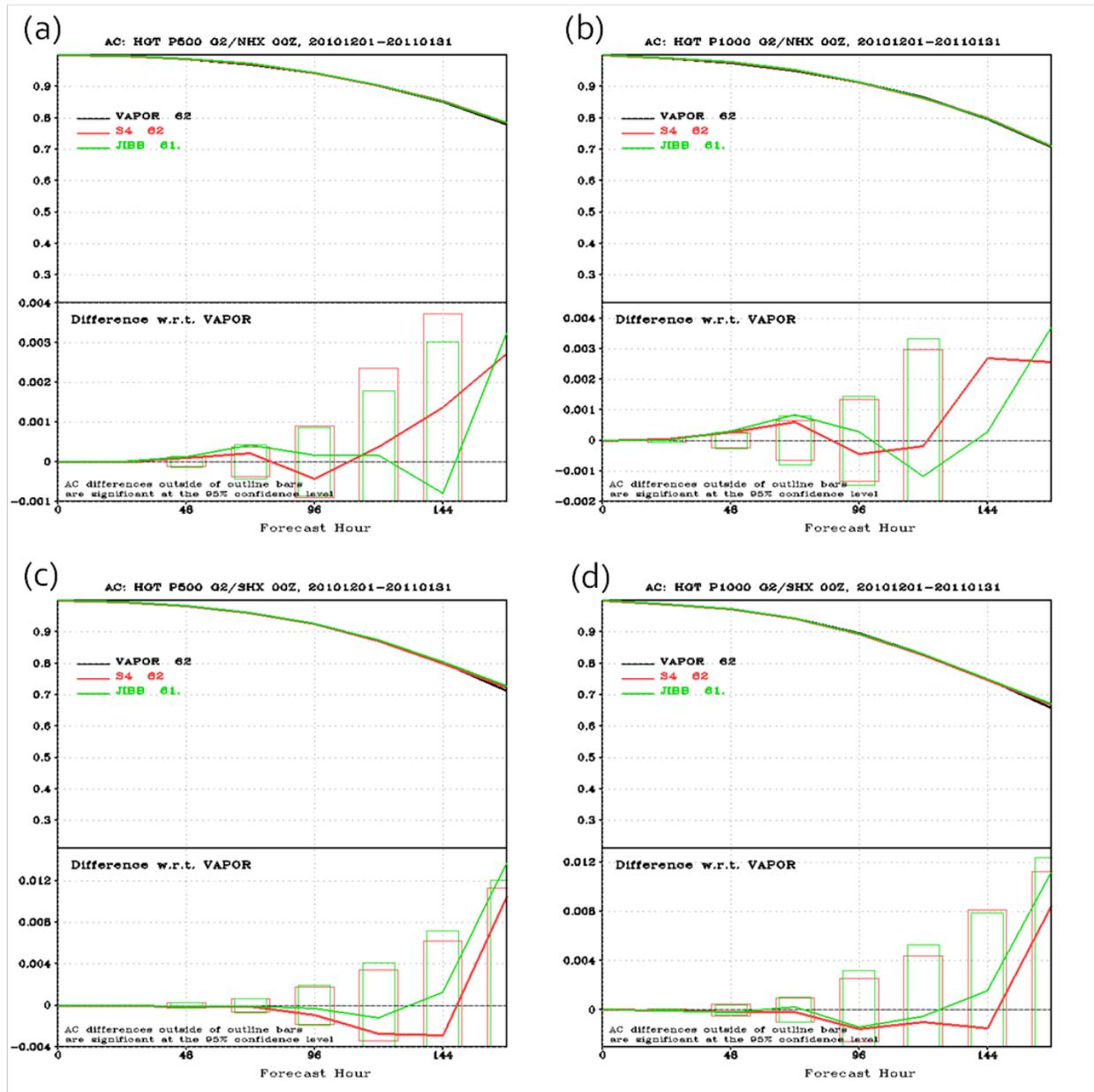
Figure 5.1.1. Geopotential height anomaly correlation die-off curves from 1 December 2010 to 31 January 2011. The scores are at 500 hPa (a and b) and 1000 hPa (c and d) for the Northern (a and c) and Southern (b and d) Hemispheres. Vapor, S4 and JIBB are plotted in black, red, and green respectively.

Data Impact Studies

The data denial experiments were conducted in the priority order directed by the JCSDA which is: 1) all satellite data, 2) all conventional data, 3) rawinsondes, 4) AMSU-A, 5) AMSU-B and MHS, 6) hyperspectral IR (AIRS and IASI), 7) all atmospheric motion vectors (Geostationary and MODIS), 8) Global Positioning System-Radio Occultation (GPSRO), and 9) all aircraft data. The tasks defined here are based on the assumption that we will complete all satellite denials as quickly as possible, then diagnose impacts similar to Zapotocny et al. (2007a and b) and Jung et

al. (2008). Verification techniques will consist of anomaly correlations and forecast impacts similar to those used by Zapotocny et al. (2007a and b) and Jung et al. (2008). All experiments were conducted at a resolution of T574L64 using the May 2011 version of the GDAS/GFS on JIBB. The experiments consist of 45 days during the summer and winter extreme seasons. The first 15 days are not used in the impact statistics to allow the forecast model to adjust to the missing data. We ran the 00Z GFS out to 7 days for our comparisons. The impact of each data type is assessed by comparing the analyses and forecasts based on an observing system using all operational data types (control). Initial anomaly correlation results from denying all of the satellite data and all of the conventional data are shown in Figure 5.1.2. Removing the satellite data has the greatest impact at both 500 and 1000 hPa in both Hemispheres. The conventional data have a greater impact in the Northern Hemisphere most likely due to the greater number of observations.

Publications and Conference Reports

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Le Marshall, J., R. Seecamp, Y. Xaio, P. Stienle, H. Sims, T. Skinner, J. Jung, and T. Le, 2011: The Generation and Assimilation of Continuous AMVs with 4-DVar. *Austr. Meteor, Ocean. Journ*. **61**, 117-123.

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Le Marshall, J. F., R. G. Seecamp, Y. Xiao, P. Gregory, J. Lee, J. Jung, P. Stienle and T. Skinner 2012: Recent Improvements in the Specification of the Atmospheric Wind and Mass Field from Space for Weather Forecasting and Climate Monitoring. 18th Conference on Satellite Meteorology and Oceanography / First Joint AMS-Asia Satellite Meteorology Conference, New Orleans, LA, 22-26 January 2012.

Le Marshall, J. F., R. Seecamp, Y. Xiao, P. Gregory, J. Jung, P. Stienle T. Skinner, J. Lee and T. Le 2012: Operational Generation of Continuous AMVs in the Australian Region and their Assimilation with 4DVAR. 11th International Winds Workshop, Auckland, New Zealand, 20-24 February 2012.

Nebuda, S., J. Jung, D. Santek, J. Daniels, and W. Bresky, 2012: Evaluation and Quality Control of Nested Tracking Approach for Atmospheric Motion Vectors (AMVs). 11th International Winds Workshop, Auckland, New Zealand. 20-24 February 2012.

Figure 5.1.2. Geopotential Height anomaly correlation die off curves from 15 August to 30 September 2010 at 500 hPa (a and b) and 1000 hPa (c and d) for the Northern (a and c) and Southern (b and d) Hemispheres. The control (CNTRL), no satellite data (NOSAT), and no conventional data (NOCONV) are shown in black, red, and green respectively.

Santek, D. A., B. T. Hoover, and J. A. Jung 2012: The Quality Control of Satellite-Derived Polar Winds Using the Expected Error. 18th Conference on satellite Meteorology and Oceanography / First Joint AMS-Asia Satellite Meteorology Conference, New Orleans, LA, 22-26 January 2012.

Santek, D., B. Hoover and J. Jung 2012: Assimilation and Forecast Impacts using the Expected Error in the Quality Control of MODIS Polar Winds. 11th International Winds Workshop, Auckland, New Zealand, 20-24 February 2012.

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Jung, J. A., T. H. Zapotocny, J. F. Le Marshall and R. E. Treadon, 2008: A Two Season Impact Study of NOAA Polar Orbiting Satellites in the NCEP Global Data Assimilation System. *Wea. Forecasting*., **23**, 854-877.

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5.2 Using Satellite Data to Improve Operational Air Quality Forecasting Capabilities

CIMSS Task Leader: Allen Lenzen
NOAA Collaborator: R. Bradley Pierce
NOAA Long Term Goals
- Weather-Ready Nation

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

CIMSS Research Themes
- Environmental Models and Data Assimilation

Proposed Work
This project utilizes the NCEP Gridpoint Statistical Interpolation (GSI) system (Wu et al., 2002) implemented into a developmental version of the Nonhydrostatic Mesoscale Model (NMMB) Community Multi-scale Air Quality (CMAQ) Modeling System (NMMB-CMAQ) to test capabilities to assimilate GOES sounder Total Column Ozone (TCO) data. NMMB-CMAQ is used for operational National Air Quality Forecast Guidance at the National Center for Environmental Prediction (NCEP) Environmental Modeling Center (EMC). Data denial studies are conducted to determine the impact of GOES TCO on regional ozone analyses via comparison with ozonesonde measurements (Thompson et al., 2008). This effort is in collaboration with

CMAQ developers at the NOAA Air Resources Laboratory (ARL) and the National Air Quality Forecasting Capability (NAQFC) team.

Summary of Accomplishments and Findings

Based on discussions with the NAQFC team we decided to focus on data denial studies during the NASA Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) field mission (July, 2011) so that the assimilation experiments could be compared with developmental NMMB-CMAQ runs conducted by ARL during DISCOVER-AQ. A major focus of these efforts has been to assess the impact of increased vertical resolution (56 level vs. 22 level) on resolving the sharp vertical gradients in ozone in the Upper Troposphere/Lower Stratosphere (UT/LS).

Accomplishments
- Conducted bias adjustment of GOES East and GOES West TCO using multi-year (2007-2008) statistics obtained from co-located GOES/OMI TCO measurements.
- Benchmarked NMMB-CMAQ and associated preprocessors on NESDIS S4 super computer at UW-Madison Space Science and Engineering Center (SSEC).
- Completed July 2011 Baseline (no GOES TCO assim) 56 level NMMB-CMAQ forecast cycling experiment.
- Completed July 2011 Static Lateral Boundary Condition (LBC), GSI GOES TCO assimilation analysis cycling experiment.
- Completed July 2011 GFS time dependent LBC, GSI GOES TCO assimilation 56 level NMMB-CMAQ analysis cycling experiment.
- Evaluated the impact of GOES TCO assimilation through comparisons with DISCOVER-AQ ozonesondes.

Findings

The DISCOVER-AQ NMMB-CMAQ/GSI experiments began on June 22nd, 2011 and extend to July 30th, 2011 with June 22-July 01st, 2011 being treated as a spin-up period. The experiments use CMAQ version 4.6 with adjusted surface deposition and include wildfire emissions from the U.S. Forest Service's Pacific Wildland Fire Sciences Laboratory BLUESKY framework (O'Neill et al., 2003). The 22 level operational NMMB-CMAQ and associated preprocessors (BLUESKY, SMOKE, PREMAQ) from the NCEP Central Operations (NCO) were ported onto S4 and used to benchmark NCO parallel runs (referred to as B1A Fire1 at NCO). Benchmarking experiments showed that the NMMB-CMAQ surface ozone forecast conducted on S4 is in very good agreement: 99.11% of the S4 48hr surface ozone prediction is within 0.001% of the NCO prediction after 8 days of forecast cycling.

Twice daily DISCOVER-AQ ozonesonde measurements from Beltsville and Edgewood, MD were used to evaluate the impact of GOES TCO assimilation and GFS LBC on the NMMB-CMAQ ozone predictions. Figure 5.2.1 shows results of these comparisons. Without GOES TCO assimilation and GFS LBC the NMMB-CMAQ ozone predictions significantly underestimate mean ozone mixing ratios above 300mb and ozone variability above 600mb, resulting in an overall correlation coefficient of 0.51. With GOES TCO assimilation and GFS LBC the UT/LS biases are significantly reduced and the variability is significantly increased, resulting in an overall correlation coefficient of 0.95.
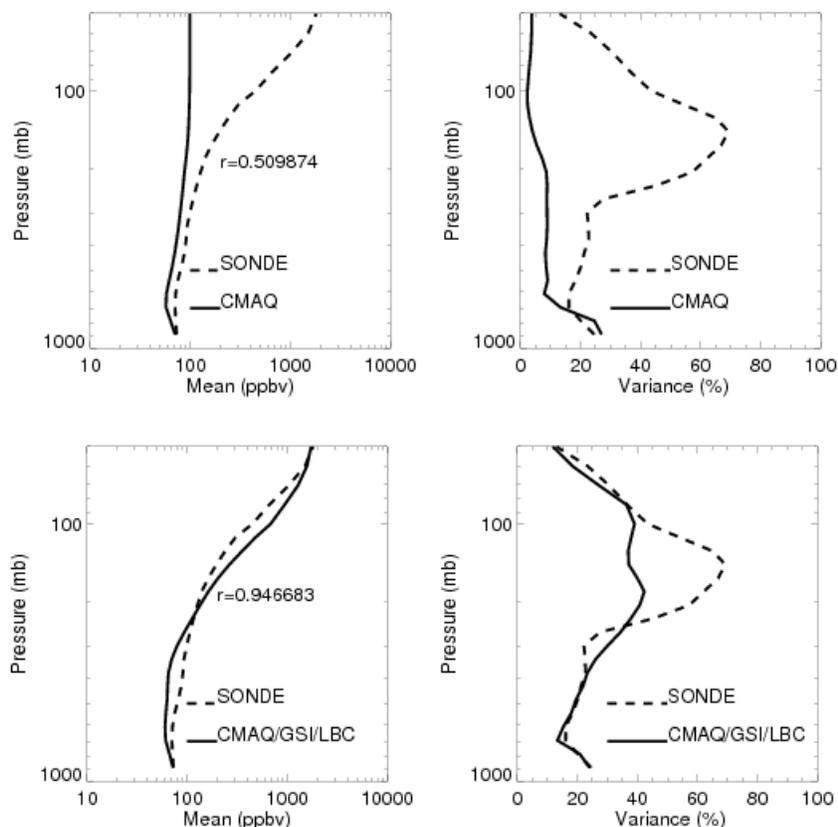
Figure 5.2.1. Comparison between Beltsville and Edgewood, MD ozonesondes and NMMB-CMAQ baseline (upper panels) and GOES TCO assimilation experiments using GFS LBC (lower panels) for 63 ozonesondes during July 2011. The left hand panels show vertical profiles of mean CMAQ (solid) and SONDE (dashed) ozone profiles (ppbv), the right hand panels show vertical profiles of ozone variance (%) for CMAQ (solid) and SONDE (dashed).

Publications and Conference Reports

Pierce et al., 2011, "Nested Global and Regional aerosol and ozone assimilation and forecasting experiments during the NOAA CalNex field mission" presented at the 3rd Annual International Workshop on Air Quality Forecasting Research, November 29 - December 1, 2011, Potomac, MD

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6. NCDC

6.1 Support for NOAA Cloud Climate Data Records

CIMSS Task Leader: Michael J. Foster
NOAA Collaborator: Andrew Heidinger
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

Proposed Work

The Pathfinder Atmospheres Extended (PATMOS-x) is a NOAA/NESDIS climate data set 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 mm reflectances. Figure 6.1.1 shows an example false-color image of the three channels used to generate the SDRs. The deadline for the initial operational CDRs was the end of the 3rd quarter, or 1 October 2010. After this initial delivery additional tasks were performed to augment the PATMOS-x Earth Radiative Budget (ERB) parameters and improve the accuracy of the record itself. It is these tasks on which this report is focused.

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:
- Incorporate internal file compression,
- Implement 0.63 μm 3x3 pixel mean parameter,
- Implement ERB parameters,
- Generate cloud field heterogeneity metric, and
- Incorporate updated calibration.

The implementation of additional parameters into the level2 and consequently level2b PATMOS-x/AVHRR product for this year has been completed. This implementation includes the incorporation of the Shortwave Algorithm for Shortwave Radiation Budget, which generates total and diffuse insolation parameters. The testing of these ERB parameters is in progress. Additional parameters include the mean and standard deviation of 0.63-micron reflectance calculated over a 3x3 grid of closest measurements for each pixel. These parameters provide the basis for a metric to estimate the heterogeneity of cloud fields and subsequent 3D radiative effects thereof.

The other milestone set for this period is the incorporation of internal compression. The implementation has been completed and has resulted in cutting the size of the average level2b file in half.

Finally the process of calibration of the AVHRR sensors is ongoing. The calibration of all AVHRR sensors included in the PATMOS-x record is up-to-date through 2011, and we are currently in the process of scheduling a new delivery of files to extend the NCDC CDR record, incorporating the new compression and calibration coefficients.

patmosx_n19_asc_2011_336.level2b
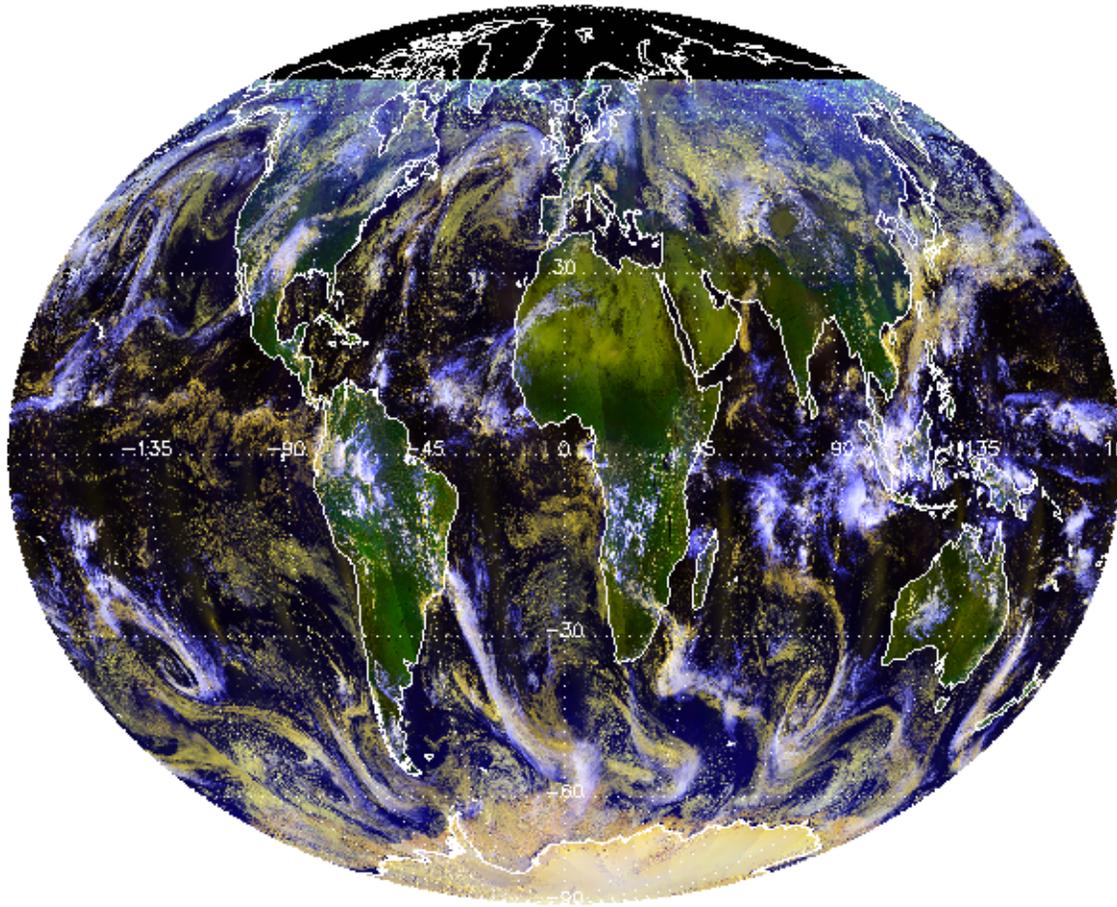
False Color Image

Red=0.63μm, Green = 0.86μm, Blue = 11μm (reversed)

Figure 6.1.1. An example image of PATMOS-x SDR values displayed as a false color image. The resolution of the PATMOS-x level-2b data is 0.1 degrees in latitude and longitude. The initial NCDC delivery provided twice-daily data separated by orbital node for all AVHRR data from 1978 to 2009.

Publications and Conference Reports

Heidinger, A. K., A. T. Evan, M. J. Foster and A. Walther (2012) A Naive Bayesian Cloud Detection Scheme Derived from CALIPSO and Applied to PATMOS-x, *J. App. Met. Clim.*, doi:10.1175/JAMC-D-11-02.1. *In press*. Online at: http://journals.ametsoc.org/doi/abs/10.1175/JAMC-D-11-02.1

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6.2 A Product Development Team for Snow and Ice Climate Data Records

CIMSS Task Leader: Yinghui Liu
CIMSS Support Scientist: Xuanji Wang
NOAA Collaborator: Jeffrey R. Key
NOAA Long Term Goals
- Climate Adaptation and Mitigation

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

CIMSS Research Themes
- Satellite Meteorology Research and Applications

Proposed Work

The availability, consistency and accuracy of cryosphere (snow and ice) products are critical for applications such as climate change detection, weather and climate modeling, shipping, and hazard mitigation. The development of cryosphere products can benefit greatly from contemporary advanced satellite remote sensing techniques along with the support provided by a coordinated group of data and applications experts. In collaboration with colleagues at NOAA/NESDIS, the University of Colorado, and NASA Goddard Space Flight Center, CIMSS is part of a Cryosphere Product Development Team that is providing such coordination for the generation, validation, and archival of fundamental and thematic snow and ice climate data records (FCDR and TCDR) that the scientific community can use to help answer the questions about a changing global climate. We are coordinating existing and new products, establishing "best practices," and updating heritage products. The CIMSS focus is on the cryosphere products that can be derived from optical (visible, near-IR, and thermal IR) imagers. FCDRs are being created where necessary and used in the production of TCDRs.

Summary of Accomplishments and Findings

This project started in July 2009. This report covers the period from 1 April 2011 to 31 March 2012, which is the third and final project year. During this period, the primary accomplishments include refining the retrieval algorithms for eXtended AVHRR Polar Pathfinder (APP-x), updating the calibrations and compositing processing to regenerate the APP data, regeneration of the APP from 1982 to the present, and scientific studies using the CDR data generated in this project.

APP-x is being further extended to include snow cover, ice extent and concentration, and ice thickness. Ice age and thickness are being produced using two approaches that are each unique yet mutually beneficial and independent of each other. For the APP-x product suite, ice thickness and age are estimated with an energy balance approach. One example of APP-x products is given in Figure 6.2.1. In addition to refining the retrieval algorithms, we revisited the calibration and compositing processes to regenerate the APP data from the AVHRR GAC data. Updates have been made to both processes for a more consistent data set. Extension of APP has been finished; the extension of APP-x to the present based on the extended APP is underway.

The CDR data have been used to generate climatologies of cloud, surface temperature, and ice thickness. The products have been used to study the feedbacks between processes in the Arctic climate system. A number of papers have been published on the use of the APP-x snow and ice CDR products for climate studies. The major findings are:
- APP-x data have been used to drive a thermodynamic model for estimating sea and lake ice thickness, creating a new climatology of Arctic sea ice thickness;
- The APP-x product was used in a study of controls on snow albedo feedback (SAF), which is important for assessing the validity of feedbacks in global climate models;
- Changes in sea ice concentration and cloud cover played major roles in the magnitude of recent Arctic surface temperature trends. Significant surface warming associated with sea ice loss accounts for most of the observed warming trend. In winter, cloud cover trends explain most of the surface temperature cooling in the central Arctic Ocean; and
- The decrease in sea ice extent leads to increased cloud cover, which generates a positive feedback for further sea ice retreat. These findings indicate a cloudier Arctic in the future with further sea ice decrease.
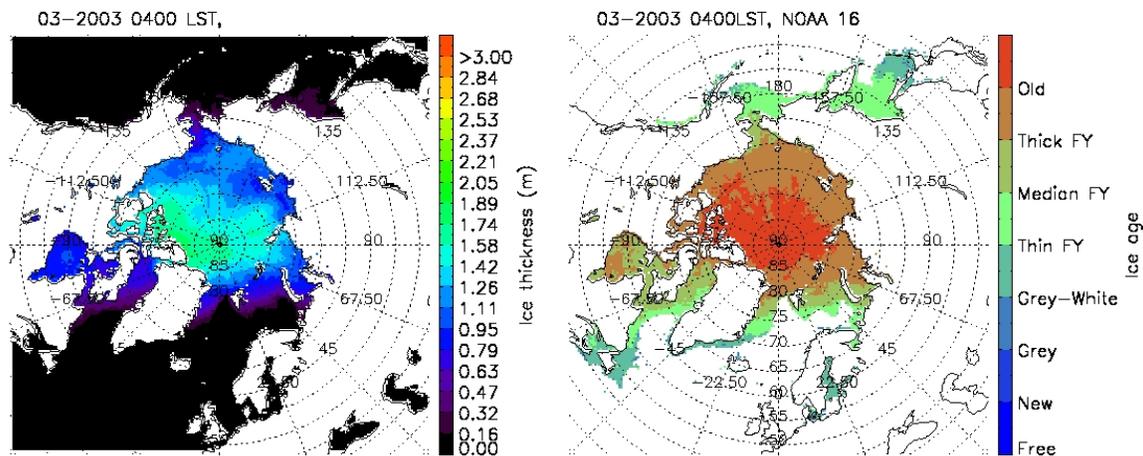
Figure 6.2.1. Ice thickness (left) and age (right) over the Arctic based on APP-x products. These two products will be part of the enhanced APP-x product set.

Publications and Conference Reports

Liu, Y., J. R. Key, Z. Liu, X. Wang, and S. J. Vavrus (2012), A cloudier Arctic expected with diminishing sea ice. *Geophys. Res. Lett.*, **39**, L05705, doi:10.1029/2012GL051251.

Xuanji Wang, Jeffrey R. Key, Yinghui Liu, Arctic Climate Change: Trends in Surface, Cloud, Radiation, and Sea Ice Properties from Satellite Data (Talk), 2012 IPY Conference: From Knowledge To Action, April 22-27, 2012, Montreal, Canada.

Xuanji Wang, Jeffrey R. Key, Yinghui Liu, Arctic Sea Ice Changes, Interactions, and Feedbacks on the Arctic Climate during the Satellite Era (Invited talk), 2011 AGU Fall Meeting, 5-9 December 2011, San Francisco California, USA.

Liu Yinghui, Key R. Jeffrey, Wang Xuanji, Understanding the interactions and feedbacks between Arctic sea ice, clouds, and the atmosphere from satellite observations, (keynote talk), 2011 EUMESAT meteorological satellite conference, September 5-9, 2011, Oslo, Norway.

Xuanji Wang, Jeffrey R. Key, Yinghui Liu, Arctic Sea Ice Properties and Changes from Satellite Data over the Period 1982-2010 (Talk), 2011 EUMETSAT Meteorological Satellite Conference, 5-9 September 2011, Oslo, Norway.

Wang, X., J. R. Key, and Y. Liu, 2010: A thermodynamic model for estimating sea and lake ice thickness with optical satellite data. *J. Geophys. Res.*, **115**, C12035, 14 PP., 2010, doi:10.1029/2009JC005857.

Liu, Y., J. R. Key, and X. Wang, 2009: The influence of changes in sea ice concentration and cloud cover on recent Arctic surface temperature trends. *Geophys. Res. Lett.*, **36**, L20710, doi:10.1029/2009GL040708.

Fernandes, R., H. Zhao, X. Wang, J. R. Key, X. Qu, and A. Hall, 2009: Controls on Northern Hemisphere snow albedo feedback quantified using satellite Earth observations. *Geophys. Res. Lett.*, **36**, L21702, doi:10.1029/2009GL040057.

7. CIMSS Research Activities in the VISIT Program in 2012

CIMSS Task Leaders: Scott Bachmeier, Scott Lindstrom, Steve Ackerman
CIMSS Support Scientists: Tom Whittaker, Jordan Gerth
NOAA Collaborators: Tim Schmit, Robert Aune, Cooperative Institute for Research in the Atmosphere (CIRA), Forecast Decision Training Branch (FDTB)
NOAA Strategic Goals
- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

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

Proposed Work
The focus for the proposed work this year was on continuing to create VISITview distance learning modules for a broad satellite meteorology audience, providing valuable satellite imagery interpretation materials that can be used in education and training, and also on maintenance and updates to existing satellite image lesson material.

There remains a lack of adequate satellite-based education and training on a number of important topics that have direct relevance to typical forecast problems. Some of these topics include: identification of deformation zones, cloud patterns related to upper level wind fields, jet streaks, moist conveyor belts, fog detection, turbulence signatures, and air quality.

The presence of fully-functioning Advanced Weather Interactive Processing System (AWIPS) workstations at CIMSS allows for faster development of new educational materials that address these types of satellite interpretation topics (and also facilitates more frequent updates to pre-existing modules) as new case study examples are observed on a daily basis. This real-time AWIPS capability gives CIMSS the unique ability to present these satellite interpretation topics in a context and format that the National Weather Service (NWS) forecaster is familiar with.

We also proposed to continue exploring the creation of lessons in the self-contained Weather Event Simulator (WES) format, which is an AWIPS training format that is widely used by NWS forecast offices. A pair of WES cases using simulated Advanced Baseline Imager (ABI) data have been developed at CIMSS as part of the GOES-R Proving Ground effort.

We planned to continue to leverage the real-time AWIPS capability at CIMSS to collect a variety of satellite and other remote sensing data during interesting or high societal impact weather events that occurred within a variety of regions and seasons. It was also proposed that CIMSS continue to act as a "beta test site" for the next-generation AWIPS II. We also proposed to continue to utilize our AWIPS capability to serve as a testbed for new satellite products in an operational environment (as was successfully accomplished with the "MODIS Products in AWIPS" and the "POES and AVHRR Satellite Data in AWIPS" projects). Imagery from the recently launched Suomi National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) instrument is also now being created in an AWIPS format, with plans to distribute these high spatial resolution satellite images to NWS forecast offices. A new VISIT lesson "Suomi NPP VIIRS Imagery in AWIPS" is also in development, to ensure forecaster readiness in concurrence with the release of the VIIRS data.

Summary of Accomplishments and Findings

Twenty-three "live" instructor-led VISITview teletraining sessions were given to a total of 82 NWS forecasters during this period, on the following ten topics: (1) Interpreting Satellite Signatures, (2) TROWAL Identification, (3) CRAS Forecast Imagery in AWIPS, (4) POES and AVHRR Satellite Data in AWIPS, (5) Morphed Total Precipitable Water Detection (MIMIC), (6) The UW-Madison NearCasting Product, (7) The UW-Madison Convective Initiation Product, (8) Mesoscale Convective Vortices, (9) Objective Satellite-based Overshooting Top and Enhanced-V Anvil Thermal Couplet Signature Detection, and (10) Basic Satellite Principles. These lessons – and others – are also available for NWS staff to access in the US Department of Commerce Learning Center.

CIMSS also made significant contributions to the development of a new lesson GOES-15 Becomes GOES-West (this important satellite transition occurred in early December 2011).

Two VISIT lessons that received significant revisions and updates were: (1) Interpreting Satellite Signatures, and (2) Mesoscale Convective Vortices. In addition, work continued on the development of another upcoming VISIT lesson: Suomi NPP VIIRS Imagery in AWIPS.

During the 01 April 2011 to 31 March 2012 period, 159 new posts were added to the CIMSS Satellite blog: http://cimss.ssec.wisc.edu/goes/blog (the top hit in a Google search for the term 'Satellite blog'). The CIMSS Satellite Blog continues to serve as an expanding, searchable library of satellite products and meteorological case studies that can be used in future VISIT teletraining modules. The CIMSS Satellite Blog also acts as an important source of "Just-In-Time" satellite training material for weather events that have recently occurred (or for important changes in operational satellites or satellite products).

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CIMSS also participated in local GOES-R Proving Ground Training activities with the National Weather Service forecast office (WFO) in Milwaukee/Sullivan, WI (MKX) – CIMSS staff traveled to MKX to interact with forecasters one-on-one about a variety of new satellite-based products (UW Convective Initiation, Overshooting Top/Thermal Couplet Objective Detection, NearCasting, and Fog/Low Cloud Identification). The results of many of these CIMSS/MKX collaborative training visits are discussed on the GOES-R Proving Ground at NOAA's Hazardous Weather Testbed site: http://goesrhwt.blogspot.com/.

Members of the CIMSS VISIT team also participated in GOES-R Proving Ground teleconference calls and VISIT/SHyMet teleconference calls. These activities are important because they help in the identification and prioritization of new satellite training topics, especially related to GOES-R Proxy data that are helping prepare NWS forecasters for the GOES-R era.
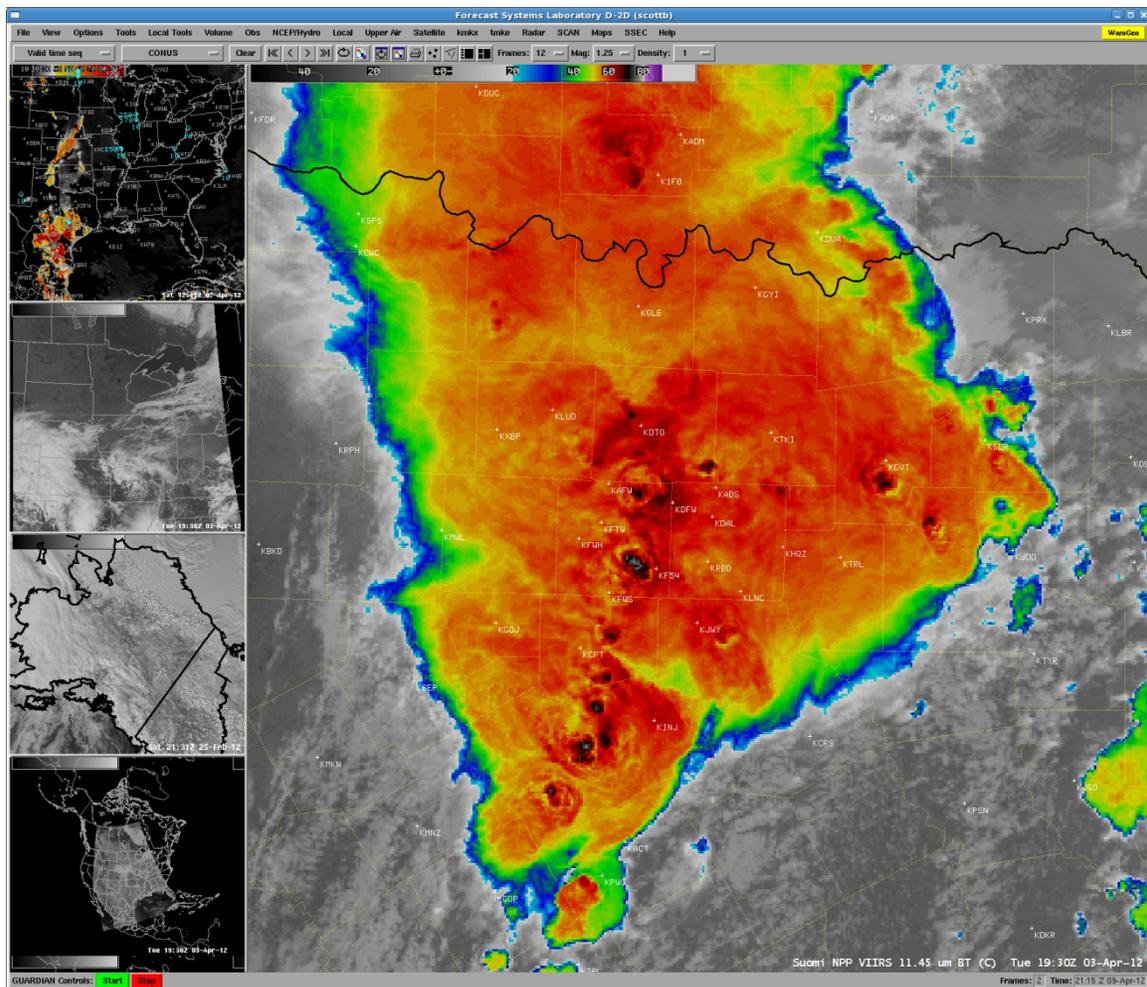
Figure 7.1. AWIPS screen capture of a Suomi NPP VIIRS infrared image of the thunderstorm complex that produced an outbreak of tornadoes and large hail in the Dallas-Fort Worth, Texas region on 03 April 2012. Examples of similar VIIRS imagery will be used in the development of a new VISIT lesson "Suomi NPP VIIRS Imagery in AWIPS."

8. CIMSS Research Activities in the SHyMet Program in 2012

CIMSS Task Leaders: Scott Bachmeier, Scott Lindstrom, Steve Ackerman
CIMSS Support Scientists: Tom Whittaker, Jordan Gerth
NOAA Collaborators: Tim Schmit, Robert Aune, Cooperative Institute for Research
in the Atmosphere (CIRA), Forecast Decision Training Branch (FDTB)
NOAA Strategic Goals
- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

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

Proposed Work

The focus for the proposed work this year was on continuing to create content for the Satellite Hydrology and Meteorology (SHyMet) course, which is designed for a broad satellite meteorology audience and provides valuable satellite imagery interpretation materials that can be used in education and training. The SHyMet course pulls together existing, new, and updated satellite training materials into a structured course with multiple tracks.

The presence of fully-functioning Advanced Weather Interactive Processing System (AWIPS) workstations at CIMSS allows for faster development of new educational materials that address important satellite interpretation topics (and also facilitates more frequent updates to pre-existing SHyMet modules or course tracks) as new case study examples are observed on a daily basis. This real-time AWIPS capability gives CIMSS the unique ability to present these satellite interpretation topics in a context and format that the National Weather Service (NWS) forecaster is familiar with.

We planned to continue to leverage the real-time AWIPS capability at CIMSS to collect a diverse set of satellite and other remote sensing data during interesting or high societal impact weather events that occurred within a variety of regions and seasons. It was also proposed that CIMSS continue to act as a "beta test site" for the next-generation AWIPS II. In addition, we proposed to continue to utilize our AWIPS capability to serve as a testbed for new satellite products in an operational environment (as was successfully accomplished with the "MODIS Products in AWIPS" and the "POES and AVHRR Satellite Data in AWIPS" projects). The latest source of new satellite data being evaluated is from the recently launched Suomi National Polar-orbiting Partnership (NPP) satellite.

Summary of Accomplishments and Findings

CIMSS contributed individual lessons that comprised the SHyMet Intern track, the SHyMet for Forecasters track, and the SHyMet: Severe Thunderstorm Forecasting track that comprise the overall SHyMet course. During the 01 April 2011 to 31 March 2012 period, 56 forecasters signed up for these three particular SHyMet course tracks, with 39 forecasters successfully completing the training material.

Imagery from the Suomi National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) instrument is now being created in an AWIPS format, with plans to distribute these high spatial resolution satellite images to NWS forecast offices. To address the training needs of this new source of satellite data, we are currently developing a new SHyMet lesson "Suomi NPP VIIRS Imagery in AWIPS," to ensure forecaster readiness in concurrence

with the release of the VIIRS data. This new lesson could then be added as an optional course for either of the SHyMet tracks.

Members of the CIMSS SHyMet team continued to participate in monthly VISIT/SHyMet teleconference calls, which were important to help in the identification and prioritization of new satellite training topics (especially related to GOES-R Proxy data that are being used to help prepare NWS forecasters for the GOES-R era).

The CIMSS Satellite Blog, http://cimss.ssec.wisc.edu/goes/blog, continues to serve as an expanding, searchable library of satellite products and meteorological case studies that can be used in future SHyMet lesson modules. There were 159 new posts to the CIMSS Satellite blog this year and it is the top hit when doing a Google search for the term "satellite blog".
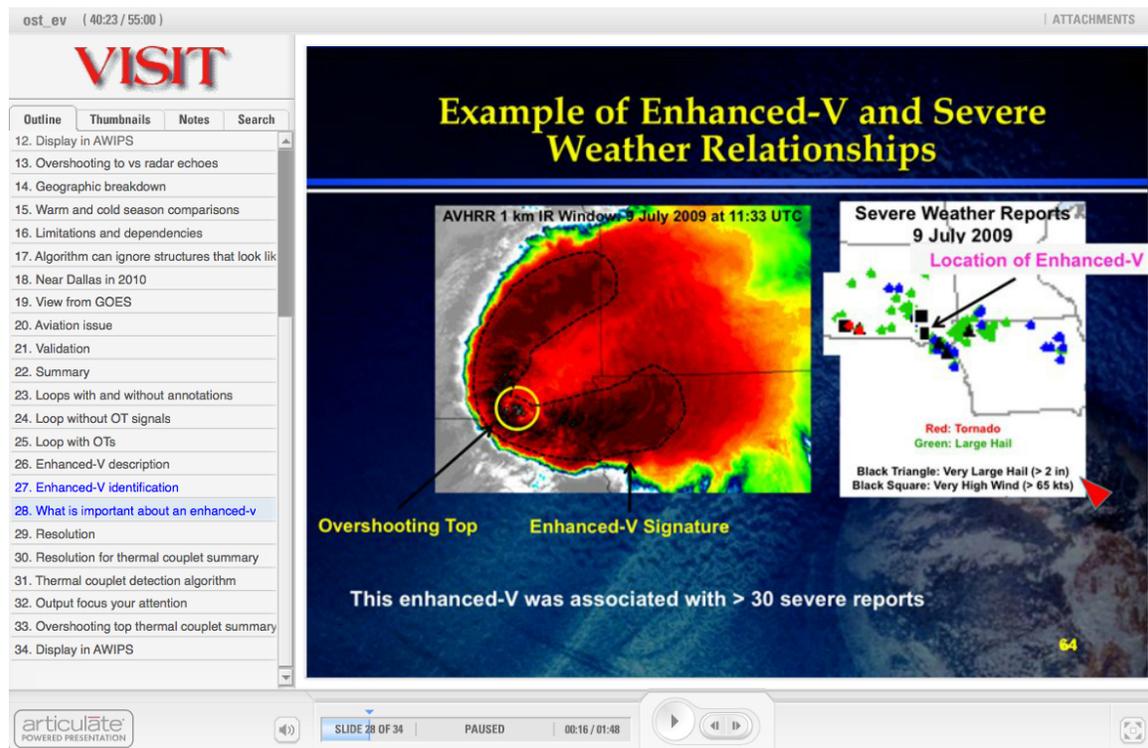
Figure 8.1. Screen capture from the Objective Satellite-Based Overshooting Top and Enhanced-V Anvil Thermal Couplet Signature Detection lesson, which is a component of the SHyMet: Severe Thunderstorm Forecasting track.

9. GOES-14 and 15 Checkout & Data Analysis

CIMSS Task Leader: Tony Schreiner
CIMSS Support Scientists: Scott Bachmeier, Mat Gunshor, Jim Nelson, Chris Velden
NOAA Collaborators: Tim Schmit, Gary S. Wade, Don Hillger
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
- Weather Nowcasting and Forecasting
- Clouds, Aerosols and Radiation
- Education, Training and Outreach

Proposed Work

A number of tasks were undertaken in order to complete the GOES-14 & -15 checkout. They include:

- Comparison of observed clear-sky brightness temperatures with current operational GOES satellites and NOAA polar-orbiting platforms. The purpose is to determine if pre-flight spectral response information and weighting functions are in need of adjustment;
- Acquisition and archive of the GOES-14 & -15 GVAR data during the NOAA Science tests;
- Management of Operational Software Production issues. In preparation for the operational insertion of GOES-14 and -15, software modifications for various operational products, such as, but not exclusive to, Clear Sky Brightness Temperature, Imager and Sounder Cloud Products, and Temperature/Moisture Retrieval algorithms will be forwarded to the operational production algorithms; and
- Generation of material regarding the radiometric and product accuracy for inclusion in the GOES-14 & -15 NOAA science technical reports.

Summary of Accomplishments and Findings

Between 1 October 2009 and 30 September 2010, one GOES satellite was launched (GOES-P/15) and two Science Tests were conducted. What follows is the work conducted over that period.

Following a 27 June 2009 successful launch and placement in geostationary orbit of GOES-O/14, a Science Test of Sounder and Imager derived products was conducted from 30 November 2009 to 4 January 2010. A detailed comparison of GOES-14 Sounder-derived Total Precipitable Water to results from GPS/MET calculations was determined from observations on 14 December 2009. These comparisons show an average difference of 2.53 mm with GOES-14 results slightly moist-biased over the GPS/MET determinations. Additional details of the Science Test can be found in the NOAA Technical report (Figure 9.1) at the following Web location: http://rammb.cira.colostate.edu/projects/goes-o/NOAA_Tech_Report_NESDIS_131_GOES-14_Science_Test.pdf.

NOAA Technical Report NESDIS 131

The GOES-14 Science Test:
Imager and Sounder Radiance and Product Validations

Washington, D.C.
August 2010

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service
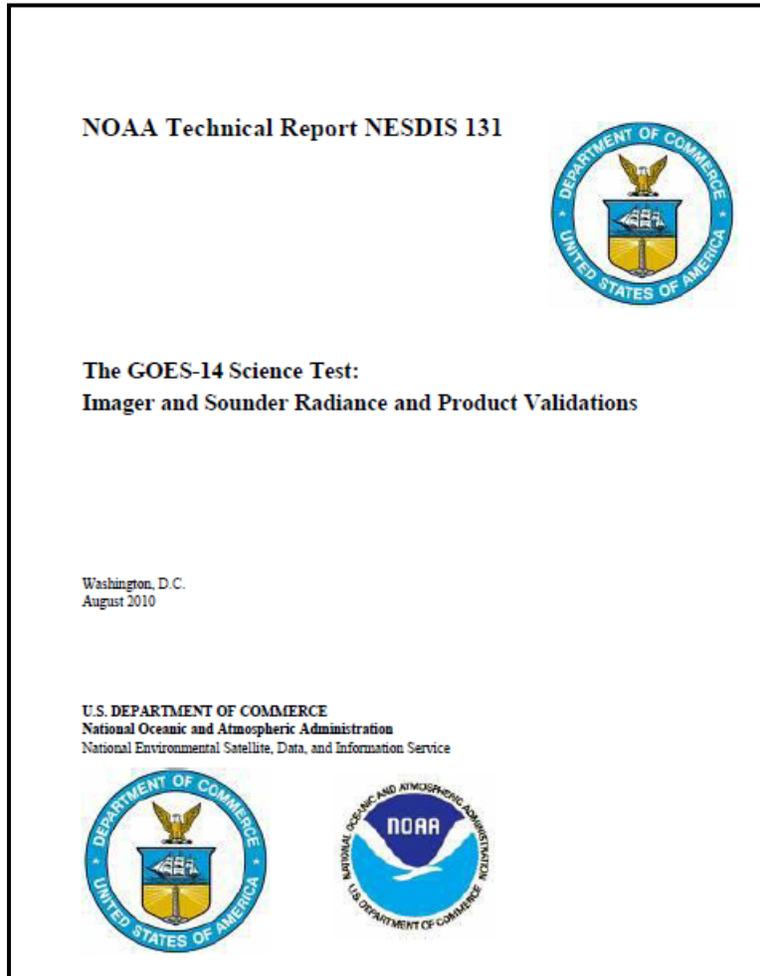
Figure 9.1. NOAA Technical Report compiling the results of the GOES-14 Science Test. This report can be found at http://rammb.cira.colostate.edu/projects/goes-o/

CIMSS supplied many inputs to this report which are briefly highlighted as follows. During the GOES-14 Science Test, CIMSS and ASPB scientists provided daily input on the scanning schedule selection. After launch, but prior to the Science Test, both the Imager and Sounder produced "first images." CIMSS, partnered with SSEC's Datacenter, was uniquely outfitted to acquire these first images and posted them to the Web as they were received. Special Sounder sectors were taken which included large sections of space so that instrument noise can be measured (standard deviation in space over multiple images during the day); the Imager regularly included space views in various scan types. CIMSS also provided analysis of radiometric accuracy for the Imager IR bands using intercalibration with a polar orbiting high spectral resolution instrument, the Infrared Atmospheric Sounding Interferometer (IASI) which is on EUMETSAT's METOP-A. Since it has higher-capacity batteries, GOES-14 can now be operated during eclipse and therefore potentially can have fewer outages. However, there are still issues with stray light at certain times of the year which CIMSS has investigated as well. CIMSS validated several products during the Science Test, such as Total Precipitable Water (TPW), Lifted Index (LI), Cloud Parameters, Atmospheric Motion Vectors (AMVs), Clear Sky Brightness Temperature (CSBT), Fire Detection, Volcanic Ash Detection, Total Column Ozone, and GOES Surface and Insolation Product (GSIP). The difference in the Imager visible spectral

response, compared to previous GOES Imagers, was observed by noting how surface vegetation is more evident in GOES-14 data.

GOES-P/15 was successfully launched on 4 March 2010 and placed into geosynchronous orbit at the Equator and 89.5W. Data collection of both Sounder and Imager radiance data for the GOES-15 Science Test began 11 August 2010 and continued through 22 September 2010 (for the science test, and later for routine data collection). As with GOES-14, GOES-15 does not experience extended data void windows during the semi-annual Keep Out Zones and Eclipse schedules during the February-April and August-October time periods. Although derived products during these two special windows must still be monitored for contamination due to "stray solar light," GOES-15 continues to provide 4 km spatial resolution CO_2 (13.3µm) band 6 Imager data compared to an 8 km version for GOES-13 and GOES-12 (Figure 9.2). More information and the rapid scan imagery can be found at http://cimss.ssec.wisc.edu/news/2010-09-24_goes15-1min.html or http://cimss.ssec.wisc.edu/goes/blog/archives/6849. Some of the early findings follow.
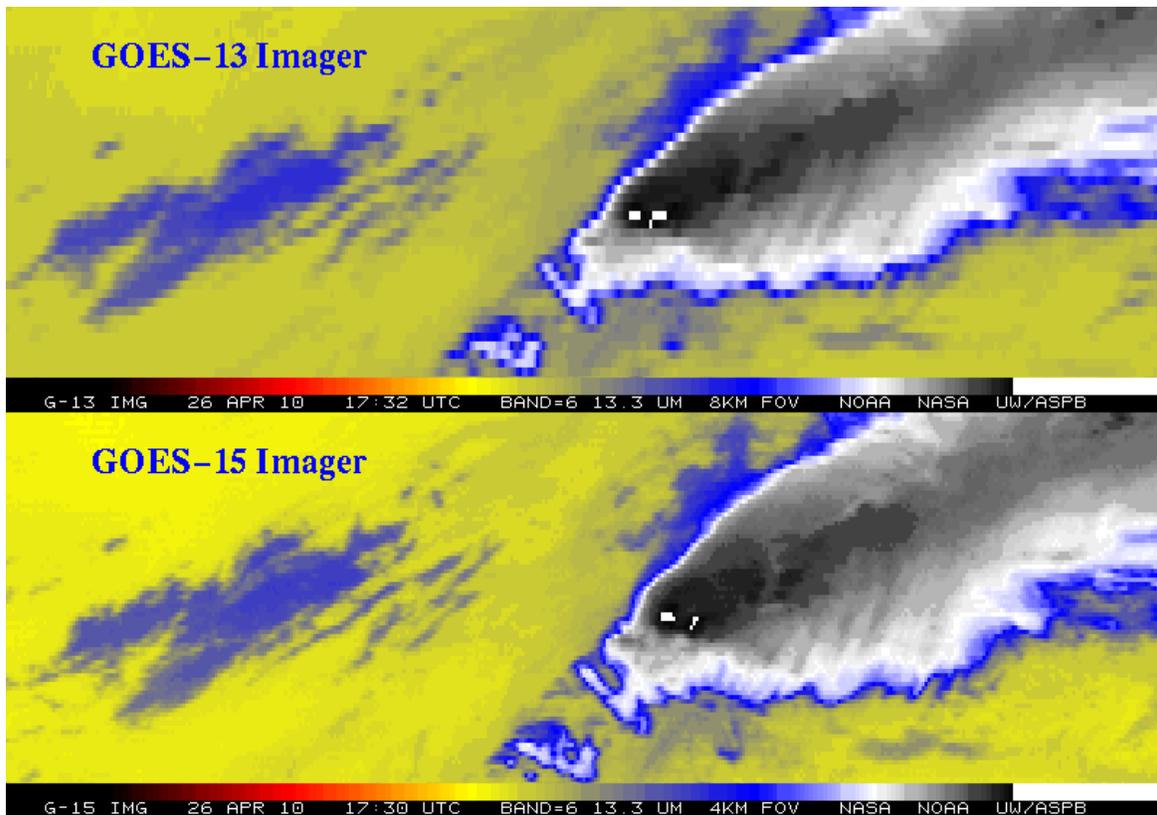
Figure 9.2. A comparison of GOES-13(8 km Instantaneous Geometric Field of View) and GOES-15 (4 km) Imager Band 6 (13.3µm) on 26 April 2010. Note the 'cleaner' image from GOES-15.

Quantitative comparison of the GOES-13 and GOES-15 Sounder Cloud Top Pressure (CTP) products show that overall the average difference between the two is about 3hPa for a number of arbitrarily chosen time periods during the Science Test. Closer comparisons showed that:
- For all observations (clear and cloudy): the average difference (bias) is 2.69 hPa (GOES-15 cloud heights are slightly higher in altitude than GOES-13 cloud heights);
- For all cloudy observations: the average difference is 5.49 hPa (same bias as above); and

- For CO_2 Absorption Height determinations only: the average difference is 5.47 hPa (same bias as above).

A similar, although more extensive, comparison of Total Precipitable Water (TPW) with rawinsonde (RAOB) data was also completed with the "Ma" version of the retrieval algorithm (Ma et al., 1999). The total number of collocations numbered more than 20,000 from 11 August 2010 to 22 September 2010. The GOES-15 and -13 retrieval statistics show that the GOES-15 retrievals had a slightly higher absolute bias (-1.16 mm) and standard deviation (6.09 mm) when compared with collocated RAOB data than the GOES-13 retrievals (-1.03 mm and 5.52 mm, respectively). Both the GOES-15 and -13 retrieval TPW exhibited a dry bias when compared with collocated RAOB data, but both sets of retrievals adjusted away from their first guess to more closely match the collocated RAOB data.

Intercalibration of the GOES-15 Imager with IASI (Infrared-Atmospheric Sounding Interferometer) was performed to test the relative radiometric accuracy. The CIMSS methodology was employed (Gunshor et al., 2009) at CIMSS, while STAR scientists did a similar study using the Global Space-based Inter-Calibration System (GSICS) methodology. In general, the two methods yield similar results and that was true for the data during the GOES-15 science test as well. The shortwave and longwave IR-window bands seem very well calibrated (Table 9.1). The results from the water vapor band are reminiscent of problems found during the GOES-13 science test for a different band. In that case, the calibration team at STAR, in conjunction with a panel that included CIMSS calibration experts and engineers from the instrument vendor, concluded that a shift to the channel spectral response was warranted. It is possible that this same process will be undertaken for the water vapor band on GOES-15's Imager. The CO_2 absorption band is not ideally calibrated in comparisons to IASI, but it is probably not bad enough that action will be taken with respect to the Spectral Response Function on this band.

Table 9.1. GOES-15 Imager minus IASI intercalibration results during the GOES-15 checkout. Only the night-time comparisons with the shortwave window band are shown due to that channel's sensitivity to reflected solar energy during the day which is difficult to compensate during the intercalibration process. "N" is the number of comparisons.

GOES-15 Band:	Shortwave Window (3.9μm)	Water Vapor (6.5μm)	IR-Window (10.7μm)	CO_2 Absorption (13.3μm)
N	25	58	56	57
ΔTbb (K)	0.0	1.98	-0.03	0.53
STD (K)	0.3	0.38	0.66	0.59

Analysis of the data compiled during the GOES-15 science test is ongoing and a detailed science report for GOES-15, similar in depth and breadth to the GOES-14 Science Test Report, will be completed in 2011.

Publications and Conference Reports
Hillger, D.W. and T.J. Schmit, 2010: The GOES-14 Science Test: Imager and Sounder Radiance and Product Validations. NOAA Technical Report, NESDIS 131, (August), 105pp.

References
Gunshor, Mathew M.; Schmit, Timothy J.; Menzel, W. Paul, and Tobin, David C. Intercalibration of broadband geostationary imagers using AIRS. *Journal of Atmospheric and Oceanic Technology, 26*, no.4, 2009, pp746-758.

Ma, Xia L., T. J. Schmit, and W. L. Smith, 1999: A nonlinear physical retrieval algorithm - Its application to the GOES-8/9 sounder. *J. Appl. Meteor.*, **38**, 501-513.

10. CIMSS Support for STAR Calibration/Validation Activities for 2011

CIMSS Task Leader: Mat Gunshor
CIMSS Support Scientist: Scott Lindstrom
NOAA Collaborator: Tim Schmit
NOAA Long Term Goals
- Climate Adaptation and Mitigation
- Weather-Ready Nation

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

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

Proposed Work
NOAA participates in research promoting and advancing the knowledge of intercalibration techniques through the Global Space-Based Inter-Calibration System (GSICS). The primary goal of GSICS is to improve the use of space-based global observations for weather, climate and environmental applications through operational inter-calibration of the space component of the WMO Global Observing System (GOS) and Global Earth Observing System of Systems (GEOSS). GSICS methodology was built in collaboration with input from CIMSS researchers and CIMSS has supported the GSICS effort throughout the development phase. This proposal supports NOAA's efforts with GSICS and also the NOAA Mission Goals of Climate and Weather and Water.

This proposal outlines a plan to perform retrospective analysis using the GSICS method. This effort builds on work done in the previous year to do similar tasks. The operational GSICS team performs intercalibration daily for their host of geostationary imagers and includes the United States, Japan, China, and Europe. CIMSS scientists will conduct a retrospective analysis of all of the instruments being done operationally, as well as several instruments no longer in operations. For FY11 it was proposed to use AIRS to intercalibrate the Meteosat, FY-2, and MTSAT Imagers using the NESDIS GSICS algorithm retrospectively for the entire period of data record overlap between AIRS and these geostationary imagers. The GSICS code will be provided to CIMSS by NOAA/NESDIS/STAR. CIMSS will implement the code locally and leverage other projects to obtain the AIRS data. The Space Science and Engineering Center (SSEC) datacenter has the geostationary data archive available for CIMSS scientists at a small cost to individual projects. The previous year's task was to perform this retrospective processing for the GOES imagers.

Summary of Accomplishments and Findings
The generation of GSICS output has gone much slower than was originally anticipated. There have been problems implementing the code at CIMSS. Another problem was accessing the local SSEC archive of AIRS data. The local AIRS data archive has been available only intermittently.

Recently this problem was overcome and processing has continued. The AIRS data are now on an ultra-fast internal network and so processing is fairly fast. Unfortunately, as a result of the earlier access problems, we are still processing the GOES intercalibration results and have not moved on to these year two tasks proposed yet. However, we will soon have completed the GOES reprocessing and should be able to start on the international suite of imagers soon.

Working in conjunction with scientists at STAR on prioritizing the order in which the data are produced, most of the GSICS data have been processed and delivered for GOES/AIRS overlap dates. For GOES-08, 2002: 59 days; 2003: 89 days. For GOES-09, 2004: 65 days. For GOES-10, 2003: 342 days; 2004: 365 days; 2005: 365 days; 2006: 171 days; 2007: 180 days. For GOES-11, 2006: 184 days; 2007: 302 days; 2008: 147 days; 2009: 342 days; 2010: 345 days; 2011: 129 days. For GOES-12, 2004: 366 days; 2005: 334 days; 2006: 365 days; 2007: 300 days; 2009: 360 days; 2010: 328 days. For years in which not every day was processed, the plan is to go back and redo those days (for reasons that are still unclear, days are missed).

During 2011 CIMSS hosted a visiting scientist from China's National Meteorological Satellite Center (NMSC), Dr. Yong Zhang. Dr. Zhang is involved in the GSICS efforts for China and is a subject matter expert on FY-2 (China's geostationary imager series) calibration. In collaboration with Dr. Zhang, a paper was submitted on FY-2C/D/E infrared intercalibration using AIRS and GSICS methods. By having the GSICS code at CIMSS installed and access to at least some of the AIRS data during his visit, CIMSS was able to host Dr Zhang and assist with his research efforts to improve calibration on environmental satellites internationally.

Publications and Conference Reports
Under Review to *IEEE Transactions on Geoscience and Remote Sensing (TGRS)*: Inter-calibration of FY-2C/D/E Infrared Channels Using AIRS by Yong Zhang and Mathew Gunshor.
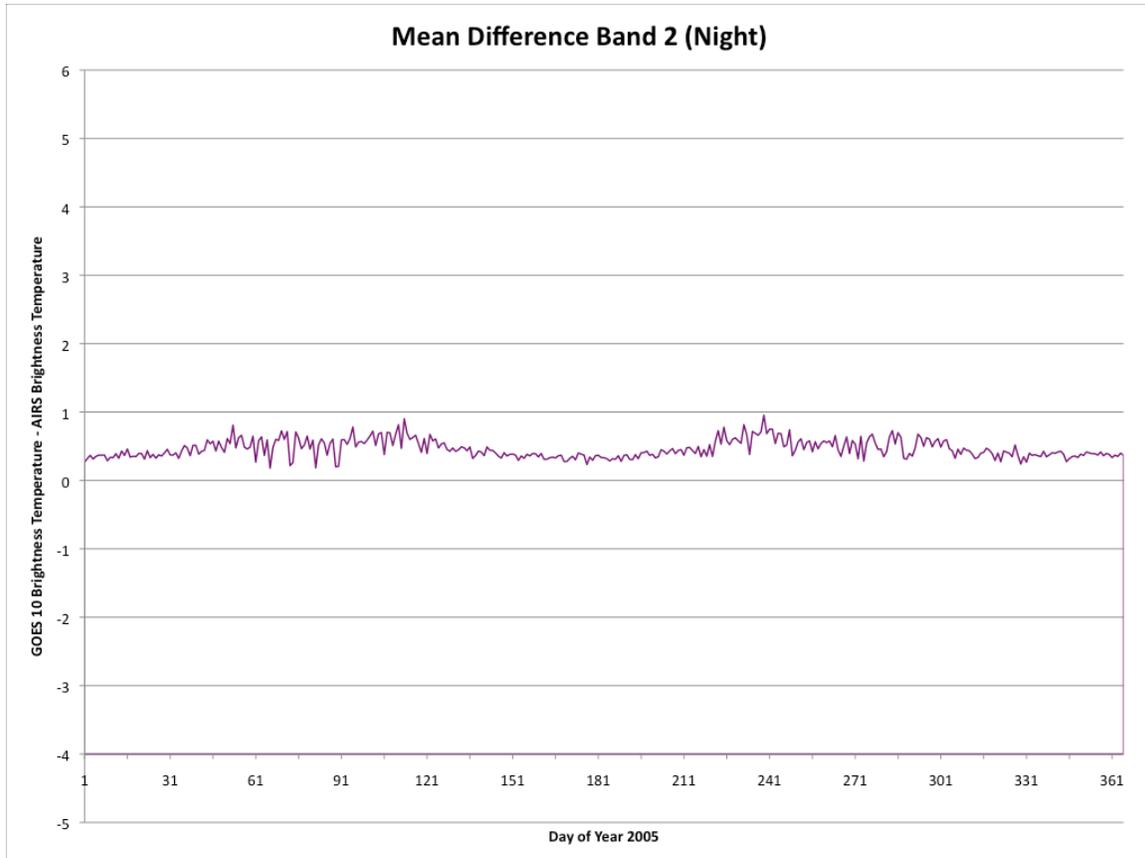
Figure 10.1. GSICS Intercalibration results for band 2 (3.9 micrometer) of the GOES-10 Imager compared to AIRS; GOES is slightly warmer than AIRS by approximately 0.5 K. Only night-time results are shown since reflected solar radiation during the day creates difficulties for comparisons in this shortwave band. The results shown are just for the year 2005.

11. Estimation of Cloud Microphysics from MODIS Infrared Observations

CIMSS Task Leader: Michael J. Foster
NOAA Collaborator: Andrew Heidinger
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

Proposed Work
The operational MODIS cloud products are produced at unprecedented spatial scales (1 or 5 km). The MODIS cloud products (designated by Earth Science data set names MOD35 and MOD06 for MODIS Terra, or MYD35 and MYD06 for MODIS Aqua) employ measurements in about 20 MODIS spectral band. While the cloud-top properties (pressure, temperature, height, thermodynamic phase) are derived exclusively from IR bands, and hence have no dependence on

the presence of sunlight, optical thickness and effective particle size are derived only for daytime conditions.

The focus of this proposal is on these missing nighttime properties. The effective particle size and optical thickness are fundamental properties and are important for studies of the radiation budget as well as the hydrological cycle.

The most commonly derived cloud microphysical parameter is a measure of the cloud particle size. Typically, estimation of particle size requires assumptions about the particle size and shape distributions. In this study, we propose to derive cloud microphysical information that requires a minimum of a priori assumptions. However, estimates of particle will also be produced based on state-of-the-art assumptions on particle size and shape as is done in the current MOD06 processing of daytime MODIS observations.

Our objectives in this project are to:
- Develop a retrieval approach using the MODIS infrared observations to estimate cloud microphysical and optical properties (particle size as well as optical thickness for non-opaque clouds) consistently during day and night operation;
- Demonstrate the consistency of the new IR-based cloud microphysical and optical properties through comparison with those available from the standard MODIS daytime cloud products (MOD06);
- Generate a new record of cloud microphysical parameters for single layer clouds using the IR-based approach for the entire AQUA record; and
- Characterize the accuracy of the infrared cloud microphysical parameters through comparison with other A-train assets (AIRS, CloudSat, CALIPSO and POLDER).

Summary of Accomplishments and Findings

The development of an algorithm to derive cirrus optical and microphysical properties from the MODIS IR observations coupled with existing MYD06 cloud heights was accomplished in prior reporting years as were studies conducted to demonstrate the consistency of the IR-based method in relation to existing daytime products. During this final reporting year, the milestones set for this project include:
- Incorporating new spectral habit libraries including roughening effects,
- Conducting diurnal studies leveraging the use of an IR-retrieval method, and
- Generating global data sets from C6 MYD06.

One of the fundamental properties of cirrus clouds is the shape distribution (or habit) of the ice crystals. Aircraft measurements have shown that the distribution (vertical and horizontal) is quite variable and remains difficult to predict and observe. The work of our Co-Investigator Professor Ping Yang has created a library of scattering properties for nine pristine (unmixed) ice crystal habits, including three roughening modes. We have incorporated this new library into our retrieval process this year. We estimate an effective radius for every pixel for every ice habit from both β-values constructed from 11 and 12 microns and from 8.5 and 11 microns. As described in Heidinger et al. (2010), β is solely a function of effective radius for a given habit. We define the optimal habit as the habit where the effective radii from the two β-values are in closest agreement.

Final analyses are being performed for day/night consistency of the IR-derived cloud microphysical parameters as well as for characterization of individual habit behavior. Figure 11.1 shows some results of this process, where the distribution of optimal habit changes as a function

of optical depth and particle size.

Finally the availability of Collection 6 MOD06 is still limited. However, single months of global data sets have been generated and are available for cloud microphysical parameters for single layer cirrus clouds using the IR-based approach. The records are sub-sampled to a 0.1° x 0.1° equal-angle grid, which we refer to as level2b format.
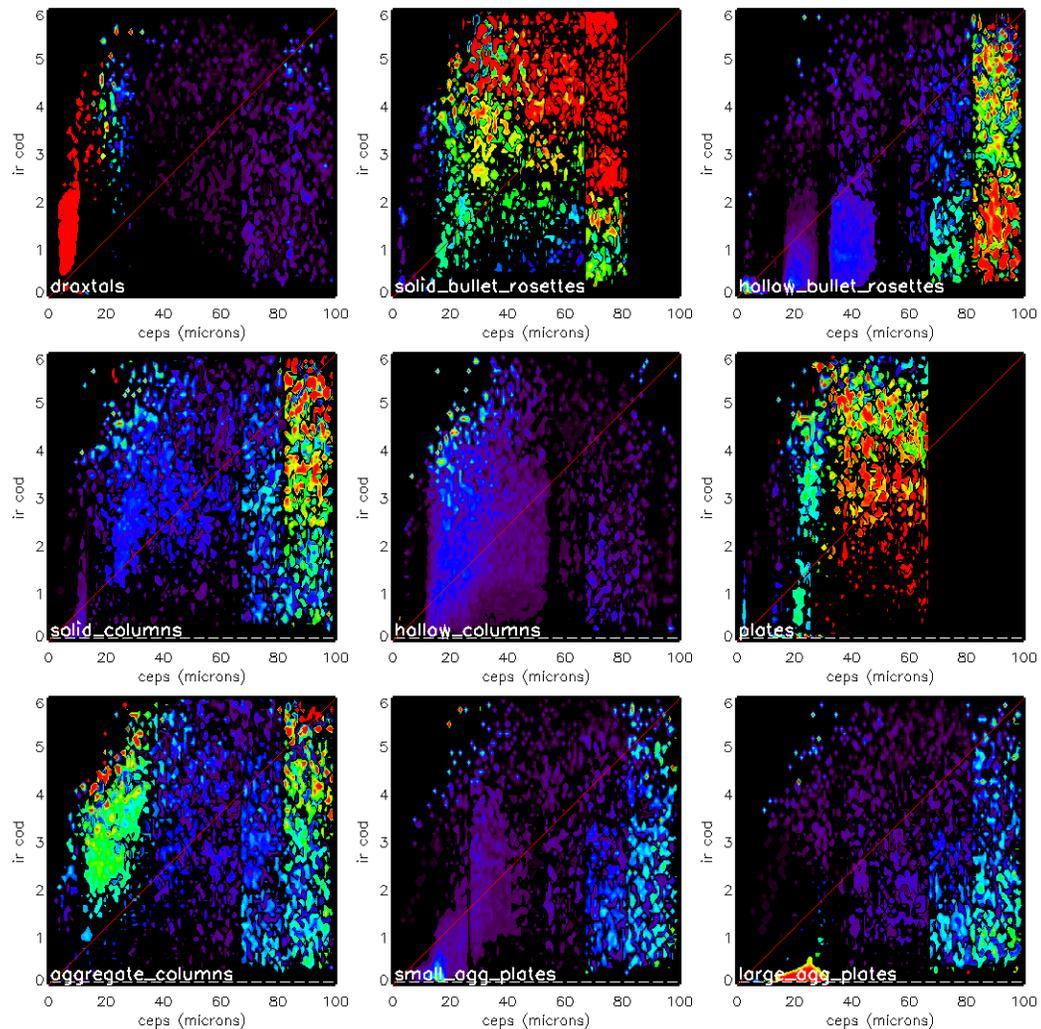
Figure 11.1. Relative frequency of occurrence of the habits from the Ping Yang Spectral Library relative to optical depth and particle size. Habits were detected when their effective radius differences between the 8.5/11μm and 11/12 μm β values were smallest in magnitudes compared to the values from all habits.

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

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Yang, Ping, Heli Wei, Hung-Lung Huang, Bryan A. Baum, Yong X. Hu, George W. Kattawar, Michael I. Mishchenko, and Qiang Fu, 2005: Scattering and absorption property database for nonspherical ice particles in the near- through far-infrared spectral region. *Applied Optics*, **44**, Issue 26, pp.5512-5523.

12. CIMSS High Impact Weather Studies for GOES-R with Advanced IR Soundings

CIMSS Task Leader: Jun Li
CIMSS Support Scientists: Jinlong Li, Elisabeth Weisz, Pei Wang
NOAA Collaborators: Tim Schmit, Chris Barnet
NOAA Long Term Goals
- Climate Adaptation and Mitigation
- Weather-Ready Nation

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

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

Proposed Work

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

Summary of Accomplishments and Findings

New Version of Clear Sky Full Spatial Resolution Soundings Provided for HIW Studies

The new version of Atmospheric Infrared Sounder (AIRS) single field-of-view (SFOV) soundings has been provided to the following collaborators for high impact weather studies:
- ESRL (Haidao Lin and Steve Weygandt) for rapid refresh model assimilation,
- CIRA (Milija Zupanski) for hurricane assimilation,
- NCAR (Hui Liu) for WRF/DART assimilation experiments,
- Thomas Jones for storm forecast studies, and

- Institute of Atmospheric Physics for convective storm precipitation forecast experiments with 4DVAR.

The new version of algorithm uses dynamic *a priori* error information according to atmospheric moistness and the use of quality controls in temperature and water vapor profile retrievals. Based on the dependency of the first-guess errors on the degree of atmospheric moistness, the *a priori* first-guess errors classified by total precipitable water (TPW) are applied in the AIRS physical retrieval procedure. Compared to the retrieval results from a fixed *a priori* error, boundary layer moisture retrievals appear to be improved via TPW classification of *a priori* first-guess errors. Six quality control (QC) tests, which check non-converged or bad retrievals, large residuals, high terrain and desert areas, and large temperature and moisture deviations from the first-guess, are also applied in the AIRS physical retrievals. Significantly large errors are found for the retrievals rejected by these six QCs and the retrieval errors are substantially reduced via QC over land, which suggest the usefulness and high impact of the QCs, especially over land. The AIRS SFOV soundings from the new version have been provided to collaborators for high impact weather (tropical cyclones, severe storms, etc.) studies.

Using MODIS Total Precipitable Water (TPW) as GOES-R ABI Proxy for HIW Assimilation Experiments

The algorithm for operational MODIS TPW retrieval was developed by the CIMSS sounding team. The spatial resolution is 5 km, and we used both Terra MODIS and Aqua MODIS TPW as GOES-R ABI proxy (TPW) for our TC assimilation experiments. In addition, the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) TPW was processed; the spatial resolution for AMSR-E is approximately 21 km, pixels with rain containaimtion were not used. MODIS has the advantage of high spatial resolution but is limited to clear skies only. AMSR-E provides TPW in both clear and cloudy skies but with coaser spatial resolution and over ocean only. Figure 12.1 shows the Terra MODIS (upper left), Aqua MODIS (lower left) and Aqua AMSR-E (upper right) TPW images over ocean for 10 September 2008.

The experiments using MODIS IR and AMSR-E MW TPW data were conducted in assimilation analyses for TC Sinlaku from 8 to 13 September 2008 with WRF/DART:
1. TPW-IR: Add only MODIS IR TPW data to the Control analyses,
2. TPW-MW: Add only AMSR-E TPW data to the Control analyses, and
3. TPW-IR-MW: Add both the MODIS and AMSR-E TPW data to the Control analyses.

The control run assimilates radiosondes, satellite atmospheric motion vectors, QuickSCAT winds, COSMIC GPS reflectivity, ship and land surface observations. The AMSR-E TPW data reduce the initial track error of the storm and improves the tropical cyclone's intensification.
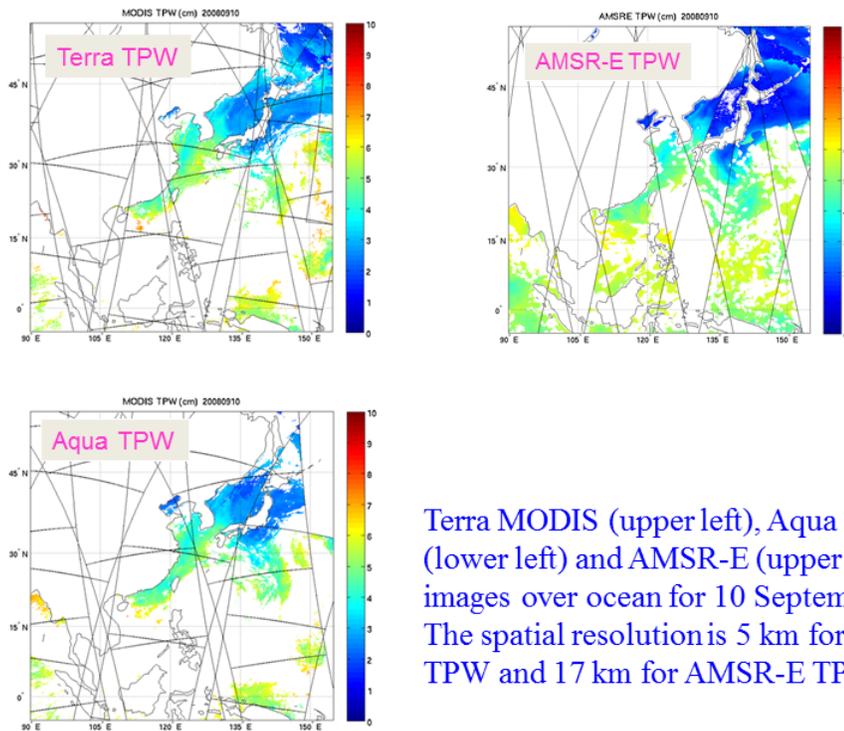
Terra MODIS (upper left), Aqua MODIS (lower left) and AMSR-E (upper right) TPW images over ocean for 10 September 2008. The spatial resolution is 5 km for MODIS TPW and 17 km for AMSR-E TPW.

Figure 12.1. The Terra MODIS (upper left), Aqua MODIS (lower left) and Aqua AMSR-E (upper right) TPW images over ocean for 10 September 2008.

Assimilation experiments also show that the combined IR (MODIS) and microwave (AMSR-E) TPW data provide positive impact on TC track and intensity analysis (Figure 12.2), especially in the first two days where control run provides large errors for both track and intensity forecasts during rapid intensitication period. The impact for MW+IR is not linear since (a) there are correlations among difference sources of data, more data usually help but they are not linear; and (b) there is predictability limitation, especially in regional model, data assimilation and forecasting is always challenging. Also there is sensitivity region where data are more important.

For IR and MW water vapor (WV) products, the information should be more independent each other, MW provide WV information in boundary layer while IR in middle troposphere. However, in our experiments, both IR and MW WV information is used as "TPW," it does not use the full advantage of IR in middle troposphere although MW TPW reflects the most information of boundary layer. GOES Sounder has three-layer PW, CIMSS sounding team will also try the PW between 300 - 700 hPa that has good information and sensitivity.
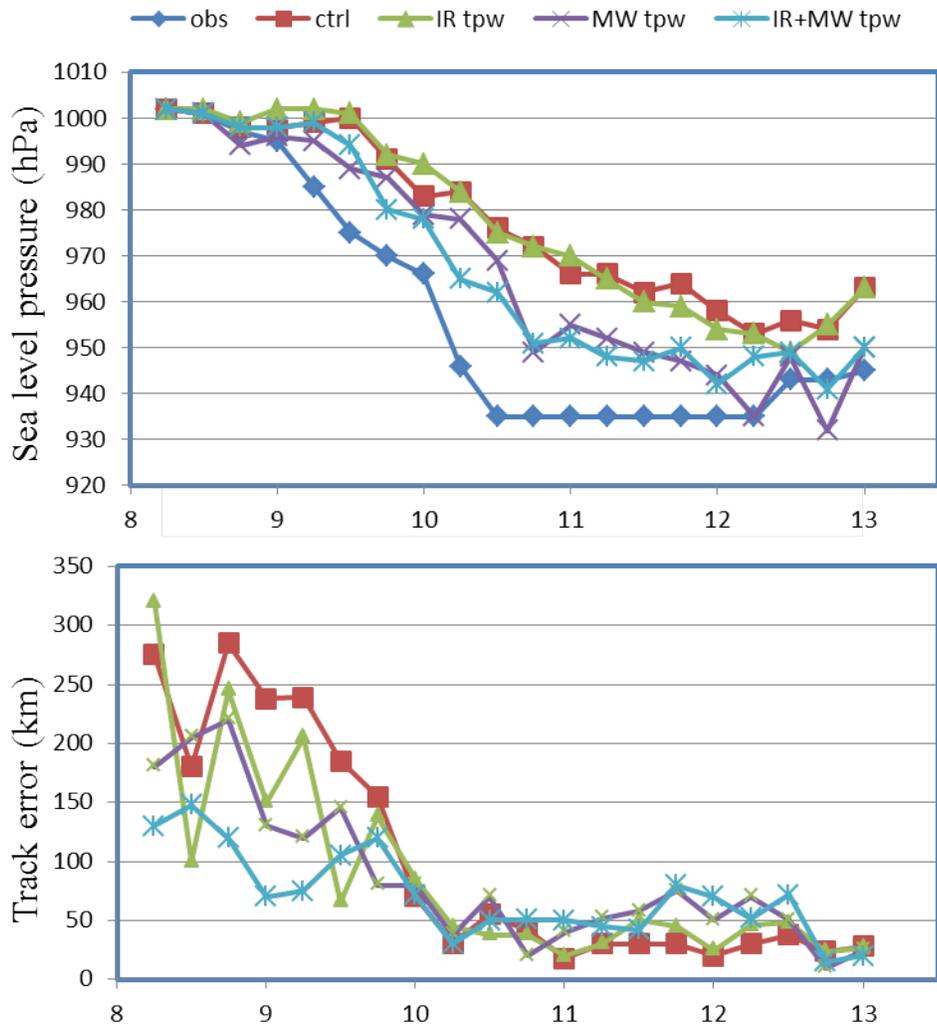
Figure 12.2. The sea level pressure (upper) and track (lower) errors of analysis (Typhoon Sinlaku 2008) with MODIS (IR)TPW, AMSR-E (MW) TPW, and IR+MW TPW, respectively.

Assimilation of AIRS SFOV Clear-sky Soundings for Hurricane Track and Intensity Forecast with WRF/3DVAR

The CIMSS sounding team has conducted assimilation experiments using WRF/3DVAR, with SFOV soundings from three AIRS granules in clear skies around 06 UTC on 06 September 2008. The control run uses NCEP 6-hour final operational global analysis including GTS radiosondes, operational satellite winds, pilot report, GPS, ship, profiler, surface observations etc., starting at 06 UTC on 06 September 2008. The AIRS (Control + AIRS) run adds the clear-sky AIRS granules and assimilates SFOV temperature and moisture profiles between 200 and 700 hPa. The upper panel of Figure 12.3 shows the 48 hour Hurricane Ike track forecasts with GTS (conventional data and other satellite measurements, dashed black), GTS + AIRS temperature profile (blue), GTS + AIRS moisture profile (green), GTS + AIRS temperature and moisture profiles (pink) assimilated, respectively. The combined AIRS temperature, moisture and GTS provide the best overall track forecast. However, it appears the temperature information leads to the greatest positive impact in this case. The lower panel of Figure 12.3 shows the respective track forecast errors.
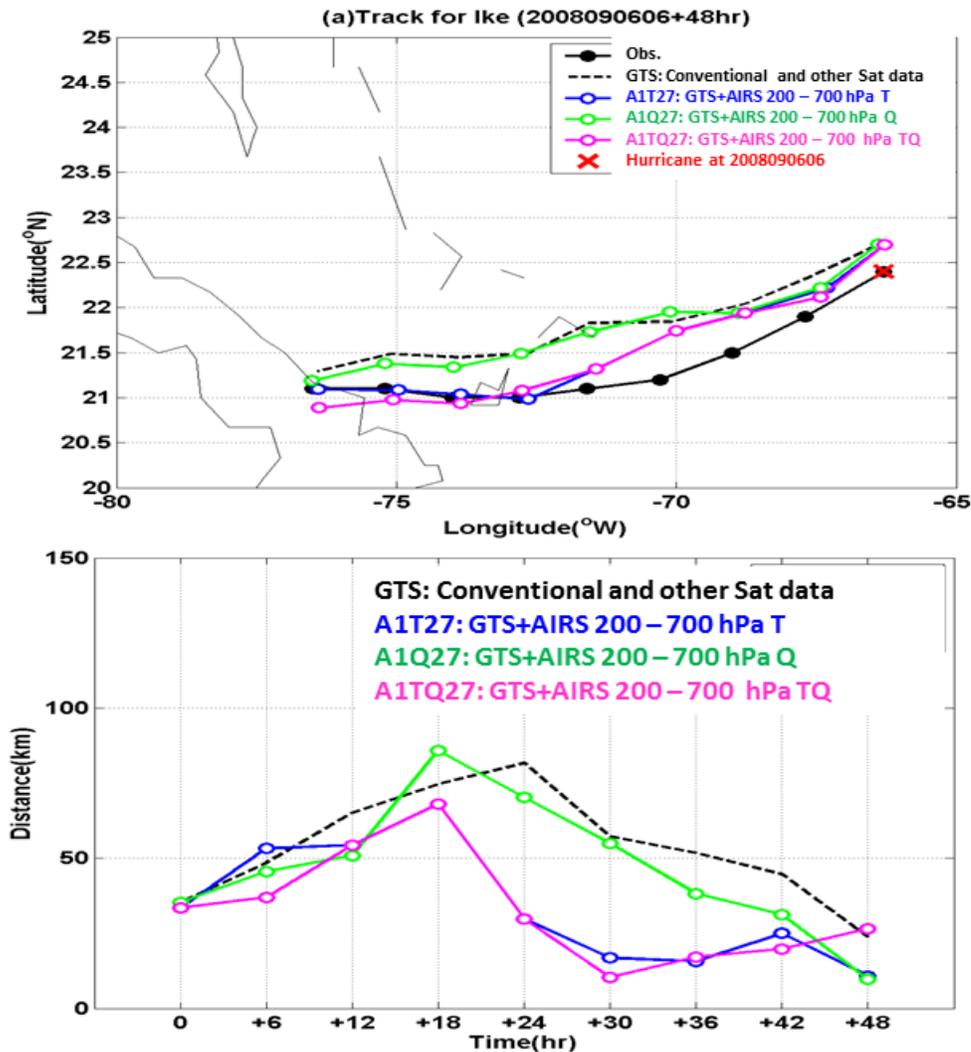
Figure 12.3. (Upper) The 48-hour forecasts with GTS (conventional data and other satellite measurements) (dashed black), GTS + AIRS temperature profile (blue), GTS + AIRS moisture profile (green), GTS + AIRS temperature and moisture profiles (pink) assimilated, respectively, for Hurricane Ike track forecasts. (Lower) The respective track forecast errors.

Lifecycle Forecast Experiments with AIRS Soundings

We have done lifecycle of forecast experiments for hurricane Ike (2008). The assimilation time window is 6 hours, every 6 hours the data are assimilated with WRF/3DVAR followed by 48-hour forecasting. Two sets of experiments are conducted, one for assimilating the conventional data and the other for assimilating conventional data plus AIRS SFOV clear sky soundings. The root mean square error (RMSE) of hurricane track forecasts are calculated against the track observations. Figure 12.4 shows the lifecycle Hurricane Ike (2008) track forecast RMSE for 0-h (analysis), 6-h, 12-h, 18-h, 24-h, 30-h, 36-h, 42-h and 48-h forecasts. The AIRS soundings consistently improve the track forecasts for hurricane Ike during its lifecycle.

Improving tropical cyclone forecasts with advanced IR soundings
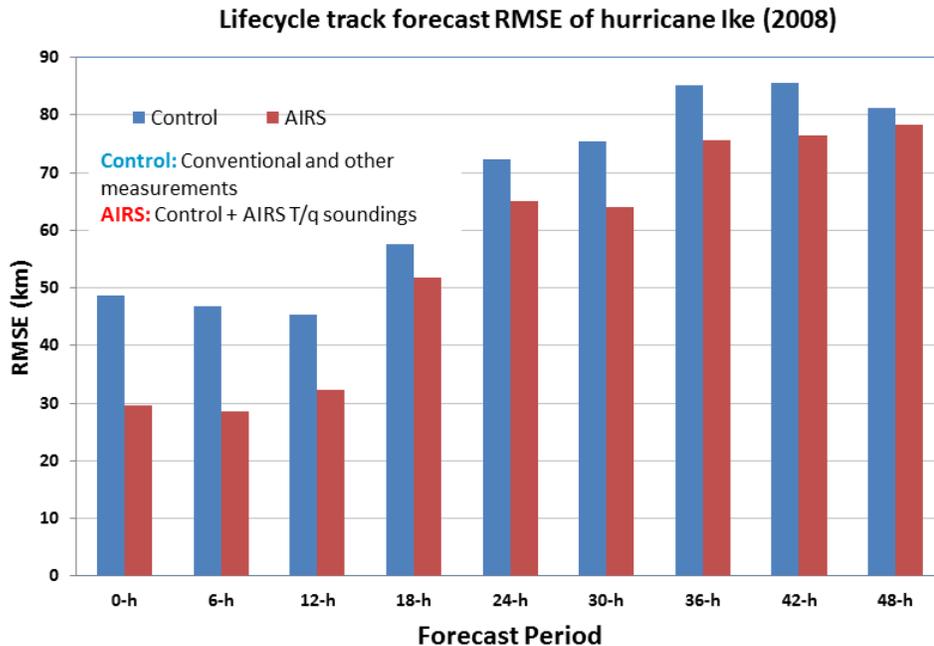
Figure 12.4. Lifecycle Hurricane Ike track forecast RMSE for 0-hour (analysis), 6-h, 12-h, 18-h, 24-h, 30-h, 36-h, 42-h and 48-h forecasts.

Studies on the Application of Advanced IR Soundings in the Pre-convection Environment

Advanced IR sounders such as the AIRS, IASI and CrIS provide atmospheric temperature and moisture profiles with high vertical resolution and high accuracy in pre-convection environments. The derived atmospheric stability indices such as convective available potential energy (CAPE) and lifted index (LI) from advanced IR soundings can provide critical information 1 ~ 6 hours before the development of severe convective storms (Li et al., 2011). Two convective storms over CONUS are selected for the evaluation of applying AIRS full spatial resolution soundings and the derived products on providing warning information in the pre-convection environments. In the first case, the AIRS full spatial resolution soundings revealed local extremely atmospheric instability 3 hours ahead the convections on the leading edge of a frontal system, while the second case demonstrates that the extremely low atmospheric instability is associated with the local development of severe thunderstorm in the following hours. The CAPE and LI from AIRS full spatial resolution and operational AIRS/AMSU soundings along with Geostationary Operational Environmental Satellite (GOES) Sounder derived product image (DPI) products were analyzed and compared. Case studies show that full spatial resolution AIRS retrievals provide useful warning information in the pre-convection environments for determining favorable locations for convective initiation (CI) than the coarser spatial resolution operational soundings and lower spectral resolution GOES Sounder retrievals.
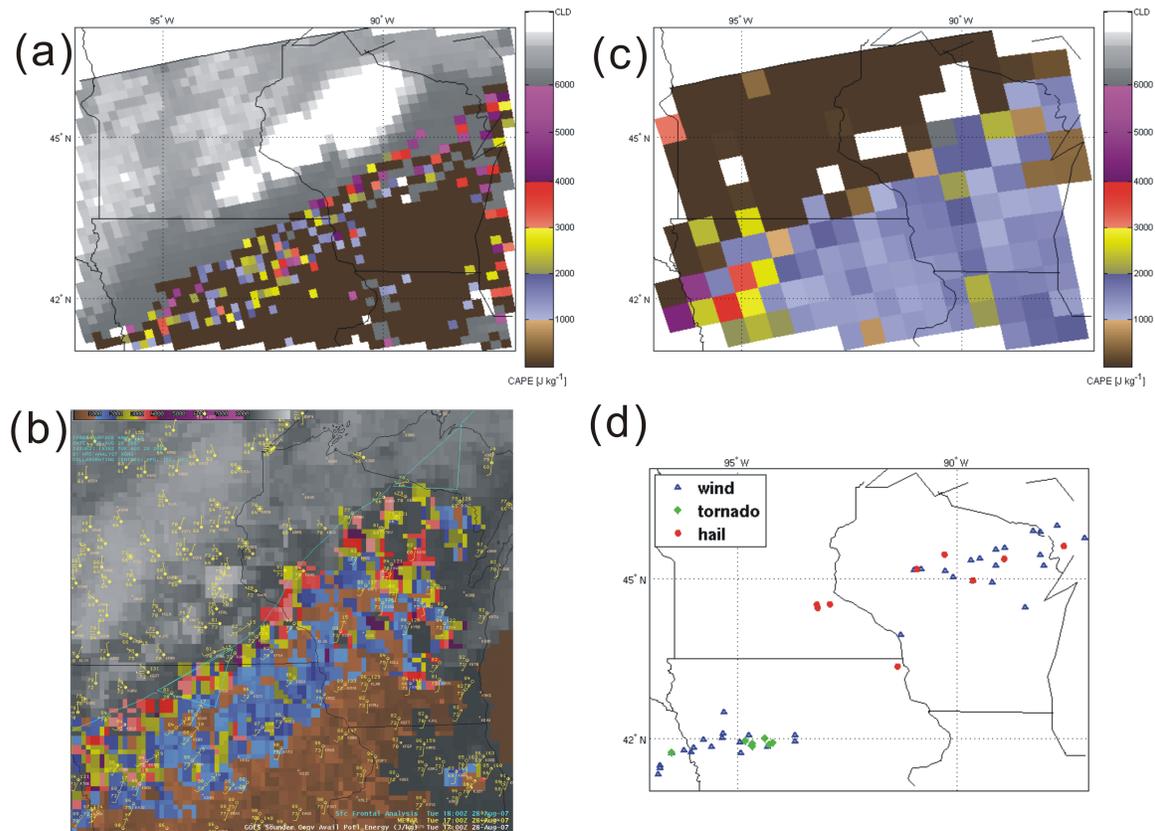
Figure 12.5. (a) The clear sky CAPE (color regions) from AIRS SFOV sounding overlaying the AIRS 11 µm brightness temperature image at 19:10 UTC 28 August 2007. (b) The clear sky CAPE (color regions) from GOES-12 DPI overlaying GOES-12 window channel brightness temperature image at 17:00 UTC 28 August 2007. (c) Corresponding science team AIRS/AMSU sounding CAPE at 19:10 UTC 28 August 2007. (d) The reported high wind, tornado and hail locations during 17:00UTC and 23:50UTC on 28 August 2007.

For example, a linear convective system was developing across parts of Iowa, Minnesota, and Wisconsin on 28 August 2007. The individual cumulonimbus towers build in northeastern Iowa between 21:00 and 22:00 UTC, and can be identified from GOES visible image (not shown). The larger cluster of thunderstorms in north-central/northeastern Wisconsin produced several reports of hail (up to 2.5 cm in diameter) and wind gusts of 90 - 130 km/hr (NOAA/SPC storm reports). The high spatial resolution MODIS observation provides useful information on clouds in cloudy areas while the high spectral resolution AIRS measurements can provide atmospheric thermodynamic structures in clear skies. A MODIS 11.0 µm IR image around 19:10 UTC depicted cloud-top brightness temperatures as cold as -79 ºC in north-central Wisconsin, with numerous clouds to ground lightning strikes. The AIRS observed the atmospheric instability at ~19:10 UTC 28 August 2007 in the pre-convection environment, around 3 hours before the storm genesis. Figure 12.5(a) shows the clear sky Convective Available Potential Energy (CAPE) (color regions) from AIRS SFOV soundings overlaying on the AIRS 11 µm brightness temperature image (black and white) at 19:10 UTC 28 August 2007. The local northeastern Iowa (center of the circle) has CAPE values exceed 4000 J/kg (magenta color), while Figure 12.5(c) is the calculated CAPE from the science team AIRS/AMSU retrieved profiles. Figure 12.5(b) is the

GOES-12 Sounder derived product images (DPI) of CAPE at 17:00 UTC for comparison. It should be noted that the CAPE images from AIRS CHISR algorithm (Figure 12.5a), science team AIRS/AMSU retrievals (Figure 12.5c), and GOES Sounder DPI (Figure 12.5b) are 3, 3 and 5 hours respectively ahead of the GOES-12 visible image.

Publications and Conference Reports

Li, J., Tim Schmit, Jinlong Li, Hui Liu and Jing Zheng, 2012: Recent Progress on High Impact Weather Forecast Improvement with GOES-R and Advanced IR Soundings, 2012 Warn-on-Forecast and High Impact Weather Workshop, Norman, Oklahoma.

Li, Jun, Jinlong Li, H. Liu, J. Zheng, and T. J. Schmit, 2012: Improving High Impact Weather Forecasts Through Assimilating the Satellite Advanced Infrared Soundings in Regional NWP Models, 92nd American Meteorological Society Annual Meeting, January 22-26, 2012, New Orleans, LA.

Zheng, J., J. Li, Jinlong Li, and T. J. Schmit, 2012: Assimilating AIRS Soundings with WRF/3DVAR for Hurricane Forecast Improvement, 92nd American Meteorological Society Annual Meeting, January 22-26, 2012, New Orleans, LA.

Zheng, J., J. Li, T. Schmit, Jinlong Li, and Z. Liu, 2012: Variational assimilation of AIRS temperature and moisture profiles for improving hurricane forecasts. *Journal of Applied Meteorology and Climate* (to be submitted).

Li, J., C.-Y. Liu, P. Zhang, and T. J. Schmit, 2012: Applications of full spatial resolution space-based advanced infrared soundings in the pre-convection Environment. *Weather and Forecasting* (in press).

Kwon, E.-H., J. Li, Jinlong Li, B. J. Sohn1, and E. Weisz, 2011: Use of total precipitable water classification of a priori error and quality control in atmospheric temperature and water vapor sounding retrieval. *Advances in Atmospheric Sciences*, **29**, 263-273.

Li, J., Jinlong Li, T. J. Schmit, and J. Otkin, 2011: Warning information in pre-convection environment from geostationary advanced infrared sounding system - a simulation using IHOP case. *Journal of Applied Meteorology and Climate*, **50**, 776 - 783.

Li, J., T. Schmit et al. 2011: Improving high impact weather forecasts with combined GOES-R measurements and advanced infrared soundings from JPSS, Presentation at the 36th NWA Annual Meeting and poster presentation at the 7th GOES Users' Conference, 15 – 21 October 2011, Wynfrey Hotel, Birmingham, AL.

Li, J., T. Schmit, H. Liu, Jinlong Li and J. Zheng, 2011: The utility of GOES-R and LEO soundings for hurricane data assimilation and forecasting, GOES-R Science Week, 19 – 23 September 2011, Huntsville, AL.

13. Investigations in Support of the GOES-R Program Office

CIMSS Task Leader: Paul Menzel
NOAA Collaborator: 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

Proposed Work
CIMSS Senior Scientist Dr. W. Paul Menzel, in collaboration with the NOAA GOES-R Program Office, will conduct and stimulate research on environmental remote sensing systems that helps to guide evolution of the NOAA satellite holdings. This effort will include facilitating research demonstrations of new capabilities from GOES-R and JPSS, participating in the Technical Advisory Committee and other evaluation boards, presenting results at appropriate venues, and collaborating with international partners pursuing the same goals.

Summary of Accomplishments and Findings

GOES-R AWG and Risk Reduction Review
In mid-June Dr Menzel participated in the GOES-R AWG Review via telephone. At the conclusion, his comments to the review chair, John LeMarshall, included the following:
1. Scientists must remain close to operational s/w - his/her role in product production efficiency, validation, and evolution must be more clearly defined;
2. Study for routine production of option 2 products (prior to operational production) should be undertaken - eventual operational production will find user community more ready for effective utilization. Recommendation: A study be undertaken to determine how Option 2 products can be produced routinely for user familiarization by STAR with existing resources;
3. Better utilization of temporal continuity for product generation and QC - some algorithms are now making good use of the temporal advantages offered by geostationary measurements; all algorithm developers should re-consider ways to make better use for consistency checks and / or QC; and
4. Data fusion of model and satellite measurements should be explored further (there are more examples like model BL RH and satellite fog) - need more JCSDA presence.

GOES-R ADEB
On 3-4 August, Dr Menzel attended the GOES-R ADEB meeting wherein option 2 products were reviewed for their readiness to be handed off for operational implementation. Several products were not ready and those that are will be handed off to STAR for possible routine production ; Harris involvement in option 2 products has been postponed into the indefinite future. His general comments to the ADEB chair included:
- There is ample evidence of good progress made possible by a talented group of people. Preparations for GOES-R products have been impressive. Some challenges remain, but many have been met;
- The algorithm change process must be treated differently when going from « broken to working » or from « adequate to better ». Algorithms must continue to be worked in the

years leading up to launch to maintain scientific activity/momentum/content. Update strategies before Day 1 and after Day 1 need to be tested and refined. A pre-planned product improvement must be developed for the program;

- Algorithms have been developed assuming perfect data. Impact of missing data and rectification / saturation / truncation / striping error on products will require a lot of attention post launch;
- Product validation needs engagement of a larger community. The Proving Ground is engaging users in a meaningful way and should be continued well into the lifetime of GOES-R/S to validate and evolve products as well as improve user utilization. In addition, post-launch validation must include considerations for field experiments; leveraging and contributing to existing plans for NASA/DOE/NOAA field experiments must be undertaken;
- Leo supplement / complement of Geo must continue to be worked. Synergy between different GOES products also needs to be enhanced; and
- ABI does not offer a sounding product; ABI offers vertical profile adjustment to a NWP model initial estimate. This issue must be made clear in the product designation.

Visit to EUMETSAT

On 26 through 28 September, Dr Menzel visited EUMETSAT and conferred with Dr Jo Schmetz. They are collaborating on an article for publication titled "Evolving Satellite Remote Sensing Capabilities and Meeting User Requirements – A Look at the Evolution of Meteorological Satellites."

IWW11

On 19 through 23 February, Dr Menzel attended the 11th International Winds Workshop (IWW11) in Auckland. 60 people from Australia, China, Europe, India, Japan, Korea, and USA attended. He gave a talk on "Comparison of CO2 AND H2O Atmospheric Motion Vector (AMV) Height Assignment Techniques using the GOES-13 Imager"; conclusions from the talk included:

- H2O/IRW & CO2/IRW CTP determinations show modest correlation for AMV cloud tracers above 4 km;
- H2O/IRW CTH estimates are about 1 km lower than CO2/IRW on average, for semi-transparent ice clouds this difference increases to 4 km;
- INSAT winds will necessarily have height assignment biases with respect to GOES and Meteosat;
- GOES-13 CO2/IRW CTH estimates are in better agreement with CALIOP; and
- ABI AMV CTH estimates are anticipated to be of better quality (better spatial resolution, spectral characterization, and radiometric calibration) with improved AMV tracer characterization (cloud phase, thickness, microphysics, …).

NOAA SAB SATTF

On 14 March, Dr Menzel participated in the first meeting of the NOAA Science Advisory Board Satellite Task Force (SATTF) in Silver Spring MD. In response to unprecedented budget challenges, NESDIS is doing a comprehensive reevaluation of future plans. The Science Advisory Board (SAB) has been asked to validate NESDIS' future plans or to recommend specific adjustments that will enhance overall value to NOAA while continuing to be executable. The Satellite Task Force (SATTF), comprised of six people, is advising the SAB on NESDIS' proposed satellite service replanning. The SATTF report is expected in late September.

Collaborations with EUMETSAT

Discussions with Dr. Dieter Klaes indicated strong interest in having an IASI sounding package for direct broadcast users. EUMETSAT does not have one. In March 2012, Dr Menzel coordinated scientists at SSEC in adapting and testing the Smith-Weisz clear and cloudy sounding code for use with AIRS, IASI, and CrIS. The IASI processing package is being tested by Dr. Klaes; upon his approval it will be added to the Community Satellite Processing Package being maintained at SSEC/CIMSS.

14. GOES-R Risk Reduction

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

CIMSS Task Leader: 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

Proposed Work

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

The first year of work at UW-Madison/CIMSS focused primarily on the development of the probabilistic ash cloud object detection portion of the alert system. The probabilistic ash detection methodology first determines the probability that each satellite pixel contains volcanic ash based upon an extensive set of training data. After the pixel-level probability has been determined, adjacent pixels with ash probability values in excess of a threshold are grouped into cloud objects. The use of cloud objects allows for the generation of spatial statistics of spectral quantitates for each cloud object; these cloud object statistics are then used to determine the probability an entire cloud is an ash cloud, again based upon an extensive set of training data. The use of spatial statistics of spectral quantities is essential for creating an alert quality ash detection scheme (alert quality meaning extremely low false alarm rate). Figure 14.1.1 illustrates how the probabilistic cloud object detection scheme is used to detect an ash cloud associated with the 2009 eruption of Redoubt volcano near Anchorage, Alaska. Much of the ash cloud identifiable in the false color imagery is captured by the probabilistic method, while the traditional brightness temperature difference approach fails to detect a significant portion of the ash cloud.

Publications and Conference Reports

Pavolonis, M. J., C. Calvert, and J. Sieglaff, 2012: New Quantitative Volcanic Cloud and Fog Products for GOES-R, presentation at the Annual AMS Meeting, New Orleans, LA.

Pavolonis, M. J. and J. Sieglaff, 2012: Satellite Retrievals of Volcanic Ash Cloud Properties: Evaluation of near Real Time Results and Suggestions for Improving Operational Satellite Products, presentation at the Annual AMS Meeting, New Orleans, LA.

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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., 2011: Advances in extracting cloud composition information from spaceborne infrared radiances: A robust alternative to brightness temperatures. Part II: Proof of concept. To be submitted to: *J. Applied Meteorology and Climatology*.

Figure 14.1.1. An example of the probabilistic ash detection scheme developed for the GOES-R Volcanic ash alert system. Top left is a false color image of the Redoubt volcano ash cloud (red areas). Top right is the same false color image with the probabilistic ash cloud object outlined in white. Bottom left are the pixel-level ash probabilities. Bottom right is the traditional 11-12 µm brightness temperature difference used to detect volcanic ash. Note the probabilistic methodology captures most of the ash cloud visible in the false color imager, while the traditional brightness temperature difference method fails to detect a significant portion of the ash cloud.

14.2 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

Proposed Work

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
In this study, we investigate the potential for satellite detection and short-term forecasting of turbulence and other aviation hazards associated with rapidly growing and mature convective cells, which are known sources of serious in-flight hazards. Satellite derived cloud top cooling rates and total (i.e., in-cloud and cloud-to-ground) lightning trends are strong inferences of convective updraft intensity and growth rate. More specifically, we utilize integrated Geostationary Lightning Mapper (GLM) and Advanced Baseline Imager (ABI) proxy cloud top cooling, overshooting-top (OT)/enhanced-V, and total lightning flash rates and densities for diagnosis of storm intensity and growth rate. GLM proxy total lightning data are obtained from the VHF-based Lightning Mapping Arrays (LMAs) over Alabama, Florida, Oklahoma and Washington DC. Cloud top cooling and OT detection are obtained from GOES-12 and GOES-13 observations over the LMA operational domains (roughly out to 150-250 km from LMA center). Turbulence occurrence is determined objectively using eddy dissipation rate (EDR) data from the NCAR turbulence algorithm applied to commercial aircraft navigation data over the LMA domains.

During Year 1, our primary efforts have been 1) identifying and developing a database of concurrent LMA, GOES, EDR and other (e.g., radar) data during a variety of convectively induced turbulence (CIT) conditions (light, moderate, severe) over Northern Alabama (NA-LMA), and 2) processing NA-LMA for total lightning flash occurrence and rates and GOES for

convective cooling rate, OT occurrence and other properties, and 3) investigating the temporal and spatial relationships between these total lightning properties, overshooting-tops (OTs), infrared (IR) cooling rates and CIT events.

We have identified and processed NA-LMA data for total lightning flashes from 28 days during 2010-2011 that have at least one moderate turbulence event (and many light turbulence events) over Northern Alabama (Figure 14.2.1). Total lightning occurrence, heights, and flash densities within various temporal and spatial radii from the EDR events on these 28 days have been investigated by turbulence intensity. Several moderate turbulence events from 2010 and 2011 are being studied in more detail with LMA, GOES and radar data (e.g., 1/24/10, 3/12/10, 5/2/10) to determine the specific concurrent relationships between lightning, infrared cloud-top cooling and radar intensity proxies and turbulence occurrence. Since the temporal and spatial relationships between the various convective intensity proxies (e.g., total lightning flash rate and OT occurrence) are not well understood, we have also identified and processed over 400 GOES-12 and -13 OT detections within 250 km of the NA-LMA center during 2009-2010 and are investigating the temporal and spatial evolution of total lightning flashes within convective radii (10 km, +/- 10 mins) of OT's in vigorous storms (Figure 14.2.2). A sample of these and other Year 1 accomplishments will be summarized along with a discussion of future (Year 2) objectives.
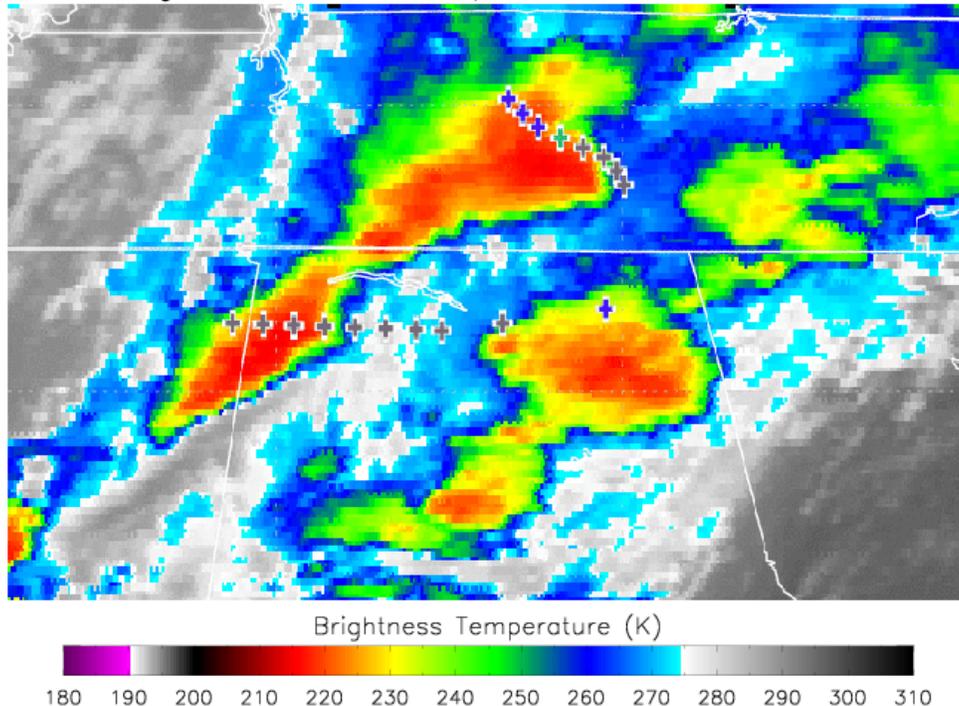
Figure 14.2.1. 10.7 micron infrared window imagery from GOES-12 and United Airline flight tracks of EDR objectively determined turbulence (grey – null, blue –week, green –moderate) from May 2, 2010 at 2302 UTC.
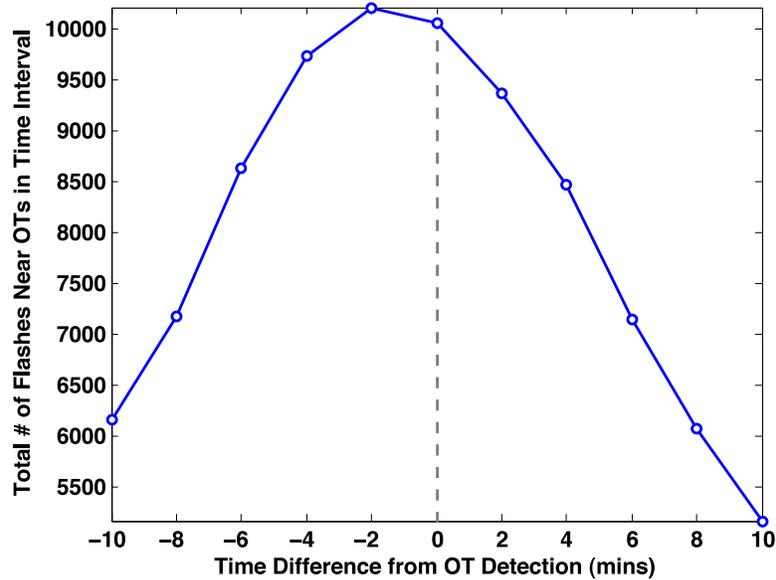
Figure 14.2.2. Total number of lightning flashes near overshooting-tops vs. time difference from GOES imager overshoot detection in minutes.

Publications and Conference Reports

Carey, Larry, W. Feltz, K. Bedka, S. Monette, C. Wang, R. Rogers, and M. Scott, 2012: Integrated GOES-R GLM/ABI approaches for the detection and forecasting of convectively induced turbulence (CIT), NOAA Science Week, Kansas City, MO, 30 April – 4 May 2012

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14.3 Investigating the Effects of Detector-Averaged SRFs

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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

Proposed Work
The primary objective to this research is to determine the effects of using detector-averaged spectral response functions (SRFs) on today's GOES imagery and products and to project how that will affect GOES-R ABI imagery and products. To study the effects of using detector-averaged SRFs on current GOES, two analyses will be performed. The first analysis will involve 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.

Using a fast forward model (PFAAST) and convolutions with SRFs, individual detector SRFs can be compared. 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 second analysis will 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 in the first task 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).

The first task proposed will be used to generate the methodology by which GOES-R ABI SRFs can be analyzed. The analysis of the first task 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.

Summary of Accomplishments and Findings

This work is still ongoing and progress is being made to advance our understanding of the effects of using detector-averaged spectral response functions. The use of the individual detectors in the fast forward model is still being developed. However, convolutions with the CIMSS-32 atmospheric spectra have occurred; these are spectra calculated using a wide variety of atmospheric (clear sky) conditions. By convolving an atmospheric radiance spectrum with a GOES SRF, a radiance can be generated which simulates what GOES should measure if it were sensing a pixel containing that atmospheric profile. The sounder has 4 detectors per infrared band, while the Imager typically has two (the exceptions for the imager are bands for which only 1 detector was present such as the water vapor band on GOES-8 thru -11 Imagers and the 13.3 micrometer band on GOES-12 and -13). Comparing the differences in radiances calculated for each detector to the specified noise for each band (using GOES-8 thru -11 spec noise values, converted to radiance) can reveal if any of the detectors are "out of family." Figure 14.3.1 shows an example of Band 7 (12.3 micrometer) for each GOES Sounder (8 through 15) convolved with the US Standard Atmosphere spectrum. The GOES-8, -12, and -13 sounders each have a detector that is "out of family," where the detector to detector difference is greater than the spec noise for that band. What this means for GOES-R ABI remains to be determined. ABI imagery will be remapped in such a way that a pixel does not correspond to a single measurement from a single detector (as is the case on current GOES). Other quantitative products derived from imagery may be affected as well.
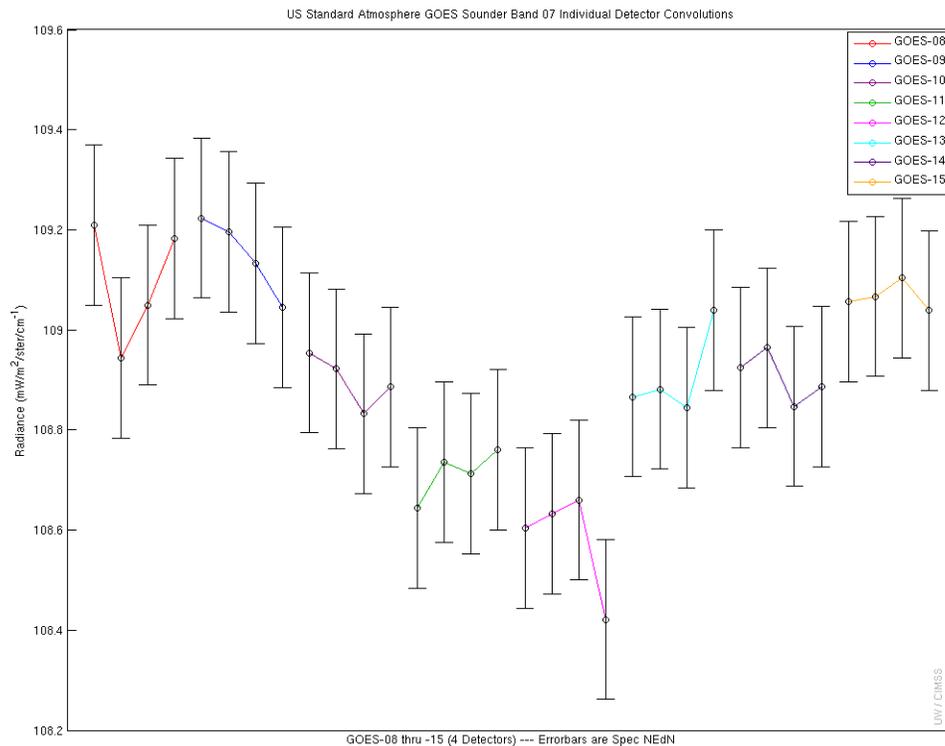
Figure 14.3.1. GOES Sounder Band 07 individual detector convolutions with the US Standard Atmosphere. The error bars represent NEdN (noise in radiance units); when the difference between two detectors exceeds NEdN it is considered "out of family" for the purposes of this study. GOES-8, -12, and -13 all have one detector that is out of family for this band in this atmosphere.

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

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CIMSS Support Scientists: Ralph Peterson, Jun Li
NOAA Collaborator: Tim Schmit
NOAA Long Term Goals
  • Weather-Ready Nation
NOAA Strategic Goals
  • Serve society's needs for weather and water
  • Support the nation's commerce with information for safe, efficient and environmentally sound transportation
  • Provide critical support for the NOAA mission
CIMSS Research Themes
  • Satellite Meteorology Research and Applications
  • Environmental Models and Data Assimilation

Proposed Work

We proposed to support selected GOES-R Risk Reduction projects by developing the capability in McIDAS-V to visualize all data used in these projects and develop analysis tools to enable quantitative evaluation of the output products. Previously, the McIDAS-V team has worked with three CIMSS groups who were funded on previous GOES-RRR development tasks to apply McIDAS-V capabilities and tools to advance their project objectives while at the same time building additional capabilities in McIDAS-V that will be of future use to all GOES-R data users.

Summary of Accomplishments and Findings

Technical issues have caused a delay in the adaptation of the NowCasting trajectory model into McIDAS-V. As a result, the majority of the funds have been saved to use once the work to adapt the NowCasting trajectory model into McIDAS-V is solidly underway. In this proposal we also stated we would support other GOES-R Risk Reduction projects that wish to utilize the capabilities of McIDAS-V. The following are examples of GOES-R Risk Reduction projects where analysis was conducted and products were displayed in McIDAS-V. These examples demonstrate how GOES-R Risk Reduction projects are using McIDAS-V as a visualization and analysis tool.

Figure 14.4.1 shows one day of MODIS polar winds over the Arctic region. The winds are color-coded based on height (blue = low; red = high) and are overlayed on a composite satellite image, displayed on a 3D globe in McIDAS-V. Only the northern portion of the globe is shown.
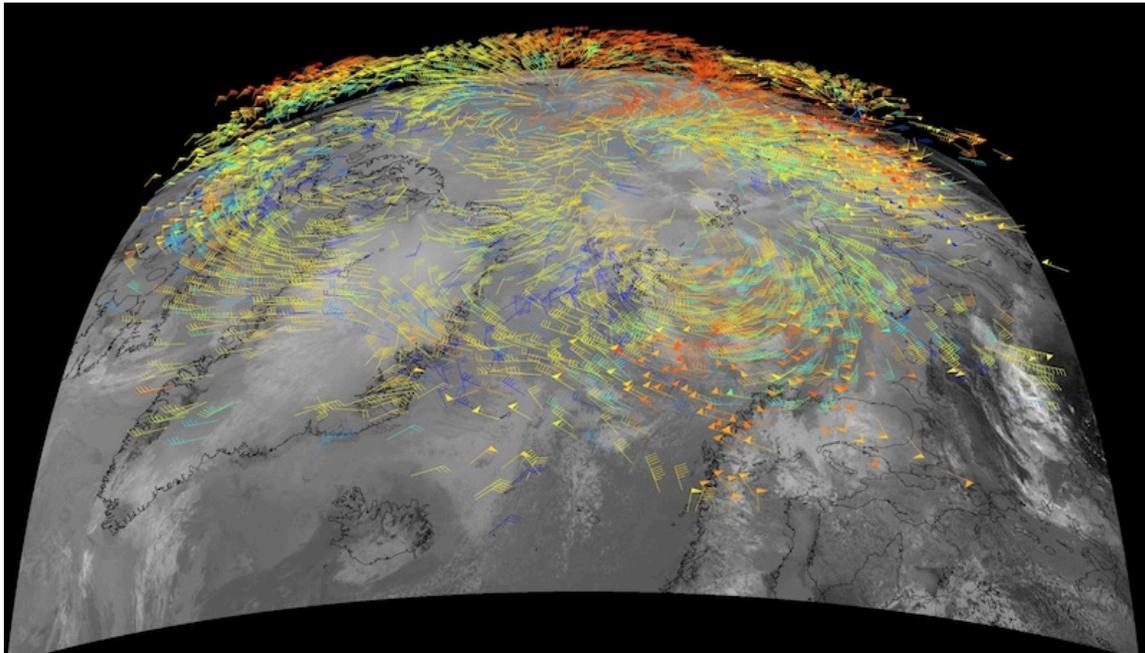
Figure 14.4.1. MODIS derived polar winds over the Arctic. The McIDAS-V globe projection is used to display the winds.

Figure 14.4.2 shows a graphic from American Airlines flight 734, which made an emergency landing after encountering turbulence on August 9th, 2011. McIDAS-V was used to compare results from the UW Convective Initiation (UWCI) Cloud Top Cooling Algorithm to the location of the plane when turbulence was reported at 19:32 UTC. The UWCI Cloud Top Cooling algorithm indicated that there was a period of rapid cooling in the region of turbulence one hour

prior to the turbulence event. This could indicate that decay of a convective storm was a possible explanation for the event.
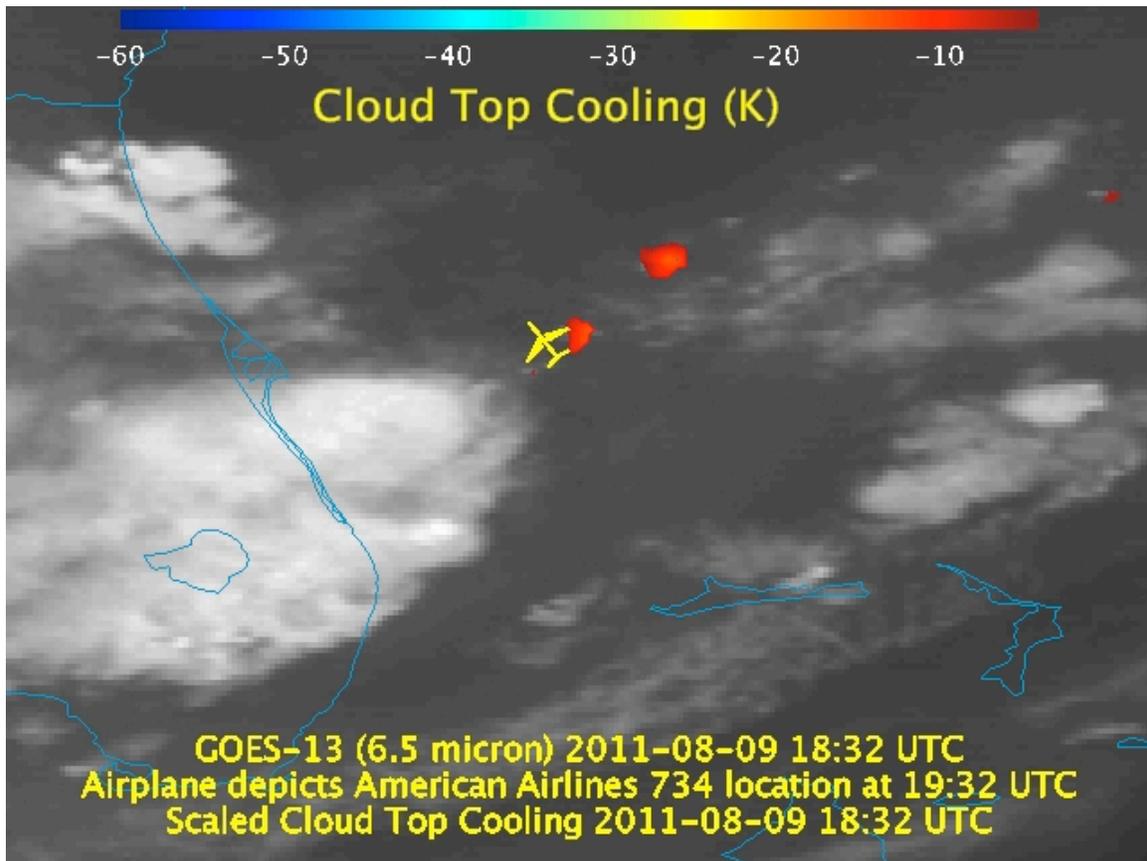
Figure 14.4.2. GOES image over Florida and Bahama Islands, with location of cloud top cooling maxima and location where airplane encountered turbulence on 9 August 2011.

Figure 14.4.3 demonstrates how the UW-CIMSS Tropopause Fold product uses gradients in GOES water vapor imagery to refine model locations of possible tropopause folding in near real-time. In this image, the GOES EAST water vapor image is enhanced to show the gradients in the field. The green boxes show regions where the tropopause fold product predicted a higher likelihood of a tropopause fold. The RUC potential vorticity field is shown as a yellow-green contour to show the model generated region of tropopause folding. On September 12th, 2011, Austrian Airline Flight 88 experienced turbulence shortly after take-off. The yellow planes show the flight path, with the red plane indicating where the turbulence was reported. The orange planes signify locations immediately previous and after the turbulence report. This confirms that the Austrian Air plane flew through a tropopause fold at that time.

AUA 88 Flight Track on 12 September 2011
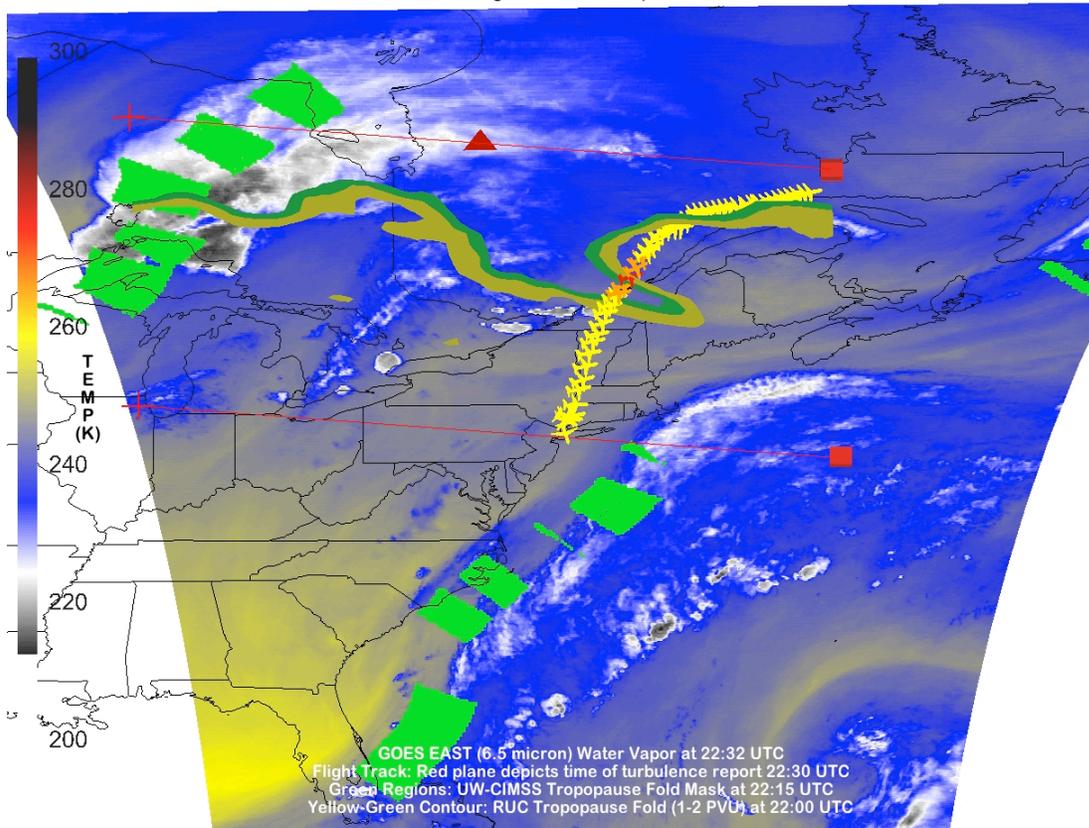
Figure 14.4.3. GOES-East water vapor image; enhancement shows water vapor gradient and associated troposphere fold. Yellow airplanes indicate flight path through troposphere fold.

On February 29th, 2012, a tornado formed and tracked through Branson, Missouri. The NEARCAST convective instability product predicted rapid destabilization in the immediate region of Branson at the time of the severe weather. The major input to the NEARCAST product are derived from the GOES sounder, similar to the DPI. Figure 14.4.4 is a comparison between the product results of the NEARCAST convective instability, the GOES sounder lifted index derived product imagery and the AIRS Dual Regression Lifted Index from an overpass near to the reported tornado formation. Crosses indicate other reported tornadoes in a 12 hour period beginning on Feburary 28th, 2012 at 0 UTC and ending on February 29th, 2012 at 12 UTC. This image demonstrates the ability of McIDAS-V to display multiple data formats, hdf, grib, McIDAS AREA format and point data. In addition, comparison between polar orbiting and geostationary satellites is made easier by the sharing of displays and automatic remapping of data.
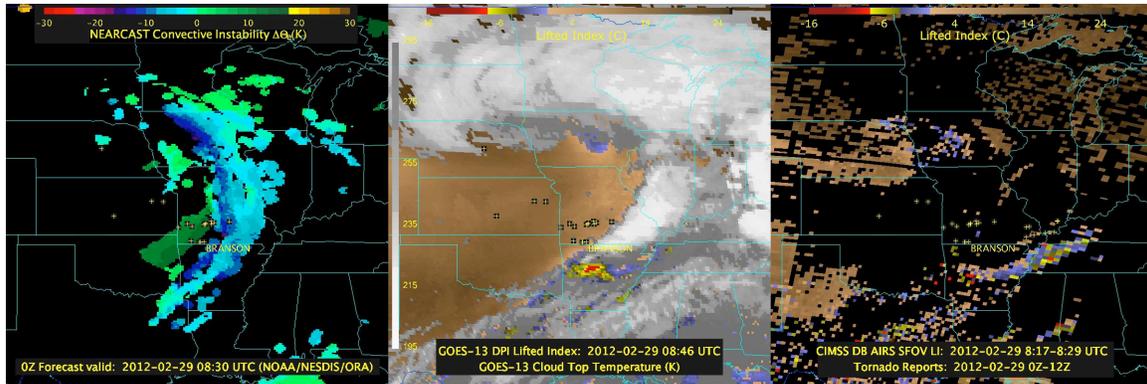
Figure 14.4.4. Comparison between the results of the CIMSS NEARCAST convective instability, the GOES sounder lifted index derived product imagery and the AIRS Dual Regression Lifted Index from an overpass near to a reported tornado formation near Branson, MO on 29 February 2012.

14.5 Improvements to QPE Using GOES Visible ABI and Model Data

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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

Proposed Work
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 from a very high resolution (0.5 km) Weather Research and Forecasting (WRF) model simulation were made available to NSSL researchers to investigate the relationship between the spatial structure of visible satellite imagery and the model precipitation and cloud top height. The WRF model simulation tracks the evolution of two mesoscale convective systems that developed across the

Upper Midwest during 19-20 July 2006. The simulation was performed at the Pittsburgh Supercomputing Center (PSC). A Web page was created to more easily compare the simulated model and satellite data.

Real-time GOES cloud top properties produced at CIMSS have also been made available for incorporation into the SCaMPR algorithm. A Web page was written to overlay the cloud top properties on visible satellite imagery and radar observed precipitation estimates:

http:/www.nssl.noaa.gov/~rabin/qpe .

14.6 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: Jamie 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

Proposed Work
To prepare for the operational status of the GOES-R ABI Atmospheric Motion Vector (AMV) product, proxy data sets have been created by applying the Nested Tracking Algorithm to imagery from the Meteosat-9 Spinning Enhanced Visible Infra-Red Imager (SEVIRI). Using this proxy data, initial data assimilation statistics have been derived for the National Center for Environmental Prediction (NCEP) Global Forecast System (GFS). Quality control procedures for using this new AMV product in the NCEP GFS are being reviewed by examining existing quality control parameters as well as considering new parameters related to the Nested Tracking Algorithm.

Summary of Accomplishments and Findings
Data assimilation statistics of AMVs compared to the NCEP GFS background winds have been computed for 25 July to 2 August 2011 for channel 14 proxy data. A second data set for 14-28 December 2011 has also been completed and is ready for analysis which includes all 4 ABI channels: 2, 7, 8, and 14. The intention for these two short runs is to compute statistics of the AMV compared with the background state as well as evaluate candidate parameters for quality control procedures. Once candidate quality control measures are determined, two different seasons will be simulated while assimilating the proxy data allowing a statistical analysis of the difference of the AMVs and the assimilation state.

Assimilation statistics of the observations minus the background state (OMB) have been computed for the July data set. Figure 14.6.1 presents the zonal mean speed bias. All proxy data is included in this calculation; no data are rejected based on quality control. The number

distribution of AMVs is shown as well; a minimum of 50 AMVs were required within the latitude and pressure bin to compute the bias. The zonal speed bias is generally near zero or positive with the exception of low level marine clouds, AMVs below 500 hPa located at 30-60S and 10N, and extra-tropical AMVs at the highest levels.

Difference in wind direction (not shown) between the AMV and the background are largest for the tropics near 500 hPa with a zonal mean average of the magnitude of the wind direction difference of approximately 30°. The direction difference is smaller for the extra-tropics (5-15°) and low level AMVs (5-10°). Likewise, normalized vector difference RMS is largest for the tropics at levels near 400 hPa and reduces in magnitude as AMV height increases.

Examining the OMB statistics did not reveal a dependence on surface type or zenith angle. The low level AMVs and mid-upper level, tropical AMVs have the best distribution of data for the range of possible zenith angles. The vector difference bias and RMS do not indicate a trend for OMB as a function of zenith angle. For surface type, the mean OMB for speed for all water and all land points are similar. Repeating this analysis for the tropics and 20-60S regions found larger difference in the means for land and water but no consistent conclusion. For mid-upper level, tropical data, the AMVs had a speed bias of 1.1 m s^{-1} for water and 0.4 m s^{-1} for land while the southern hemisphere mid-upper level AMVs had a speed bias of 0.5 m s^{-1} for water and 1.3 m s^{-1} for land. Direction statistics did not indicate a dependency either. Analysis will be repeated on the December data set to confirm this conclusion.

Statistics as a function of cloud type of the tracked cluster were begun but determined to have a small sample size for useful analysis. Cloud type is most strongly dependent on the location of the AMV and each region tends to have a dominant cloud type. The combination of both data sets may allow enough number to examine OMB for the range of clouds identified within the region.

To identify candidate quality control parameters, the number distribution and OMB statistics were computed on binned AMVs for discrete ranges of parameter values. Existing quality control parameters include the Quality Indicator (QI) and its components as well as the Expected Error (EE). For QI values above 83, all bias and RMS indicate AMVs are more similar to the background as QI increases with the exception of directional bias for mid-upper level, extra-tropical AMVs. For EE values above 3.5, an increasing EE generally indicates an increasing bias and RMS for speed, direction, and vector difference. Algorithm parameters include cluster size, correlation, and standard deviation as well as number of clusters found in the target box. The OMB dependence on these algorithm parameters indicate that for smaller clusters, cluster selected from a box with many clusters, and AMVs with low standard deviations, the AMVs are the most different compared to the background state. Analysis will continue for the algorithm parameters to determine if the difference between the forward and reverse vector parameter values reveal a dependence on OMB statistics.
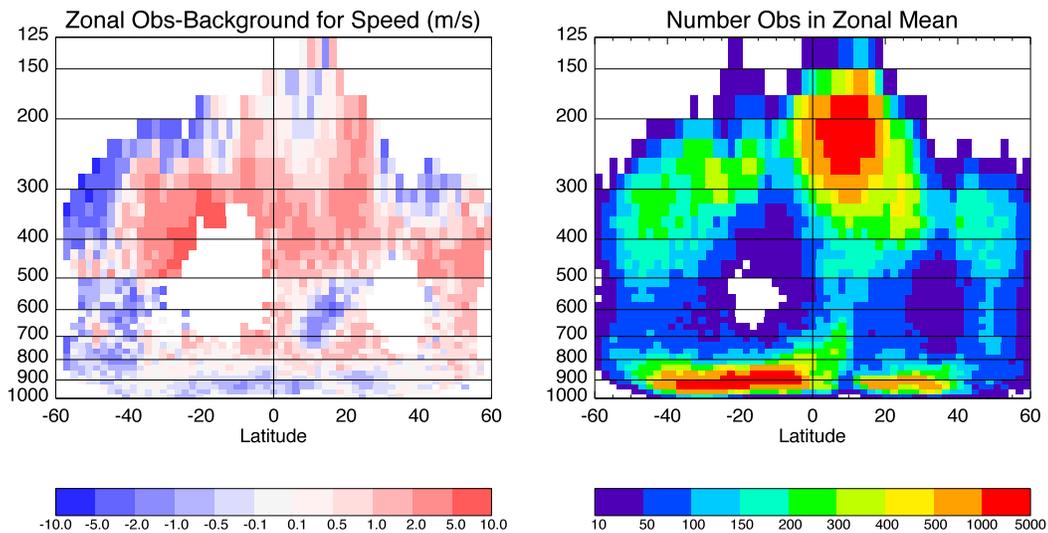
Figure 14.6.1. Zonal Mean for Observation minus Background GFS state of speed m s^{-1} and number of AMVs.

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Le Marshall, J., R. Seecamp, Y. Xiao, P. Gregory, J. Jung, P. Steinle, T. Skinner, C. Tingwell, T. Lee, 2012: The Operational Generation of Continuous Winds in the Australian Region and their Assimilation with 4DVar., Submitted to *Wea and Forecasting*.

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Jung, J. A., K. Garrett and L. P. Riishojgaard, 2012: Atmospheric Motion Vector Impact Study Using the NCEP Global Forecast System. 11th International Winds Workshop, Auckland, New Zealand, 20-24 February 2012.

Le Marshall, J. F., R. G. Seecamp, Y. Xiao, P. Gregory, J. Lee, J. Jung, P. Stienle and T. Skinner 2012: Recent Improvements in the Specification of the Atmospheric Wind and Mass Field from Space for Weather Forecasting and Climate Monitoring. 18th Conference on Satellite Meteorology and Oceanography / First Joint AMS-Asia Satellite Meteorology Conference, New Orleans, LA, 22-26 January 2012.

Le Marshall, J. F., R. Seecamp, Y. Xiao, P. Gregory, J. Jung, P. Stienle T. Skinner, J. Lee and T. Le 2012: Operational Generation of Continuous AMVs in the Australian Region and their Assimilation with 4DVAR, 11th International Winds Workshop, Auckland, New Zealand, 20-24 February 2012.

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Santek, D., B. Hoover and J. Jung 2012: Assimilation and Forecast Impacts using the Expected Error in the Quality Control of MODIS Polar Winds. 11th International Winds Workshop, Auckland, New Zealand, 20-24 February 2012.

Su, X., J. Derber and J. Jung 2012: Atmospheric Motion Vector Quality Control Procedure Improvements in the NCEP Data Assimilation System. 11th International Winds Workshop, Auckland, New Zealand, 20-24 February 2012.

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

CIMSS Task Leader: Ralph A. Petersen
NOAA Collaborators: Robert Aune, Gary Wade, Tim Schmit
NOAA Long-Term Goals
  • Weather-Ready Nation
NOAA Strategic Goals
  • Serve society's needs for weather and water
  • Support the nation's commerce with information for safe, efficient and environmentally sound transportation
  • Provide critical support for the NOAA mission
CIMSS Research Themes
  • Satellite Meteorology Research and Applications
  • Environmental Models and Data Assimilation

Proposed Work
The overall objectives of this multi-year effort are twofold: 1) to determine how information contained in hyperspectral POES retrievals and other independent a-synoptic observations can be used to enhance GOES-R products by removing biases and "extending" the high-resolution POES data from their native 6-hourly observing frequency to the much shorter time and higher spatial resolution GOES observation intervals and then using these products in NearCasts covering the 6-8 hours interval until the next POES products are available, and 2) to perform a comprehensive assessment and validation of the NearCasting products across all of the participating GOES-R Proving Ground sites.

The primary developmental effort was designed to meld information from GOES with POES retrievals, as well as other independent a-synoptic observations, as a means of improving upon the GOES products (developed by the GOES Algorithm Working Groups (AWGs)) both at the time of the POES observations and into the near future. The inclusion of improved vertical resolving power of the POES hyperspectral products (developed by POES programs) was thought to be especially important prior to hazardous weather events when the vertical structure of the thermodynamic fields (especially vertical and horizontal moisture gradients) is key to determining where the events are and are not likely to occur. The GOES data, in return, could increase the horizontal detail and fill the time gaps between POES overpasses.

Due to excessive day-to-day variations detected in Biases in the "AIRS Team Retrievals" during the first year of this effort, alternatives were investigated as vehicles for recalibrating the GOES derived moisture products, including GPS TPW, AMDAR WVSS-II aircraft observations and Raman Lidar profiles from the ARM CART site. Converting the NearCasting system from an Isobaric to an isentropic framework is underway to further to enhance the use of the satellite products and short-range forecasts. The isentropic analyses and NearCasts should provide both a better picture of the total amount of moisture and energy being transported adiabatically into areas of interest and an improved understanding of near-term vertical transports. These efforts 1) will give forecasters better and more time consistent real-time products than could be provided by GOES alone, 2) will provide an opportunity to use the higher time/space resolution products in extended NearCasting applications, and 3) may provide an alternative for developing bias-removal procedures needed for using GOES data in short-range NWP systems.

Comprehensive validation efforts will also be continued at several of the GOES Proving Grounds sites, including already planned tests at NCEP's Storm Prediction Center (SPC) and Aviation Weather Center (AWC) and anticipated tests at the Hydrological Prediction Center (HPC) and Ocean Prediction Center (OPC) in the next several years. Validations at each of the Centers will likely use a variety of different parameters, e.g., SPC will need to focus on Convective Instability while HPC may be more interested in the structure and timing of small-scale moisture plumes. Since one of the primary goals on the NearCasting products is to improve forecaster awareness of areas where isolated weather events may and may not occur, it is important that quantitative validations be available to assess the performance and utility of the system. A number of methodologies will be explored, including both observed data and gridded data sets. The validation results, in turn, will be used to update training materials so that forecasters can better understand the situations when the NearCasts are more (or less) useful to their individual forecast problems.

Summary of Accomplishments and Findings

Summary of Forecaster Evaluations Obtained in 2011
During the past year, a major emphasis of CIMSS NearCasting activities has focused on testing and evaluation of the short-range forecasting system internally at CIMSS, at local US National Weather Servicer (NWS) Forecast Offices, and both the Storm Prediction Center (SPC) and the Aviation Weather Center (AWC) divisions of the National Centers for Environmental Prediction (NCEP). The tests at the two centers had different objectives according to their missions: at SPC, they focused on identifying areas where severe convection **would** occur, while at AWC, they attempted to identify areas where all forms of deep convection **would** *and* **would not** occur. However, all groups wanted to: a) Increase lead-time, b) Reduce false alarms and increase probability of detection, c) Provide updates / detail to NWP guidance for next several hours, and

d) Increase use of satellite products (they currently rely heavily on Numerical Weather Prediction (NWP) models and radar observations).

NearCast products were evaluated from periods ranging from several months to several weeks. Forecaster appraisals of the current and potential value of existing and future products included the following observations/recommendation:
- Provide information about dynamic triggering;
- Extend forecast length;
- NearCast fields (especially tendencies) were most useful when used to diagnose initial growth and coverage;
- Clouds limit the usefulness of product at times;
- Nearcasts were most valuable when used in conjunction with observations and other model data (both where convection will and will not occur):
  - Especially useful in updating / verifying mesoscale NWP and Ensemble guidance, especially during summer when only ~15% of NWP precipitation forecasts are correct; and
- More experience was needed using the product to help with interpreting the observed fields and combined parameters.

Extending NearCast Length and Areal Coverage
A number of research and applications activities were undertaken to address the issues listed above. The first of these addressed both the issues that forecasters wanted the NearCast guidance extended beyond 6 hours into the future and wanted to have fewer areas blocked by cloud cover. Before evaluation activities were initiated at SPC and AWC, the length of the NearCasts was successfully increased from 6 to 9 hours into the future. Since the NearCast products are generally available within less than one hour after the GOES observing sequence is begun, the maximum useful time of the NearCast products is effectively expanded by 60% (from 5 to 8 hours).

Extending the length of the NearCast predictions also benefitted the data coverage in both the initial analyses and the NearCast predictions. The NearCasting system is unique in that it uses Lagrangian trajectory techniques to project geostationary satellite observations forward in time to future geographical locations. This projection is done once every hour as new observations become available, with the information about trajectory location and parameters stored every 15 to 30 minutes. Graphical NearCast products are then produced by 'binning' all of the trajectory data from all previous observations valid at the same time onto a regularly spaced grid. As such, data from up to 9 previous observation times can impact the graphical NearCast analyses and predictions.

NearCast Analysis at 0800 Local Time using only data valid at that time

NearCast Analysis at 1200 Local Time using data valid at that time plus data projected forward from previous 4 hrs

NearCast Analysis at 1700 Local Time using data valid at that time plus data projected forward from previous 8 hrs
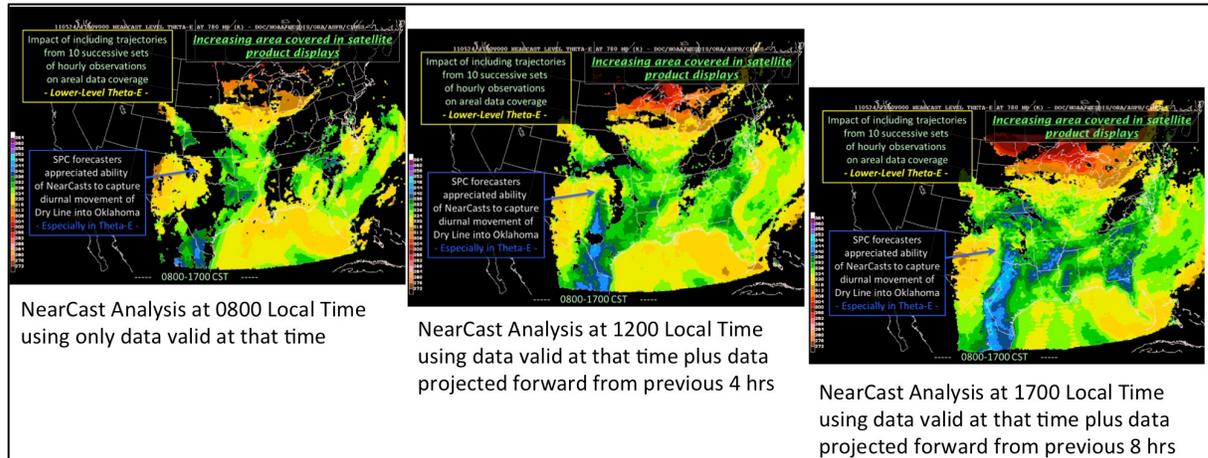
Figure 14.7.1. Comparisons of NearCast low-level Equivalent Potential Temperature (θ_E) analyses for 24 May 2011showing increased analysis coverage when using one hour of on-time observations only (left), on-time observations plus forward projections of data from four previous hours (center) and on-time observations plus forward projections of data from nine previous hours (right).

Figure 14.7.1 shows the impact of including projections of previous observations in improving the spatial coverage of the NearCast analyses. In this case, the left panel shows an analysis based only on date from 1300 UTC 24 May 2011. The center right panel shows the effect of including both observation at 1700 UTC and projections of data from the previous four observing times (1300, 1400, 1500 and 1600 UTC), effectively tripling the number of 'data points' available to the analysis. By including data from nine successive observing times at 2200 UTC, the 'missing data' area (black regions over the central and eastern US on the left panel) has been reduced by between 60-80% compared to the analysis made using only on-time data. It should also be noted that forecasters at SPC were especially impressed by the ability of the GOES data and NearCast system to detect and monitor the progression of the 'dry line', an important factor in initiating severe convection, eastward from the Texas panhandle into western Oklahoma during the morning and early afternoon.

Providing Information about Dynamic Triggering

Although previous examples have shown the ability to identify areas where convective storms are likely to develop, many of the areas characterized as being convectively unstable never experience convection due to either the presence of a strong capping inversion (as described in Petersen et al., 2010) or the lack of a sufficiently strong low-level lifting mechanism. In addition, both thermodynamic and momentum-based parameters are needed to differentiate the probable severity of the ensuing storms.

Initial investigation of the lower- and mid-level wind fields showed that the NearCast models has information and sufficient detail about the low-level convergence and atmospheric shear to isolate areas of substantial lifting and deep-layer shear. Case study results (for a case over Europe, not illustrated here) show the development of a low-level jet during the 6-hour NearCast period with a region of strong convergence (divergence) couplet forming near (upwind) and slightly before the tornado formation. This information about dynamical lifting, combined with the information about convective instability and change in capping inversion presented in the previous report, help to identify where within the areas of convective instability storms are and are not likely to occur. The results also show the development of a low-level moisture flux and wind shear during

the 6-hour NearCast period before the tornado formation. The development of strong moisture transport and intensifying wind shear in the vicinity (southwest) of the tornadic convection points to the ability of the NearCast trajectories to provide dynamical information about both the thermodynamic and wind fields immediate prior to storm genesis, even when using wind data obtained from relatively low resolution global NWP models.

Helping Interpret the NearCast Fields and Combined Parameters

SPC and AWC forecasts noted that the NearCast fields (especially lower-level transport and stability <u>tendencies</u>) were most useful when used to diagnose initial storm growth and coverage. The NearCasts also added significantly to the value of NWP guidance in helping determine where convection *would* and *would not* occur. They were especially useful in updating / verifying NWP/Ensemble guidance during summer, when only ~15% of short-range NWP precipitation forecasts are correct in the US. Forecasters also noted that much more experience was needed using the product to help them interpret the observed and NearCast GOES fields and combined parameters. Specifically, users need:

- *Extended Training* on use of NearCasts products,
- *Enhanced Education* on both the Satellite Observations and Products, as well as the NearCasting Process, and
- *To 'Break the Bond' to NWP output*
  Especially the heavy reliance of forecasters on NWP precipitation guidance as a primary tool in predicting the location and timing of severe convection.
  This can be accomplished through a combination of 1) improved image display capabilities in operations to help forecasters <u>understand</u> physical/dynamical processes occurring in the atmosphere, and 2) new displays to improve forecaster understanding and <u>reduce information overload</u>.

Figure 14.7.2 illustrates a static view of one such display option. Although these display combination are best viewed in time loops, the single-time display of a 6-hour NearCast provides a good example for discussion. When loops of only the right panel were presented to forecasters, they had difficulty determining where to focus their attention. Although in retrospect forecasters noted that convection tended to occur in areas where the convective instability was increasing, their attention was initially drawn to the larger areas of convective instability, which often persisted in areas of strong capping inversions or minimal low-level lifting.

By including synchronized, but smaller-sized loops of the two component parameters predicted by the NearCasting system on the left of the same display, forecasters were much more able to visualize and <u>understand</u> 1) where the low-level thermal/moisture patterns were most favorable, 2) how the differential transport of drier/cooler air aloft could increase the Convective Instability, 3) where stability *tendencies* (both positive and negative) were largest (e.g., near Dallas, Texas, where sustained convection was observed at this time, over NE Colorado, where low-top supper cells formed as very cold/dry air moved over moderately warm/moist air at lower-levels, and over northern Pennsylvania, where the lack of warm/moist air at low-levels inhibited convection) and 4) how all of this Nearcasts related to the dryness patterns observed in GOES moisture imagery.
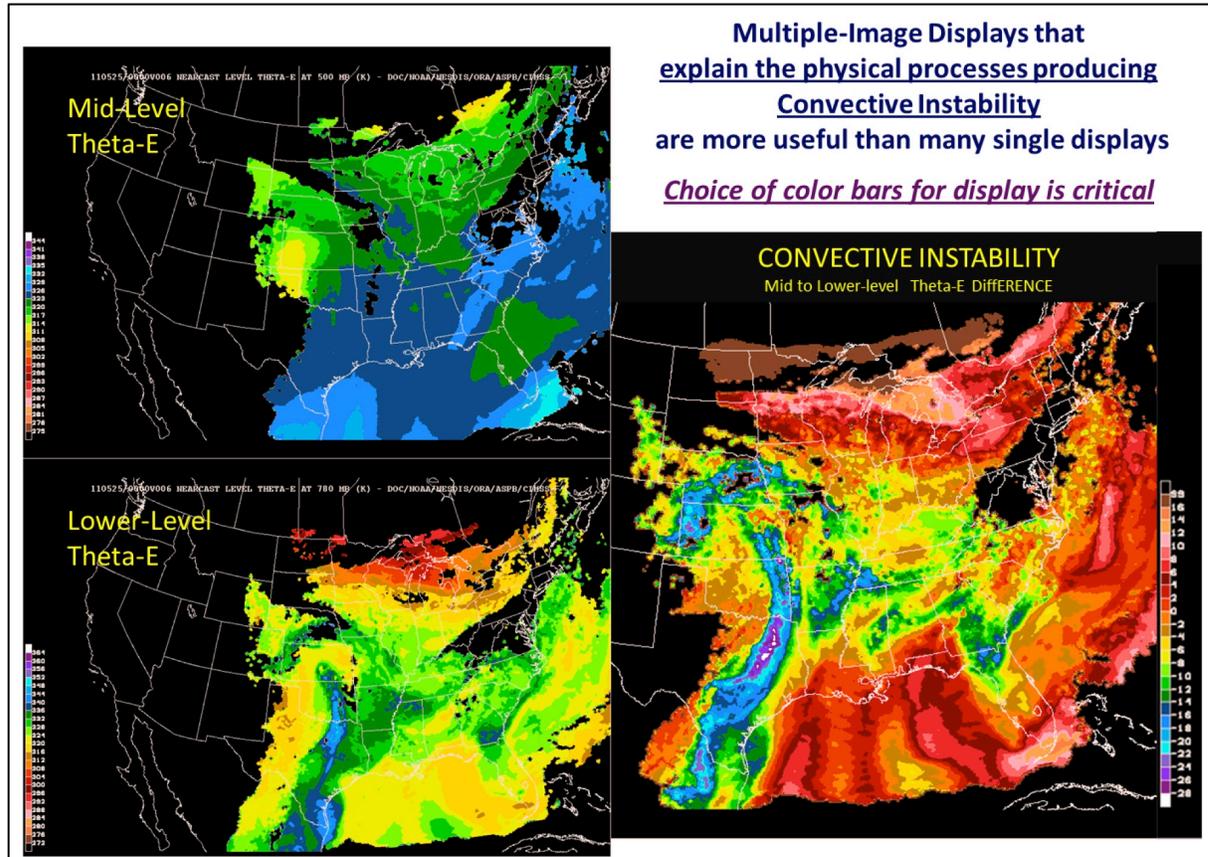
Figure 14.7.2. Example of multiple panel display of a 6 hour NearCast of derived Convective Instability (right panel) and component parameter fields (left panels) from 0000 UTC 25 May 2011. Reds and yellows in left panels indicate areas of lower θ_E (cooler, drier air) and greens and blues indicate higher θ_E (warmer, moister air). Scales change from lower to upper panels. Red areas in right panel are convectively stable (θ_E increases with height) and blue/purple/white regions indicate greatest convective instability (θ_E increases with height).

Another aspect of the displays that drew comment from forecasters was use of Convective Instability as a primary GOES NearCast guidance parameter. The NearCast products were developed to take advantage of the parameters that GOES observes best (e.g., 2-3 deep layers of moisture). Adding temperature data to produce θ_E improved further upon the moisture-only products and provided the basis for calculating Convective Instability as the difference in θ_E for a deep layer between the lower- and middle-troposphere. The choice of this parameter was consistent with many years of observations that convection tended to form along the trailing and especially leading edges of dry bands observed in water-vapor imagery.

The relationship between deep-layer Convective Instability (CI) and other more common indices such as the Lifted Index (LI) or CAPE was also explained. Tests comparing LI and deep-layer CI for a variety of temperature/moisture conditions at 850 and 500hPa typical of convective events yielded a linear relationship, with the stable/unstable threshold point (where LI crosses 0°) shifted slightly in CI to about -3°. The result showed that deep-layer CI not only can be treated as a substitute for LI, but also that it retains important information about mid-level dryness that is observed well by GOES but is not included in the LI.

Finally, a new index intended to help forecasters identify areas where new convection is likely to longer-lived was demonstrated. This parameter is the product of the Convective Instability, the lower-level Precipitable Water (PW – indicating ample lower-level moisture) and the lower-level θ_E (indicating lower-level heating). It proved successful in being able to differentiate the area of prolonged convection from short-lived but still severe storms, as was the case for example in Figure 14.7.2, where the new parameter flagged the storms that formed near Dallas as being much more long-lasting than the storms that formed earlier over center OK.

Combining GOES Retrievals Using Information from POES Soundings and Other Asynoptic Data Sets

The objective of this effort is both to give forecasters better and more temporally-consistent, real-time products than can be provided by GOES alone, as well as to provide a possible methodology for using higher time/space resolution GOES products in NWP.

Efforts originally focused on melding radiances information from POES and GOES observations. Few attempts had previously been made to use the regionally varying biases observed between a wide variety of contemporaneous GOES retrievals and other observations (including hyperspectral POES, GPS TPW, automated aircraft WVSS-II and Raman Lidar data) as a means of improving derived GOES products both at the time of the ancillary observations and into the near future. Combining the improved vertical resolving power of the POES hyperspectral products (and to a more localized extend WVSS-II and Raman Lidar observations) with the horizontal and temporal resolving power of GOES was considered to be especially important prior to hazardous weather events, since the vertical structure of the pre-storm thermodynamic fields (particularly the vertical and horizontal moisture gradients) are key to determining strength of the storms and the locations where the events both are and are not likely to occur.

Initial evaluations assessed the operational "AIRS Science Team" AIRS and GOES sounder moisture data (in the integrated form of Total Precipitable Water, TPW) over land using GPS TPW as a comparison standard. Preliminary results, however, showed that although the AIRS retrievals have a smaller overall Bias than the GOES TWP, the AIRS products have a consistently larger Standard Deviation (StDev) - indicating that the current AIRS retrievals (which have been applied mostly over oceans) have larger random errors than the GOES data. The AIRS retrievals also showed excessive day-to-day variations in Bias, which prevented them from being used as a correction standard. Several other AIRS retrieval schemes are now also being assessed.

Currently, the GPS TPW data are being considered as the primary Bias-correction mechanism for the GOES moisture products. The GPS TPW data have been helpful in identifying the times of year when the GOES retrievals add the most information to the NWP model (GFS) first-guess fields – during the warm season, when NWP models have their lowest precipitation forecasting skill.

The GPS TPW data also have shown that both the GOES retrievals (and the GFS first-guess fields) have a diurnal variation in skill and bias, with products based on the 0000 UTC GFS run showing the least skill and highest bias. This is also the time when the short-range GFS precipitation forecasts show their largest over-forecasts.

Future work will use temperature and moisture profiles obtained from the Raman Lidar at the ARM CART site to help determine how best to distribute the GPS TPW-based bias corrections

throughout the depth of the GOES retrievals. When this work is completed, an initial bias-correction procedure will be added to the NearCast data processing systems.

Reconfiguring the NearCast Model into Isentropic Coordinates

The NearCasting model is also on schedule in being reconfigured into isentropic coordinates to extend further the value of the enhanced data sets. It is particularly appropriate for the GOES NearCasting since all of the GOES sounder products used in the model are obtained under conditions of clear skies when flow in the free atmosphere is by definition adiabatic. This enhancement will also allow forecasters to observe the *total* amount of moisture (the combination of the mixing ratio and the stability) being transported adiabatically above the boundary layer, as well as to determine the location and strength of adiabatic lifting. Both of these aspects will improve the ability to determine areas of long-lived convection and heavy rainfall events.

The use of isentropic trajectories adds a 4th dimension to the NearCasting system that can be extremely useful in delineating air-masses, source regions (e.g., the development of the low-level dry line) and changes in vertical structures (intrusion of dry air over moist creating convective instability) prior to convective events. In addition to separating air masses and defining adiabatic vertical motion, the use of isentropic coordinates could be beneficial in interpreting satellite retrievals, since the areas of important low-level moisture are defined by the combination of static stability and moisture across layers – the basic quantities observed by satellite sounders. Finally, the intrusion of sinking dry air aloft, which is necessary to create both convective instability and an inhibiting "cap," occurs through adiabatic transport. Not only is this process extremely well represented as simple flow along, rather than through, the sloping isentropic surfaces, but the required upper-level dryness is also one of the best observations made by GOES-R. The combination of all of these factors will improve the utility of products from the current NearCast system.

A new graduate student is focusing on this effort. To date, the conversion of the input GOES data from isobaric to isentropic coordinates is nearing completion and the interpolation of the initial wind and geopotential (in this case Montgomery stream function) fields from constant pressure surfaces is underway. Once these tasks are completed, modification of the model will be straightforward and parallel testing will begin.

It should be noted, that at the request of EUMETSAT, WMO and CGMS, a transportable version of the NearCasting model is also be constructed for use over eastern Europe, South Africa and eastern-equatorial Africa. Results from this version of the model using SEVIRI data are planned to be assessed during 2013 at the European Severe Storms Laboratory. These tests will also serve as an advanced Risk Reduction for data from the future GOES-R ABI instrument.

NearCast Model Validation

Previous support from the GOES-R Risk Reduction Program has allowed the NearCasting system to reach sufficient maturity to be tested at several of the GOES Proving Grounds sites. Initially, tests are planned for NCEP's Storm Prediction Center (SPC) and Aviation Weather Center (AWC), but it is also anticipated that tests will also occur at the Hydrological Prediction Center (HPC) and Ocean Prediction Center (OPC) in the next several years. Validations at each of the Centers will likely use a variety of different parameters, e.g., SPC will need to focus on Convective Instability while HPC may be more interested the structure and timing of small-scale moisture plumes. Since one of the primary goals on the NearCasting products is to improve forecaster awareness of areas where isolated summer convection may and may not occur, it is

important that quantitative similar validations be available to assess the performance and utility of the NearCasts as well.

In order to support these activities and provide users with information about the accuracy and utility of the NearCast tools for a variety of different weather events, a number of methodologies have begun to be developed under a single larger effort. In addition to supporting the Bias removal efforts described above, the validation results will also be used to update training materials so that forecasters can better understand the situations when the NearCasts are more (or less) useful to their individual forecast problems.

Candidate validation sets will include both observed data from a variety of sources and gridded data sets, ranging from conventional NWP analyses to NCEP's 3-hourly precipitation grids to gridded national radar products. When possible, the comparisons should consider both a) full values (including separating systematic biases and random errors) and b) parameter tendencies (which reduce the influences of stationary biases) – especially prior to isolated convection Unlike NWP fields, which are available in all areas above ground, special consideration also needs to be given to identify situations where the lack of IR satellite observations caused the NearCasts to be unavailable. Phenomenon specific validation will be explored using a variety of resources not typically used in verifying NWP products, including some developed at CIMSS under other GOES-R projects. For example, we will attempt to verify cases of rapid convection development against sequences of satellite (and possibly radar) images using tools developed to detect Convective Initiation. Based on the overall validation results, training materials will be updated to provide forecasters a better understanding of the situations in which the NearCast products are more (or less) useful to their individual forecast problems of the day. This effort was initially planned to be the focus of a second graduate student beginning in late 2012. However, due to budget constraints, the effort is being re-scoped and preformed as a part-time activity by an existing CIMSS research support scientist.

Publications and Conference Reports

Petersen, R. A., R. Aune, T. Rink, 2010: Objective short-range forecasts of the pre-convective environment using SEVIRI data, EUMETSAT Conference, Cordoba, Spain

Petersen, R. A., R. Aune, T. Rink, 2011: Enhancing objective short-range forecasts of the pre-convective environment using SEVIRI data, EUMETSAT Conference, Oslo, Norway

14.8 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

CIMSS Research Themes
- Satellite Meteorology Research and Applications

Proposed Work

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 previous work to report and 2012 proposed activities described below will reflect only those to be performed by CIMSS.

Summary of Accomplishments and Findings

In year 1 of this effort, the CIMSS team began work on Mesoscale Atmospheric Motion Vectors (AMVs) derived from simulated GOES-R ABI data, in order to provide information on the mesoscale wind field for the CI scheme. The added value of the simulated AMVs in locating low-level moisture convergence, upper-level divergence, and identifying jet streaks will be explored in the context of pre-convective environments.

We began the ABI-simulated meso-AMV product development using a pre-convective environment simulation performed by CIMSS using the National Center for Supercomputing

Applications (NCSA) facility at the University of Illinois at Urbana-Champaign. Simulated atmospheric fields were generated using version 2.2 of the WRF model (ARW core). The simulation was initialized at 00 UTC on 04 June 2005 with 1° GFS data and then run for 30 hours using a triple-nested domain configuration. The outermost domain covers the entire area with 6-km horizontal resolution while the inner domains cover the CONUS and MESO regions with 2-km and 0.667-km horizontal resolution, respectively. Images exist every 30 minutes during the 30-hour period. For a nested 6-hour period, 5-minute imagery exists (commensurate with the expected GOES-R CONUS scanning frequency), which we exploit for our study here.

The currently available meso-AMV processing routines and settings were adapted to the GOES-R AMV processing algorithm. AMV fields and some limited diagnostics were produced for the case study above (i.e., fields of convergence, divergence, vorticity) that will be combined and integrated with analyses produced by the co-investigators toward the ultimate goal of creating an objective system for predicting CI.

Employing the AMV data sets derived in the first case study above, we will work with our cooperating partners at NSSL to merge the winds with vectors produced from radars into an integrated product. From this data set, new diagnostics will be produced and analyzed. Our evaluation will include the potential for this combined data set to produce parameters that can be important inputs to the ultimate CI prediction scheme.

To demonstrate real-time feasibility of the GOES-R mesoscale wind product and its potential applications to the CI problem, we plan to produce AMV data sets from WRF model output images in near real time during the 2012 severe storm season. After the season, the resulting data sets and diagnostics will be used in combined analyses with the other collaborators to evaluate the potential scheme as a CI predictor, per the overarching goal of this study.

Publications and Conference Reports
Mecikalski, J., D. T. Lindsey, C. S. Velden, B. L. Vant-Hull, and R. M. Rabin, 2012: Convective Storm Forecasting 1-6 Hours Prior to Initiation. AMS Eighth Annual Symposium on Future Operational Environmental Satellite Systems, New Orleans, LA.

14.9 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: Lee Cronce
NOAA Collaborator: Steve Weiss, Fuzhong Weng, Jack Kain, and David 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

Proposed Work
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 HWT Spring Experiment. Since the ensemble forecasts employ different parameterization schemes, an evaluation of the radiative transfer models, microphysics 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

During Year 1 of this project, the Successive Order of Interaction (SOI; Heidinger et al., 2006) forward radiative transfer model was installed on the 'athena' and 'kraken' supercomputers at the National Institute for Computational Sciences (NICS) at the University of Tennessee. A program that computes the effective particle diameters for each hydrometeor species predicted by a given cloud microphysical parameterization scheme was updated to account for the inclusion of new parameterization schemes in recent versions of the WRF model. These modifications will allow us to produce simulated satellite imagery for most of the CAPS ensemble members during the 2012 HWT Spring Experiment. Shell scripts were also written to efficiently process WRF model output from multiple model output times and ensemble members. Initial tests were performed on the 'athena' supercomputer during the 2011 HWT; however, since it was de-commissioned last year, the processing system was reinstalled on 'kraken' during March 2012. The processing system will be used to generate synthetic GOES-R, GOES-13, and GOES-15 imagery during the 2012 HWT Spring Experiment.

Figure 14.9.1 shows a representative example of the simulated ABI imagery generated using model output from four of the CAPS ensemble member forecasts of the devastating tornado outbreak that occurred across the southeastern U.S on 27 April 2011. The influence of the different cloud microphysical, planetary boundary layer, and radiation parameterization schemes in the WRF model is shown by the different forecast depictions of the severe weather event. The ability to generate simulated satellite observations and ensemble derived products during the 2012 HWT will be very beneficial to the HWT participants and to the GOES-R Proving Ground project.

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

Heidinger, A. K., C. O'Dell, R. Bennartz, and T. Greenwald, 2006: The successive-order-of-interaction radiative transfer model. Part I: Model development . *J. Appl. Meteor. Clim.,* **45**, 1388-1402.
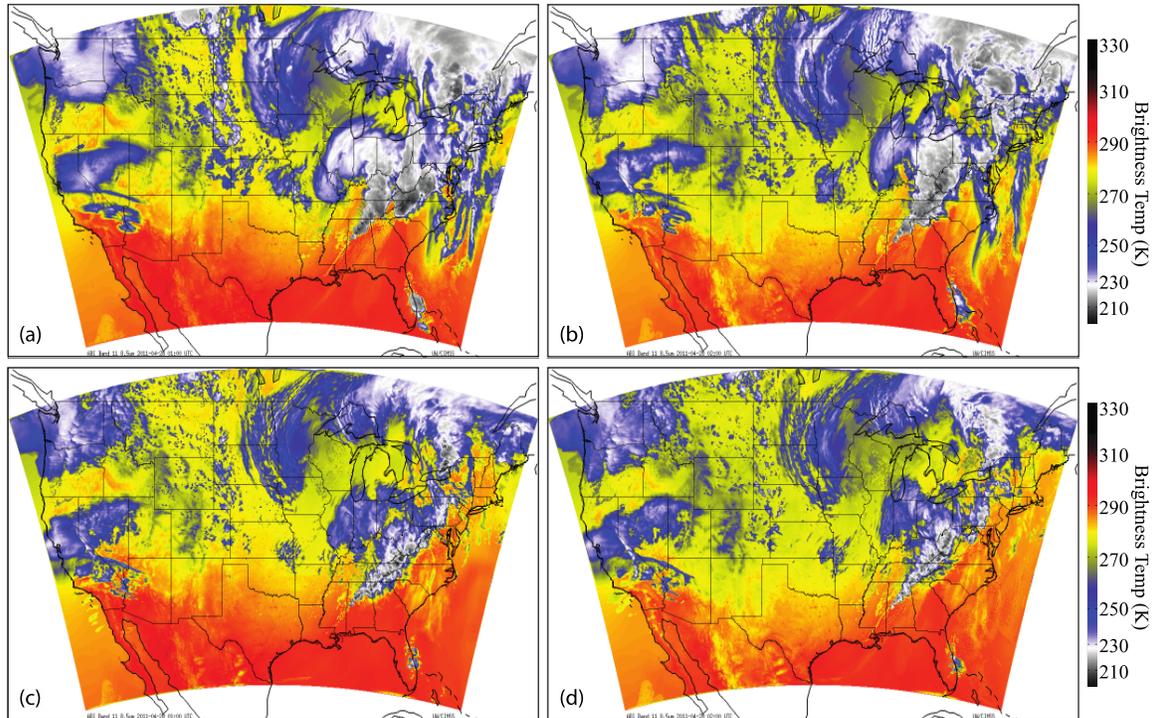
Figure 14.9.1. Simulated ABI 8.5 μm brightness temperatures (K) valid at 0100 UTC on 28 April 2011 for four of the CAPS ensemble members.

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

CIMSS Task Leaders: Margaret Mooney and Steve Ackerman
NOAA Collaborators: Nina Jackson and Tim Schmit
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

Proposed Work

The need for teacher training around the topic of satellite meteorology is stronger than ever as we approach the 2015 GOES-R launch. To address this need, CIMSS plans significant updates to the "Satellite Meteorology for Grades 7-12" CD and on-line resource which includes incorporating user feedback to existing content and developing case studies based on recent large-scale environmental events. Upon completion of these revisions and additions, CIMSS will promote and distribute the revised resource at annual meetings of the American Meteorological Society (AMS), summer meetings of the Federation of Earth Science Information Partners (ESIP) and future Satellite Educators Conferences.

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

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
Previously existing content in the Satellite Meteorology for Grades 7-12 on-line course underwent a complete makeover in 2011 to create a modernized and visually appealing interface. (http://cimss.ssec.wisc.edu/satmet/) Content updates included the addition of the 2005 Hurricane Season and user feedback. Other updates underway include a case study on the 2010 Gulf Oil Slick which is being developed to provide comparisons to current GOES platforms (what we were able to see) and glimpses into future GOES-R capacities (what we will be able to see) and links to NOAA's restoration efforts. (www.gulfspillrestroration.noaa.gov)

Still pending but in development are content revisions to include information about the Suomi NPP satellite and a module dedicated to GOES-R. All revisions and updates will be completed prior to the Satellite Educators conference scheduled for August 2012 where we also plan to begin teacher recruitment for the CIMSS Education Proving Ground.

Publications and Conference Reports
NPP Educator Launch Conference presentation, Oct 2011, Vandenberg Air Force Base, CA.

References
Margaret Mooney, and S. A. Ackerman, 2006: Satellite meteorology resources for K-16 educators and students, 15th Symposium on Education, Atlanta, GA, Jan 30-Feb 2.

Mooney, M., S. A. Ackerman, T. H. Achtor, and J. Brunner, 2005: Satellite meteorology for middle and high school students and teachers. 14th Symposium on Education at 85th AMS Annual Meeting San Diego, CA, 10 Jan – 13 Jan.

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, pp. Paper 1.10.

Figure 14.10.1. http://cimss.ssec.wisc.edu/satmet/

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

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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
- Environmental Models and Data Assimilation

Proposed Work

Improving TC intensity forecasts is one of the most important goals of tropical cyclone (TC) research. However, TC structure change is another challenging aspect of TC forecasting that deserves further examination in remote sensing research as structural changes related directly to the area of damaging winds and the extent of the storm surge associated with a TC landfall. The products of GOES-R offer significant potential in the diagnosis of important TC features related to structural evolution.

To add to GOES-R TC structure algorithms, we propose to continue a multi-institutional project consisting of NOAA and UW-Madison/CIMSS collaborators to develop a variety of tools that will improve the diagnosis and forecasting of TC structure change. The NOAA Project Leads and NOAA collaborators will continue to carry out tasks incorporating GOES-R advanced baseline imagery (ABI) and GOES lightning mapper (GLM) proxy data sets, including developing algorithms to improve estimates of TC location, determine TC size and radius of maximum winds, and better understand the role of total precipitable water on TC size. The CIMSS project component employs proxy ABI data to improve the diagnosis of TC structural changes. The project groups will work together on developing statistical-dynamical models that incorporate many of the new structure-related ABI and GLM forecast products developed here.

Summary of Accomplishments and Findings

A high-resolution simulation of a TC was run with the Weather and Research Forecast (WRF) model to study the impacts on the TC vortex structure to the location and strength of latent heating. Analysis of this data set confirms diabatic heating associated with rainband activity converges angular momentum outside of the TC inner-core and leads to the growth and strengthening of the wind field there. Future rainband activity/diabatic heating is also found to be increasingly efficient at increasing the outer wind field as it grows (Rozoff et al., 2012).

A successive order of interaction forward radiative model (Heidinger et al., 2006) available at CIMSS is being used to obtain synthetic ABI radiances. These synthetic radiances are dependent upon WRF's microphysics. In the Task Leader's previous experience with WRF-derived ABI data, there was some question as to how realistically the WRF model handled dense overlying cirrus clouds. A previous WRF simulation lacking thick, overlying cirrus may have artificially enhanced bi-spectral techniques for the detection of secondary eyewalls. As such, sensitivity tests are being carried out with the idealized WRF simulation to determine the impact of WRF's various microphysical schemes and the vertical resolution on upper-level clouds associated with the TC's outflow layer to examine the impact on synthetic multi-channel ABI products. Sensitivity tests will also be carried out on the radiative transfer model itself to quantify its impact on various multi-channel ABI products. These sensitivity tests are being carried out for relatively short time integrations for reasonable use of computational resources.

Multi-channel products developed from synthetic ABI proxy data sets are being explored to improve the depiction of latent heating structures related to structural evolution. So far, we have used the multi-layered cloud diagnostics (e.g., Pavolonis and Heidinger 2004; Naud et al., 2007) in diagnosing cloud types associated with TC structure change.

We have applied the multi-layered cloud algorithm to MSG-SEVIRI imagery of Atlantic Hurricane Julia (2010), a classic Cape Verde hurricane that experienced rapid intensification, an eyewall replacement cycle, and reached a maximum intensity of 120 kt (Category 4). The scenes associated with Julia contained clear skies, liquid water clouds, supercooled liquid water clouds, mixed cloud types, "overlap" clouds, cirrus clouds, and thick ice clouds. Thick ice clouds, as

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expected, were dominant over the inner-core of the storm, obscuring internal precipitation structure, and were most active in the region prior to the maximum lifetime intensity of Julia. The other cloud types were more commonly seen in the outer rainbands. The most obvious result of this case study is that thick ice clouds near the inner core precede maximum lifetime intensity (Fig. 14.11.1) while outer rainband, thick ice clouds are most active around the time of maximum intensity, precluding the expansion of the wind field. SHIPS developmental data set (DeMaria et al., 2005) predictors based more on the inner 300-km of the storm appear consistent with the vigor of thick ice clouds within 300-km here. Because thick ice clouds obscure many other species of clouds (e.g., liquid water, supercooled water clouds), there is often an inverse relationship between thick ice clouds and other cloud species. However, overlap clouds lag thick ice clouds (Figure 14.11.1a vs. Figure 14.11.1b). Part of this lagged relationship relates to the weakening and thinning of thick ice clouds. More subtle details about the temporal and spatial relationships of different cloud species continues for this case study.

(a)   **(b)**
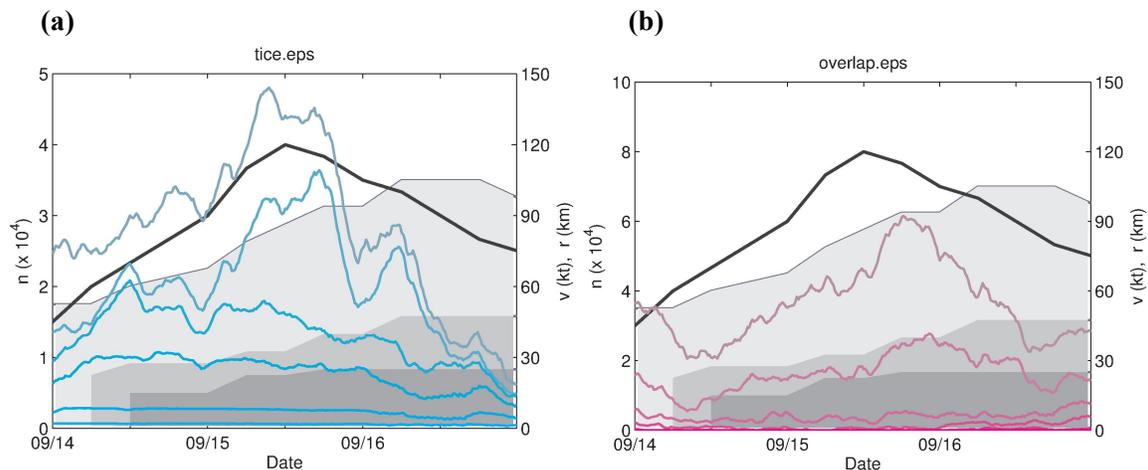
Figure 14.11.1. Julia's (2010) intensity (kt) (black) (from best track data), the radius (km) of 34-kt (light gray shading), 50-kt (medium gray), and 64-kt (dark gray shading) winds (from ATCF data), along with (a) the number of MSG-SEVIRI-based thick ice pixels within 50, 100, 200, 300, 500, and 1000 km of center (bright to dull blue), (b) the number of MSG-SEVIRI-based overlap cloud type pixels within 50, 100, 200, 300, 500, and 1000 km of center (bright to dull magenta).

We will continue to test new IR-based predictors developed from proxy ABI data and the climatological infrared satellite imagery from the hurricane satellite (HURSAT) data set (Knapp and Kossin 2007; Kossin et al., 2007a,b) to develop statistical algorithms for the prediction of TC structure change. So far, case studies with observational data and from full-physics modeling simulations suggest satellite-based predictors that account for the distribution and intensity of outer rainband activity offer the most promising upgrade from existing SHIPS developmental data set IR-based predictors that focus more on the inner core. These new predictors will be used to develop statistical models for the prediction of structure change. In particular, we will incorporate logistic regression and Bayesian models (e.g., Rozoff and Kossin 2011) for this effort.

Publications and Conference Reports
Rozoff, C. M., D. S. Nolan, J. P. Kossin, F. Zhang, and J. Fang, 2012: The roles of an expanding wind field and inertial stability in tropical cyclone secondary eyewall formation. *J. Atmos. Sci.*, accepted with revisions.

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Knapp, D. R., and J. P. Kossin, 2007: A new global tropical cyclone data set from ISCCP B1 geostationary satellite observations. *J. Appl. Remote Sensing*, **1**, 013505, doi:10.1117/12.731296.

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Pavolonis, M. J., and A. K. Heidinger, 2004: Daytime cloud overlap detection from AVHRR and VIIRS. *J. Appl. Meteor.*, **43**, 762-778.

Rozoff, C. M., and J. P. Kossin, 2011: New probabilistic forecast models for the prediction of tropical cyclone rapid intensification. *Wea. Forecasting*, **26**, 677-689.

14.12 A Blended, Multi-Platform Tropical Cyclone Rapid Intensification Index

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NOAA Collaborators: James P. Kossin (NCDC/CIMSS), John Kaplan (NOAA/HRD)
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
- Environmental Models and Data Assimilation

Proposed Work
The physical processes accompanying rapid intensification (RI, defined as an increase in the analyzed maximum sustained surface winds by at least 25 kt in 24 h) in tropical cyclones (TCs) remain unresolved. Moreover, predicting these events is one of the most challenging aspects of

intensity forecasting. Improving the prediction of RI is a top priority at NOAA's National Hurricane Center (NHC) and Central Pacific Hurricane Center (CPHC).

The GOES-R GLM and ABI, integrated with other observational platforms, have the potential to improve RI prediction through improved detection of important structural features associated with RI. A team consisting of CIMSS, CIRA, NOAA/RAMMB, and NOAA's Hurricane Research Division (HRD) has been working together for the past 2 years to develop improved forecasting tools that will incorporate GLM and ABI data. The focus at CIMSS has centered on developing predictive features found in passive microwave imagery (MI) captured aboard low-Earth-orbiting satellites. These predictors will be used in empirical forecast algorithms for RI.

Probabilistic RI schemes incorporating environmental data and GOES-IR imagery have improved RI prediction (Kaplan et al., 2010; Rozoff and Kossin 2011). Environmental data, such as a TC's potential intensity, ocean heat content, and vertical wind shear, represent some of the kinds of variables found in empirical forecast schemes for RI as these features describe whether the necessary background conditions for RI exist. GOES-IR-based predictors also describe aspects of the environment such as vertical wind shear and upper-level divergence, but are particularly useful in depicting certain cloud structures relevant to RI. It is generally believed that RI is strongly tied to the organization of and relationships between precipitation and the kinematic structure of a TC. It is therefore not surprising that GOES-IR imagery adds forecast skill to empirical RI prediction. A primary shortcoming of IR imagery is that it often cannot discern the organization of inner-core TC precipitation due to the fact that upper-level cirrus clouds obscure the detection of such internal structure. Although MI has lower temporal coverage in comparison to IR imagery, MI can more readily resolve precipitation patterns underneath the cirrus canopy. Therefore, the use of MI in RI prediction is believed to be quite advantageous.

Summary of Accomplishments and Findings

We have tested select MI-based predictors to enhance SHIPS-RII (Kaplan et al., 2010), the Bayesian model, and the logistic regression model (Rozoff and Kossin 2011). In the following, we focus on results from the logistic regression model.

The RI models use optimal environmental and GOES-IR-based predictors from the SHIPS developmental data set (DeMaria et al., 2005). The SHIPS-based predictors for the logistic regression model are identical to those described in Rozoff and Kossin (2011). A new developmental data set of MI brightness temperatures (T_b) at 18.7-19.4, 36.5-37.0, and 85.5-89.0 GHz from SSM/I, TRMM TMI, AMSR-E, and WINDSAT was assembled for our experiments. Currently, the MI development sample of storms covers the Atlantic and Eastern Pacific basins spanning the period of 1998-2008. Data from 2009-2011 will be added soon.

To create predictors from satellites measuring slightly different microwave frequencies from one another, an empirical histogram matching technique similar to Jones and Cecil (2006) was applied to AMSR-E and WINDSAT T_b to ensure they have similar cumulative distribution functions to TMI and SSM/I T_b. Once this procedure was carried out, simple MI predictors were defined such as the minimum, average, and maximum values for the vertically (V pol) and horizontally polarized (H pol) T_b in regions depicting the eye, eyewall, and general inner- and outer-cores. All center fixes and eyewall/eye identifications were based on the objective technique of Wimmers and Velden (2010). Optimal predictors were found for each RI threshold in the Atlantic and Eastern Pacific. As an example, Table 14.12.1 shows the optimal, statistically independent MI-based predictors for the logistic scheme in the North Atlantic for an RI threshold of 35 kt per 24 h. In addition, it shows the mean values of the predictors for the RI and non-RI

samples. In testing the microwave predictors in the RI models, which was done at the synoptic times of 00, 06, 12, and 18 UTC, the most recent imagery was only used if it is less than 6-h old.

Table 14.12.1. Microwave-determined features applied to the logistic model in the North Atlantic for an RI threshold of 35 kt per 24 h. Also, the mean values of each predictor in the RI and non-RI samples are shown. Their differences are statistically significant.

Feature Description	RI mean	Non-RI mean
19.4-GHz ave. T_b (V pol) (r = 100-300 km)	215.0 K	198.1 K
19.4-GHz min. eye T_b (V pol)	231.2 K	208.7 K
19.4-GHz ave. ring T_b (H pol)	230.1 K	226.4 K
37.0-GHz radius of max. T_b (H pol)	73.9 km	88.3 km
37.0-GHz ave. T_b (V pol) (r = 0 -100 km)	256.2 K	246.2 K

The Brier skill score (BSS) for the logistic regression model based on leave-one-year-out cross-validation is shown in Figure 14.12.1. The BSS values show the impact of adding MI predictors to the logistic scheme for both the Atlantic and East Pacific Ocean basins. The BSS values are higher with the inclusion of MI-based predictors for all RI and intensity thresholds. The promising results of this project have led to a NOAA Joint Hurricane Testbed grant, in which all three RI models are being tested with the addition of the MI predictors in real-time for operational evaluation.
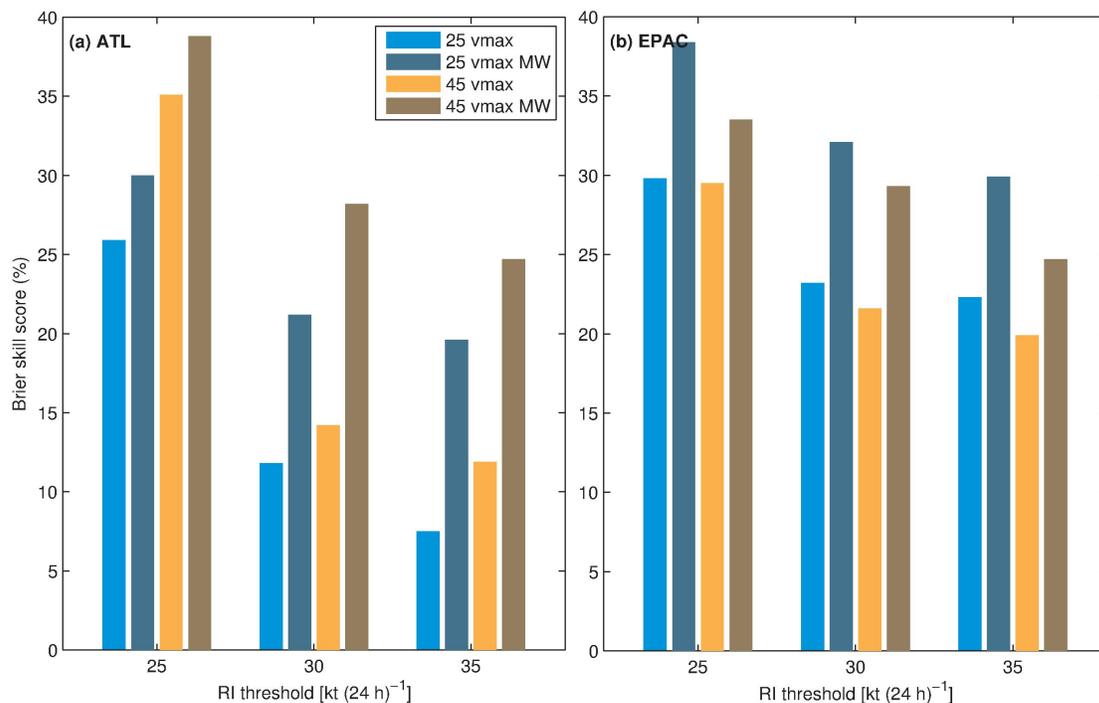
Figure 14.12.1. Comparative Brier skill scores (BSS) for TCs tested in the (a) Atlantic Ocean and (b) East Pacific Ocean, for RI thresholds of 25, 30, and 35 kt (24 h)$^{-1}$ for the logistic RI scheme using no MI predictors [light blue for all TCs (N = 1360 and 1120 for the ATL and EPAC, respectively); orange for TCs with v_{max} of at least 45 kt (N = 1013 and 733 for the ATL and EPAC, respectively)] and including MI predictors (dark blue for all TCs; brown for TCs with v_{max} of at least 45 kt).

Publications and Conference Reports

Velden, C. S., C. Rozoff, A. Wimmers, M. Sitkowski, M. E. Kieper, J. Kossin, J. Hawkins, and J. Knaff, 2010: An objective method to predict near real time rapid intensification of tropical cyclones using satellite passive microwave observations. 29th Conference on Hurricanes and Tropical Meteorology, Tucson, AZ, May 10-14.

Rozoff, C. M., J. Kossin, C. Velden, A. Wimmers, M. Kieper, J. Kaplan, J. Knaff, and M. DeMaria, 2011: Improvements in the statistical prediction of tropical cyclone rapid intensification. 65th Interdepartmental Hurricane Conference, Miami, FL, Feb. 28-Mar. 3.

Rozoff, C. M., C. S. Velden, J. Kaplan, A. Wimmers, and J. P. Kossin, 2012: Improvements in the probabilistic prediction of tropical cyclone rapid intensification resulting from inclusion of satellite passive microwave observations. 66th Interdepartmental Hurricane Conference, Charleston, SC, Mar. 5-Mar. 8.

Rozoff, C. M., C. S. Velden, J. Kaplan, A. Wimmers, and J. P. Kossin, 2012: Improvements in the probabilistic prediction of tropical cyclone rapid intensification resulting from inclusion of satellite passive microwave observations. 30th Conference on Hurricanes and Tropical Meteorology, Ponte Vedra Beach, FL, April 15-20.

Rozoff, C. M., C. S. Velden, J. Kaplan, A. Wimmers, J. P. Kossin, and M. Kieper, 2012: Improvements in the probabilistic prediction of tropical cyclone rapid intensification resulting from inclusion of satellite passive microwave observations. *Wea. Forecasting*, in preparation.

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Kaplan, J., M. DeMaria, and J. A. Knaff, 2010: A revised tropical cyclone rapid intensification index for the Atlantic and Eastern North Pacific basins. *Wea. Forecasting*, **25**, 220-241.

Rozoff, C. M., and J. P. Kossin, 2011: New probabilistic forecast schemes for the prediction of tropical cyclone rapid intensification. *Wea. Forecasting*, **26**, 677-689.

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

14.13 Combined Geo/Leo High Latitude Atmospheric Motion Vectors

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CIMSS Support Scientists: Brett Hoover, Rich Dworak, Nick Bearson
NOAA Collaborator: Jeff Key
NOAA Long Term Goals
- Weather-Ready Nation

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

- Provide critical support for the NOAA mission

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

Proposed Work

The spatial coverage of satellite-derived Atmospheric Motion Vectors (AMV) is generally equatorward of 60° latitude for geostationary satellites and poleward of 70° latitude for the polar satellites. This results in a 10-degree gap in coverage (Figure 14.13.1), which has been noted as a problem by numerical weather prediction (NWP) centers (Riishojgaard 2005). Specifically, the dynamically active polar jet stream can be located in this latitudinal zone and improper model initialization can lead to rapidly growing errors in the forecasts. Other research has also shown that the addition of the polar winds can be especially important in the active polar jet stream region (Dworak and Key 2009, Santek 2010). Therefore, developing novel ways to fill this AMV-void gap is the next logical step toward providing complete wind coverage for the NWP applications.
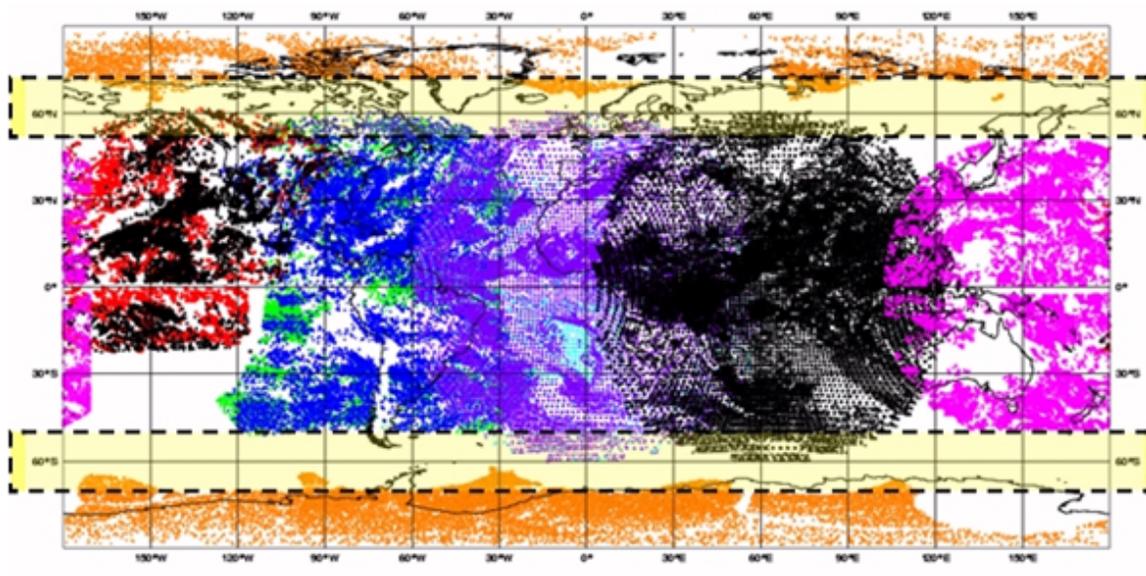
Figure 14.13.1. Daily satellite-derived AMV coverage from polar (orange) and geostationary (other colors) satellites. The yellow-filled rectangles denote the approximate gap in coverage.

By drawing on the extensive experience of the proposing team in generating AMVs from geostationary Earth orbit (GEO)/low earth orbit (LEO) satellites and developing innovative techniques in blending satellite data to create composite imagery, we propose to explore the prospect of generating AMVs in the geographic gap from 60° to 70° N/S latitudes. This effort will require an advanced image compositing technique designed to blend the data from a variety of satellites with differences in calibration, viewing geometry, and temporal offsets. The resulting images would be composites of the GEO (including GOES) and LEO satellites (NOAA-15 through NOAA-19 and Metop-A, along with NASA's Terra and Aqua). Upon the successful development and demonstration of our proposed new blended product, we will have addressed a request by NWP centers to fill the remaining AMV gap, and achieved a true global coverage.

Summary of Accomplishments and Findings

Four major areas were addressed over the past year:

1. Fine tuning the algorithm,
2. Running case studies to determine the forecast impact of the Leo/Geo winds,
3. Continuing the real-time production of the product for use by the Numerical Weather Prediction (NWP) community, and
4. Investigating the use of the product in GOES-R Proving Ground activities.

Algorithm Tuning

Several changes were made to the algorithm to improve the product:

a) Moderate Resolution Imaging Spectroradiometer (MODIS) images from Terra and Aqua were added;
b) Meteosat-7 and FY-2E data were removed due to poor navigation in high latitudes. Removing these winds was resulting in very few winds over Asia and similar longitudes in the southern hemisphere; and
c) The time interval between images was increased from 30 minutes to 45 minutes. Since the composites are made of images ±15 minutes of a nominal time, there were cases when the feature being tracked were separated in time by only a few minutes.

Forecast Case Studies

A twelve-week summer experiment was run using the National Centers for Environmental Prediction (NCEP) Global Data Assimilation/Global Forecast System (GDAS/GFS) to determine the forecast impact of the Leo/Geo winds. Figure 14.13.2 shows the average 500 hPa heights Anomaly Correlation Coefficient (ACC) for the control (blue) and the experiment containing the Leo/Geo winds (red) for the southern hemisphere. A positive impact is evident from the Day 5 forecast and outward. A similar analysis for the northern hemisphere resulted in a neutral impact.

Further investigation of this first experiment found that the Leo/Geo winds had the most impact in the forecast for cases where the high-speed jet stream was captured by the Leo/Geo winds, at approximately 60 deg. latitude. During the northern 2011 summer season, the jet was primarily south of 60N in the northern hemisphere (where there was a neutral forecast impact), while in the southern hemisphere the jet was centered on 60S (where a positive impact was noted).

Brett Hoover presented these results at the Eleventh International Winds Workshop. Efforts are underway to evaluate a companion wintertime case.

Use by NWP Centers

Beginning in November 2010, we have been providing the Leo/Geo winds product to Nancy Baker (NRL) and Randy Pauley (FNMOC) for inclusion into the US Navy numerical modeling system. Assimilation impacts in the NRL Atmospheric Variational Data Assimilation System Accelerated Representer (NAVDAS-AR) show a positive impact, similar to that of the MODIS polar winds. Additionally, they have commented that receipt of the product has been timely and reliable.

The United Kingdom Met Office is retrieving the winds and have provided monitoring statistics and graphs on their Web site (James Cotton, personal communication):
http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/12_03/density_polar.html
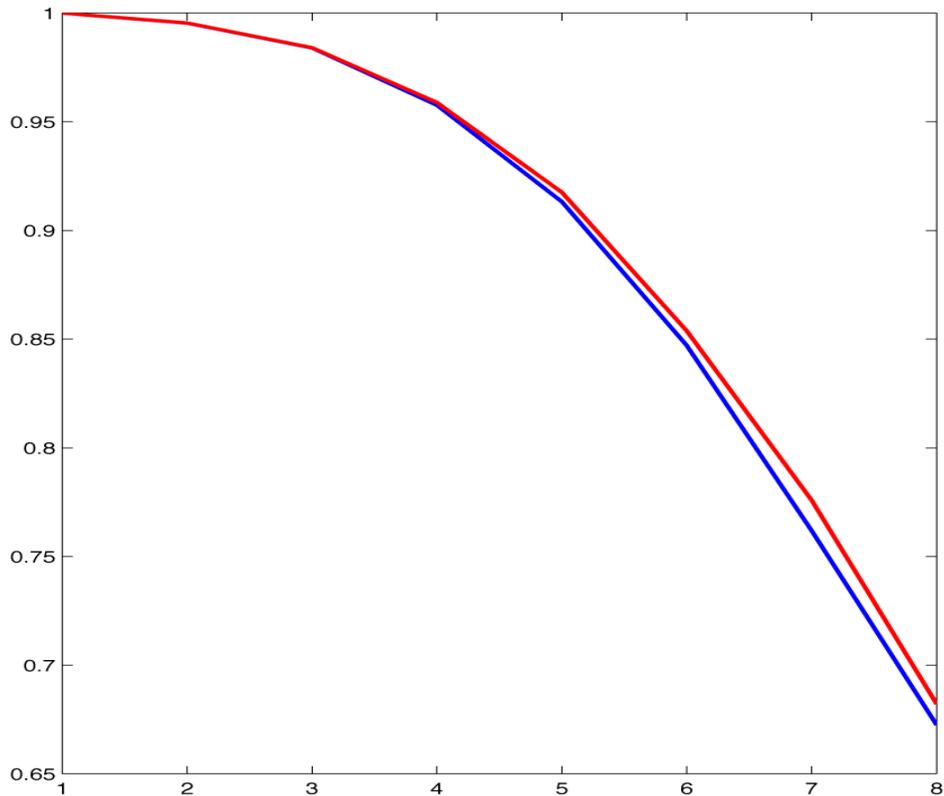
Figure 14.13.2. The Anomaly Correlation Coefficient (ACC) vs. forecast day for the 500 hPa heights in the southern hemisphere for the control (blue) and experiment (red). This is an average over 12 weeks: 02 May 2011 – 24 July 2011.

The National Center for Atmospheric Research (NCAR) Antarctic Mesoscale Prediction System (AMPS) has used Leo/Geo winds since August 2011; however, they have not measured the impact of the winds in their system (Jim Bresch, personal communication).

GOES-R Proving Ground
The Leo/Geo winds are routinely generated in near real-time at CIMSS and it is expected that they will be of benefit for forecasters and other logical needs in higher latitudes. Therefore, we are pursuing their use at GOES-R Proving Ground locations.

Publications and Conference Reports
Hoover, B., D. Santek, M. Lazzara, R. Dworak, J. Key, C. Velden, N. Bearson, 2012. High Latitude Satellite-Derived Winds From Combined Geostationary and Polar Orbiting Satellite Data. Proc. of the Eleventh International Winds Workshop, Auckland, NZ, 20-24 February 2012.

Lazzara, M., R. Dworak, N. Bearson, D. Santek, C. Velden, and J. Key, 2011: Polar Satellite Composite Atmospheric Motion Vectors. 6th Antarctic Meteorological Observing, Modeling, and Forecasting Workshop, Hobart, Tasmania, Australia, 22-24 June 2011.

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

Riishojgaard, L. P. 2005. High-latitude winds from Molniya orbit. Proc. of the Third International Workshop on the Analysis of Multi-temporal Remote Sensing Images. Biloxi, MS, 16-18 May 2005.

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

14.14 Travel Grant: Generating Simulated ABI imagery for the CAPS Ensemble During the NOAA Hazardous Weather Testbed Spring Experiment

CIMSS Task Leader: Jason Otkin
NOAA Collaborator: Steve Weiss
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

Proposed Work
The primary goal of this project was to implement an automated processing system to generate synthetic GOES-R Advanced Baseline Imager (ABI) brightness temperatures using numerical model output from a high-resolution ensemble run each day during the Hazardous Weather Testbed (HWT) Spring Experiment (Clark et al., 2012) by the Center for the Analysis and Prediction of Storms (CAPS). This work was used to support current and future GOES-R Proving Ground and GOES-R Risk Reduction activities.

Summary of Accomplishments and Findings
A one-week visit was made to CAPS and to the Storm Prediction Center during the 2011 HWT Spring Experiment. During 2011, the CAPS Weather Research and Forecasting (WRF) model ensemble was run each day on the 'athena' supercomputer located at the National Institute for Computational Sciences at the University of Tennessee. Several tasks were completed during my visit. First, the Successive Order of Interaction (SOI; Heidinger et al., 2006) forward radiative transfer model that is used to generate synthetic brightness temperatures was installed on 'athena'. Second, a program that computes the effective particle diameters for each hydrometeor species predicted by a given microphysics parameterization scheme was updated and modified so that simulated satellite observations can be produced for most of the CAPS ensemble members. Third, shell scripts were written to efficiently post-process the WRF model output and to generate synthetic brightness temperatures for multiple model output times and ensemble members with no user interaction. Last, the forward model implementation and associated scripts were tested on a subset of the CAPS ensemble forecasts that were run during the devastating tornado outbreak that occurred across the southeastern U.S. on 27 April 2011.

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

Heidinger, A. K., C. O'Dell, R. Bennartz, and T. Greenwald, 2006: The successive-order-of-interaction radiative transfer model. Part I: Model development . *J. Appl. Meteor. Clim.,* **45**, 1388-1402.

14.15 Travel Grant: Development of Geostationary Satellite Products for Observing Tropical Cyclone Intensity Change and Saharan Dust Storms

CIMSS Task Leader: Chris Velden
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

Proposed Work
For this task we proposed to provide a travel grant for Jason Dunion to visit CIMSS and collaborate with CIMSS scientists from 19-22 March 2012. The main objectives of this visit were to:
1. Implement an improved real-time Web page on the CIMSS tropical cyclone site to monitor tropical cyclone diurnal pulsing in the North Atlantic basin; and
2. Set up real-time Saharan Air Layer and Pseudo Natural Color McIDAS AREA files on servers at CIMSS to facilitate the implementation of this imagery for the GOES-R Proving Ground demonstration at the National Hurricane Center.

Summary of Accomplishments and Findings
The first objective of this visit was to implement an automated Web page on the CIMSS tropical cyclone site that will facilitate real-time monitoring of tropical cyclone diurnal pulsing using GOES-East infrared imagery. Discussion of this phenomenon and the GOES satellite imagery/algorithms developed to track it were included in the first trip report provided to the GOES-R PG (November 2011). An example of the new experimental Web page that was designed on this most recent trip is shown in Figure 14.15.1. The TC Diurnal Pulsing page will use tropical cyclone center positions being tracked by the CIMSS Advanced Dvorak Technique, real-time GOES imagery, and statistical calculations of the changes in a storm's brightness temperature field over time to continuously track the progression of diurnal pulses. These pulses appear to initiate in the storm's inner core each evening (at sunset) and progress to peripheral radii (e.g., as far as 400-600 km from the center) during the evening and following morning/afternoon. We expect this Web page to be fully operational before the start of the 2012 Atlantic hurricane season.

The second main objective of this visit was to set up real-time Saharan Air Layer and Pseudo Natural Color McIDAS AREA files on servers at CIMSS. This effort will help facilitate the implementation of this imagery being developed under the GOES-R Proving Ground demonstration at the National Hurricane Center. Feedback from NHC forecasters participating in the 2011 GOES-R PG demo included a specific request that the SAL and Pseudo Natural Color imagery be integrated into their NAWIPS system. During this most recent trip, Dunion worked with scientists at CIMSS to address this feedback request. Scripts were developed that will run this real-time imagery on servers at CIMSS and McIDAS ADDE groups were also set up on

CIMSS servers so that the NASA Short-term Prediction Research and Transition Center (SPoRT) can access these files in real-time. Scientists at SPoRT will eventually integrate these McIDAS AREA files into the NAWIPS system at NHC. The goal is to have the capability to visualize the SAL and Pseudo Natural Color imagery on the NHC NAWIPS system in real-time during the 2012 Atlantic hurricane season.

Dunion also presented a seminar for the UW-Madison Department of Atmospheric & Oceanic Sciences colloquium series titled, "*Diurnal Pulsing of Tropical Cyclones: An Overlooked, Yet Fundamental TC Process?*". This second trip by Dunion marks the end of the efforts planned under this proposal.
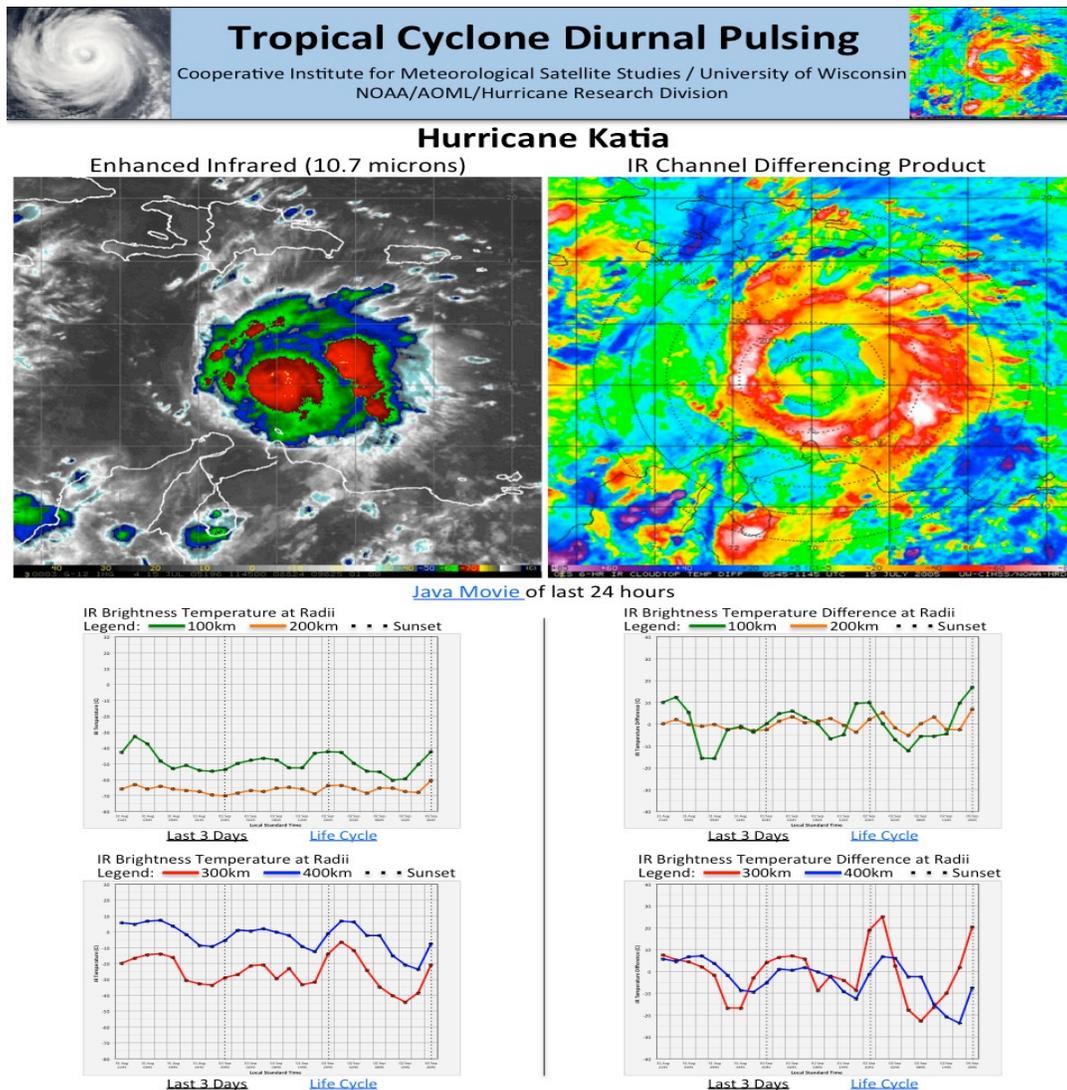
Figure 14.15.1. Experimental real-time tropical cyclone diurnal pulsing Web page being implemented on the CIMSS TC Web site. The tracking of North Atlantic TCs will be automated and will generate a) (top left) enhanced 10.7 micron GOES IR imagery centered over the storm, b) (bottom left) plots showing the 6-hr fluctuations of the mean azimuthal brightness temperatures at select radii (100-600 km) from the storm center, c) (top right) GOES 6-hr infrared brightness temperature difference imagery showing areas of cooling (blues to purples) and

warming (yellows to reds) over time (6-hr) around the storm, and d) (bottom right) plots showing the 6-hr fluctuations of the mean azimuthal brightness temperature differences at select radii (100-600 km) from the storm center.

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

CIMSS Task Leader: Wayne Feltz
CIMSS Support Scientists: Scott Bachmeier, Scott Lindstrom, Lee Cronce, Justin
    Sieglaff
NOAA Collaborators: 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

Proposed Work

This project supports the NOAA GOES-R Proving Ground that tests and validates ideas, technologies and products before they are integrated into operational use. The Proving Ground mission design ensures User Readiness on Day 1 for GOES-R. To this end, UW-CIMSS supported the GOES-R Proving Ground in evaluating the GOES-R Algorithm Working Group demonstration algorithms and baseline products, testing enhancements and advanced products (Risk Reduction), and providing user assessments and feedback to the product developers. The development of the algorithms and associated research and validation are considered to be out of the scope for the Proving Ground part of the program. However, CIMSS scientists developed GOES-R era products from existing measurement systems and simulations. They expanded partnerships with NWS Forecast Offices to provide these products, train forecasters in their applications, and evaluate their utility. This work helpes to ensure that GOES-R products will be available and useful to forecasters soon after launch. In 2011, the primary focus was to test, apply, and improve select GOES-R AWG satellite baseline and future capability imagery/products in support of National Centers and Local NWS offices. The first official version of our simulated ABI WES case, that runs in the current AWIPS, has been released and is ready for distribution. Also, comments that have been received from the beta testers of the ABI WES case have been evaluated and implemented, where appropriate. This WES case contains four separate cases of simulated ABI loops for all 16 of the ABI bands, and sample band differences. Also included is a WES guide containing set-up procedures and key information on each ABI band and some of the new or improved features of ABI that can be used to help forecasters. UW-CIMSS participated in the spring 2011 Hazardous Weather Testbed (HWT) in Norman, Oklahoma at the National Weather Center and a summertime local PG demonstration interaction with Milwaukee, Sullivan (MKX) Weather Forecast Office throughout summer of 2011.

Summary of Accomplishments and Findings

CIMSS participated in a May 2011 Proving Ground review meeting in Colorado and regular GOES-R Proving Ground coordination/reporting teleconferences. UW-CIMSS also participated

in Pacific Region and Alaska region Proving Ground demonstration planning workshops in Juneau, Alaska. Internet Web site access to GOES-R Proving Ground activities was developed and is hosted at: http://cimss.ssec.wisc.edu/goes_r/proving-ground.html.

2011 Hazardous Weather Testbed Participation

UW-CIMSS primarily engaged in demonstrations within the NOAA spring 2011 Hazardous Weather Testbed (HWT) where University of Wisconsin Convective Initiation (UWCI), GOES overshooting-top/enhanced-V (OTTC), and WRF ARW simulated decision support products were made available and NWS end user evaluation accomplished as GOES-R proxy information. UW-CIMSS provided real-time access to University of Wisconsin Convective Initiation (UWCI) and GOES overshooting-top/enhanced-V (OTTC) decision support products via AWIPS and N-AWIPS to the Storm Prediction Center (SPC) as part of the Hazardous Weather Testbed Experimental Warning Program (HWT EWP) Spring 2011 experiment as a proxy for future GOES-R future capability detection capabilities. The UWCI decision support products were provided within the HWT via N-AWIPS gridded format, and the EWP in AWIPS gridded format for the 2011 Spring Experiment.

Based upon forecaster and PG executive board feedback at Storm Prediction Center, UW-CIMSS was tasked to provide products listed in Table 15.1 (PG Operations HWT Plan 2011, http://www.goes-r.gov/users/pg-activities-01.html).

Table 15.1. UW-CIMSS PG Products demonstrated at 2011 HWT.

Demonstrated Product	Category
Cloud and Moisture Imagery	Baseline
Enhanced "V"/Overshooting Top Detection	Future capability
Nearcasting Model	GOES-R Risk Reduction
Convective Initiation (University of Wisconsin)	GIMPAP

Cloud and Moisture Imagery

Simulated cloud and moisture imagery from the Advanced Baseline Imager (ABI) was provided by UW-CIMSS to the SPC for use in the Spring Experiment. This effort provided the GOES-R Proving Ground with direct collaborations within the modeling community, as synthetically produced satellite imagery can provide insight into model performance. UW-CIMSS provided the radiance calculation from NSSL WRF ARW 4-km 00 UTC for each ABI infrared channel involving several steps within the forward modeling system. First, Compact OPTRAN, which is part of the NOAA Community Radiative Transfer Model (CRTM), is used to compute gas optical depths for each model layer from the WRF-simulated temperature and water vapor mixing ratio profiles and climatological ozone data. Ice cloud absorption and scattering properties, such as extinction efficiency, single-scatter albedo, and full scattering phase function, obtained from Baum et al. (2006) are subsequently applied to each frozen hydrometeor species (i.e., ice, snow, and graupel) predicted by the microphysics parameterization scheme. A lookup table based on Lorenz-Mie calculations is used to assign the properties for the cloud water and rain water species.

Simulated GOES-R ABI imagery generated from the NSSL-WRF 00Z 4km model run was provided within the HWT N-AWIPS systems from UW-CIMSS (see Figure 15.1). UW-CIMSS provided simulated satellite data for all GOES-R ABI IR bands from the 12 Z through 03 Z forecast times. Data from UW-CIMSS arrived locally at SPC by 9:15am CDT out to the 00 Z forecast time. An update at 11am CDT pulled in the bands extended out to the 03Z forecast time

from UW-CIMSS. UW-CIMSS has shown the simulated satellite imagery as a proof-of-concept of what is possible for new methods of displaying model output.
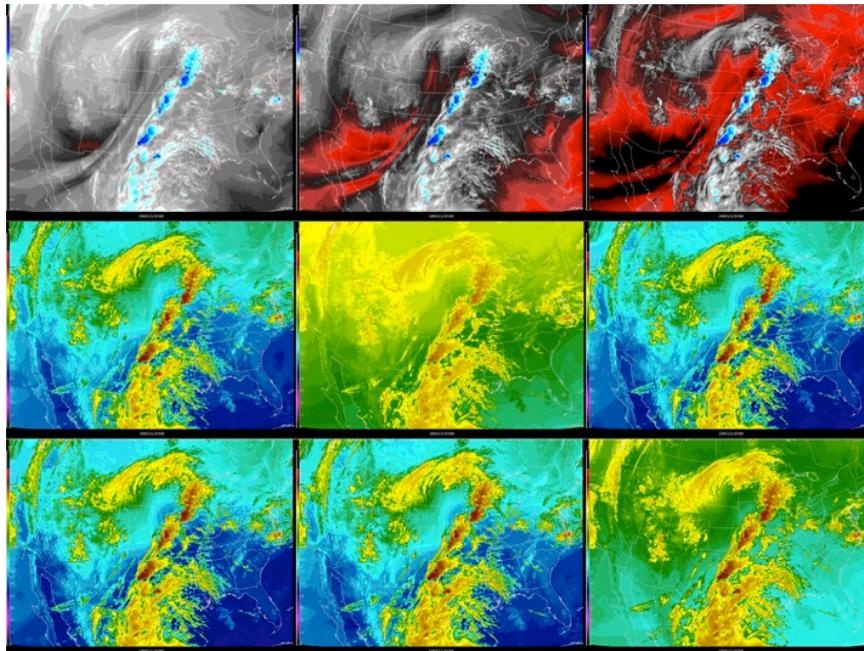
Figure 15.1. UW-CIMSS NSSL-WRF simulated GOES-R ABI IR imagery. All 9 non-solar bands can be produced from the NSSL-WRF.

Feedback – Simulated Imagery

The simulated satellite imagery was examined within the EFP during morning forecast operation, particularly at the newly created CI desk. Participants found the simulated satellite data invaluable during their forecasts and often used 1300 UTC forecast imagery to verify the performance of the NSSL-WRF for that day by comparing it to observed satellite imagery. While participants found the use of 3 WV channels useful in identifying mid- and upper-level atmospheric features that would lead to convection, they primarily focused on the mid-level WV channel because of the limited amount of time they had to interrogate a large amount of experimental model data.

As part of the EFP's CI desk's morning forecasts, they asked for demonstrations of the NSSL-WRF simulated 10.3-12.0 micron band difference provided to us by CIRA on multiple occasions. This channel difference was used extensively by the EFP's CI desk as a tool to forecast CI. One of the advantages of simulating satellite data from a model is that we have the opportunity to produce channels that we don't have currently. Neither of these channels is currently available together on our operational GOES satellites, but will be available on the GOES-R satellite once it launches. The 10.3-micron channel is a very clean window, and thus is very sensitive to surface temperature.

The simulated satellite imagery and band differences from the NSSL-WRF continue to flow into the SPC and HWT and are now being provided within SPC operations for year-round demonstration.

2010 Action Items
- Temporal improvement of NSSL WRF data to UW-CIMSS needed to make sure ABI simulated radiance are available for forecaster situational awareness during shift.
  - Status – improved temporal resolution and expanded time frame.
- Band differences and synthetic GOES-R proxy products should be added (CIRA supporting).
  - Status – CIRA has implemented.
- WRF Ensemble member ABI synthetic data should be investigated to provide optimal radiance forecast imagery.
  - Status – funded through Risk Reduction - still in progress.

2011 Lessons Learned – Future Improvements
- *Very little feedback — forecasters are comfortable with the product.*

Enhanced "V"/ Thermal Couplet (OTTC)

The OTTC product (Figure 15.2) was examined exclusively within EWP warning operations when the product seemed the most relevant to severe weather. Similar to last year, the EWP forecasters saw the potential uses for the OTTC, but the spatial and temporal limitations of the current GOES satellite made utilizing the OTTC product during warning operations very difficult, especially with rapidly updating radar during times where satellite data may not arrive for 30 minute periods. Quite often the operator using visible/IR satellite imagery or radar made OTTC detections before the OTTC product would detect anything:

> "Thermal couplet showed up over SW WI, but warning was already issued and radar was showing clear signals of severe weather."

However, when OTTC detections were made, forecasters generally noticed increases in reflectivity aloft on radar, sometimes a few minutes following the OTTC detection. This result is promising for when satellite data increases in spatial and temporal resolution with GOES-R and these features are more readily detectable.

The OTTC products will continue to flow within the SPC and HWT non-operational N-AWIPS systems and will also be available for evaluation within the HWT AWIPS-II systems.

Feedback – OTTC
HWT feedback on this product was limited due to lessons learned in 2010 regarding limited utility in radar rich environments and limitations is temporal resolution of GOES.

2010 Action Items
- GOES-13 product would be more useful tested over oceanic or mountainous terrain within another testbed.
  - Status – overshooting top and "new" tropical overshooting top detection decision support is being distributed to Hurricane and Ocean Prediction Center PG demonstrations for 2012 testing.
- Resolution of current imagery severely limits OTTC detect utilization.
  - Status – function of satellite horizontal resolution.
- OT and TC need to be combined within same field.
  - Status – done.
- Optimal in RSO mode and at night.
  - Status – Open.
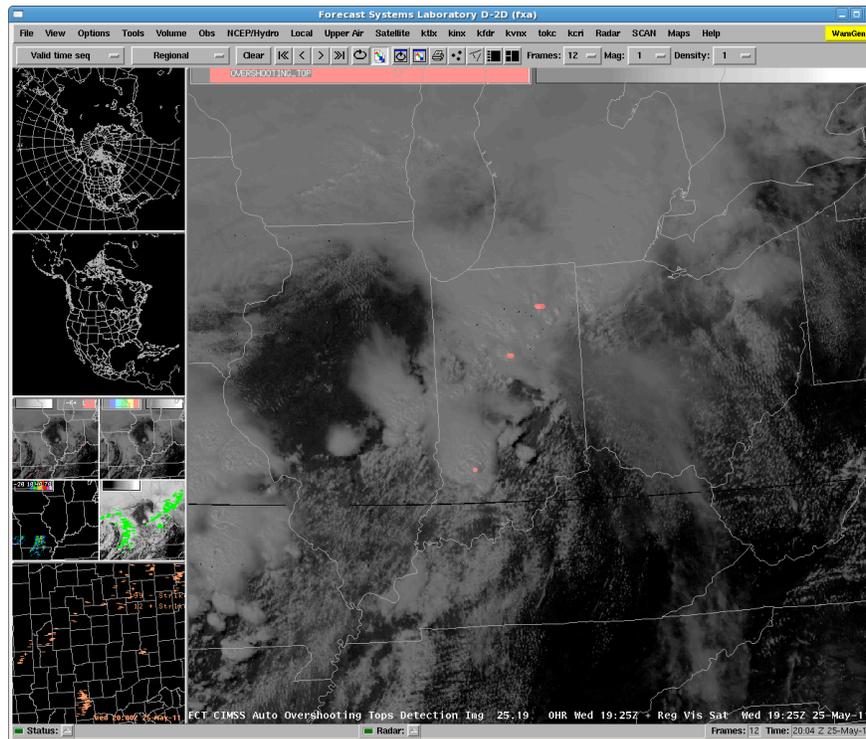
Figure 15.2. OTTC overlaid on GOES-13 visible imagery within HWT AWIPS workstations at 1925 UTC on 25 May 2011. Red areas indicate detections of overshooting-tops by the OTTC product.

2011 Lessons Learned – Future Improvements
- Used sparingly in 2011 HWT, focus of this product needs to shift to marine/OCONUS/ or areas of poor radar coverage to get fair assessment.

0-9 Hour differential Theta-e / Precipitable Water Nearcast

A Nearcast model that assimilates full resolution information from the current 18-channel GOES sounder and generates 1-9 hour "nearcasts" of atmospheric stability indices was provided within the 2011 SPC Spring Experiment. The system fills the 1-9 hour information gap, which exists between radar nowcasts and longer-range numerical forecasts. The Nearcast system uses a Lagrangian approach to optimize the impact and retention of information provided by GOES sounder. It also uses hourly, full resolution (10-12 km) multi-layer retrieved parameters from the GOES sounder. Results from the model enhance current operational NWP forecasts by successfully capturing and retaining details (maxima, minima and extreme gradients) critical to the development of convective instability several hours in advance, even after subsequent IR satellite observations become cloud contaminated. The Nearcast products were delivered to SPC and HWT within the Spring Experiment in GRIB2 format via the UW-Madison LDM for display within the EFP N-AWIPS (see Figure 15.3) and EWP AWIPS systems (see Figure. 15.4).
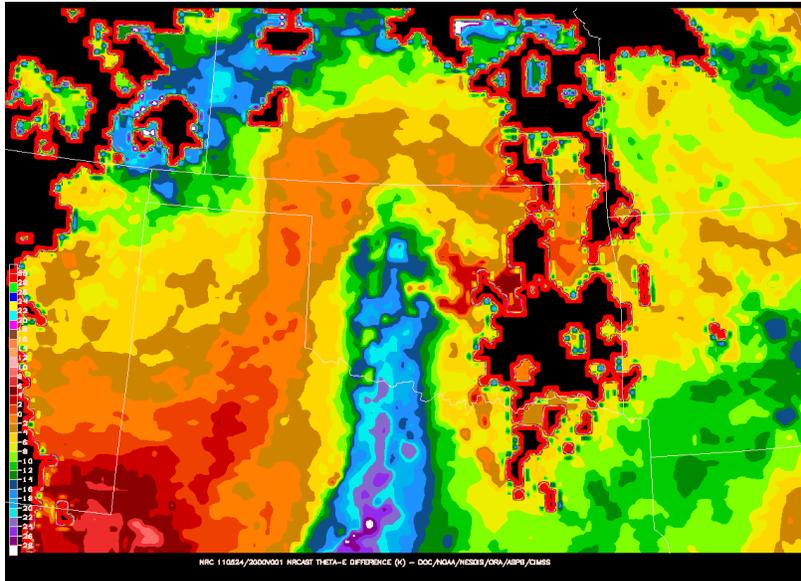
Figure 15.3. Nearcast differential theta-e product displayed within HWT N-AWIPS workstations at 2000 UTC on 24 May 2011.
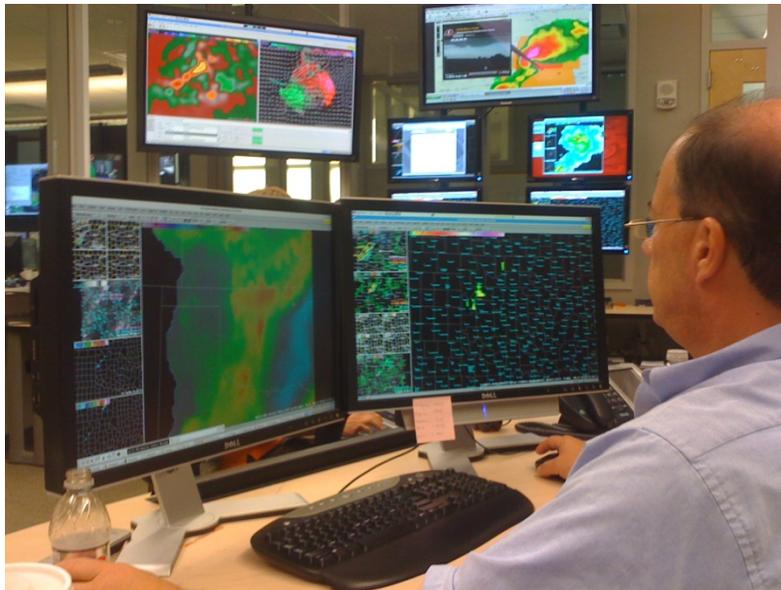
Figure 15.4. Nearcast differential theta-e product evaluated by NWS forecaster during EWP warning operations on 9 June 2011.

The product was demonstrated equally within the EFP CI, severe and QPF desks, as well as the EWP morning forecast shift, where it was used to help forecasters determine areas conducive to future convective development leading to severe weather, tornadoes and flooding. There were also occasions where EWP forecasters would use the Nearcast output of differential theta-e and precipitable water to monitor near-storm environments during warning operations. In these instances forecasters would use the 0-2 hour forecasts and analyze environments that mature storms were moving into and diagnose whether the storm would intensify or weaken based on the environment it was moving into. The information provided to them by Nearcast would help them

decide whether or not to continue warning on a storm that had already shown severe characteristics.

EFP forecasters used the Nearcast product daily as part of their afternoon forecast updates, taking advantage of the rapidly updating nature of the product, as well as its increased amount of horizontal detail, which model guidance did not provide. The usefulness of the data varied from day to day, with some days performing better than others. This variation was sometimes due to the amount of cloud cover early on in the day, limiting new sounder retrievals of theta-e and precipitable water over the areas of interest. In these cases, the Nearcast product had to rely on older retrievals that may not have been as representative of the atmospheric conditions because of the rapidly changing nature of these severe environments:

> "I can see the utility in using this product to diagnose how convective instability is evolving with time (keeping its limitations in mind). However, I would rely more on trends than on raw numbers."

Quite often, convective initiation occurred along boundaries, or gradients, within the differential theta-e or precipitable water fields, and the shape of the convection often resembled these gradients, which suggests that the product may have some utility in forecasting convective mode:

> "Initial convection in area of responsibility was correlated with higher values as indicated by vertical precipitable water difference products."

According to EWP post-event surveys, the Nearcast product was used 41% of the time during their forecast/warning operations. EWP forecasters noticed a lead-time on convective initiation of less that 1 hour in 53% of the events, with between 1 and 2 hours being the next most common at 24%. These results may be somewhat biased because the EWP forecasters did not begin looking at the Nearcast product often until after lunch. EWP forecasters did often see how it could be used within WFO operations:

> "I think it could be useful during elevated instability/elevated convection cases, especially when the larger-scale pattern is more dynamic."

The Nearcast product continues to be delivered within the SPC and HWT N-AWIPS and AWIPS workstations and is expected to receive some exposure within SPC operations starting this fall.

2011 Lessons Learned – Future Improvements
- Training needs to be streamlined.
- Product needs a method of more clear decision support interpretation.

University of Wisconsin Convective Initiation (UWCI)
The UWCI and associated cloud-top cooling rate product has been delivered to the SPC and HWT since the 2009 Spring Experiment. The product was again provided to the HWT and SPC within N-AWIPS and AWIPS for evaluation within the EFP and EWP during the 2011 Spring Experiment. The product utilizes GOES-13 infrared (IR) window brightness temperature changes based on an operational day/night cloud mask to infer cloud-top cooling as a proxy for vertical development in growing cumulus clouds as described by Sieglaff et al. (2010). UWCI provides regions of ice-cloud exclusion as designated by the cloud mask, as well as 3 "levels" of CI nowcast: pre-CI growth, CI-likely, and CI-ongoing (see Figure 15.5). UWCI is generated at UW-

Madison for each GOES-13 scan, including rapid-scans, and distributed via LDM in GRIB2 format to AWIPS and N-AWIPS systems.
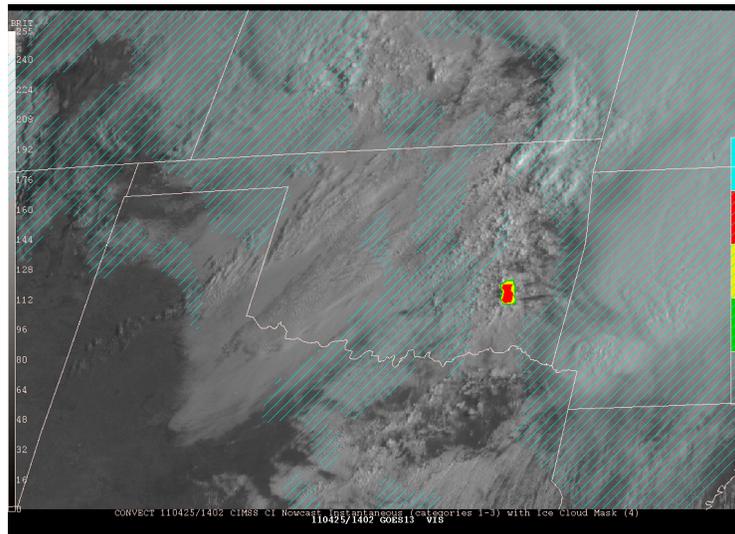
Figure 15.5. UWCI overlaid on GOES-13 visible imagery within HWT N-AWIPS workstations at 1402 UTC on 25 April 2011. Blue dashed areas indicate ice-cloud exclusion regions where the convective cloud mask has determined CI nowcasts cannot be made. Pre-CI growth is indicated by green filled areas, CI-likely is indicated by yellow filled areas, and CI-ongoing is indicated by red filled areas.

UWCI was primarily demonstrated within the EWP during the first half of their forecast period to monitor CI along with other GOES-R proving ground products. The forecasters were able to develop their own displays within AWIPS, often choosing to overlay the UWCI product on visible or IR satellite imagery.

Feedback – UWCI

According to post-event surveys, 71% of HWT Experimental Warning Program (EWP) participants used UWCI during their forecast/warning operations. Responses from the survey show a wide range of lead-times for the detection of a first 35 dBZ radar reflectivity echo from the UWCI, extending anywhere from 0 minutes up to 45 minutes. However, the most common response suggested an average lead-time of 15 minutes. When compared to the first occurrence of lightning, the average lead-time extended about an additional 15 to 30 minutes. EWP forecasters noticed a more conservative approach to the UWCI product in nowcasting CI versus the SATCAST product, but in general did find the idea of a satellite-based CI nowcast product useful:

The UWCI products will continue to flow within the SPC and HWT N-AWIPS systems, and will also be available for evaluation within the HWT AWIPS-II systems.

Feedback from the real-time and archive case events were usually discussed the following morning during the EWP daily briefing, with some significant events discussed immediately following EWP operations. All forecasters also completed online surveys immediately following a shift where they used the UWCI data. Summary information from these surveys is available online at: http://goesrhwt.blogspot.com/search/label/UWCI.

In general, forecasters found that the UWCI products are **a useful tool to help them increase situational awareness prior to warning operations during severe weather days.** One particular comment from the online survey echoed the UWCI potential:

"It is conservative, but in general it seems to have a low FAR and good POD. However, it is challenged in this rapidly developing storm environment. This application definitely has potential particularly with very high-resolution satellite data. The SATCAST in contrast had a very high POD but also very high FAR."

"The CI product had a 0 FAR, but a relatively low POD (probably around 0.50). Although I call this a weakness, it does provide some value, as it indicates that 'triggering' of the CI product essentially guarantees convective development."

The forecasters were well aware of the effect that cirrus had on the UWCI product following the training sessions and through direct interactions with the visiting scientists and would generally not use the product in cirrus contaminated scenes. Further training on cirrus will be a subject of research in Spring 2012.

Forecasters mentioned that "it was also nice to see the actual values of cloud top cooling" since it provides them with a more physical interpretation of what is going on with the developing convection. Also, forecasters mentioned that the cooling rate product provided more signal than the more stringent convective initiation nowcast, which, as mentioned above, missed some instances of initiation due to various reasons.

Progress on 2010 Lessons Learned and Future Improvements – UWCI
- A quality control mask is needed to convey to forecaster that UWCI methodology was not employed due to cirrus/glaciation/ice and provided within AWIPS.
  - o Status implemented: Figure 15.5.
- More research needs to be done to relate CI cloud top cooling and likelihood of surpassing certain dBz threshold gates, thus allowing forecaster to relate satellite signal to radar signal, the use of this combination in forecasting is being studied using WDSS-II within another project.
  - o Status – this study has occurred and papers submitted for peer review, testing is to occur 2012 HWT.
- Cloud top cooling tracking will be investigated using WDSS-II.
  - o Status – CTC rate is not continuous enough from scene to scene at current GOES temporal resolution to implement.
- Work with the University of Alabama to provide transition support to SATCAST version 2 which should provide a methodology more like GOES-R convective initiation proxy. SATCAST version 2 will become GOES-R PG CI proxy once capable of day/night processing, RSO capability, and improved time latency.
  - o Status – Meeting set up on March 9, 2012 to discuss.
- Implement on GOES-West (GOES-11).
  - o Status – Implemented on GOES-15 for distribution to Hawaii.

New 2011 Lessons Learned and Future Improvements – UWCI
- GOES(-R) derived cloud properties should be evaluated if the event of CI is within thin cirrus; this satellite-based CI shortcoming was frequently mentioned by forecasters, GIMPAP award is pending to look at Pavolonis/Heidinger cloud optical depth temporal transitions.

- GOES cloud top cooling will be translated to probability of radar MESH and reflectivity within AWIPS to help with anticipation of future radar growth.
- NOAT recommend much broader integrated CI algorithm to include radar, surface data, and models, a focus on this area will occur.

NOAA Aviation Weather Testbed (Leads: Wayne Feltz/Mike Pavolonis/Ralph Petersen)

CIMSS is responsible for the four products demonstrated in the Aviation Weather Experiment and they are described below. A new GOES-R satellite champion AWC hire by UW-CIMSS is ongoing and will help with implementation. The products are: Volcanic Ash: Detection and Height, Low Cloud and Fog, SO_2 Detection, University of Wisconsin cloud top cooling/convective initiation and Nearcasting. Currently UWCI and low cloud/fog products are available at AWC and Chad Gravelle (NWS TC Satellite Champion) is assisting in transitioning the other products. No formal AWC testbed evaluation has yet occurred but the plan is to involve convective related products in AWC testbed evaluation. New UW-CIMSS AWC hire should be in place by late spring 2012.

NOAA NWS Training Center Testbed (Lead: Wayne Feltz)

Chad Gravelle was hired in November 2011 to assist in developing NWS Training Center testbed operations plan to integrate formal satellite decision support training into NWS TC. Chad spent 30 days at UW-CIMSS for orientation to our center and GOES-R PG developer activity at SSEC/CIMSS. Once plan is in place UW-CIMSS will provide any products requested and help implement with tight coordination with AWC satellite champion hire and John Ogren.

NOAA High Latitude/Alaska/AAWU PG Demonstration (Mike Pavolonis/Justin Sieglaff)

CIMSS is currently responsible for providing the following products to HLT, Alaska and AAWU testbeds: Volcanic Ash (Detection and Height), Cloud Phase, Cloud/Snow Discrimination, Low Cloud and Fog, SO_2 Detection. All products listed are being distributed for evaluation at High Latitude tested in NetCDF and IC4D by UAF-GINA. Evaluation and proving ground feedback will be captured by GINA and feedback returned to developers. Currently UW-CIMSS has not received any reports from GINA regarding 2011-2012 evaluations, therefore at this time no specific product feedback is within this proposal.

NOAA Hawaii/Pacific Region PG Demonstration (Lead: Wayne Feltz/Mike Pavolonis)

CIMSS is currently responsible for providing the following products to NOAA Hawaii/Pacific Region PG Demonstration: UWCI, Total Precipitable Water, SO2, and Volcanic Ash: Detection and Height. The new University of Hawaii/NWS "satellite champion" Roy Huff visited UW-CIMSS the week of January 30th – February 3rd for orientation with developers of specific products of interest. This demonstration will receive a strong focus in Spring 2012 with initial visit by Jordan Gerth to occur the week of March 5 – 9th.

NOAA Joint Hurricane Center Testbed (Lead: Chris Velden)

The purpose of the GOES-R Proving Ground (PG) demonstration at the National Hurricane Center (NHC) is to provide NHC forecasters with an advance look at tropical cyclone forecast products for evaluation and feedback during the peak of the hurricane season (August 1 – November 30). On September 13, 2011, the mid-term review for this demonstration was held at the NHC to evaluate the progress of the PG demonstration and strategize to make adjustments for the second half of the evaluation period, if necessary. Mid-term report is available at:

http://www.goes-r.gov/users/pg-activities-01.html

Hurricane Intensity Estimate

The HIE product was generated from MSG and GOES-East and available to the NHC forecasters via a Web page. Although there were very few storms in the eastern Atlantic this season, the forecasters were able to use the HIE product during Katia when deciding to upgrade the storm. Mike Brennan, Senior Hurricane Specialist, said, "I found the GOES-R Proving Ground HIE product useful on my midnight shift on August 30 when I made the decision to upgrade TD 12 to Katia. The HIE was more responsive in showing intensification compared to the operational ADT, and reached a 2.5 by the time I put out the 09Z advisory in agreement with the 06Z classifications from SAB and TAFB." It was noted that the HIE was higher than the ADT during Katia (perhaps a factor of higher temporal resolution) and was a supporting factor in upgrading the storm. It was also mentioned that addition of GOES-east HIE estimates this year is providing a much larger sample for evaluation. Jack Beven from NHC is conducting the post-season quantitative evaluation of the HIE.

GOES Super Rapid Scan Imagery

The SRSO was called for GOES-West for one day during Tropical Storm Don and three days during Tropical Storm Nate in the Western Gulf and made available on a CIRA Web page. This arrangement enabled the forecasters at NHC and satellite analysts at the NESDIS Satellite Analysis Branch to get several visible images just after sunrise to aid in determining Nate's center position, which was further north than originally indicated in the multi-channel IR imagery before sunrise on September 11th. Currently, the multi-channel IR imagery used at night is only produced every 30 minutes due to an internal limitation at the NHC, so the SRSO visible imagery provided a much higher temporal refresh rate supporting NHC operations. The hurricane specialists identified a particular application of SRSO: it may be utilized at sunrise to support (1) center finding and (2) aircraft reconnaissance go/no go decisions. They commented that it would be nice to get a mini-super rapid scan during and just after sunrise to provide decision support. It was recommended that a Web site be created to provide access to the SRSO cases from the Proving Ground for later analysis and training.

SAL Imagery

The Saharan Air Layer (SAL) product imagery developed and provided by CIMSS would be much easier to evaluate if it can be displayed within N-AWIPS.

TOT Product

A new product evaluated in 2011 is the Tropical Overshooting Top (TOT) detection algorithm developed at CIMSS. This product currently displays Atlantic TOT activity derived from GOES and Meteosat at 15-min intervals. NHC was unable to look at this product much, but TAFB is already finding it useful to their tropical analyses. This product will be more rigorously evaluated in the 2012 hurricane season. CIMSS continues to investigate quantitative relationships between TOT activity and TC genesis and rapid intensification.

New 2011 Lessons Learned and Future Improvements – Hurricane Testbed

- In future training it would be helpful to clearly spell out the differences between the HIE and the ADT.
- In the future CIMSS should determine if the OT product can be displayed in N-AWIPS.
- CIMSS and CIRA product developers should determine the relationships between OT and lighting activity. Do these provide independent information?

- CIMSS, SPoRT and CIRA should coordinate in the off season to determine if the SAL and Pseudo Natural Color products can be provided in N-AWIPS format.

NOAA Ocean Prediction Center/ Hydrological Prediction Center/ Satellite Applications Branch PG Demonstrations (Leads: Wayne Feltz/Andy Heidinger)

CIMSS is currently responsible for providing the following products to OPC/HPC/SAB PG demonstrations: Cloud and Moisture Imagery, Enhanced "V"/Overshooting Top Detection, Volcanic Ash Detection and Height, Cloud Phase, Cloud Top Height and Temperature. UW-CIMSS is coordinating product integration with CICS GOES-R satellite champion hire Michael Folmer. All products above are available at UW-CIMSS for integration. Currently OT and cloud moisture imagery have been successfully implemented within N-AWIPS and an Abstract Data Distribution Environment (ADDE) has been set up and tested to deliver the volcanic ash products to SAB. Delay in integration is occurring for a variety of reasons including IT needs, firewalls, and expected move to new NOAA building in near future. No formal evaluation has been conducted to this point to provide to developers.

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. CIMSS is following this work. AWIPS II will soon be accessible for use at CIMSS, with training modules employing the new AWIPS software included as part of the VISIT/COMET training programs for operational satellite meteorology professional development. UW-CIMSS participated in multiple GOES-R Proving Ground organizational telecons.

Presentations and Conference Reports

Bah, Kaba; Achtor, T.; Rink, T. D.; Schmit, T. J.; Otkin, J. and Gerth, J. Preparation for use of the GOES-R Advanced Baseline Imager (ABI). Annual Symposium on Future Operational Environmental Satellite Systems, 8th, New Orleans, LA, 22-26 January 2012. American Meteorological Society, Boston, MA, 2012. Manuscript not available for publication.

Brunner, Jason C.; Bedka, K.; Dworak, R.; Feltz, W. F. and Cronce, L. M. GOES-R overshooting top and enhanced-V signature detection product objective validation efforts. Conference on Satellite Meteorology, Oceanography and Climatology, 18th, and Joint AMS-Asia Satellite Meteorology Conference, 1st, New Orleans, LA, 22-26 January 2012. American Meteorological Society, Boston, MA, 2012. Manuscript not available for publication.

Dworak, Richard; Bedka, K.; Brunner, J. and Feltz, W. Comparison between GOES-12 overshooting top detections, WSR-88D radar reflectivity and severe storm reports. Conference on Satellite Meteorology, Oceanography and Climatology, 18th, and Joint AMS-Asia Satellite Meteorology Conference, 1st, New Orleans, LA, 22-26 January 2012. American Meteorological Society, Boston, MA, 2012. Manuscript not available for publication.

Feltz, Joleen M.; Bah, K.; Rink, T. and Achtor, T. GOES-R proving ground aviation weather products displayed in McIDAS-V. Conference on Satellite Meteorology, Oceanography and Climatology, 18th, and Joint AMS-Asia Satellite Meteorology Conference, 1st, New Orleans, LA, 22-26 January 2012. American Meteorological Society, Boston, MA, 2012. Manuscript not available for publication.

Gerth, Jordan, 2011: The Magic of Moisture in Numerical Weather Prediction Oral, National Weather Association Annual Meeting—General Session V (Birmingham, Alabama) October 18, 2011.

Gerth, Jordan, 2011: How AWIPS II will bring GOES-R Capabilities and Science to the Field, both Pre- and Post-Launch oral presentation, National Weather Association Annual Meeting—Joint NWA/GUC Session I (Birmingham, Alabama) October 20, 2011.

Gerth, Jordan, 2011: The Reemergence of Satellite Imagery and Products in Weather Forecasting and Warning oral presentation, AOS Department Seminar, University of Wisconsin (Madison, Wisconsin) December 7, 2011.

Gerth, Jordan, 2012: How AWIPS II Is a Tool to Further R2O in the GOES-R Era
Talk, American Meteorological Society Annual Meeting—18th SATMET Conference (New Orleans, Louisiana) January 26, 2012.

Gurka, James J.; Goodman, S.; Schmit, T. J.; DeMaria, M.; Mostek, A.; Siewert, C. W. and Reed, B. The GOES-R proving ground: 2012 update. Annual Symposium on Future Operational Environmental Satellite Systems, 8th, New Orleans, LA, 22-26 January 2012. American Meteorological Society, Boston, MA, 2012. Manuscript not available for publication.

Otkin, Jason A.; Bikos, D.; Sieglaff, J.; Linsday, D. T.; Grasso, L.; Siewert, C. W.; Rabin, R.; Kain, J. S. and Dembek, S. R. Using synthetic satellite imagery to evaluate real-time model forecast performance during the Hazardous Weather Testbed Spring Experiment. Conference on Satellite Meteorology, Oceanography and Climatology, 18th, and Joint AMS-Asia Satellite Meteorology Conference, 1st, New Orleans, LA, 22-26 January 2012. American Meteorological Society, Boston, MA, 2012. Manuscript not available for publication.

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Goodman, S. J., J. Gurka, M. DeMaria, T. Schmit, G. Jedlovec, C. Siewert, W. Feltz, J. Gerth, R. Brummer, S. Miller, B. Reed, and R. Reynolds, 2012: The GOES-R Proving Ground: Accelerating User Readiness for the Next Generation Geostationary Environmental Satellite System. *Bulletin of the American Meteorological Society*, Early on-line release, February 2012 http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-11-00175.1

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16. GOES-R Algorithm Working Group

16.1 GOES-R Proxy Data Sets and Models to Support a Broad Range of Algorithm Working Group (AWG) Activities

CIMSS Task Leaders: Tom Greenwald and Allen Huang
CIMSS Support Scientists: Jason Otkin, Eva Borbas, Jim Davies, Yong-Keun Lee, Justin Sieglaff
NOAA Collaborator: Tim Schmit
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

Proposed Work
This multi-year project provides high quality proxy ABI data sets derived from NWP model simulations to many GOES-R activities and teams, including the GOES-R Proving Ground Program, the Algorithm Integration Team (AIT), the GRAFIIR, and the AWG Sounding, Winds, Clouds, Aviation, and Imagery/Visualization teams. Applications have included testing and evaluating AWG team algorithms, supplying data for responding to instrument waivers put forth by the GOES-R instrument vendors, and providing data to help train weather forecasters on the capabilities of ABI observations.

The objectives for this year's work are to:
  • Produce new proxy ABI data from Weather Research & Forecasting (WRF) model simulations and provide data user support,
  • Improve and validate these proxy ABI data sets as well as the forward radiative transfer models (RTMs) used to generate them, and
  • Transition to the CRTM for the production of future proxy ABI data.

Summary of Accomplishments and Findings
Several new proxy ABI data sets were produced. For example, proxy ABI imagery is currently provided in near-real-time at certain bands (visible band 2, and thermal IR bands 8-16) for Proving Ground using NOAA's National Severe Storms Lab (NSSL) WRF model output and the CIMSS RTM (see http://cimss.ssec.wisc.edu/goes_r/proving-ground/nssl_abi/nssl_abi_rt.html.) We take advantage of direct broadcast MODIS data collected here at CIMSS to produce 16-day composite bi-directional reflectance distribution function (BRDF) fields for the visible band calculations, which are updated daily. Similar synthetic ABI data sets were generated in a quasi-operational setting for last year's NOAA Hazardous Weather Testbed Spring Experiments. Simulated imagery like these will enable forecasters to familiarize themselves with the additional spectral information available from the ABI in a near-real-time environment. One of our colleagues, Jason Otkin, was a co-author, along with scientists from CIRA and NSSL, on a paper describing the simulated ABI data sets used in the Testbed experiments (Bikos et al., 2011). We also delivered proxy ABI data to NOAA that were used by the AWG Winds teams to test and evaluate their atmospheric motion vector algorithms. These data were derived from a 4 km WRF model simulation over CONUS obtained from NSSL and were produced every 5 min from 1700 to 2355 UTC on 21 May 2011 and 0000 to 0155 UTC on 22 May 2011. Simulated ABI thermal

IR data (bands 8-16) were available, as well as band 2 (0.64 µm) data produced from our quick (i.e., 3-layer) solar RTM. Limited simulated ABI solar data (bands 1-7) were available 1700-1715 UTC, 21 May using the more sophisticated CIMSS Solar RTM.

Enhancing and validating the proxy ABI data and RTMs included evaluating cirrus scattering properties in both the CRTM and CIMSS RTM and investigating the addition of zenith angle dependence to the UW/CIMSS global IR land surface emissivity database and the development of a visible/near-IR (VIS-NIR) global land surface reflectance database. The cirrus scattering properties were evaluated using collocated CloudSat, CALIPSO, and MODIS observations for thin nonprecipitating clouds during 2007. Results at window infrared wavelengths (11 and 8.5 µm) showed that CIMSS RTM-derived brightness temperatures were generally 5 K larger than the MODIS observations; however, these differences were within the errors associated with uncertainties in the CloudSat-derived ice water content and MODIS-derived particle effective radius estimates used as input into the RTMs. Brightness temperatures simulated by the CRTM showed much larger differences (as large as 15 K) for cloud optical depths of 1 to 2 when compared to MODIS observations.

Work has begun on introducing zenith angle dependence into the UW/CIMSS global infrared land surface emissivity database that is used extensively in generating proxy ABI data, not only in our work but also in the work of many other groups outside of CIMSS. This enhancement is expected to provide better estimates of infrared land surface emissivity at larger zenith angles and, hence, improve proxy ABI imagery. As an example, Figure 16.1.1 shows the zenith angle dependence of the 8.3 µm MODIS band over a selected area of the Sahara.

Preliminary work was also been done on developing a VIS-NIR global land surface database for generating proxy ABI data sets and for possible use in data assimilation. A meeting to exchange ideas on this topic was held at CIMSS. Participants were Allen Huang (CIMSS), Paul Menzel (CIMSS), Bryan Baum (CIMSS), Eva Borbas (CIMSS), Bob Knuteson (CIMSS), Tom Greenwald (CIMSS), René Preusker (FUB), Ralf Bennartz (UW-Madison AOS) and Jérôme Vidot (Meteo-France). One outcome of the meeting was to apply the Principal Component Analysis regression to laboratory measurements and MODIS 16-day CMG BRDF-corrected nadir reflectance for the VIS-NIR spectral region separately from the originally planned combined IR + VIS-NIR spectra.

In preparation for the move to the CRTM we further enhanced our f90/95 interface for using the CRTM with WRF model output (dubbed WCRTM). One advantage of this interface is that proxy satellite data for nearly any type of sensor can be generated by simply entering keywords on the command line. Two main accomplishments were extending the code to use WRF-Chem model output and adding the capability to compute radiances at solar wavelengths. A beta version of WCRTM (without WRF-Chem and solar capabilities) was supplied to our colleagues at CIRA to enable them to generate proxy ABI data. The latest version of WCRTM was delivered to NOAA.
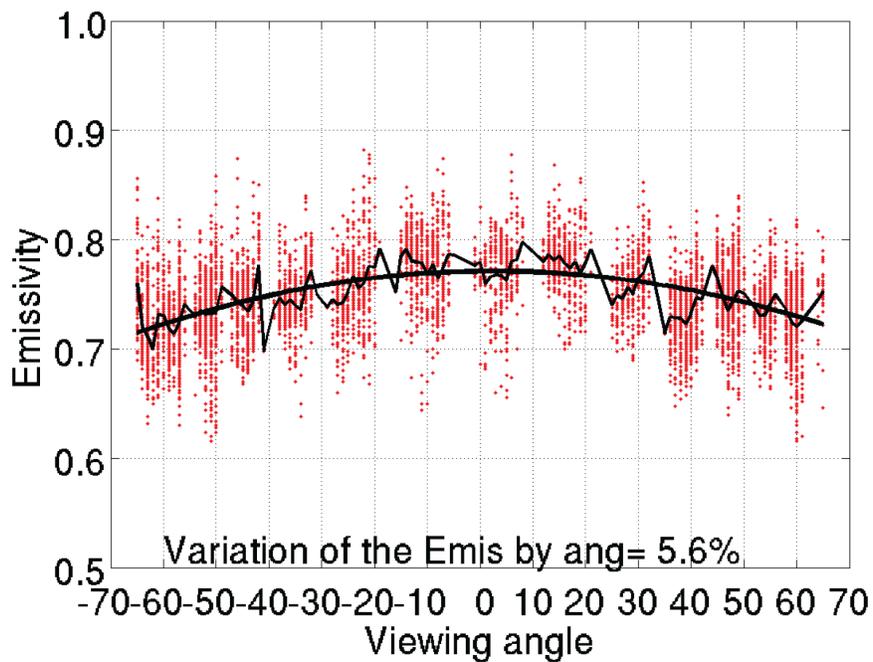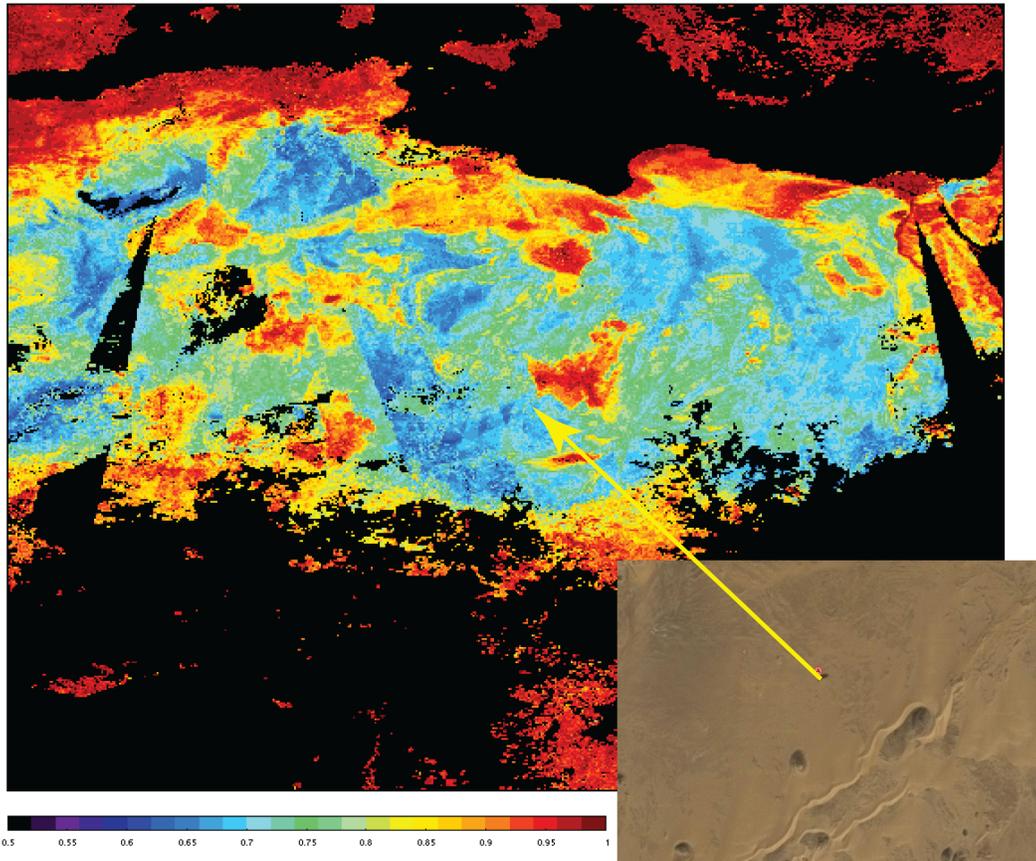
Figure 16.1.1. Top panel: Selected homogenous sandy area for the angular dependence study. The main picture shows the 8.3 µm MYD11C3 monthly mean emissivity for January 2011 and the sub-image shows the zoomed Google map image of that area. Bottom panel: Angular dependence of the MODIS MYD11C1 emissivity products at 8.3 µm for January 2011.

Publications and Conference Reports

Bikos, D., D. T. Lindsey, J. A. Otkin, J. Sieglaff, L. Grasso, C. Siewert, J. Correia, M. Coniglio, R. Rabin, J. Kain, and S. Dembek, 2011: Synthetic satellite imagery for real-time high resolution model evaluation. Accepted for publication in *Weather and Forecasting*.

Borbas and Knuteson, 2012: The recent update of the UW/CIMSS high spectral resolution global IR land surface emissivity database: the satellite viewing angle dependence, 18th International TOVS Study Conference, 21-27 March 2012, Toulouse, France.

Greenwald, T., Y.K. Lee, and A. Huang, 2012: Validation of Cirrus Infrared Scattering Properties Used in the Production of Simulated GOES-R ABI Proxy Data. 8th Annual Symposium on Future Operational Environmental Satellite Systems, 22-26 January, New Orleans, LA.

Otkin J. A., D. Bikos, J. Sieglaff, D. T. Lindsey, L. Grasso, C. W. Siewert, R. Rabin, J. S. Kain, and S. R. Dembek, 2012: Using Synthetic Satellite Imagery to Evaluate Real-Time Model Forecast Performance During the Hazardous Weather Testbed Spring Experiment. 18th Conference on Satellite Meteorology, Oceanography, and Climatology, 22-26 January, New Orleans, LA.

Vidot and Borbas, 2011: Developing a VIS and NIR surface reflectance model for RTTOV, 3rd Workshop on Remote Sensing and Modeling of Surface Properties, 18-20 Oct 2011, Beijing, China.

Vidot and Borbas, 2012: Developing a VIS and NIR surface reflectance model for RTTOV, 18th International TOVS Study Conference, 21-27 March 2012, Toulouse, France.

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

CIMSS Task Leaders: Mat Gunshor, Allen Huang
CIMSS Support Scientists: Hong Zhang, Eva Schiffer
NOAA Collaborator: Tim Schmit
NOAA Long Term Goals
- Weather-Ready Nation

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

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

Proposed Work
The proposed activities for 2011 were the following:
- Respond to proposed changes in ABI instrument specifications to assess their potential effects on products and ABI waiver analysis when requested. As part of this activity the GRAFIIR team will interface with the Integrated Modeling Working Group (IMWG), participate in the Government's waiver response plan development, and provide a response to actual instrument waiver requests that go to AWG/GRAFIIR.

A waiver response report contains several elements. A description of the proxy data used and how those data were adjusted to reflect the effects of the instrument waiver. A description of the analysis techniques, such as an analysis using AWG algorithms to generate pertinent products. The 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). Finally, a summary and possible recommendations from the pertinent AWG teams/chairs, including the GRAFIIR team.

- Continue to expand and improve the GRAFIIR analysis tool Glance. This effort would include, but not be limited to, incorporating new data formats AWG teams plan to use in validation, expanding capability to analyze current GOES products for validation, responding to AWG science team requests to meet the specific needs of their algorithms, continuing to expand features of GRAFIIR to model ABI instrument effects, and continuing to interface with visualization team and AWG science teams to better utilize visualization tools.

Summary of Accomplishments and Findings

The primary diagnostic tool, called Glance, was expanded and improved throughout the project year. Updates of Glance were provided to the AWG's Algorithm Integration Team (AIT) 4 times during the year (at the end of each project quarter). The GRAFIIR team continues to consult with the Integrated Modeling Working Group (IMWG) on behalf of the AWG. There were no official ABI waivers this year, but there were responses provided for two issues that went through the pre-waiver process; one issue had to do with band to band registration and the other issue had to do with calibration accuracy of the 1.38 micrometer band. For the former, analysis of the cloud algorithms were provided using navigation errors added to the 11.2 micrometer band. For the latter, a sensitivity study of ABI band 4 (1.378μm) on cloud products was performed.

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

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

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

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

The AWG team at CIMSS updated the cluster computing system where GRAFIIR applies instrument perturbations to proxy data. The GRAFIIR proxy data perturbation software was tested on the new cluster computing system and while there were bugs to work out and there may still be room for optimization, especially with a new storage system, the data perturbation software is running on the new system. This exercise also gave the opportunity to update a few things that have changed in terms of proxy data, imagery requirements, and the way perturbed data sets are output (such as missing data value codes, quantization of data).
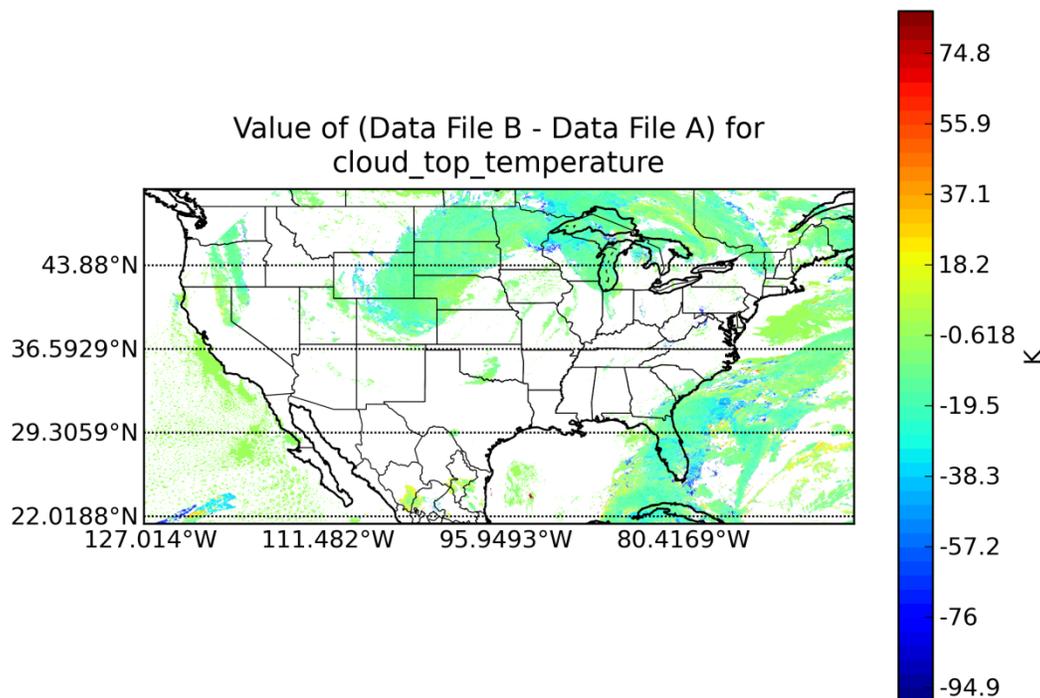
Figure 16.2.1. The difference in cloud top temperature between WRF model generated cloud top heights and those measured in WRF-generated (proxy) ABI data using the ABI cloud top temperature algorithm. A cold bias in the differences are seen, indicating that model cloud top temperatures are colder than those sensed by the ABI algorithm.

Publications and Conference Reports
Presented poster "GRAFIIR – An Efficient End-to-End Semi Automated GOES-R ABI Algorithm Performance Analysis and Implementation Verification System" the 92nd AMS

Annual Meeting (Eighth Annual Symposium on Future Operational Environmental Satellite Systems).

16.3 AIT Technical Support

CIMSS Task Leaders: Ray Garcia, Robert Holz, Graeme Martin
CIMSS Support Scientists: Erik Olson, Greg Quinn, Eva Schiffer, William Straka III
NOAA Collaborator: Michael Pavolonis
NOAA Strategic Goals
- Provide Critical Support for the NOAA Mission

Proposed Work
The AIT technical support group proposed activities principally related to "computer science" aspects of algorithm development. This work includes:
- Improving profiles in terms of performance, accuracy, and reproducibility of the reference algorithm implementation;
- Reviewing updated software and deliverables with CIMSS science staff ;
- Creating accessible archive of test and ancillary data sets in support of AWG deliverables;
- Maintaining, expanding, and deploying automated verification test tools in coordination with GRAFIIR and AIT-East;
- Providing guidance to science staff as needed to improve computer science aspects of algorithm reference software;
- Assisting in implementation of collocation software and framework capabilities needed for cal/val of GOES-R data with other data sources including AQUA and TERRA;
- Continuing migrating science software towards framework. Refactor to use platform agnostic software interfaces in order to simplify code and provide new avenues for rapid algorithm development;
- Working with proxy team to prepare additional proxy data for cal/val;
- Continuing development of the offline research framework;
- Testing integration work in cooperation with visualization group and AIT-East;
- Maintaining CIMSS/SSEC infrastructure in support of AWG algorithm work and cal/val;
- Participating in technical interchanges with AIT-East and Harris/AER regarding computer science concerns in algorithm implementations; and
- Coordinating schedules, deliveries, software configuration items in cooperation with AWG and Harris/AER.

Summary of Accomplishments and Findings

Visualization and Verification Tool Development
AIT continues to provide technology, tools, and expertise to algorithm scientists, including feature updates and fixes to the 'glance' verification utility. Development of a portable, interactive GUI for the software commenced and has proceeded to beta testing. Alternative uses of glance, such as pass/fail batch mode for background production as well as statistical report generation for data set validation were addressed. Additional plots were added to glance's reports, including a hex-tile density scatter plot. Glance has also found applications in SNPP data set verification and GOES-R instrumentation software development.
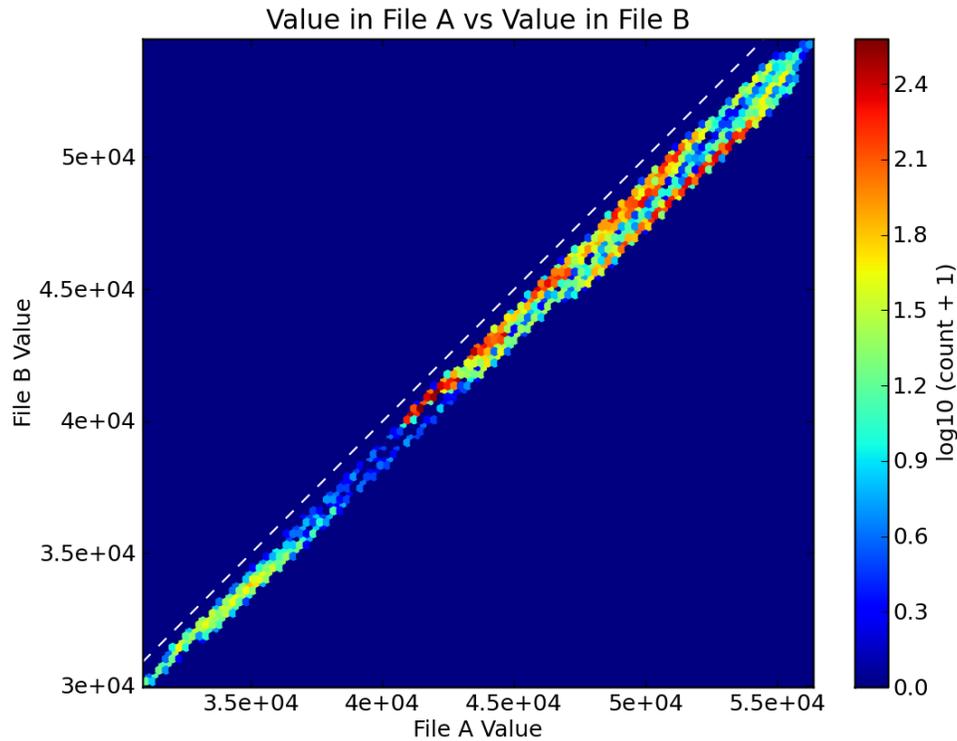
Figure 16.3.1. Sample diagnostic hex-density scatter plot of Suomi NPP ATMS unscaled brightness temperatures which was created as part of regression testing of data processing software. A semi-automated search for this systematic bias was implemented using glance, which pointed directly at a reconfiguration event and allowed rapid remediation by obtaining updated configuration data.

Test Framework Development
Both 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 which also led to refinements in the test data sets used for verification of contractor implementations of GOES-R algorithms.

Data Set Collocation Work for GEO/LEO Algorithm Validation
The development of a suite of collocation software for use in product validation continued with an increased focus on combining geostationary and polar observations. In addition to previous work using CALIOP and MODIS to evaluate GOES-R algorithms run against SEVIRI and GOES data, similar capabilities are being developed to include the CrIS and VIIRS sensors aboard SNPP. Work has continued on both the per-pixel physical collocation algorithms and on tools for interpreting sensor data. Effort has also begun on deploying a processing system that will make the resulting validation products available in near real-time. This system will allow algorithm developers to rapidly obtain validation data collocated to match a SEVIRI or GOES domain within hours of the data becoming available for download to CIMSS.

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 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.

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

Data Processing and Storage Systems Maintenance and Management

2011 infrastructure work continued to support cluster systems, storage consolidation, and reliability improvement. Significant work went into on phasing older hardware out of critical roles prior to repair contracts expiring. Our research cluster was upgraded with additional compute capability, which included a large Lustre filesystem shared over Infiniband network. This storage system provides much faster speeds and the ability to serve data to greater than 100 concurrent processes. These capabilities allows GOES-R and other satellite programs to have a single source for validation and testing data sets.

16.4 Total Ozone Retrieval from ABI

CIMSS Task Leader: Chris Schmidt
CIMSS Support Scientists: Jay Hoffman, Jinlong Li
NOAA Collaborators: Shobha Kondragunta (NOAA/NESDIS/STAR), Brad Pierce
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
- Environmental Models and Data Assimilation

Proposed Work
The legacy GOES I-M Sounder experimental total column ozone (TCO) algorithm from CIMSS is a regression-based method for estimating ozone that can be applied to the Advanced Baseline Imager (ABI) on GOES-R. ABI covers sufficient spectral range, most importantly the 9.6 μm ozone absorption band, to retrieve total column ozone over its coverage area. ABI ozone will provide high spatial and temporal resolution sampling of ozone features that primarily reflect ozone distribution in the stratosphere and upper troposphere. ABI ozone will provide continuity with the current GOES ozone capabilities.

Prior to FY2011 CIMSS had completed development and delivery of the ABI Ozone algorithm. Focus shifted to development of routine validation tools, deep-dive validation tools, and routine maintenance updates of the algorithm. Development of the routine and deep-dive validation tools was proposed to continue. The ABI ozone product validation effort proposed to use SEVIRI data as a proxy for ABI as well as model-generated ABI proxy data containing ozone in the model. The TCO derived from SEVIRI data is compared to that from the Ozone Monitoring Instrument (OMI) aboard NASA's Aura platform. OMI utilizes ultraviolet data to obtain its ozone measurements and is known to have a high accuracy, making it a good reference comparison. Model-generated ABI proxy data has known TCO to compare results to. Deep-dive validation tools were proposed to utilize the less frequent though very important data sources provided by ozonesondes, Dobson-Brewer Photospectrometers, and other measurements. Integration of the Ozone algorithm by the Harris/AER team was not expected in 2011 as Ozone is considered an Option 2 product despite being on a baseline product schedule.

Summary of Accomplishments and Findings
Development of the validation tools continued in 2011. The routine validation tools involving comparison of SEVIRI-based ozone data to OMI were developed and implemented in real-time at CIMSS, providing constant updates of algorithm performance. Figure 16.4.1 provides an example image of the ozone output. Performance has generally been acceptable though the algorithm's precision metrics have suffered due to undetected clouds and bad SEVIRI data causing extremely bad ozone values to be produced on a nearly daily basis. CIMSS has made efforts to filter out the bad data to reduce the scatter in the OMI-SEVIRI ozone comparisons. The overall accuracy (bias) has stayed within specifications. Development of the deep-dive validation tools reached the point where manually-operated code could be used to compare SEVIRI ozone to total column ozone from other sources.

In 2011 CIMSS was informed that as with other Option 2 products implementation of ABI Ozone would not proceed at this time. As a result the expected steps of fully documenting and delivering validation code did not proceed.

The ozone product has seen use by members of the AWG Aerosols team as a source function for tropospheric ozone. Ozone could yet be indicated as a product precedent for a baseline product, thus requiring its implementation; however, there are no signs of that at this time. It is hoped that the production of ozone using SEVIRI data will show the utility of high temporal and spatial frequency total column ozone data for aerosol modeling, tracking of potential vorticity, and monitoring of atmospheric features that could indicate turbulence.
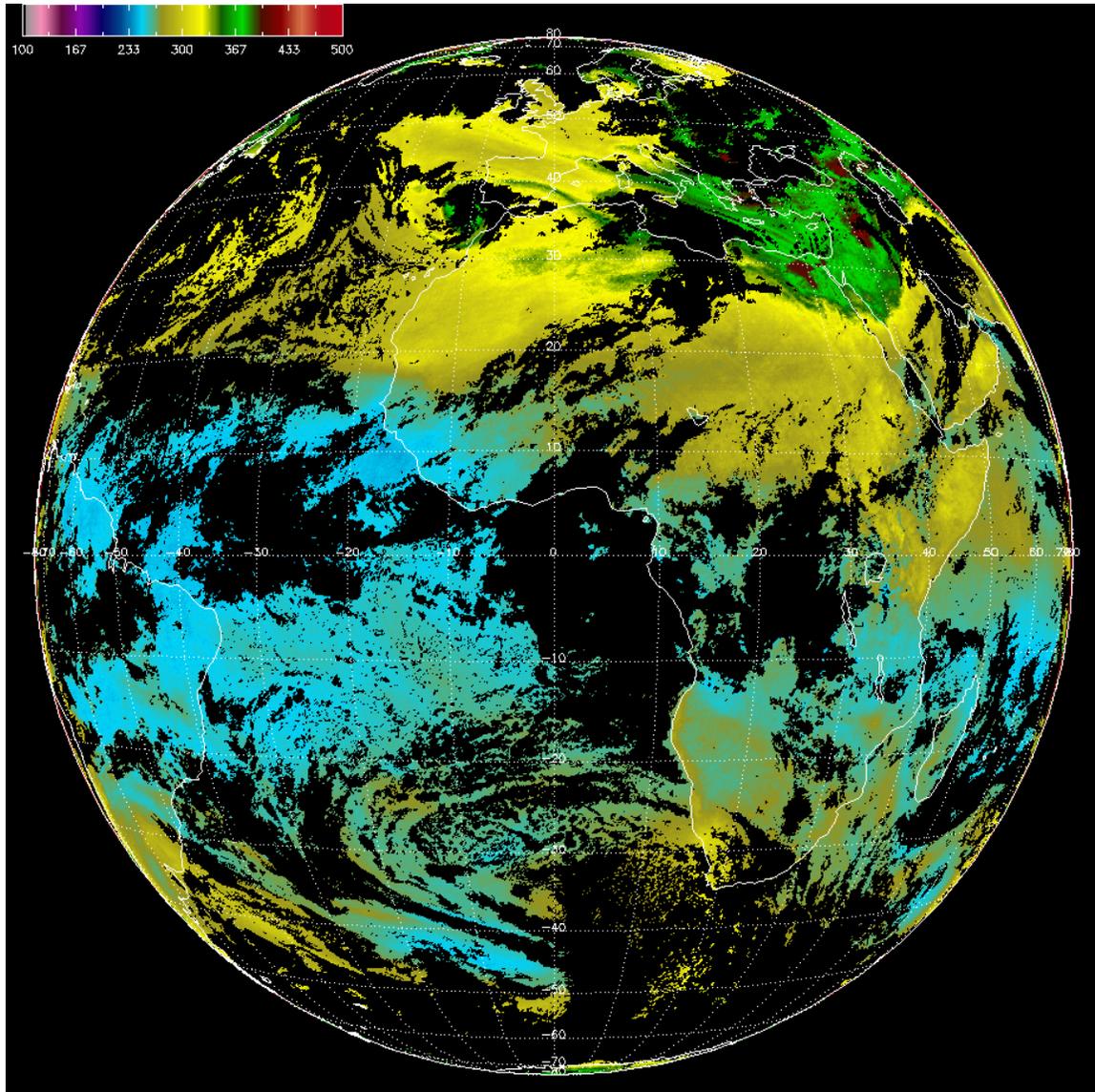
Figure 16.4.1. SEVIRI Total Column Ozone on 30 March 2012 at 8:30 UTC. A cut-off low pressure system is seen off the coast of Spain. Pixels with fully transparent clouds have been excluded. Some surface features, such as along the south western coast of Africa, can be seen contaminating the ozone field. Additionally, there are suggestions of surface contamination in the Middle East as well.

16.5 ABI Cloud Products

CIMSS Task Leaders: Andi Walther, Pat Heck
CIMSS Support Scientist: William Straka III
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

Proposed Work

National Environmental Satellite, Data, and Information Service, Center for Applications and Research (NESDIS/STAR) and the Cooperative Institute for Meteorological Studies (CIMSS) have been developing a suite of products that will offer advanced cloud detection and retrievals of cloud properties utilizing the GOES-R ABI instrument. The Cloud 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 Cloud AWG has done a significant amount of work this year on the continued development of the Cloud algorithms, along with the validation of the various cloud algorithms. The Cloud AWG has been working with the GOES-R Ground Segment System Prime, Harris Corporation and AER, to help answer questions that they had regarding the implementation of the GOES-R cloud products.

In June, the members of the Cloud AWG participated in the 2011 GOES-R AWG Annual Meeting, where a presentation was made regarding the cloud algorithms along with a summary of validation techniques.

In addition to the various documents produced during the last year, the Cloud AWG has continued to improve upon each of the algorithms. While the ABI has not been launched at this point, the Cloud AWG is continues using the SEVIRI instrument onboard the EUMETSAT Meteosat Second Generation geostationary orbiters as a proxy. In addition, several of the algorithms have been modified to work on other sensors, such as current GOES, MTSAT, MODIS and VIIRS.

For validation studies we have been using extensively other satellite sensors, such as spaceborne lidars, (CALIPSO), passive microwave satellite sensors (AMSU, AMSR-E), ground microwave profilers (MWR at ARM site) and passive imagers (MODIS, AVHRR), as independent data sources. In addition, the Cloud AWG has made extensive use of the lidar on-board CALIPSO to tune the cloud mask for the least number of false detections.

In January 2012, the Cloud AWG supported the NOAA field campaign TORERO (Tropical Ocean tRoposphere Exchange of Reactive Halogen Species and Oxygenated). The left panel of Figure 16.5.1 shows an example of the AWG Cloud Height product, which was provided via ftp-push on a real-time basis to the field project scientists. The right image shows how it was used together with airplane measurements.
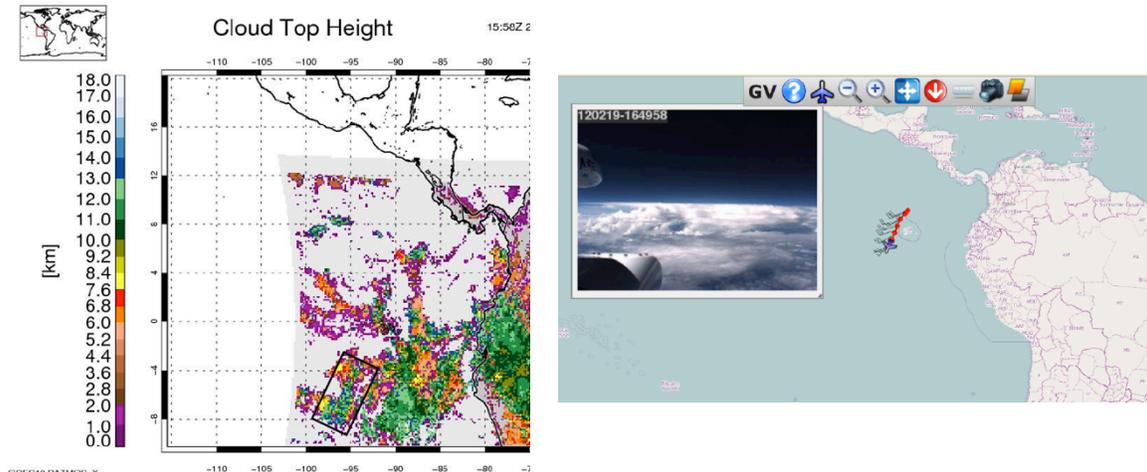
Figure 16.5.1. Left image shows Cloud AWG Cloud Top Height product, which was provided in real-time. The right side shows a camera view onboard the project airplane. (right side image was provided by Brad Pierce/NOAA.)

Finally, the Cloud AWG team continues to work with the other Algorithm Working Groups, such as the Derived Motion Winds AWG, as well as other groups to continue to validate and improve the algorithms. In the next year, the Cloud AWG will continue to be developing automated tools for the validation of the cloud algorithms.

Publications and Conference Reports
GOES-R ABI Cloud Mask Algorithm Theoretical Basis Document (100% delivery)
GOES-R ABI Cloud Type/Phase Algorithm Theoretical Basis Document (100% delivery)
GOES-R ABI Cloud Height Algorithm Theoretical Basis Document (100% delivery)
GOES-R ABI Daytime Cloud Optical Properties Algorithm Theoretical Basis Document (100% delivery)
GOES-R ABI Nighttime Cloud Optical Properties Algorithm Theoretical Basis Document (100% delivery)

Heidinger, A. K., A. T. Evan, M. J. Foster and A. Walther (2012) A Naive Bayesian Cloud Detection Scheme Derived from CALIPSO and Applied to PATMOS-x. *J. App. Met. Clim.*, doi:10.1175/JAMC-D-11-02.1. *In press*

Walther, A. and A. Heidinger, 2012: Implementation of the Daytime Cloud Optical and Microphysical Properties Algorithm (DCOMP) in PATMOS-x. *J. Appl. Meteor. and Climatol.*, doi: 10.11.1175/JAMC-D-11-0108.1, in press

16.6 Active Fire/Hot Spot Characterization (FIRE)

CIMSS Task Leader: Chris Schmidt
CIMSS Support Scientists: Jay Hoffman, Elaine Prins (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

Proposed Work

This effort has adapted the current GOES Wildfire Automated Biomass Burning Algorithm (WF_ABBA) to GOES-R ABI. CIMSS continued building on historical and current expertise at CIMSS in fire algorithm development for the GOES Imager and the global geostationary fire observation network by revising the WF_ABBA to address GOES-R ABI observational requirements. The updated WF_ABBA utilizes the improved fire monitoring capabilities on GOES-R and contains updates to the modules that identify and characterize sub-pixel fire activity. After the 100% delivery of the algorithm in 2010, the FY11 task plan included continued development of routine validation tools, deep-dive validation tools, any needed routine maintenance updates of the algorithm, and working with the system prime contractor on their adaptation of the Algorithm Theoretical Basis Document (ATBD) and delivered code into an Algorithm Description Document (ADD) and code within their system. CIMSS also proposed to coordinate with the NPOESS VIIRS fire team, UMD (Justice, Giglio, Schroeder), and STAR on fire code updates/modifications.

Summary of Accomplishments and Findings

Work continued on the use of proxy data for testing the ABI Fire algorithm. An additional data set of simulated ABI radiances developed from a CIRA model and using WF_ABBA fire data from current GOES as the "truth" for fires covering British Columbia was delivered from CIRA. The algorithm performance was in line with the performance in other test cases. Figure 16.6.1 shows a scatter plot developed at CIMSS that is used to analyze algorithm performance, applied to all 8 of CIRA's cases. The horizontal axis is a logarithmic scale of fire size, and the vertical scale is fire temperature. The color coding indicates the type of fire or whether the fire was detected at all. Green indicates that the fire was not detected, red indicates a detected fire that was characterized, yellow indicates a saturated fire pixel, magenta indicates a cloud covered pixel, orange a high possibility fire pixel, and blue a medium possibility fire pixel. While the size and temperature are known going into the model, the model output is remapped to the ABI projection, which effectively changes the fire properties. To account for that, it is assumed that the net fire area of the scene is unchanged by the remapping. The FRP is defined as fire size times fire temperature to the fourth power times the Stephan-Blotzman Constant. Each individual fire in the model output has an FRP, which is used with the "truth" fire temperature to calculate the fire size for each fire. Then the fire size is scaled by the factor necessary to take the sum total "truth" fire area of the scene match the sum total fire area calculated using this method. That size becomes the horizontal axis. The result is generally smooth separations between the different fire categories, especially between processed, saturated, and undetected fires. The plotted are lines of constant FRP, in powers of 10 MW. The heavy magenta line is the 75 MW line, below which very few fires are detected. This analysis represents our estimate of the lower intensity threshold for ABI fire detection. General trends are the same in all 8 cases. British Columbia shows a

number of fires undetected above 75 MW. The BC case is located at a higher latitude and scan angle than the other cases, so this result is expected.

CIMSS continued to collaborate with STAR on the Validation Plan for the ABI Fire algorithm. This validation is based primarily on using high resolution data (e.g., 30m resolution Terra/ASTER and Landsat 7/ETM+ data) to validate the ABI fire algorithm in a variety of biomes. Due to lack of accurate ground truth data, application of high resolution satellite data remains the preferred and recommended method of validation in the biomass burning field. The method is currently labor-intensive and requires finding numerous ASTER scenes and the associated TERRA MODIS images that contain fires. The ASTER data are remapped to ABI using a method similar to that used to remap MODIS data to ABI. It was discovered that there appears to be a navigation offset between the proxy ABI data and ASTER data. MODIS fires derived from the same ASTER imagery show a very strong match with ASTER, whereas ABI proxy fires are offset by approximately 1.5 pixels to the southeast. The source of this offset has been tentatively identified and a fix is in the works. This particular issue highlights just how sensitive fire detection is to navigation issues, both in simulation and in the real world.

CIMSS responded to 10 sets of questions regarding the fire algorithm from the Harris/AER team. Those responses prompted a number of edits to the ATBD as well as development of several detailed flowcharts. A small bug was also detected in the fire code and repaired. The CIMSS team also provided feedback on the first version of AER's ADD.

Publications and Conference Reports
Hoffman, Jay P., Schmidt, C. C., Prins, E. M., Brunner, J. C.: The GOES-R ABI Wild Fire Automated Biomass Burning Algorithm, Abstract IN53C-1636 presented at 2011 Fall Meeting, AGU, San Francisco, Calif., 4-9 December 2011.

Hoffman, Jay P.; Schmidt, C. C.; Prins, E. M. and Brunner, J. C.: The GOES-R fire detection algorithm from research to operations. 8th Annual Symposium on Future Operational Environmental Satellite Systems at the 92nd American Meteorological Society Annual Meeting, New Orleans, LA, 22-26 January 2012.
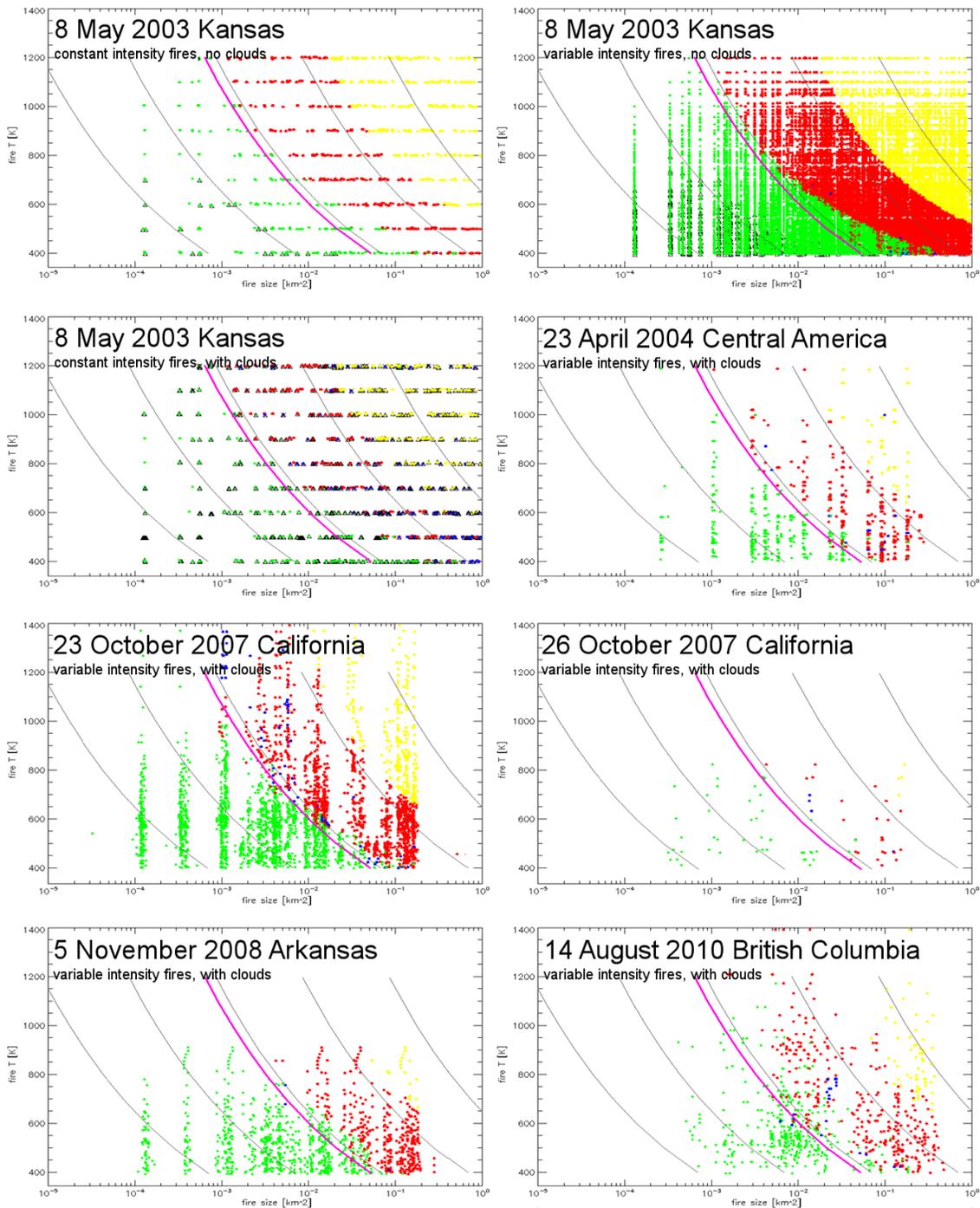
Figure 16.6.1. Scatter plots developed at CIMSS from the 8 ABI model-derived proxy cases developed at CIRA. Fires detected by the current GOES WF_ABBA were used as inputs. The horizontal axis is a logarithmic scale of fire size, and the vertical scale is fire temperature. The color coding indicates the type of fire or whether the fire was detected at all. Green indicates that the fire was not detected, red indicates a detected fire that was characterized, yellow indicates a saturated fire pixel, magenta indicates a cloud covered pixel, orange a high possibility fire pixel, and blue a medium possibility fire pixel. The curved lines are lines of constant FRP, in powers of 10 MW. The heavy magenta line is the 75 MW line, below which very few fires are detected.

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16.7 GOES-R Legacy Atmospheric Profile (LAP) Algorithm Development and Validation

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CIMSS Support Scientists: Zhenglong Li, Jim Nelson, Yong-Keun Lee, Graeme Martin
NOAA Collaborators: Tim Schmit, Bob Yu
NOAA Long Term Goals
- Climate Adaptation and Mitigation
- Weather-Ready Nation

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

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

Proposed Work

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. This project supports product validation which uses the collocated global numerical weather prediction (NWP) forecast and analysis fields, radiosonde observations, ground in-situ measurements, and sounding measurements (e.g., AIRS, IASI and CrIS) from polar-orbiting satellites. The current GOES Sounder, Spinning Enhanced Visible and Infrared Imager (SEVIRI), and Moderate Resolution Imaging Spectroradiometer (MODIS) data are used as proxy in the GOES-R LAP product validation. The 100% Algorithm Theoretical Basis Documents (ATBDs) for LAP, TPW, LI, CAPE, TT, SI and KI have been provided, it will be updated and maintained. In 2012, algorithm maintenance and technical support will continue to be provided to AIT/AER/Harris. Validation will be conducted with the current GOES Sounder, MODIS and SEVIRI. Validation tools including deep-diving tool will continue to be developed and improved for GOES-R ABI LAP products, TPW and atmospheric instability indices.

Summary of Accomplishments and Findings

Progress on GOES-R Legacy Atmospheric Profile (LAP) Algorithm Development and Validation

Response to Harris/AER questions on GOES-R LAP algorithm and implementation, 100%ATBD

CIMSS sounding team have answered all questions/issues from Harris/AER regarding the GOES-R legacy atmospheric profile (LAP) algorithm, software and implementation, as well as 100%ATBD. The questions/issues cover the use of community radiative transfer model (CRTM), cloud mask, Jacobian calculations, K-Matrix, field-of-regard, SATLFT, and WLIFT5, surface level index calculation, relative humidity calculation, dew point calculation etc. The questions cover all the products including temperature profile, moisture profile, TPW, LI, CAPE, KI and SI. All the questions/issues are answered and explained. CIMSS sounding team have also worked with GOES-R AWG algorithm integration team (AIT) in DC on testing the GOES-R LAP GEOCAT version to assure the consistency between the mainframe and the CIMSS GEOCAT local versions. Some difference issues in LAP retrieval between AIT frame and GEOCAT system are addressed and solved. AIT team found differences in LAP retrieval between AIT frame and GEOCAT system, particularly for moisture profile which shows the differences propagate downward during the physical retrieval process. CIMSS sounding team investigated this problem and found that it is related to different input for two systems caused by different interpolations and internal precision of machines, a resolution has been found.

Delivery of GOES-R AWG version 5.1.1, and the updated GOES-R LAP software was tested

The latest GOES-R LAP software was delivered to Algorithm Integration Team (AIT) and tested; also a document on testing information is developed. This document describes testing that was done for the version 5.1.1 delivery of the GOES-R LAP algorithm to the AIT. There are three changes from the previous release, version 5.1. The first is that the weighting function for surface temperature is set to 0 for ocean pixels in the physical retrieval. This change affects ocean pixels. The second change in that water vapor is interpolated in log-pressure rather than pressure in the TPW calculation as mentioned above. The TPW outputs are affected by this change, and the affect is minimal. The third change is to correct pre-processor directives that were mistakenly made upper-case in the last release (although there were no reports of any problems). The impact of the v5.1.1 changes on the products has been assessed with both simulated ABI and Met-8 test cases, and results are reasonable and acceptable.

Implementation and validation of GOES-R LAP algorithm with the current GOES Sounder and MODIS radiance measurements

CIMSS sounding team has implemented the GOES-R AWG LAP algorithm for the current GOES Sounder and MODIS for validation purpose. The CRTM is used in the GOES Sounder and MODIS atmospheric temperature and moisture profile retrieval process, TPW, LI, CAPE, KI, and SI can be generated from the atmospheric temperature and moisture profiles. The GOES-R LAP algorithm is applied to GOES-13 Sounder radiance measurements. The retrieved moisture profiles are integrated to obtain total precipitable water (TPW) – GOES-R TPW for simplicity. CIMSS also routinely generates three versions of the current GOES Sounder TPW: Li-Reg, Li-GFS, and Ma-GFS. The Li-GFS uses GFS forecast as first guess, and the Li-Reg uses regression as first guess. In the regression, the GFS forecast is used as predictors. The Ma-GFS is the old operational algorithm, and it uses GFS forecast as first guess. It has been demonstrated that the Ma-GFS has limitation on retrieval accuracy so the Li-Reg is currently on the transition to replace

the Ma-GFS for operational GOES sounding product generation. The collocated GFS forecast data, GPS retrieved TPW, and microwave radiometer (MWR) generated TPW along with GOES Sounder TPW (with different algorithms) at CART ARM site at Lamont OK are used for validation purpose. The MWR TPW is used as true because of it excellent accuracy.
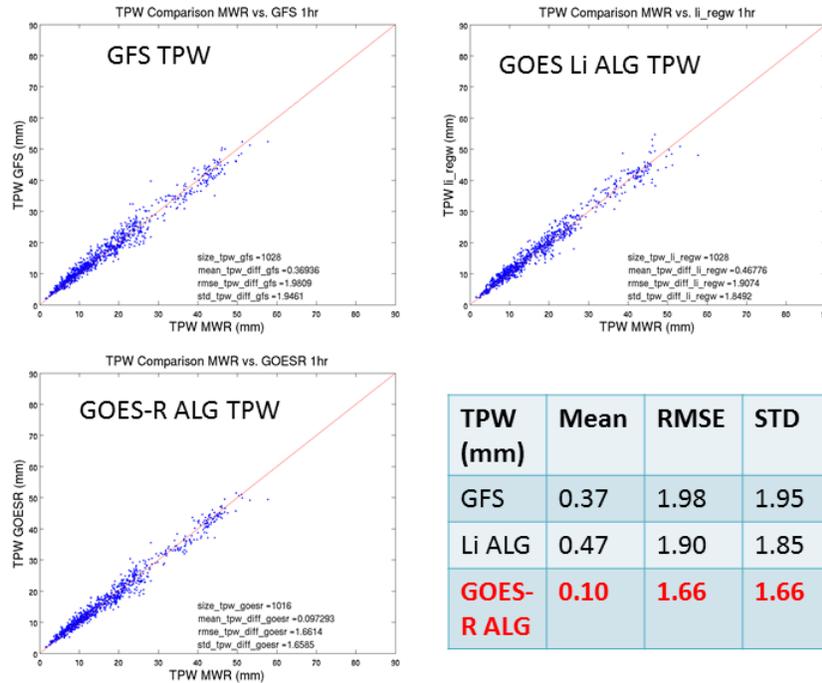
Figure 16.7.1. Scatter plot of GFS TPW (upper left), GOES Sounder Li-ALG TPW (upper right) and GOES-R ALG TPW (lower left) using MWR as reference. The biases, RMSE and Standard Deviation (STD) are also shown the in the table (lower right).

The time coverage is from August 2010 to March 2011. The GOES Sounder cloud mask is used to remove any cloudy or cloud contaminated FOVs. Figure 16.7.1 shows the scatter plot of GFS TPW (upper left), GOES Sounder Li-ALG TPW (upper right) and GOES-R ALG TPW (lower left) using MWR as reference. The GFS at CART ARM site shows great agreement with MWR. The standard deviation (STDDEV) is only 1.946 mm, and the RMSE is only 1.981 mm. The GFS forecast at ARM site is always excellent. It's possibly due to the assimilation of intense observations at ARM site. The Li-Reg shows slightly better results than GFS; the STDDEV is 1.849 mm (GFS is 1.946 mm). Therefore, the Li-Reg is able to generate TPW product with slightly better precisions than GFS at Cart site. The GOES Sounder with GOES-R ALG has the smallest STDDEV among all GOES TPWs; the STDDEV is only 1.659 mm, about 0.2 mm smaller than Li-Reg. The results with GOES-R algorithm is the best among the current GOES Sounder algorithms based on the comparisons with the MWR TPW measurements at ARM CART site. The GOES-R algorithm is also applied to process MODIS radiance measurements, validation is ongoing.

GOES-R validation tool development
CIMSS sounding team has developed the GOES-R LAP validation tool, the first version has been developed, the functions include the time series of TPW, CAPE, KI, TT, LI, SI from forecasts, retrievals and radiosondes, and the deep diving tools are also being developed. The deep diving tools include the atmospheric profiles (SkewT) from GOES Sounder/ABI and radiosondes.

GOES-R sounding team Co-Chair Tim Schmit has reviewed the GOES-R LAP validation tools and has made suggestions on future improvements. TPW time series from GFS, GOES Sounder physical retrieval (with GOES-R LAP algorithm), radiosonde observations, MWR TPW measurements, and global positioning system (GPS) TPW measurements between 2011.01.26 00 UTC and 2011.01.28 23 UTC over ARM CART site can be plotted. GOES Sounder TPW with GOES-R LAP algorithm provides reasonable results when compared with the MWR TPW measurements. The deep diving information such as atmospheric temperature and moisture profiles can be plotted at any given time. Figure 16.7.2 shows the skew-T diagram includes the temperature and dewpoint temperature profiles for GFS, GOES Sounder physical retrieval (with GOES-R LAP algorithm), and radiosonde measurements on 2011.01.26 00UTC over ARM CART site located at latitude 36.61 degree North and longitude 97.49 degree West.
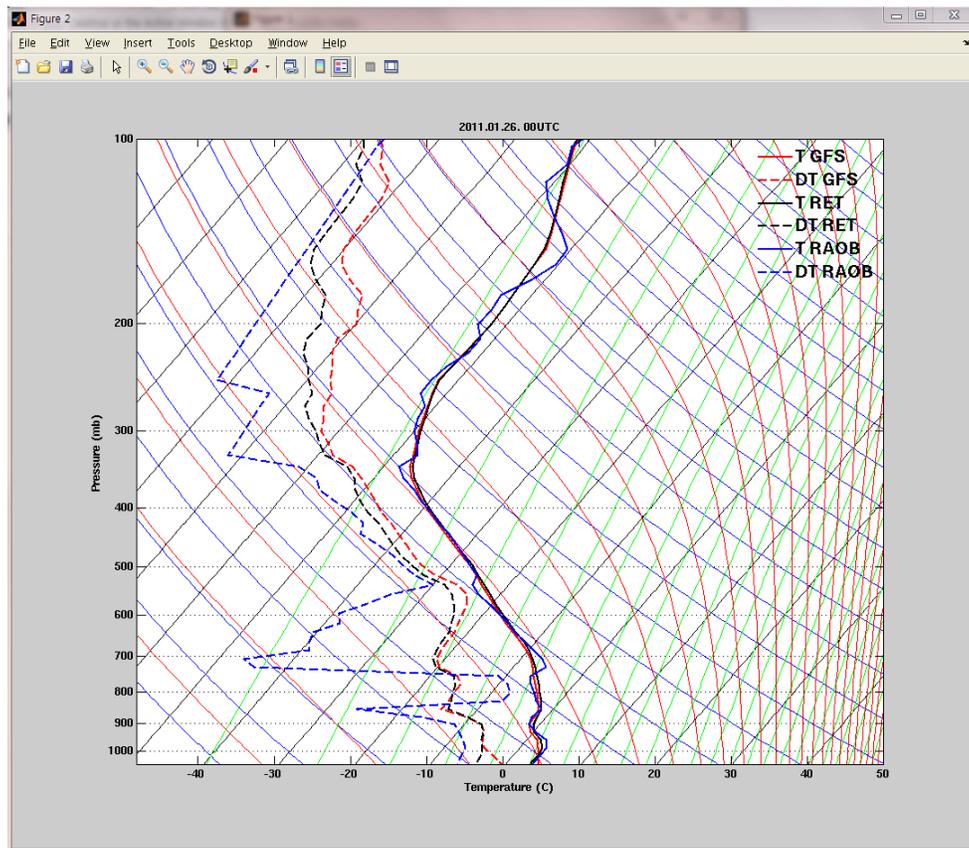
Figure 16.7.2. The skew-T diagram includes the temperature and dewpoint temperature profiles for GFS, GOES Sounder physical retrieval (with GOES-R LAP algorithm), and radiosonde measurement on 2011.01.26 00UTC over ARM CART site.

Progress on GOES-R Land Surface Emissivity (LSE) Algorithm Development and Validation

The GOES-R ABI emissivity algorithm is applied to 10 weeks of disk SEVIRI data, the same algorithm is applied to SEVIRI measurements at SAF (satellite application facility) site in Namibia. The latitude and longitude are -23.0 and 18.34 degree, and the local zenith angle is 33.9 degree. The SEVIRI measurements are prepared by SSEC/Data Center, from 08/01/2009 to 08/31/2009. Along with SAF measured land surface temperature (LST), the STAR LST products using split window technique by Bob Yu's group is also used in the comparisons. Figure 16.7.3

shows the daily average of the 3 infrared window channel emissivities. Although there are temporal variations, no substantial diurnal changes are seen in any of the three window channels.
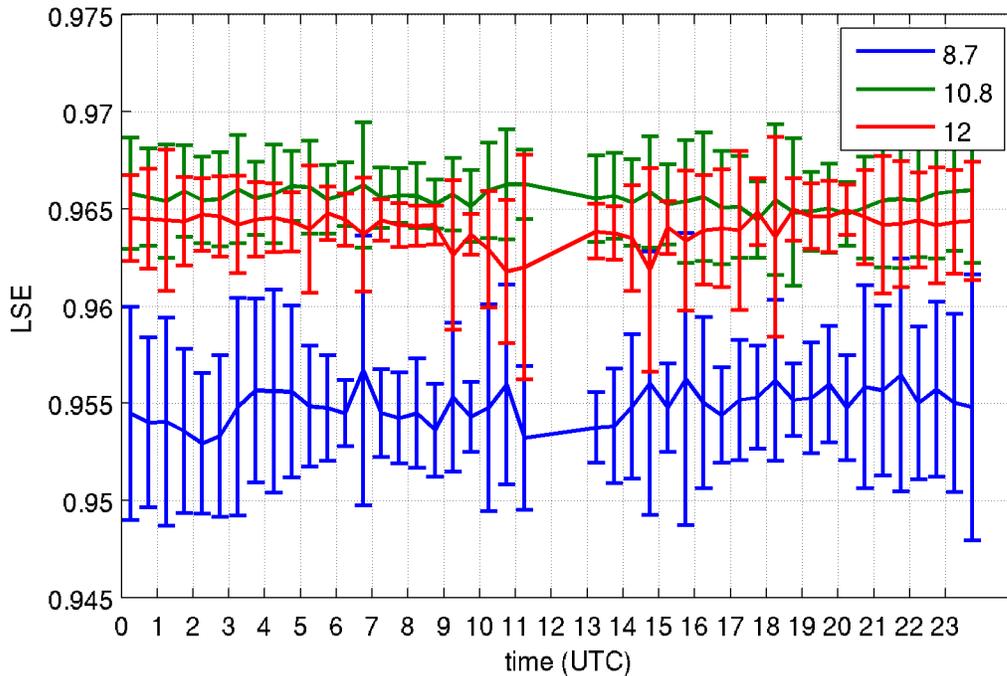
Figure 16.7.3. The daily average of the 3 SEVIRI window channel emissivities retrieved using GOES-R ABI emissivity algorithm. The bar denotes the standard deviations.
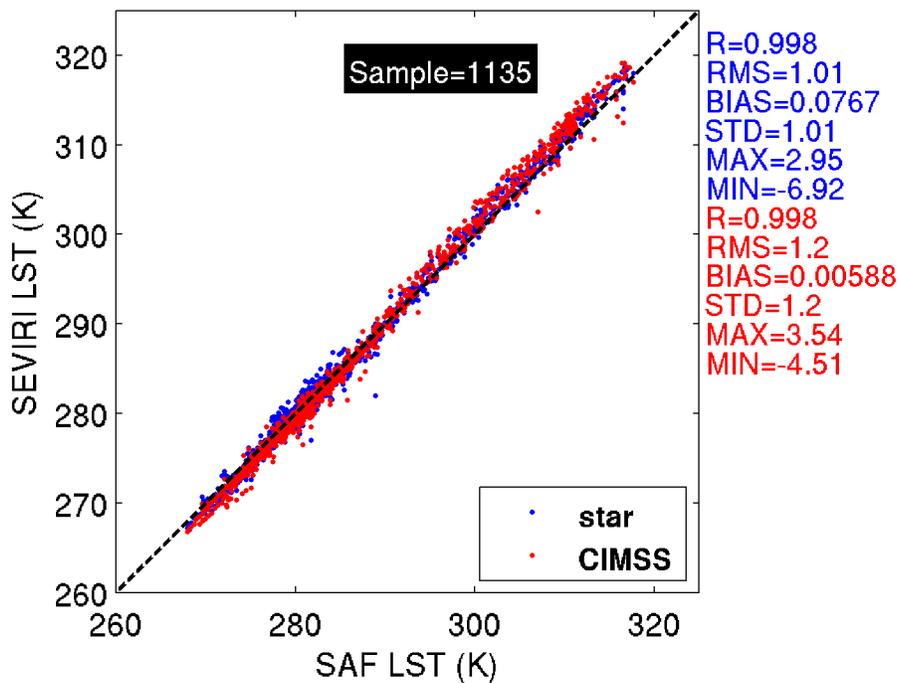
Figure 16.7.4. Scatter plots of LST from CIMSS and STAR using SAF (satellite application facility) LST measurements as reference.

Figure 16.7.4 shows the land surface temperature (LST) scatter plot along with the statistics. The CIMSS LST shows a similar bias pattern as shown by STAR LST; warm scene has warm bias and cold scene has cold bias – what we call twisted bias. There are three possible reasons for the twisted bias. If the real emissivity has diurnal change and the retrieval algorithm is not able to capture that, the retrieved LST will have twisted bias. However, the SAF LST is derived using emissivities with very little temporal variations. From 8/1/2009 to 8/31/2009, the emissivity is changed from 0.975 to 0.972. Since the CIMSS-retrieved LSE does not show strong diurnal changes either, it is reasonable to assume the twisted LST bias is not due to emissivity diurnal change. Another possible reason is calibration. More specifically, a bias adjusted is needed to remove warm bias in warm scene and cold bias in cold scene. Another possible reason is the retrieval algorithm. Due to error correlation between LSE and LST, the retrieval algorithm might generate the twisted LST bias. Through simulation study, it is possible to check if the algorithm generates those twisted LST bias.

In Figure 16.7.4, there are some CIMSS retrievals with significant cold biases compared with SAF measurements. Those are possibly cloud contaminated. When there are clouds contaminated, the observed SEVIRI Tbs in the three window channels are no longer like clear sky Tbs. The retrieval algorithm will have difficult to converge. Figure 16.7.5 (c) shows the time series of the averaged residuals after the physical retrieval. When residuals are larger than 0.2 K in Figure 16.7.5 (c), the retrieved LST in Figure 16.7.5 (a) appears to have more cold bias, indicating possible cloud contaminations. And the retrieved LSE appears to have abnormal values too. Therefore, it is suggested to look at the residuals to check if retrieval is reasonably converged or not. If it is not well converged, there might be something wrong with the LSE/LST retrieval, and the retrieval should be flagged as bad retrieval.

After removing pixels with averaged residual larger than 0.2 K, Figure 16.7.6 shows the scatter plots of the LST and when compared with Figure 16.7.4, both CIMSS and STAR LSTs show better agreement with SAF measurements. Specially, CIMSS LST shows an improvement of STDDEV error from 1.2 K to 1.15 K.

The results above show that: (a) the LSE retrievals are affected by bias adjustment. Unreasonable bias adjustment may generate artificial emissivity diurnal changes (not shown); (b) the bias adjustment appears to have smaller impacts on the LST retrieval; and (c) The retrieval algorithm might be able to detect abnormal retrievals by examining the averaged BT residuals. In a perfect situation, the averaged residual should be very small. Any averaged residual larger than 0.2 K might indicate there is something wrong with the retrieval. We will look at the 10 weeks data to see if the diurnal changes exist by using SEVIRI measurements without any bias adjustment, in addition, we will use simulation to study if the algorithm generates the twisted LST bias.

Publications and Conference Reports

Jin X., J. Li, T. Schmit, and M. Goldberg, 2011: Evaluation of radiative transfer models in atmospheric profiling with broadband infrared radiance measurements, *International Journal of Remote Sensing*, **32**, 863-874.
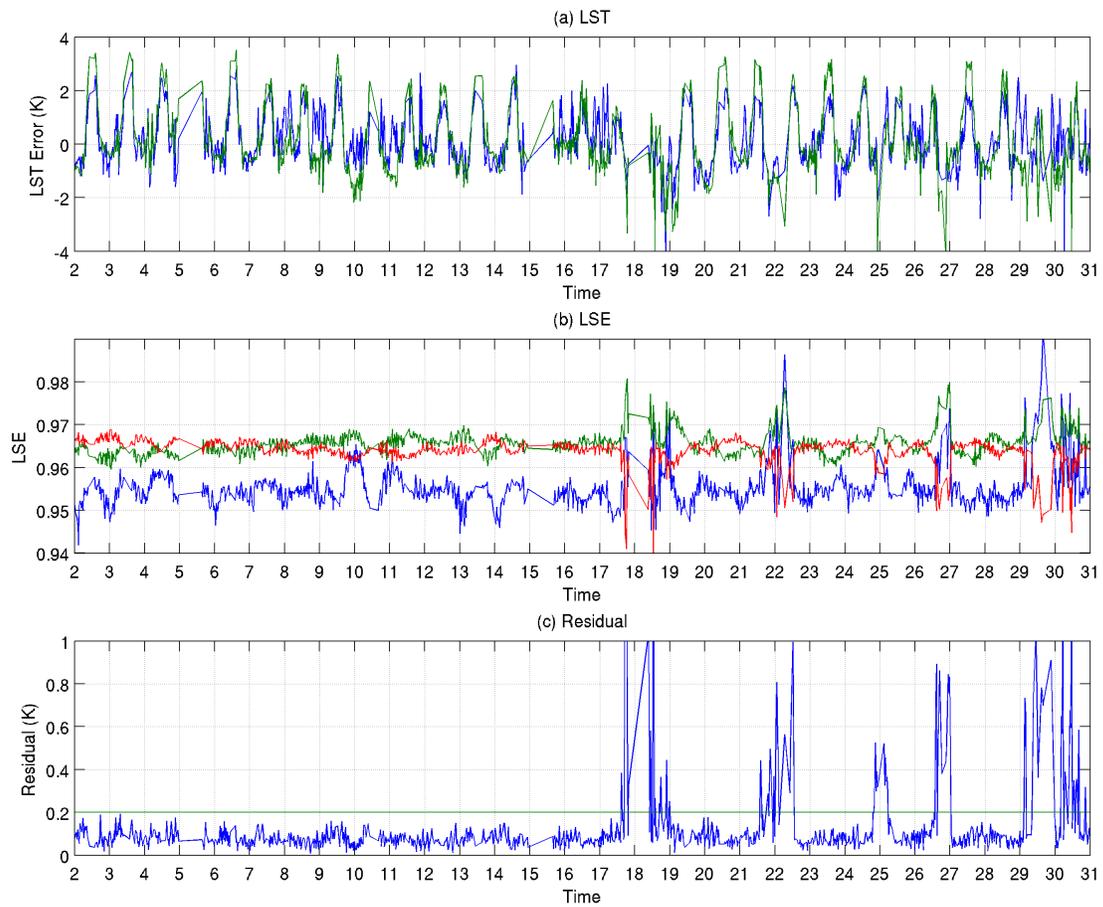
Figure 16.7.5. Time series of (a) retrieved LST errors (green is CIMSS LST, blue is STAR LST), (b) retrieved LSE, and (c) averaged residual.
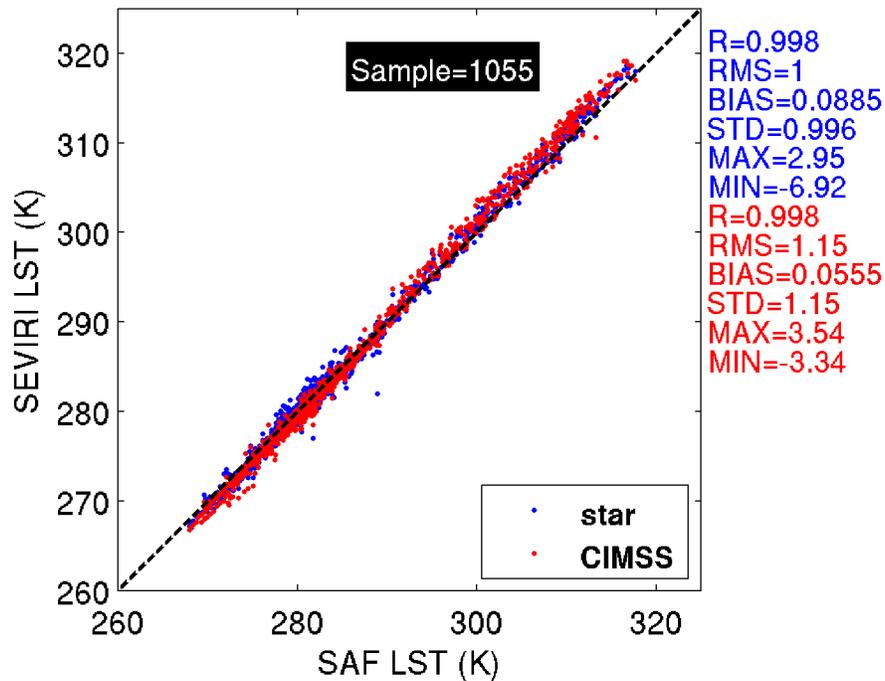
Figure 16.7.6. Same as Figure 16.7.4 except that retrievals with averaged BT residuals larger than 0.2 K are not included.

References

Jin X., J. Li, T. Schmit, and M. Goldberg, 2011: Evaluation of radiative transfer models in atmospheric profiling with broadband infrared radiance measurements, *International Journal of Remote Sensing*, **32**, 863-874.

Li, J., Z. Li, X. Jin, T. Schmit, L. Zhou, and M. Goldberg, 2011: Land surface emissivity from high temporal resolution geostationary infrared imager radiances: Methodology and simulation studies, *Journal of Geophysical Research - Atmospheres*, **116**, D01304, doi:10.1029/2010JD014637.

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

16.8 GOES-R AWG ABI Winds

CIMSS Task Leaders: Chris Velden and Steve Wanzong
NOAA Collaborator: Jaime Daniels (STAR)
NOAA Strategic Goals
- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

CIMSS Research Themes
- Weather Nowcasting and Forecasting

Proposed Work
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 semi-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.

We propose to take the hourly AMVs from Meteosat-9 in near real-time and validate them 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, and wrote an AMV-CALIPSO collocation software system. We have been compiling AMV GFS analysis match statistics since May 2011. Although the following figures show that the statistics stop at the end of December 2011, the project has continued. The GFS model analysis wind fields are used to measure the performance of the AMV product over oceanic regions. Here, 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.

The following sets of images show how the algorithm is performing with respect to the GOES-R requirements. Each image has a light blue line at the top, which marks the GOES-R accuracy requirement (7.5 m/s). The second light line in red is the GOES-R precision requirement (4.5 m/s). The observed data are the thicker lines. Observed accuracy is blue, observed precision is red, and green is the speed bias. In all cases, the requirements are being met.
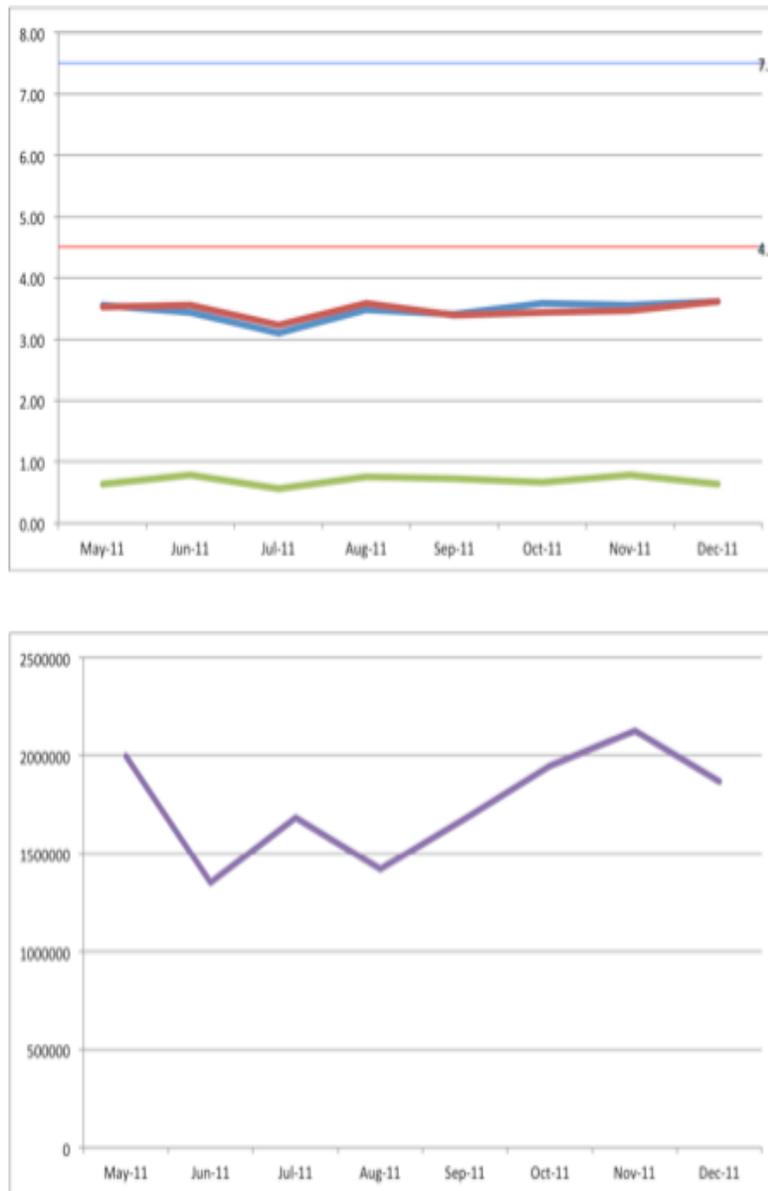
Figure 16.8.1. Monthly comparison statistics (ocean only) between AMVs computed using all bands and all levels from full disk Meteosat-9 and NCEP GFS Analysis winds (valid at all synoptic times) for the months of May 2011 through December 2011. Bottom image is the number of AMV GFS analysis matches.
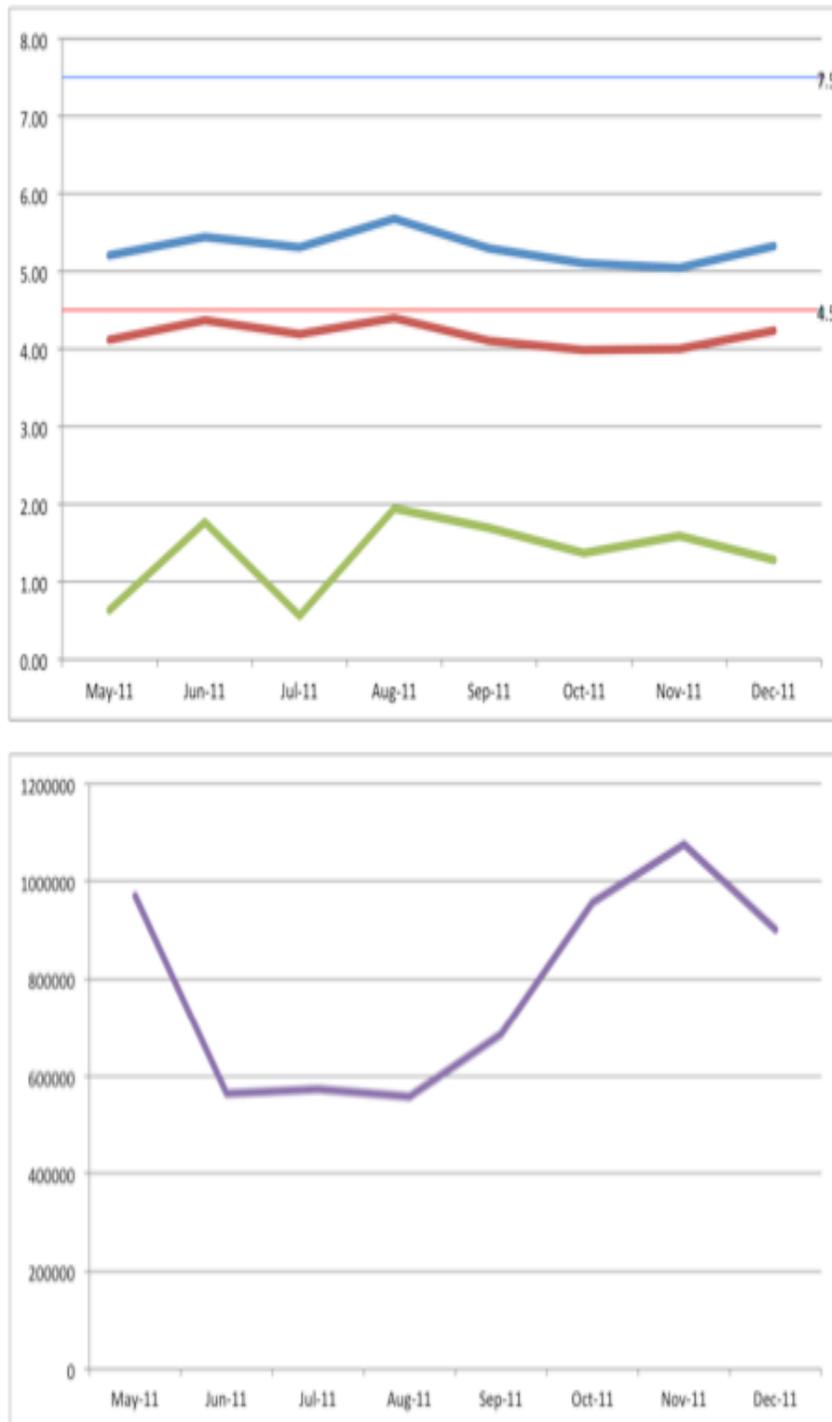
Figure 16.8.2. Monthly comparison statistics (ocean only) between AMVs computed using all bands at upper levels (100 – 400 hPa) from full disk Meteosat-9 and NCEP GFS Analysis winds (valid at all synoptic times) for the months of May 2011 through December 2011. Bottom image is the number of AMV GFS analysis matches.

Figure 16.8.3. Monthly comparison statistics (ocean only) between AMVs computed using all bands at mid levels (400 – 700 hPa) from full disk Meteosat-9 and NCEP GFS Analysis winds (valid at all synoptic times) for the months of May 2011 through December 2011. Bottom image is the number of AMV GFS analysis matches.

Figure 16.8.4. Monthly comparison statistics (ocean only) between AMVs computed using all bands at low levels (below 700 hPa) from full disk Meteosat-9 and NCEP GFS Analysis winds (valid at all synoptic times) for the months of May 2011 through December 2011. Bottom image is the number of AMV GFS analysis matches.

Publications and Conference Reports

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Wanzong, Steve; Bresky, W.; Velden, C.; Daniels, J. and Bailey, A., 2012: GOES-R Readiness: Atmospheric Motion Vectors (AMVs) Validation Activities. 11th International Winds Workshop, Auckland, New Zealand, 20-24 February 2012.

Wanzong, Steve; Bresky, W.; Velden, C.; Daniels, J.M. and Rink, T.D. GOES-R AWG Atmospheric Motion Vectors: Validation Activities. Conference on Satellite Meteorology, Oceanography and Climatology, 18th and Joint AMV-Asia Satellite Meteorology Conference, 1st, New Orleans, LA, 22-26 January 2012.

Zhang, Hong; Gunshor, M.; Straka, W.; Martin, G.; Wanzong, S.; Schiffer, E.; Garcia, R. and Huang, A. GRAFIIR – An efficient end-to-end semi automated GOES-R ABI algorithm performance analysis and implementation verification system. Annual Symposium on Future Operational Environmental Satellite Systems, 8th, New Orleans, LA, 22-26 January 2012.

Daniels, Jaime M.; Bresky, W.; Wanzong, S. and Velden, C.S.: Atmospheric motion vectors derived via a new nested tracking algorithm developed for the GOES-R Advanced Baseline Imager (ABI). Annual Symposium on Future Operational Environmental Satellite Systems, 8th, New Orleans, LA, 22-26 January 2012.

Zhang, Hong; Gunshor, M.; Straka, W.; Martin, G.; Wanzong, S.; Schiffer, E.; Garcia, R. and Huang, A. GRAFIIR – An efficient end-to-end semi automated GOES-R ABI algorithm performance analysis and implementation verification system. Annual Symposium on Future Operational Environmental Satellite Systems, 7th, Seattle, WA, 23-27 January 2011.

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

CIMSS Task Leaders: Chris Velden and Tim Olander
NOAA Collaborator: Jaime Daniels (STAR)
NOAA Strategic Goals
- Serve society's needs for weather and water
- Provide critical support for the NOAA mission

CIMSS Research Themes
- Weather Nowcasting and Forecasting

Proposed Work
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. In addition, we continued to develop and deliver additional routine and deep dive validation software for the AIT framework as required, as well as derived any necessary validation documentation.

Specifically, a majority of the work focused on reviewing documentation written by Harris/AER programmers in order to recode the HIE algorithm from scratch within their development platform. The development of the Algorithm Description Document (ADD), based upon the HIE Advanced Theoretical Basis Document (ATBD) delivered previously by CIMSS scientists, was undertaken to provide a much more detailed description of the entire HIE code, including flowcharts, constant definitions, and algorithm pseudo-code outlining the logic used within the HIE, than provided in the ATBD. Several different reviews of the AER/Harris interpretation of the ATBD, as well as questions relating to their development of the ADD, have been performed.

Testing and validation of a 10 storm test data set was performed to document the use of the externally-derived Passive Microwave (PMW) "eye score" within the HIE (something not done with the original tests outlined in the 100% HIE ATBD). During testing an issue related to the implementation and use of the PMW data on the AIT framework was diagnosed and fixed through collaborative efforts between CIMSS and AIT programmers. The issue was found to be a simple file access and update issue within the AIT framework. Test comparisons between the CIMSS and AIT framework versions were found to produce results within the thresholds defined by previous testing efforts once the issue was solved.

In addition, reviews of initial documentation relating to the HIE Validation software has been performed to answer questions and clarify issues raised by reviewers. The HIE initial validation software was developed and delivered on-time on December 15, 2010.

Publications and Conference Reports

Olander, T., and C. Velden, 2011: The GOES-R AWG Hurricane Intensity Estimation (HIE) Algorithm, GOES-R Algorithm Working Group Meeting, Ft. Collins, Colorado, June 14-16.

Olander, T., and J. Daniels, 2011: GOES-R Hurricane Intensity Estimation Validation Tool Development, GOES-R Validation Workshop, Camp Springs, Maryland, May 10-11.

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.

16.10 Turbulence – Tropopause Folding

CIMSS Task Leaders: Anthony Wimmers, Wayne Feltz
NOAA Collaborators: Ken Pryor (Aviation team), GOES-R AWG members
NOAA Long Term Goals
- Weather-Ready Nation

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

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

Proposed Work
The tropopause folding turbulence product (TFTP) resolves regions of dynamical turbulence caused by tropopause folds at air mass boundaries. Identifying these regions of turbulence is important to the aviation community (commercial and non-commercial) for purposes of hazard awareness and safety (Wimmers and Feltz, 2005). Tropopause folds are located by their association with gradients in moisture, which are evident in the ABI band sensitive to upper-tropospheric water vapor (Wimmers and Moody, 2004a, 2004b). The TFTP automatically detects these gradients in moisture, imposes extra conditions for association with flow instability and presents a distribution of regions of expected turbulence. The tasks proposed for the previous year are summarized as follows:
- Complete the Tropopause Folding algorithm to 100% maturity: Develop and deliver Version 5 (conforming to Comprehensive Unit Test Review) to the GOES-R Algorithm Integration Team;
- Conduct cal/val to validate 100% algorithm performance using proxy data sets; and
- Develop/document routine and deep-dive validation tools.

Summary of Accomplishments and Findings
The development and delivery of the algorithm proceeded on schedule and as planned. Delivery of Version 5 included the successful demonstration of the algorithm on Meteosat imagery (crossing the prime meridian), GOES-West imagery (crossing the antemeridian), and GOES-East full disk imagery. The algorithm parameters were calibrated to each of these platforms, as well as GOES-R ABI, which is the most similar to Meteosat-8 in wavelength band. An application of the algorithm to Meteosat imagery is shown in Figures 16.10.1 and 16.10.2.

The algorithm was validated with a data set of GOES-12 (East) imagery and ancillary GFS model fields from 2005 to 2007, collocated to automated aircraft eddy dissipation rate (EDR) data from contributing commercial aircraft (Boeing 737 and 757). While the algorithm performance threshold is 50% accuracy, the algorithm achieved 53% accuracy. In addition, the performance was valid for 12 months of the year, while the previous testing indicated that it might have only been applicable for 8 months of the year (away from summer months when tropopause folding is diminished).

Finally, routine and deep dive validation tools were developed and delivered at the "Version 1" stage and documented in the algorithm's Validation Plan (Wimmers and Feltz, 2011).
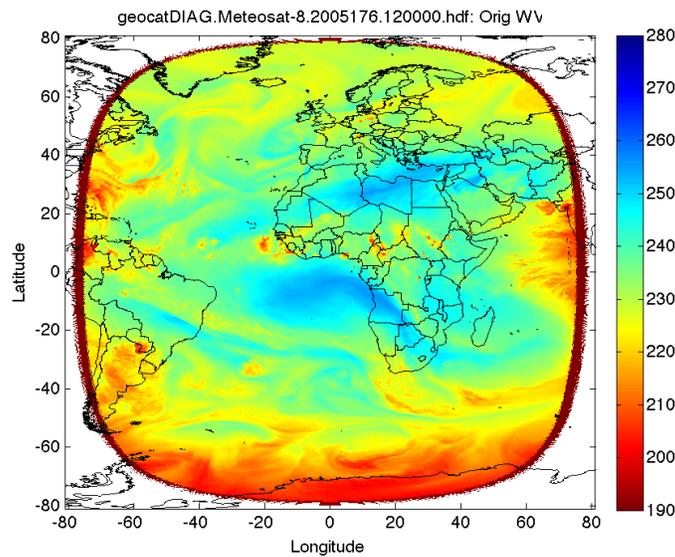
Figure 16.10.1. Meteosat-8 Water vapor channel (brightness temperature) for 1200 UTC on June 25, 2005.
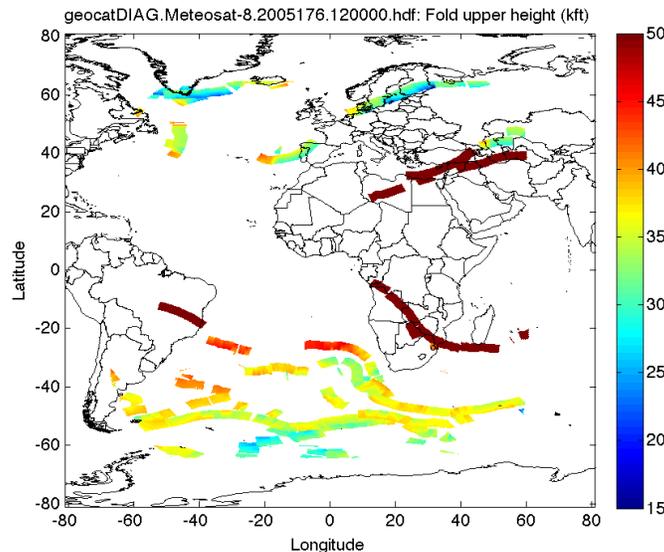
Figure 16.10.2. Tropopause folds for previous image, displayed as the maximum height (units: kft). In the midlatitudes of the northern hemisphere, significant tropopause folds occur at blocking boundaries in the North Atlantic and southern Greenland, at a low pressure system west of the Iberian peninsula, and in connection with a polar air mass front across Scandinavia.

Publications and Conference Reports

Wimmers, A. J. and W. F. Feltz, 2011: GOES-R AWG Aviation Team: Tropopause Folding Turbulence Product. GOES-R AWG Annual Meeting. Ft. Collins, CO, June 2011.

Wimmers, A. J. and W. F. Feltz, 2012: The GOES-R Tropopause Folding Turbulence Product: Finding clear-air turbulence in GOES water vapor imagery. 18th Conference on Satellite Meteorology and Oceanography. New Orleans, January 2012, Amer. Meteor. Soc.

References

Wimmers, A. J., and J. L. Moody, 2004a: Tropopause folding at satellite-observed spatial gradients: 1. Verification of an empirical relationship. *J. Geophys. Res.*, **109**, D19306, doi:10.1029/2003JD004145.

Wimmers, A. J., and J. L. Moody, 2004b: Tropopause folding at satellite-observed spatial gradients: 2. Development of an empirical model. *J. Geophys. Res.*, **109**, D19307, doi:10.1029/2003JD004146.

Wimmers. A. J. and W. Feltz, 2005: Estimating regions of tropopause folding and clear-air turbulence with the GOES water vapor channel. World Research Symposium on Nowcasting and Very Short Range Forecasting.

Wimmers. A. J. and W. Feltz, 2011: Product Validation Plan Document: Tropopause Folding Turbulence Prediction.

16.11 GOES-R AWG Volcanic Ash

CIMSS Task Leader: 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

Proposed Work
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 have participated in Technical Interchange Meetings and AERs with the ground segment to resolve questions related to the implementation of the GOES-R Volcanic ash algorithm.

Additional work has focused on developing a validation tool that utilizes spaceborne lidar (CALIPSO). The validation tool has been used to validate GOES-R ash cloud height retrievals (and mass loading, not shown) of recent volcanic eruptions, including Eyjafjallajökull (Iceland),

Grimsvotn (Iceland), and Cordon Caulle (Chile). These eruptions were observed by SEVIRI on Meteosat-9 (proxy for GOES-R ABI) as well as CALIPSO. Figure 16.11.1 shows the validation of Eyjafjallajökull and Grimsvotn/Cordon Caulle ash cloud heights. The accuracy was -1.12 km and -2.62 km, respectively and precision was 1.68 km and 3.41 km, respectively. The low bias of the GOES-R ash cloud height retrievals are due to the coarse vertical resolution of the broadband infrared measurements compared to fine vertical resolution of the visible lidar measurements.
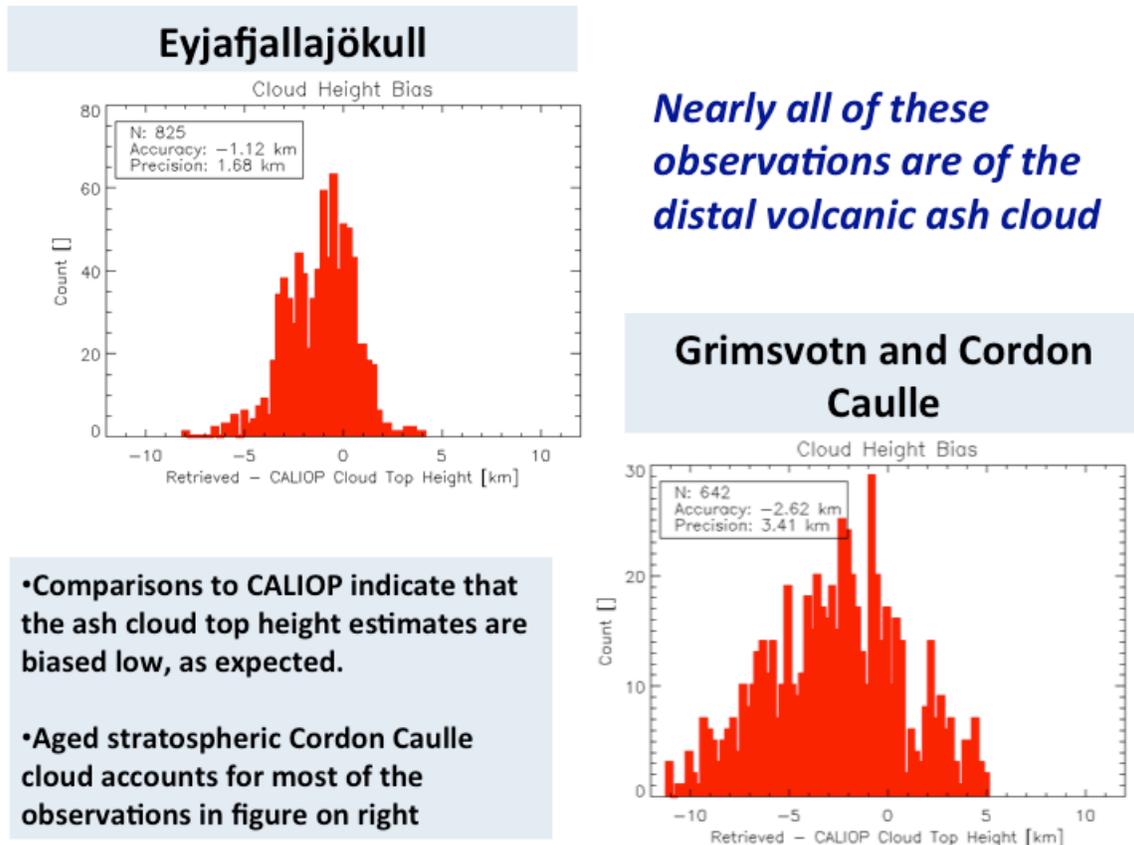
Figure 16.11.1. GOES-R Volcanic ash cloud height validation for Eyjafjallajökull (left) and Grimsvotn and Cordon Caulle (right) eruptions. The GOES-R retrieved height minus CALIOP cloud top height are displayed in each figure. The GOES-R ash cloud height low bias is expected given the coarser vertical resolution of broadband infrared measurements compared to visible lidar observations.

Publications and Conference Reports

Pavolonis, M. J., C. Calvert, and J. Sieglaff, 2012: New Quantitative Volcanic Cloud and Fog Products for GOES-R, presentation at the Annual AMS Meeting, New Orleans, LA.

Pavolonis, M. J. and J. Sieglaff, 2012: Satellite Retrievals of Volcanic Ash Cloud Properties: Evaluation of near Real Time Results and Suggestions for Improving Operational Satellite Products, presentation at the Annual AMS Meeting, New Orleans, LA.

References

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

Pavolonis, M. J., 2011: Advances in extracting cloud composition information from spaceborne infrared radiances: A robust alternative to brightness temperatures. Part II: Proof of concept. To be submitted to: *J. Applied Meteorology and Climatology*.

16.12 AWG SO$_2$

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

CIMSS Research Themes
- Satellite Meteorology Research and Applications

Proposed Work

We have implemented an infrared-based SO$_2$ detection algorithm. We propose to conduct the cal/val and development work required to assure that we achieve the F&PS specifications for the SO$_2$ product. The SO$_2$ product will be primarily validated against SO$_2$ loading amounts derived from the Ozone Monitoring Instrument (OMI). Any problems discovered in the cal/val process will be addressed. Much of the work will also be aimed at documenting the software and algorithms using AIT standards in preparation for code and documentation deliveries (e.g., ATBDs). This work will insure the readiness of the SO$_2$ algorithm for operational implementation upon the deployment of GOES-R.

Summary of Accomplishments and Findings

Previously, an SO$_2$ detection algorithm was developed that utilizes the four infrared channels: 7.3, 8.5, 11 and 12 μm. The 7.3 and 8.5 μm channels are sensitive to SO$_2$ absorption, while the 11 and 12 μm channels are not. The 8.5, 11 and 12 μm channels are sensitive to small particles, which are often present in SO$_2$ contaminated ice clouds. Radiances at the four wavelengths are converted to cloud optical depth, and ratios of the optical depth pairs (β ratios) (Pavolonis, 2010) are used to distinguish meteorological clouds from ice clouds that contain SO$_2$. For example, the 7.3/11 optical depth ratio is sensitive to SO$_2$ absorption and the 11/12 optical depth ratio is sensitive to small particles. An example of the GOES-R SO$_2$ product is in Figure 16.12.1.
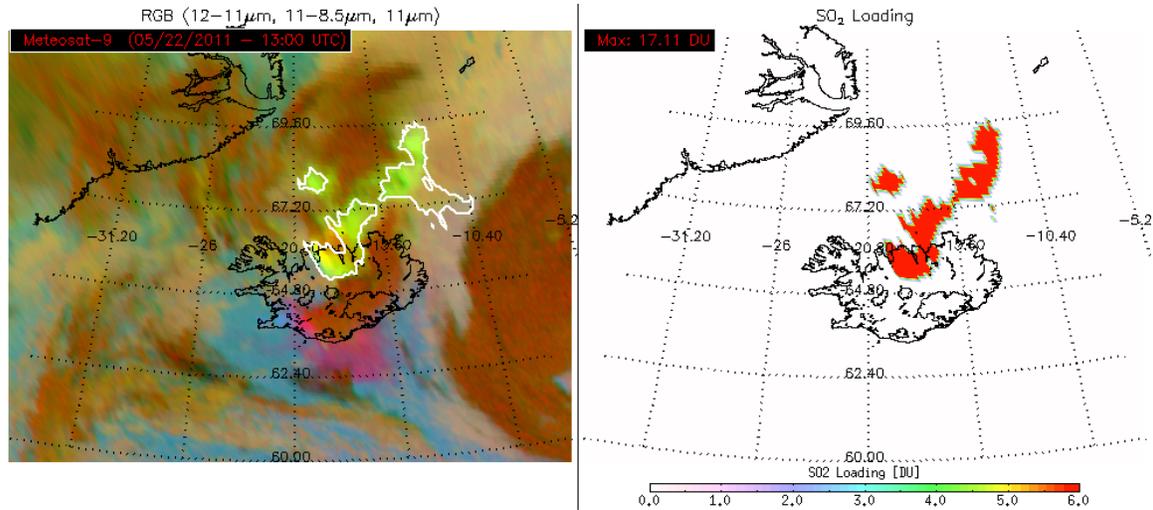
Figure 16.12.1. The results of the binary (e.g., yes/no) GOES-R SO_2 detection algorithm are overlaid on a false color image (left panel) and estimates of the total SO_2 loading are shown in the right panel. The SO_2 cloud shown in this example was produced by an eruption of Grimsvotn (Iceland) on May 22, 2011.

The GOES-R SO_2 detection methodology has been validated against SO_2 loading estimates derived from hyperspectral ultra-violet measurements made by the OMI. Comparisons to the OMI indicate that the GOES-R product meets the required accuracy specifications. More specifically, as shown Figure 16.12.2, a true skill score of 0.7 is obtained when the OMI estimated SO_2 loading is 14 Dobson Units or greater.

In addition, the following project milestones were also achieved:
- Delivery of 100% Algorithm Theoretical Basis Document (ATBD) and Version 4 of the SO_2 detection code to GOES-R Algorithm Implementation Team (AIT), and
- Completion of Algorithm Readiness Review (ARR)

Publications and Conference Reports
Pavolonis, M. J. and A. Parker: GOES-R SO_2 Detection Algorithm Theoretical Basis Document (ATBD), 100% Delivery, June 2011.

References
Pavolonis, M. J., 2010: Advances in extracting cloud composition information from spaceborne infrared radiances: A robust alternative to brightness temperatures. Part I: Theory. *J. Applied Meteorology and Climatology*, **49**, 1992-2012.
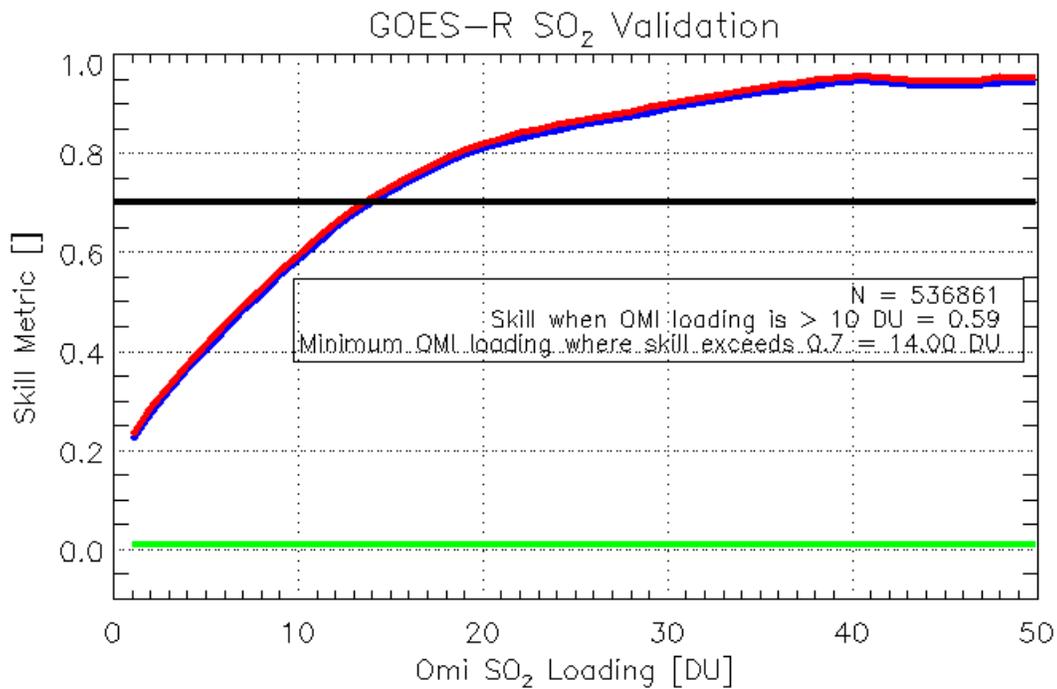
Figure 16.12.2. The true skill score statistic (red line) of the GOES-R binary SO_2 detection algorithm is shown as a function of the SO_2 loading estimated by the OMI. The hit (detection) rate is shown in blue and the false alarm rate is shown in green.

16.13 Fog/Low Cloud

CIMSS Task Leader: Corey Calvert
CIMSS Support Scientist: William Straka
NOAA Collaborator: Michael Pavolonis
NOAA Long Term Goals
 • Weather-Ready Nation
NOAA Strategic Goals
 • Serve society's needs for weather and water
 • Support the nation's commerce with information for safe, efficient and environmentally sound transportation
CIMSS Research Themes
 • Satellite Meteorology Research and Applications

Proposed Work
The final version of the GOES-R Advanced Baseline Imager (ABI) fog/low cloud detection algorithm was created and implemented on the Algorithm Integration Team's (AIT's) test computer. This algorithm utilized spatial and spectral characteristics of the imager data using pre-determined look-up tables (LUTs) to produce a probabilistic approach to detection. A limit to this approach was fog/low cloud could only be detected if it was the highest cloud layer. We proposed merging the satellite data with modeled relative humidity (RH) data to estimate the probability that fog/low cloud is present for all pixels even with overlaying clouds. We implemented a new fog/low cloud definition that will more accurately relate to aviation weather. Fog/low cloud is

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now defined as a cloud meeting ceiling and/or surface visibility requirements to produce Instrument Flight Rules (IFR) conditions, defined as having a ceiling below 1000 feet, or surface visibility less than three statute miles. Along with the IFR probability we also added an additional probability that Low Instrument Flight Rules (LIFR) conditions are present. LIFR conditions are defined as having a cloud ceiling less than 500 feet or a surface visibility less than one statute mile. New LUTs were created to take into account the new definition of fog/low cloud. The thickness of the highest liquid water cloud is also estimated using a linear relationship between the 3.9 μm pseudo-emissivity (night) and liquid water path (LWP) (day). The algorithm was updated in a real-time GOES EAST/WEST processing stream (http://cimss.wisc.edu/geocat) for continuous evaluation. This project will ensure the readiness of the fog/low cloud algorithm for operational implementation upon the deployment of GOES-R.

Summary of Accomplishments and Findings

The GOES-R fog/low cloud algorithm is designed to quantitatively identify clouds that produce IFR conditions, defined as having a cloud ceiling below 1000 ft above ground level or a surface visibility less than three statute miles. The fog detection algorithm utilizes textural and spectral information, model RH data, and the difference between the cloud radiative temperature and modeled surface temperature. Fog often has a temperature similar to the surface temperature. Therefore, under cloudy conditions, small temperature differences between the cloud top and surface generally indicate areas of low cloud. Fog/low stratus clouds also tend not to be associated with spatially varying vertical motion (e.g., cumulus clouds), which results in it being relatively uniform spatially in albedo and temperature. Clouds form when the atmosphere is at or near saturation so fog/low clouds have a relatively high RH. At night, the algorithm utilizes modeled RH data along with the 3.9 and 11 μm channels to detect IFR conditions. Fog/low cloud detection during the day is determined using modeled RH data along with the 0.65, 3.9, and 11 μm channels. LUTs were created using a 3.9 μm pseudo-emissivity (night), 3.9 μm reflectance (day), a 3x3 pixel 0.65 μm reflectance spatial uniformity metric (day), the difference between the cloud radiative temperature and surface temperature (both day and night), and modeled RH (both day and night) from both fog and non-fog water clouds determined by surface observations and the GOES-R cloud type algorithm. Information obtained from the LUTs is combined using the naïve Bayesian method to produce a probability that fog/low cloud is present at any given pixel. The fog/low cloud depth is calculated for each pixel flagged by the detection algorithm (excluding pixels containing ice or overlaying clouds) based on a linear relationship between the 3.9 μm pseudo-emissivity (night) and LWP (day). Examples of the final output determined by the fog/low cloud detection algorithm are shown in Figure 16.13.1.

The following additional project milestones were achieved:
- Delivered the fog/low cloud 100% code to the Algorithm Implementation Team (AIT) – September 2011;
- Completed the final draft (100%) of the fog/low cloud Algorithm Theoretical Basis Document (ATBD) – September 2011; and
- Evaluated the GOES-R Fog/Low Cloud algorithm during the GOES-R proving ground by the NWS in Sullivan, WI during the fall/early winter of 2011. The GOES-R Fog/Low Cloud algorithm will also be evaluated by the GOES-R proving ground (NWS central region) starting in the early spring of 2012.
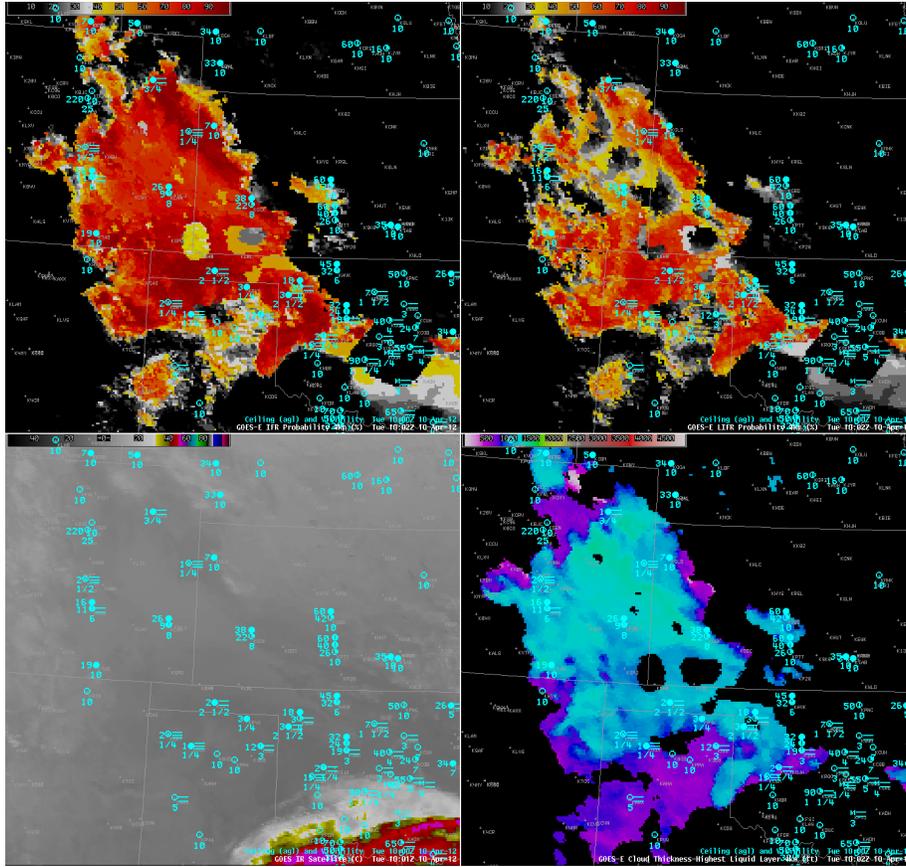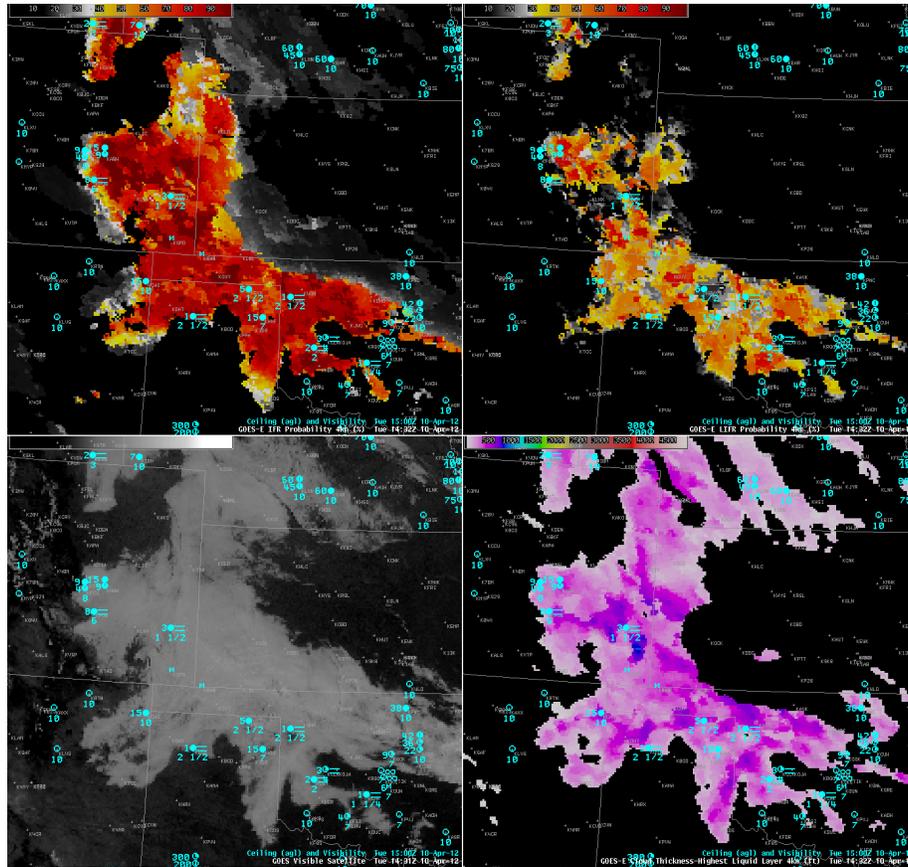
Figure 16.13.1. Example output from the GOES-R fog/low cloud algorithm from April 10, 2012 at 10:02 UTC (night) (top four images) and 14:32 UTC (day) (bottom four images) centered over N. Texas, E. Colorado and W. Kansas. The top, left panels in each 4-panel image are the probabilities that IFR conditions are present. The top, right panels are the probabilities that LIFR conditions are present. The bottom, right panels show the estimated thickness of the highest liquid water cloud layer. The bottom, left panels are the 11 μm brightness temperature (night) and 0.65 μm visible reflectance (day). The blue symbols are surface observations with surface visibility, in miles, on the bottom and cloud ceiling, in 100's of feet, on the left.

Publications and Conference Reports

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

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

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

16.14 Overshooting Top/Enhanced-V

CIMSS Task Leaders: Jason Brunner and Wayne Feltz
CIMSS Support Scientists: Lee Cronce and Richard Dworak
NOAA Collaborator: Ken Pryor (NOAA/NESDIS/STAR)
Other Collaborator: Kristopher Bedka (Science Systems and Applications, Inc. at NASA Langley Research Center)
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

Proposed Work

This work represents the fourth year of a multi-year effort to develop algorithms to objectively identify overshooting convective cloud tops and the enhanced-V signature within GOES-R ABI imagery as required by the GOES-R Aviation Algorithm Working Group. These algorithms must be able to operate during both day and night and meet coding standards and accuracy requirements specified by the GOES-R Algorithm Integration Team. As GOES-R ABI will offer 2 km spatial resolution in the infrared channels, we can use current satellite instruments to emulate the imagery that will be available in the future with GOES-R ABI.

An overshooting convective cloud top is defined by the American Meteorological Society as "a domelike protrusion above a cumulonimbus anvil, representing the intrusion of an updraft through its equilibrium level." A single overshooting top (OT) often exists for less than 30 mins and has a maximum diameter of ~15 km. Despite their relatively small size and short duration, storms with OTs often produce hazardous weather conditions such as aviation turbulence, frequent lightning, heavy rainfall, large hail, damaging wind, and tornadoes. Though it is commonly understood that a small cluster of very cold IRW brightness temperatures relates well with the presence of an OT, this characteristic has yet to be exploited in any operational objective OT detection technique. Spatial IRW BT gradients ("IRW-texture" hereafter) can be combined with NWP-based tropopause temperature information and knowledge of the characteristic size of an OT to objectively identify them at their proper scale (Bedka et al., 2010). Such a technique would have some advantages over existing OT detection techniques such as the WV-IRW BTD in that: 1) it is not explicitly affected by the spatial/vertical distribution of atmospheric water vapor, 2) it does not over-diagnose the size of an individual OT, and 3) it does not use WV BT information which can be affected by variation in the central wavelength and/or spectral coverage of the WV absorption channel.

OTs found in combination with a U or V shaped region of cold infrared window brightness temperatures (BTs) are often indicative of an especially severe thunderstorm. Once OTs have been identified by the IRW-texture technique, the focus can be directed toward the objective detection of the enhanced-V signature. While the enhanced-V is often highly variable in infrared imagery, one aspect of the enhanced-V remains fairly constant in that the "arms" of the V signature enclose a warm region downwind of the overshooting top to form an "anvil thermal couplet." Brunner et al. (2007) showed that these cold (or enhanced)-U/V producing storms with

a minimum IRW BT of ≤ 205 K in the OT region and an anvil thermal couplet of ≥ 7 K magnitude produced severe weather for greater than 90% of all events during summers 2003 and 2004. UW-CIMSS and Kristopher Bedka (SSAI at NASA LaRC) have developed a technique with IRW imagery to objectively detect anvil thermal couplets associated with the enhanced-V signature.

Summary of Accomplishments and Findings

The Algorithm Readiness Review for the enhanced-V and OT product was successfully completed on August 15, 2011. Also, the Version 5 enhanced-V and OT product was delivered to the Algorithm Implementation Team in June 2011. In addition, the 100% ATBD for the enhanced-V and OT product was delivered to the Algorithm Implementation Team in June 2011. The version 1 validation delivery of OT and enhanced-V validation code and deep dive tools occurred in December 2011.

A creative technique to validate objective OT detection output must be used since a large database of all OT locations throughout the world does not exist. This technique looks at deep convective storms through NASA CloudSat and CALIPSO profiles. Figure 16.14.1 shows that these satellites passed directly over an OT over the Atlantic Ocean offshore of North Carolina. Aqua MODIS IRW and WV BT data and IRW-texture OT detections are co-located with these two satellite profiles to compare IRW-texture and WV-IRW BTD performance. The comparison indicates that the IRW-texture technique performs well in detecting this OT. If a 2 K WV-IRW BTD threshold were used here for OT detection, no OT pixels would be detected. If simply a positive BTD were used here, nearly the entire anvil cloud would be detected which would produce a very high false alarm rate.

An example of objective enhanced-V/anvil thermal couplet detection is provided in Figure 16.14.2. ABI proxy IRW 2 km imagery from this 10 May 2004 2317 UTC event shows four enhanced-V producing severe storms. OTs and anvil thermal couplets were detected for all four of the severe storms. There were no false detections for this case. This detection algorithm was applied to 629 enhanced-V producing storms that occurred across 196 MODIS or AVHRR images. The validation indicates that the probability of enhanced-V detection was 52% and the false alarm rate was 25%. 73% of the storms detected by the algorithm produced severe weather within +/- 30 mins of the time of the image and within 60 km of the OT location while 57% of the undetected storms were severe, indicating that this algorithm is detecting a larger fraction of the severe storms in our database. Both the overshooting top (20% FAR) and enhanced-V detection products (25% FAR) meet the FP&S specifications for product accuracy (25% maximum FAR).
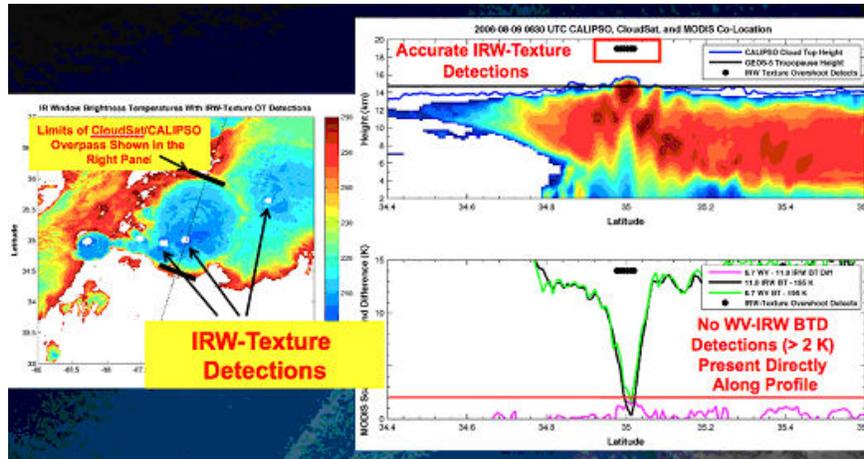
Figure 16.14.1.(left) Aqua MODIS 1 km 10.7 μm brightness temperature imagery with IRW-texture OT detections (white dots). (right) IRW-texture OT detections co-located with MODIS brightness temperatures, CloudSat radar reflectivity, CALIPSO cloud top height, and the NASA GEOS-5 model tropopause height analysis.
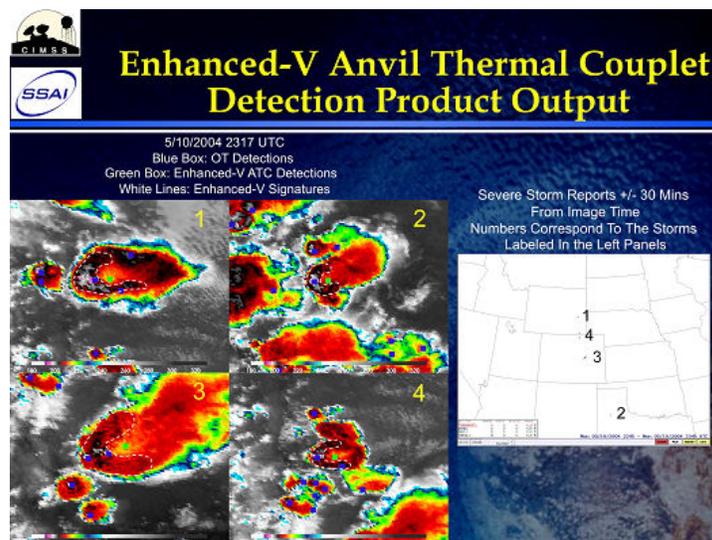
Figure 16.14.2. ABI proxy IRW (10.7 μm brightness temperature) 2 km imagery of a set of four enhanced-V producing severe storms that occurred on 10 May 2004 at 2317 UTC. Each enhanced-V signature is outlined with a white dashed line. Overshooting top detections are shown with blue squares and anvil thermal couplet detections are shown with green squares.

Publications and Conference Reports

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Brunner, J.C., S.A. Ackerman, A.S. Bachmeier, and R.M. Rabin, 2007: A Quantitative Analysis of the Enhanced-V Feature in Relation to Severe Weather. *Wea. Forecasting*, **22**, 853–872.

Dworak, R., K. Bedka, J. Brunner, and W. Feltz, 2012: Comparison between GOES-12 Overshooting Top Detections, WSR-88D Radar Reflectivity, and Severe Storm Reports. *Wea. Forecasting*, In Press.

16.15 CIMSS GOES-R Algorithm Working Group (AWG) for 2011: Visibility

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CIMSS Support Scientists: Allen Lenzen, Jason Brunner
NOAA Collaborator: R. Bradley Pierce
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

Proposed Work
The Advanced Baseline Imager (ABI) visibility product is produced using a number of other ABI products including the low-cloud/fog detection, cloud optical thickness, and aerosol optical depth. To determine the range of visibilities associated with low-cloud/fog the visibility product uses the ABI cloud optical thickness (COT). To determine the range of visibilities associated with haze, dust, and smoke the visibility product uses the ABI aerosol optical depth (AOD) retrieval. Under low-cloud/fog, haze, dust, and smoke conditions the visibility algorithm must be able to relate COT and AOD (at a particular wavelength) to horizontal visibility within the planetary boundary layer. Thresholds for Poor, Low, Moderate, and Clear visibilities will be developed based on statistical regression of proxy satellite AOD and COT measurements and planetary boundary layer thermodynamic properties against Automated Surface Observing System (ASOS) extinction measurements. Conversion from AOD or COT to extinction requires knowledge of the depth of the aerosol or fog/low-cloud layer, which is assumed to be determined by the depth of the planetary boundary layer (PBL) or fog depth.

Summary of Accomplishments and Findings
Activities during this period focused on delivery of the Version 3 (V3) and V4 Visibility Algorithms to the GOES-R Algorithm Working Group (AWG) Algorithm Integration Team (AIT). These versions use a single sensor (MODIS) as proxy for the GOES-R ABI instrument. These algorithm versions use MODIS L1 radiances to compute fog probability and auxiliary L2 MODIS AOD and COT input to compute aerosol and fog extinction and fog depth. Regressions of AVHRR Pathfinder Atmospheres – Extended (PATMOS-x) DCOMP COT vs. ASOS visibility are used to generate the fog LUT. The V3 Visibility algorithm uses MODIS AOD and COT to determine monthly and categorical bias corrections based on comparisons with ASOS measurements. May-June 2010 validation showed that V3 merged visibility retrieval results in a 59.2% categorical success rate and an estimated precision of 0.60. The V3 categorical success rate is less than was obtained using the V1 merged visibility retrieval (72.8%), due primarily to a change in the threshold visual contrast used to convert extinction to visibility to be consistent with WMO and NWS definitions. This coupling results in a significant shift in the ASOS and

ABI categorical histograms (reduction in the number of clear visibility classifications and increases in the number of moderate, low, and poor visibility classifications).

The V4 algorithm uses multiple regression approaches instead of simple bias correction in an attempt to improve the categorical skill of the algorithm. We no longer include the visibility class as a category in the LUT to increase the dynamic range of the data used in the multiple linear regression, which improves the overall fit to the ASOS measurements used to develop the V4 LUT. The 10 predictors for V4 aerosol visibility consist of 1) AOD, 2) temperature at the top of the PBL, 3) 2m temperature, 4) height of the PBL above sea level (including topography), 5) PBL lapse rate, 6) first guess aerosol visibility, 7) 2m relative humidity, 8) relative humidity at the top of the PBL, 9) PBL mean relative humidity, and 10) PBL depth. The 11 predictors for V4 fog visibility consist of 1) fog probability, 2) PBL mean relative humidity, 3) relative humidity at the top of the PBL, 4) height of the PBL above sea level (including topography), 5) 2m relative humidity, 6) PBL lapse rate, 7) PBL depth, 8) 2m temperature, 9) first guess fog visibility, 10) temperature at the top of the PBL, and 11) COT. The V4 algorithm has been validated using independent (not used in the LUT regression) ASOS visibility measurements during May-June 2010. Figure 16.15.1 shows categorical histograms of the coincident ASOS and ABI merged visibilities. The merged aerosol and low-cloud/fog visibility retrieval results in a 66.9% categorical success rate for 11,697 coincident ASOS/ABI measurement pairs during May-June 2010. This result is significantly better than that of the V3 algorithm for the same period.
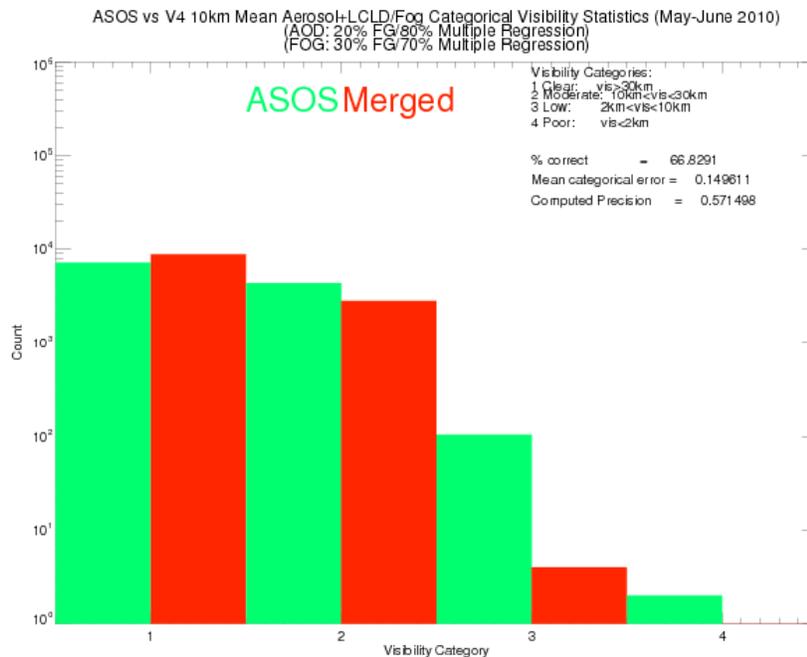
Figure 16.15.1. Categorical Histogram of V4 Merged ABI (red) and ASOS (green) aerosol and fog/low cloud visibility for May-June 2010 coincident pairs.

16.16 Estimation of Sea and Lake Ice Characteristics with GOES-R ABI

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CIMSS Support Scientist: Yinghui Liu
NOAA Collaborator: Jeff 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

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

Proposed Work
To accomplish the goals outlined in the GOES-R AWG Project Plan, we must evaluate, improve, and further develop sea and lake ice property retrieval algorithms for application with GOES-R ABI. This project is dedicated to the estimation and analysis of sea and lake ice products from GOES-R ABI data. We are evaluating, testing, validating, and documenting retrieval algorithms for sea and lake ice products, which includes ice identification/extent, ice concentration, ice thickness, ice age, and ice motion. Validation and maturity studies are also being done by comparing the products to data from numerical model simulations, submarine sonar measurements, moored sonar measurements, surface-based measurements, and passive microwave derived ice products. The work will serve as a test-bed of the algorithms for ice products, and will allow for algorithm testing and optimization to be done in consistent manner. This activity will ensure enhanced future geostationary cryosphere applications in the GOES-R era.

Summary of Accomplishments and Findings
This report covers the work done from 1 April 2011 to 31 March 2012, and is the final report for this project, as work on "option 2" products will not be funded for the foreseeable future. The major accomplishment during this period was the validation, test run, and uncertainty assessment of the final version 5 algorithms that generate the ice products, and 100% software code and 100% ATBDs deliveries to the Algorithm Integration Team (AIT). We have delivered proxy data for offline runs here at CIMSS and their results to the AIT. It was found that the results from the CIMSS offline run and AIT independent run within the AIT Framework with the same proxy data are almost identical; very small differences resulted from different computer compilers and/or architectures. AVHRR, MODIS, and SEVIRI data were used as proxy data for the purpose of the algorithm testing and example output. Submarine, mooring, and meteorological station measurements were used for the comparison and validation. Meta data have been added to the products output. Maturity studies were performed to quantify algorithms uncertainty, and algorithms limitations and deficiencies were assessed.

Ice Concentration and Extent

A sea ice concentration and extent algorithm was further improved and validated with passive microwave derived ice concentration. Version 5 of this algorithm has been delivered and has been tested with proxy data, including AVHRR, MODIS and SEVIRI data. The retrieved products are in good agreement with Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) Level-3 gridded daily mean product. Validation of sea ice concentration with high-resolution vis/IR sensors such as LandSat TM has been done also. Figure 16.16.1 shows an example of ice concentration from MODIS and AMSR-E proxy data.

Ice Thickness and Age

A One-dimensional Thermodynamic Ice Model (OTIM) has been further improved with respect to its built-in parameterization schemes. In particular, a parameterization of residual heat flux was added to make the model more robust over a broad range of seasonal and environmental conditions. Validation has been further investigated by collecting and using more in-situ truth data from submarine and moored upward looking sonar, weather stations, and field experiments. Results demonstrate that the Ice Age algorithm will meet the requirements of 80% accuracy and less than one category precision. The Sea & Lake Ice Age Product has been run offline and within the framework and the results are exactly the same. Figure 16.16.2 is one of the offline test run results with MODIS Aqua proxy data.

Ice Motion

The heritage ice motion algorithm developed by Fowler et al. (2004) has been adopted for use with ABI and has been applied over the Great Lakes and the Arctic Ocean. Ice motions retrieved from MODIS proxy data were validated with ice motions derived from drifting ice buoy data as "truth." Validation of ice motion vectors using MODIS proxy data with ice motion derived from buoy data shows that current products meet the required accuracy and precision of ice motion speed and direction.

Figure 16.16.1. Lake ice concentration (%) with MODIS Aqua data (left), MODIS true color image (middle), and from AMSR-E (right) over Great Lakes on February 24 2008.
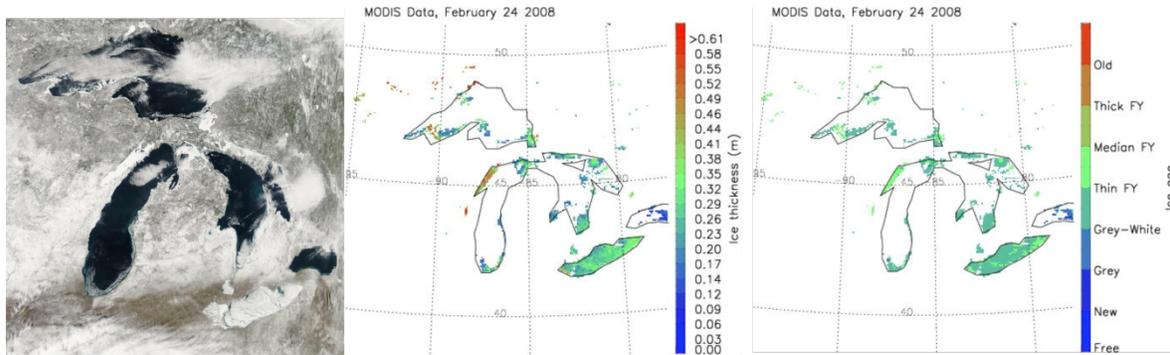
Figure 16.16.2. MODIS Aqua true color image (left) on February 24, 2008 over Great Lakes, retrieved ice thickness (middle) in meter, and ice age (right).

Publications and Conference Reports

Liu, Y., J. R. Key, Z. Liu, X. Wang, and S. J. Vavrus (2012), A cloudier Arctic expected with diminishing sea ice. *Geophys. Res. Lett.*, **39**, L05705, doi:10.1029/2012GL051251.

Wang, X., J. Key, Y. Liu, Arctic Climate Change: Trends in Surface, Cloud, Radiation, and Sea Ice Properties from Satellite Data (Talk), 2012 IPY Conference: From Knowledge To Action, April 22-27, 2012, Montreal, Canada.

Wang, X., J. Key, Y. Liu, Arctic Sea Ice Changes, Interactions, and Feedbacks on the Arctic Climate during the Satellite Era (Invited talk), 2011 AGU Fall Meeting, 5-9 December 2011, San Francisco California, USA.

Wang, X., J. Key, Y. Liu, Yinghui Liu, Arctic Sea Ice Properties and Changes from Satellite Data over the Period 1982-2010 (Talk), 2011 EUMETSAT Meteorological Satellite Conference, 5-9 September 2011, Oslo, Norway.

16.17 GOES-R Imagery and Visualization

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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

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

Proposed Work

McIDAS-V is open source, freely available software package that allows a scientist, researcher and/or educator to analyze, visualize and synthesize with other data, including past and current GOES, common meteorological in-situ, model forecast and reanalysis.

For 2012 we proposed the following:
- 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. Support and contribute to development of finalized version of the ABI FGF. Develop time sequence recognition for single or multi-time, single or multi-band NetCDF files (animation of ABI proxy data);
- Improve 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;
- Develop scripts for routine product validation in McIDAS-V, including generation of static and animated images for ABI bands and products. Demonstrate validation scripts, first with current GOES (ongoing), and later ABI proxy data sets, which automatically post captured images to a Web site;
- Support Proxy team efforts by validation of proxy data output;
- Develop optimal strategies for efficient high-resolution imagery display;
- Support GOES-R Ground Segment Contractor Verification; and
- Work on imagery algorithm development to support the maintenance delivery.

Summary of Accomplishments and Findings

GOES-R Fixed Grid Format

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

AWG Imagery and Visualization Scripting Tools

The co-chairs of the Imagery and Visualization group have emphasized that background processing of satellite, weather data, imagery and products is an essential tool for real-time displays and routine scientific analysis. Scripting tools currently being developed under Imagery and Visualization will provide a simple and efficient means to access the diverse capabilities of McIDAS-V. In the first phase of development, simple jython methods will allow scientists to access, display and perform simple statistical data analysis for netCDF, hdf, and traditional

McIDAS Area files. In the next phase, the tools will provide scientist with the capability to manipulate some of the 3D aspects of McIDAS-V. The ultimate goal of this effort is to give the scientists all the tools of the interactive display in a scripting language. This effort will free scientists from repetitive tasks, providing the opportunity for continual product validation, products and imagery.

Visualization and Data Analysis

Significant improvements to minimize system resource allocation, memory and cpu time for satellite image display have been made. An animation sequence of several hundred, 1000x1000, images can now be handled on a 32bit, 2GB system, much more on higher end platforms (64bit). Built in support detects when 8bit (grey-scale only), or 32bit (millions of colors and transparency) imagery is opened, greatly increasing the number and/or size of images that can be handled if a simple grey scale is only required. Display of large images is greatly improved; e.g. 8600x8600, displayed on a 32bit, 1GB machine. With the development of multi-tile texture mapping, 64bit systems, with mid-range graphics should be able to display an ABI, hkm, full disk image.

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

Improved support for CALIOP and CLOUDSAT, level1 and level2 products is available through the McIDAS-V interactive mode. Users can select a piece of the orbit track from a geographic GUI selector, and either visualize or resample other fields via the Jython shell. For example, users can compare cloud height estimates from model output or satellite observations to CALIPSO cloud height measurements. This comparison method has been used in the validation of the AWG Cloud Top Height product derived from proxy data.

16.18 WRF-CHEM Aerosol and Ozone Proxy Data Simulations

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NOAA Collaborator: R. Bradley 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
  • Satellite Sensors and Techniques
  • Environmental Models and Data Assimilation

Proposed Work
The main focus of this project is to augment the current GOES-R AWG WRF Advanced Baseline Imager (ABI) proxy data capabilities with proxy data sets for aerosols and ozone. The aerosol and ozone proxy data sets are generated with WRF-CHEM air quality simulations (Grell et al., 2005) coupled to global chemical and aerosol analyses from the Real-time Air Quality Modeling

System (RAQMS) (Pierce et al., 2007). Chemical data assimilation is used to provide observational constraints on the global chemical and aerosol analyses. Output from the coupled RAQMS/WRF-CHEM ozone and aerosol simulations are used to construct simulated radiances using the NOAA Community Radiative Transfer Model (CRTM) (Han et al., 2006). The addition of aerosol and ozone distributions into the WRF proxy data set will allow generation of synthetic radiances for all ABI bands and thus facilitate the development of algorithms supporting retrievals of aerosol properties (optical depth, aerosol type, effective radius, fine vs. coarse mode fraction), total column ozone, and detection of dust, smoke and SO_2. This work will be conducted in close collaboration with the existing GOES-R WRF proxy data simulation team at CIMSS (Lead, Allen Huang, CIMSS) and with the ABI aerosol retrieval and GOES-R aerosol assimilation activities under the GOES-R Air Quality and Aerosols AWG (Lead, Shobha Kondragunta, NOAA/NESDIS).

Summary of Accomplishments and Findings

FY2011 WRF-CHEM Aerosol and Ozone proxy data activities focused on evaluation of the uncertainties in the ABI simulated radiances associated with the WRF-CHEM/CRTM forward modeling system. High-resolution (4km) WRF-CHEM simulations were conducted over Southern California and coastal waters during May and June 2010. Synthetic radiances were generated using Version 2.0.4 of the CRTM. Evaluation of WRF-CHEM uncertainties has focused on aerosol composition through comparisons with ground based and airborne measurements during the NOAA CalNex field mission. An emphasis of the evaluation has been on representation of land surface emissivity and reflectivity, which is poorly treated within the CRTM. The May-June 2010 CalNex CRTM runs utilized the 16 day MODIS BRDF/Albedo Model Parameters Product (MOD43B1) which provides coefficients that can be used to generate direct reflectance for each of the MODIS spectral bands. The UWIREMIS emissivity data base, developed by Eva Borbas (CIMSS) was used to generate surface emissivities for each ABI spectral band. The UWIREMIS uses a principle component analysis of laboratory measured emissivity spectra and the 10 hinge points of the high spatial resolution (0.05 degree) MODIS Baseline Fit (BF) emissivity data base to generate a high-spectral resolution (416 points between 3.6 and 14.3μm) emissivity data base. Synthetic radiances using these user defined land surface reflectivities and emissivities as well as the default CRTM LUT estimates have been compared to collocated hourly GOES-11 radiances and brightness temperatures during May-June 2010.

Figure 16.18.1 shows an example of these comparisons for the 10.7 micron band at 00Z on May 16, 2010. The comparisons are restricted to a subset of the full WRF-CHEM domain along the coast of central California that are largely under clear sky conditions over land so that differences between the CIMSS UWIREMIS and default CRTM LUT land emissivities can be investigated. The default CRTM LUT show significant underestimates in 10.7 micron brightness temperatures over the Central Valley compared to GOES-11. Use of the CIMSS UWIREMIS data base results in much better agreement with GOES-11 observations.
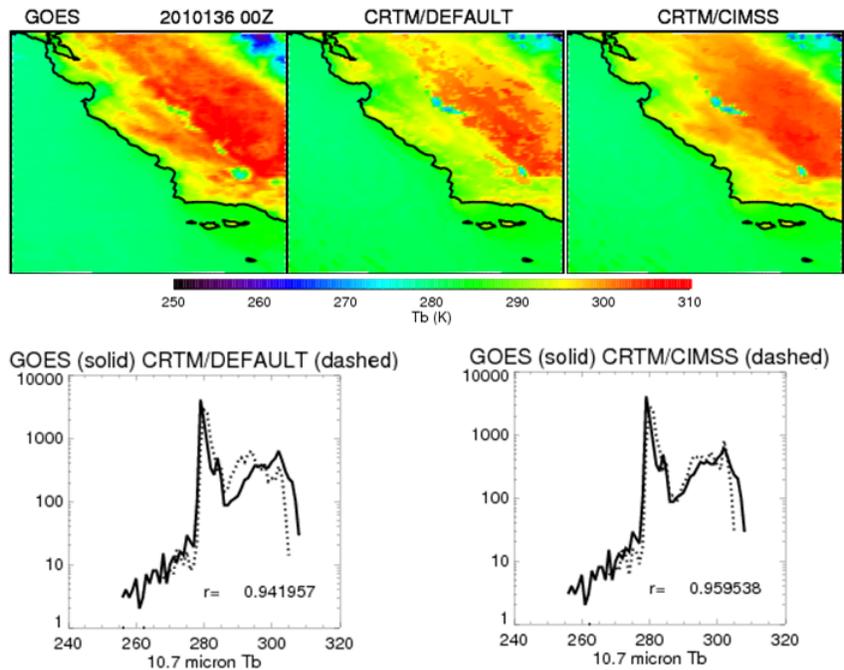
Figure 16.18.1. Comparison between GOES-11 (upper left) and CRTM 10.7 micron brightness temperatures at 00Z on May 16, 2010 using the default CRTM land emissivity LUT (upper center) and the CIMSS UWIREMIS land emissivity data base (upper right). The lower panels show histograms of GOES (solid) and default (dashed, lower left) and UWIREMIS (dashed, lower right) brightness temperatures.

Figure 16.18.2 shows comparisons between GOES-11 and CRTM 10.7 micron brightness temperatures using the UWIREMIS land emissivity data base for the entire CalNex domain based on hourly comparisons of collocated GOES-11 brightness temperatures for all of May-June, 2010. Overall, the CRTM with the UWIREMIS land emissivity is able to capture the observed 10.7 micron brightness temperature distribution very well with a mean correlation of 0.647 and with the distribution of differences sharply peaked near zero. The CRTM tends to overestimate the frequency of the coldest brightness temperatures (<240K) due to overestimates in the optical thickness of thin cirrus clouds. The hourly spatial correlation between GOES-11 and the CRTM is greater than 0.6 for 65% of the time period while periods of persistent cirrus result in lower (<0.5) correlations for 16.7% of the time period.
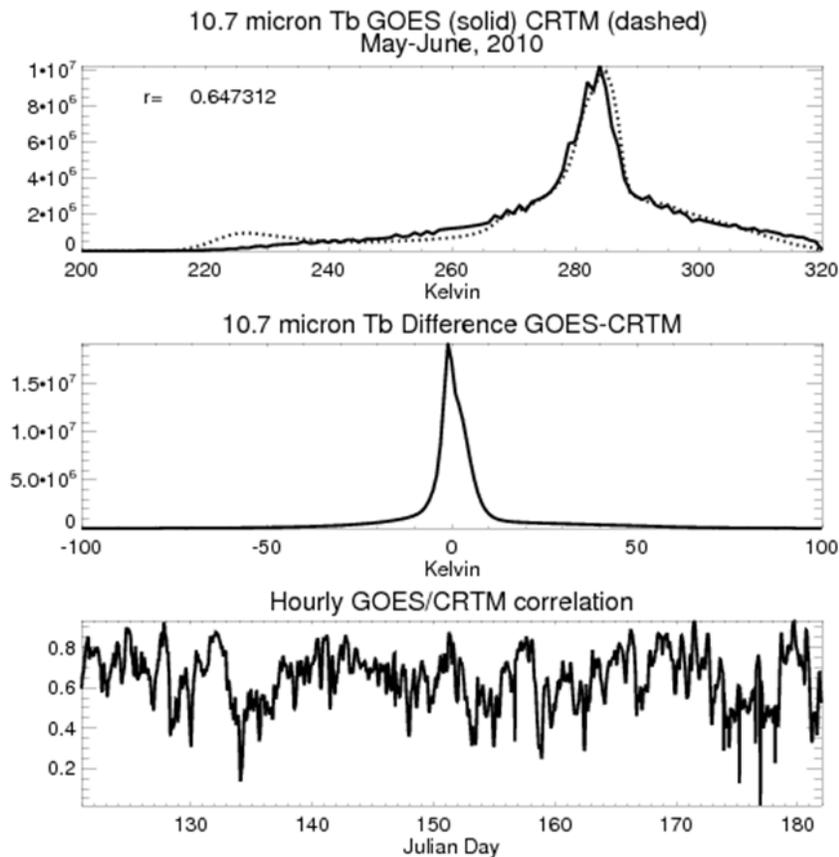
Figure 16.18.2. The upper panel shows histograms of GOES (solid) and CRTM (dashed) 10.7 micron brightness temperatures. The middle panel shows the histogram of 10.7 micron brightness temperature differences (GOES-CRTM), and the lower panel shows a time series of hourly spatial correlations between GOES and CRTM 10.7 micron brightness temperatures over the CalNex domain during May-June 2010.

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16.19 WRF Processing Through GPU Integration

CIMSS Task Leaders: Bormin Huang, Allen Huang
CIMSS Support Scientists: Jarno Mielikainen, Jun Wang
NOAA Collaborator: Mitch Goldberg

NOAA Long Term Goal
- Weather-Ready Nation

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

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

Proposed Work

The core WRF model consists of a dynamic solver and 8 physics packages. Each physics package also includes several schemes as users' options. For FY2011 we proposed to implement 4 physics packages (microphysics, cumulus parameterization, long wave radiation, short wave radiation) on GPUs.

Summary of Accomplishments and Findings

WRF Module name	Speedup
Single moment 6-class microphysics	500x
Eta microphysics	272x
Purdue Lin microphysics	692x
Stony-Brook University 5-class microphysics	896x
Betts-Miller-Janjic convection	105x
Kessler microphysics	816x
New Goddard shortwave radiance	134x
Single moment 3-class microphysics	331x
New Thompson microphysics	153x
Double moment 6-class microphysics	206x
Dudhia shortwave radiance	409x
Goddard microphysics	1311x
Double moment 5-class microphysics	206x
Total Energy Mass Flux (TEMF) surface layer	214x
Mellor-Yamada Nakanishi Niino (MYNN) surface layer	113x
Single moment 5-class microphysics	350x
Pleim-Xiu surface layer	665x
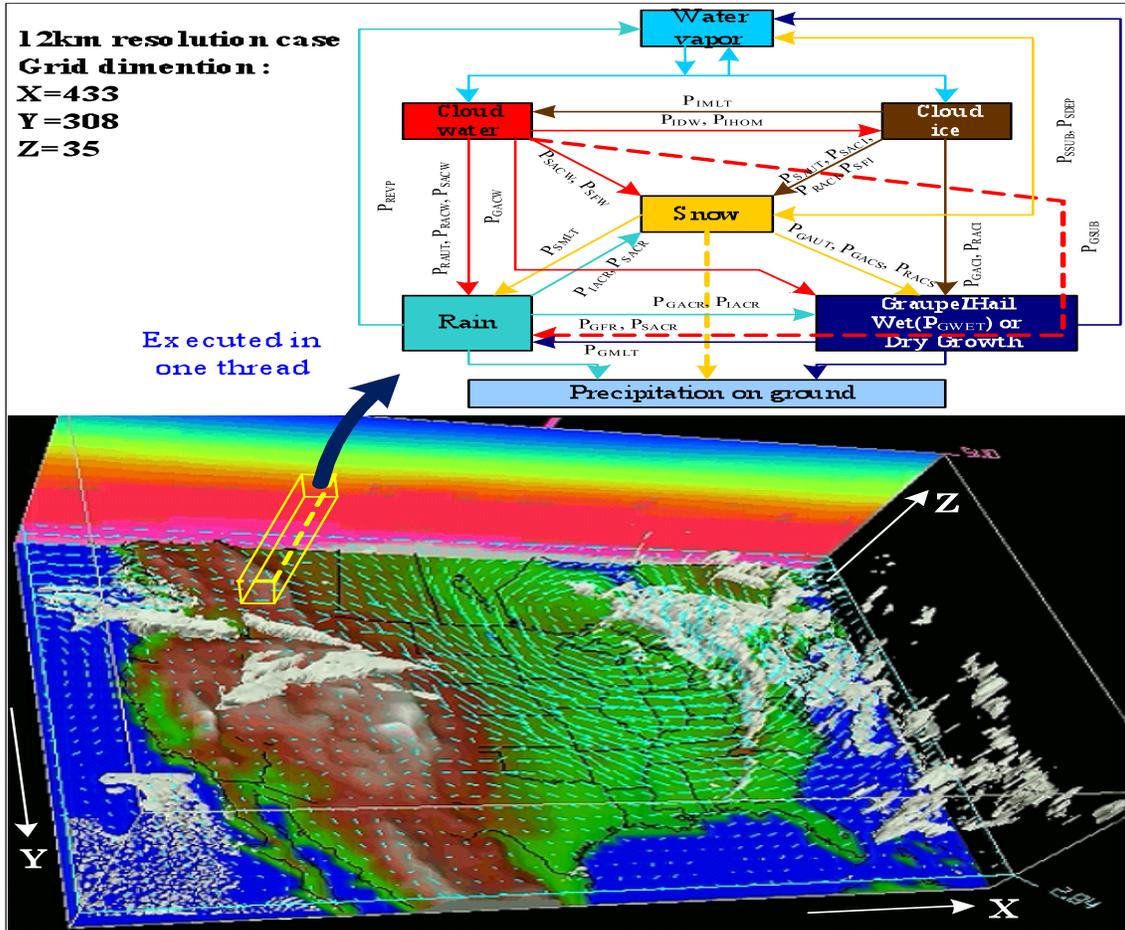
Publications and Conference Reports

J. Mielikainen, B. Huang, A. Huang and M. Goldberg, GPU Implementation of Stony-Brook University 5-Class Cloud Microphysics Scheme in the WRF, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (J-STARS), doi: 10.1109/JSTARS.2011.2175707.

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J. Mielikainen, B. Huang, A. Huang and M. Goldberg, Improved GPU/CUDA Based Parallel Weather and Research Forecast (WRF) Single Moment 5-class (WSM5) Cloud Microphysics, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (J-STARS); doi: 10.1109/JSTARS.2012.2188780.

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J. Mielikainen, B. Huang, and H.-L. Huang, Accelerating the RTTOV-7 IASI and AMSU-A radiative transfer models on graphics processing units: evaluating central processing unit/graphics processing unit-hybrid and pure-graphics processing unit approaches. *J. Appl. Remote Sens.*, **5**, 051503 (Nov 18, 2011); doi:10.1117/1.3658028.

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C. Song, Y. Li, B. Huang, A GPU-Accelerated Wavelet Decompression System With SPIHT and Reed-Solomon Decoding for Satellite Images, IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 4, no. 3, pp. 683-690, Sept. 2011, doi: 10.1109/JSTARS.2011.2159962.

17. CIMSS GOES-R Proving Ground Collaboration with the Hawaii National Weather Service

CIMSS Task Leader: Wayne Feltz
CIMSS Support Scientist: Kathy Strabala
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
- Education and Outreach

Proposed Work

CIMSS proposes to support the expanding use of satellite-based GOES-R Proving Ground products by placing a CIMSS research scientist at the Honolulu, HI NWS office. The CIMSS scientist will provide leadership, satellite expertise, and meteorological support for the GOES-R Proving Ground efforts based at the National Weather Service (NWS) Honolulu, HI. This funding resource will provide PI and logistical support for up to four research scientists to travel to and from Hawaii and provide housing, car rental, as well as daily food per diem.

This project will entail activities focused at maximizing the forecast value of geostationary satellite data and products, particularly activities centered on over ocean nautical and aviation weather impacts to the Pacific Region. The CIMSS research scientists will interact with NWS operational forecasters to prepare them for new satellite dependent products that will become available operationally after the launch of the GOES-R satellite series. The goal of the CIMSS satellite experts is to transition their knowledge to the Pacific Region Proving Ground on-site scientists, specifically a local satellite meteorology expert that will be hired as the longer term on-site subject matter expert.

The salary and other costs for this endeavor will be funded through CIMSS general GOES-R Proving Ground support, which is a separate grant funded under the CIMSS Cooperative Agreement with NOAA.

Summary of Accomplishments and Findings

This proving ground demonstration interaction and collaboration requires CIMSS scientists and researchers to rotate through Hawaii NWS WFO and U of Hawaii to provide GOES-R PG product training, familiarity, and learn from forecasters how the decision support help forecasters situational awareness region where satellite data are heavily utilized. This funding grant is being used to cover travel, hotel, and per diem. During the first visit by Jordan Gerth, we worked closely with Roy Huff, the new satellite champion hired by the University of Hawaii with implementation of these products. Jordan Gerth provided U of Hawaii with transition of AWIPS dissemination of GOES-R PG convective product during the week of March 5-9, 2012. Several more visits are planned throughout 2012-2013 PG time domain as new direct broadcast antenna is installed.

18. CIMSS Collaboration with the Aviation Weather Center

CIMSS Task Leader: Wayne Feltz
NOAA Collaborator: Tim Schmit
NOAA Long Term Goals
- Weather-Ready Nation

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

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

Proposed Work

CIMSS proposes to support the expanding use of satellite-based weather products by placing a CIMSS satellite scientist at the Aviation Weather Center (AWC) in Kansas City, MO. The CIMSS scientist will provide leadership, satellite expertise, and meteorological support for the GOES-R Proving Ground efforts based at the NWS Training Center (NWSTC).

The new position works closely with CIMSS researchers, scientists at the NOAA/NESDIS/STAR and GOES-R Program Office and the staff at the NWS Training Center. The position is with UW-Madison and the position's duty station is in Kansas City, MO.

This project will entail activities focused at maximizing the forecast value of geostationary satellite data and products, particularly activities centered on weather forecast office operations to improve forecast and warning services to the nation. The incumbent will interact with NWS operational forecasters and NESDIS satellite analysts to prepare them for new satellite dependent products that will become available operationally after the launch of the GOES-R satellite series.

Summary of Accomplishments and Findings

Amanda Terborg was hired on 9 April 2012 to serve as Aviation Weather Center "Satellite Champion." She has spent one week in Madison, WI undergoing initial training and will now be stationed permanently at the Aviation Weather Center in Kansas City, MO. CIMSS participated in hiring process and Wayne Feltz will be her immediate supervisor at UW-Madison.

19. CIMSS Collaboration with the NWS Training Center

CIMSS Task Leader: Wayne Feltz
NOAA Collaborator: Tim Schmit
NOAA Long Term Goals
- Weather-Ready Nation

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

- Provide critical support for the NOAA mission

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

Proposed Work
CIMSS proposes to support the expanding use of satellite-based weather products by placing a CIMSS satellite scientist at the National Weather Service Training (NWS) Center in Kansas City, MO. The CIMSS scientist will provide leadership, satellite expertise, and meteorological support for the GOES-R Proving Ground efforts based at the NWS Training Center (NWSTC).

The successful candidate will work closely with CIMSS researchers, scientists at the NOAA/NESDIS/STAR and GOES-R Program Office and the staff at the NWS Training Center. The position is with UW-Madison and the position's duty station is in Kansas City, MO.

The position will be embedded within the NOAA/NWS Operations Proving Ground (OPG) at the NWSTC. The OPG provides the infrastructure and facilities to effectively transfer new and emerging scientific techniques, products, and services into NWS forecast office operations. The OPG actively engages in the research-to-operations process by supporting applied research, verifying the quality and scientific validity of new techniques and products, and providing a common venue for both forecasters and researchers to engage in developing and testing state-of-the-art aviation weather services.

This project will entail activities focused at maximizing the forecast value of geostationary satellite data and products, particularly activities centered on weather forecast office operations to improve forecast and warning services to the nation. The incumbent will interact with NWS operational forecasters and NESDIS satellite analysts to prepare them for new satellite dependent products that will become available operationally after the launch of the GOES-R satellite series.

Summary of Accomplishments and Findings
Dr. Chad Gravelle was hired on 11 November 2011 to serve as National Weather Service Training Center (NWS TC) "Satellite Champion." He spent five weeks in Madison, WI undergoing initial training and now is stationed permanently at the NWS TC in Kansas City, MO. CIMSS participated in hiring process and Wayne Feltz will be his immediate supervisor at UW-Madison.

20. Support for a NESDIS/STAR Supercomputer

CIMSS Task Leader: Liam Gumley
CIMSS Support Scientists: Jason Otkin, Allen Lenzen
NOAA Collaborator: Sid Boukabara
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
- Environmental Models and Data Assimilation

Proposed Work

The Space Science and Engineering Center (SSEC) at UW-Madison offered to host a Numerical Weather Prediction (NWP) supercomputer for the NOAA/NESDIS Center for Satellite Applications and Research (STAR). The system is intended to allow Data Assimilation experiments as well as Observing System Simulation Experiments (OSSEs) in a research environment using U.S. operational data assimilation and forecast models, at both global and regional scales. The supercomputer system will be used to conduct data assimilation and OSSEs experiments in support of NESDIS/STAR's efforts to enhance the accuracy of weather prediction systems through improved use of satellite data within the U.S. Operational data assimilation and forecast systems, at global and regional scales. This system will be synchronized with the Joint Center for Satellite Data Assimilation (JCSDA) IT infrastructure located in NASA/GSFC (Greenbelt, MD). Applications for the system include preparation for utilization of data from new instruments (ABI and GLM from GOES-R, ATMS, CrIS, VIIRS, OMPS from NPP and JPSS, etc), and the testing of advanced data assimilation approaches such as variational and Ensemble Kalman filter (or hybrid EnKF/Variational). Other applications include the study of the impact of future observing systems, such as the ABI, on the forecast skills of US NWP models through the use of high-resolution, regional-scale OSSEs. SSEC/CIMSS will have access to 10% of the system resources for other research projects.

Summary of Accomplishments and Findings

The system known as the Supercomputer for Satellite Simulations and data assimilation Studies (S4) was procured in April 2011, installed in May 2011, and declared operational in August 2011. The system has a CPU core count of 3072 cores in 64 Dell R815 compute servers, and 8192 Gigabytes (GB) of total memory. The system includes 26 Dell R515 storage servers providing one 180TB filesystem of high reliability data storage and four 72TB filesystems of high performance scratch space. Quad data rate InfiniBand interconnects are used to provide low-latency communication between compute servers and storage servers. The system design was optimized for total system throughout (i.e., total number of jobs executed within a certain time) rather than raw performance (i.e., speed of any individual job). Commodity hardware from Dell was selected to provide the best performance for the allotted budget, while in-house skills in cluster administration, file systems, job scheduling, and hardware integration were utilized to keep total cost low.

The S4 hardware is housed in 5 full-height racks in the SSEC Data Center (room 649). All servers are connected to uninterruptible power supplies, and gateway servers (login server, cluster head node) are connected to the in-house SSEC Gigabit Ethernet network.

SSEC provided the design, procurement, and hardware installation services for the S4 system. SSEC and UW-Madison facilities management provided upgrades to the SSEC Data Center infrastructure for power, cooling, and rack. The SSEC Technical Computing (TC) group was responsible for:
- installing the operating systems on all servers (92 servers total);
- configuring and testing the Infiniband networking;
- configuring, testing, and optimizing the Gluster filesystem for data storage;
- configuring, testing, and optimizing the Lustre filesystems for scratch space;
- installing and configuring the Grid Engine job scheduling system;
- installing the necessary compilers and toolkits to support building NWP model code;

- working with NESDIS staff including Eve-Marie Devaliere, Aaron Pratt, and Jim Jung to optimize the settings for compiling and running MPI and OpenMP jobs under Grid Engine control;
- analyzing performance of S4;
- developing all system level and user level documentation for the system;
- creating all user accounts following authorization by NOAA/NESDIS.

NESDIS staff were assigned the task of building and testing the core NWP software to be run on S4, including GSI, GFS, and WRF. As of August 2011, all had been built and tested successfully. The following models and tools are now installed on S4:

- Global Data Assimilation System (GDAS) (including the new Hybrid Ensemble system),
- Grid Statistical Interpolation (GSI),
- Weather Research & Forecast (WRF),
- Hurricane Weather Research & Forecast (HWRF),
- Microwave Integrated Retrieval System (MIRS),
- Community Radiative Transfer Model (CRTM), and
- Verification Statistics Data Base (VSDB).

As of April 11, 2012, the Grid Engine job scheduling system had logged 686 years of CPU time used on S4. Twenty two researchers have been authorized by NESDIS to use the S4 system for research projects. There is an open policy for user access on S4, since it is hosted at a university. Only open source and non-restricted data are allowed on S4 (commercial tools such as compilers and analysis environments are permitted).
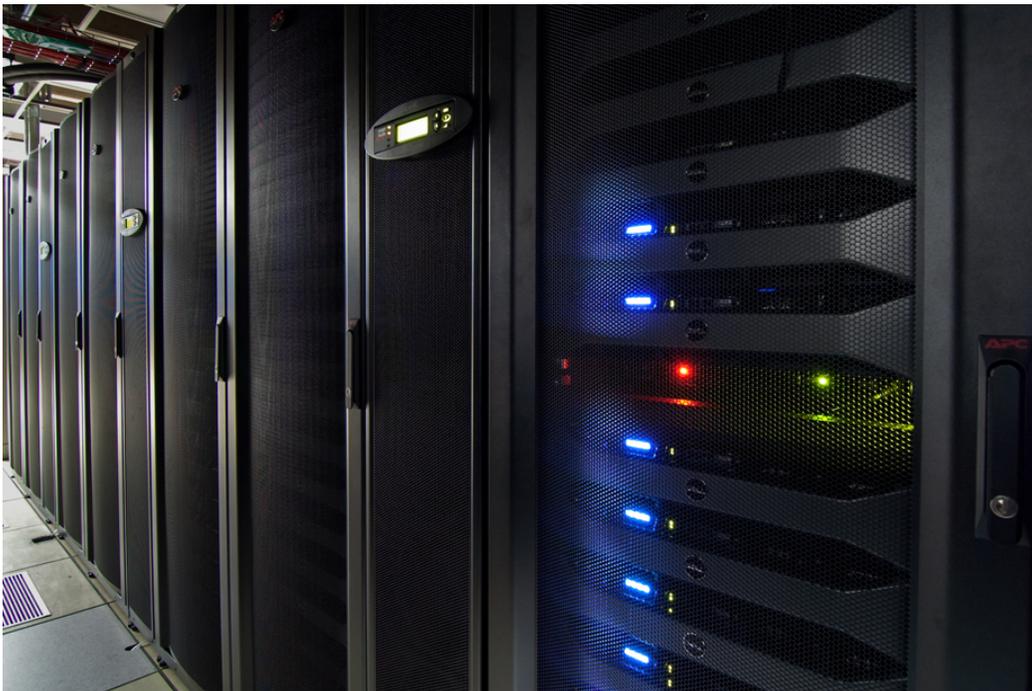
Figure 20.1. S4 Hardware in the SSEC Data Center.
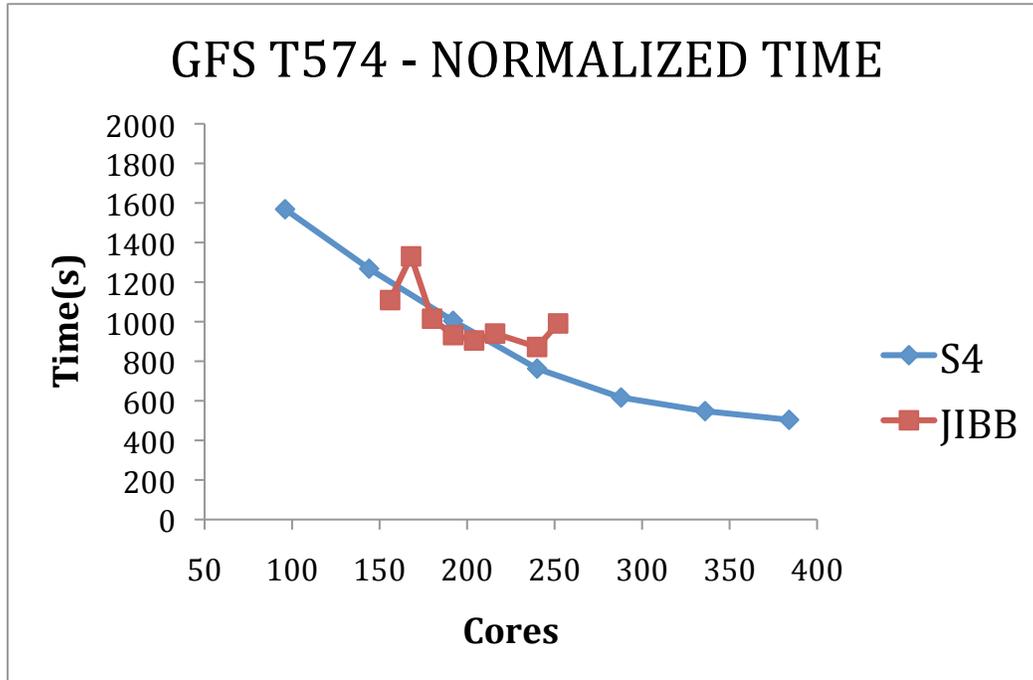
Figure 20.2. Scaling Performance vs. Number for Cores for S4 and JIBB/GSFC System.

21. Support for the NOAA JPSS Cloud Remote Sensing

CIMSS Task Leader: Christine Molling
CIMSS Support Scientists: Eva Borbas, Denis Botambekov, Mike Foster, Rich Frey, Min Oo, Andi Walther
NOAA Collaborator: Andrew Heidinger
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
- Protect, restore and manage the use of coastal and ocean resources through an ecosystem approach to management
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

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

Proposed Work
The Joint Polar Satellite System (JPSS) is the successor to NOAA's Polar Orbiting Environmental Satellite series. The polar orbiting satellites provide essential weather and climate

data globally, especially in the high latitudes, where the geostationary satellites have low to no resolution. The first JPSS satellite to be launched, the NPOESS Preparatory Project (NPP), contains the Visible/Infrared Imager and Radiometer Suite (VIIRS) instrument, an improvement to the POES Advanced Very High Resolution Radiometer (AVHRR) instruments. CIMSS personnel are collaborating with NOAA, CIRA, Northrop Grumman, and University of Utah personnel to create a suite of high quality cloud products. NOAA, along with Northrup Grumman have created the algorithms to ingest VIIRS raw data and produce cloud products from these data, including cloud presence, cloud water phase, cloud top height, cloud base height, and cloud water optical depth. CIMSS personnel support the NOAA mission in the following ways:

- Examining VIIRS cloud products for possible processing errors and metadata errors;
- Validating VIIRS cloud products against cloud products from instruments on other satellites, such as MODIS and CloudSat;
- Validating VIIRS cloud products against data measured from earth's surface;
- Validating VIIRS cloud products against different algorithms;
- Providing user feedback on the utility of the VIIRS cloud products and metadata; and
- Suggesting improvements in cloud product algorithms.

Summary of Accomplishments and Findings

Accomplishments and findings thus far include:

- Using McIDAS (Man-Computer Interactive Data Access System) software to have first look at on-orbit VIIRS Cloud Mask (VCM) product with all VIIRS bands available for use in the algorithm. McIDAS allows quick comparisons between geolocated radiance data and VCM output, including individual cloud tests. First impressions include:
    o Overall quality of non-polar mask is good for first days of operations;
    o Satisfied with performance of M15-M16 BTD, tri-spectral (M15-M16 and M14-M15 BTDs), M9, M15-M12 BTD cloud tests;
    o M9 test can easily be tuned to detect more thin cirrus over daytime oceans, probably vegetated land surfaces as well;
    o Difficult to fully evaluate daytime ocean results because of M7 degradation issue;
    o Discovered eastward and northward coastline "shift" in VCM processing probably due to geo-location errors leads to false cloudiness along some coastlines and misplaced ephemeral water;
    o M9 test over-clouds high-elevation Antarctic surfaces; and
    o Too many probably cloudy and probably clear pixels in ocean scenes.
- Creating the ability to produce global mosaic quick look images of VIIRS scientific data records for proxy and on-orbit data;
- Ability to ingest VIIRS radiances into the CLAVR-x processing system and produce cloud products equivalent to those produced from AVHRR; and
- Producing global comparisons between VCM and mask computed from CLAVR-x. Comparisons show the masks are quite close, which is encouraging, considering that the updated calibration coefficients have not been released and have not been used to compute the cloud masks.

VIIRS cloud optical depth artifacts were discovered and attributed to a maximum value of 30 in the VIIRS lookup table. These artifacts cause more scatter in the VIIRS product compared to MODIS than if a different algorithm (DCOMP) is used to produce optical depth. (2011/10)

At-launch NDVI fields seem to be inadequate, perhaps from the wrong season. Some desert scenes are not correctly identified, leading to false cloud determinations. The problem could also be from an inappropriate desert/non-desert threshold value in the VCM.

In some obviously cloudy pixels where only one spectral test finds evidence of cloud, the final VCM result is "probably clear" (0.5 < final confidence of clear sky < 0.90), rather than "probably cloudy" or "confident cloudy." This evidence may require "nudging" several cloud test thresholds and/or a change in clear-sky confidence thresholds.

I4 and I5 variability tests are detecting radiometric noise as well as clouds, resulting in muddled VCM results in broken and scattered cloud fields, and along cloud edges. The problem is also seen in clear pixels in the non-aggregated and lesser-aggregated pixels on either side of nadir, where they are sometimes identified as "probably clear" or "probably cloudy." This situation may be remedied by raising the I4 and I5 variability thresholds. Geolocation is much improved; displaced coast issue in VCM processing has been resolved. The ephemeral water test misidentifies some cloud shadows as water.

Agreement tables comparing collocated CALIOP and VCM cloud determinations have been produced for day 20120217 (Fig. 21.1 and 21.2). The agreement is very similar to that found using proxy MODIS data as input to the VCM for day land, night land, and day desert. Differences are larger (show lesser agreement) for oceans (probably due to overly aggressive I-band tests) and night desert. Performance differences for night deserts have not yet been investigated. Comparisons of collocated VCM vs. CALIOP cloud determinations during VCM threshold tuning (ICV period) will aid in fine-tuning of thresholds.

Publications and Conference Reports

R. Frey, 2011, American Geophysical Union Fall Meeting, December 5-9, San Francisco, CA, poster "VIIRS Cloud Mask Validation Exercises."
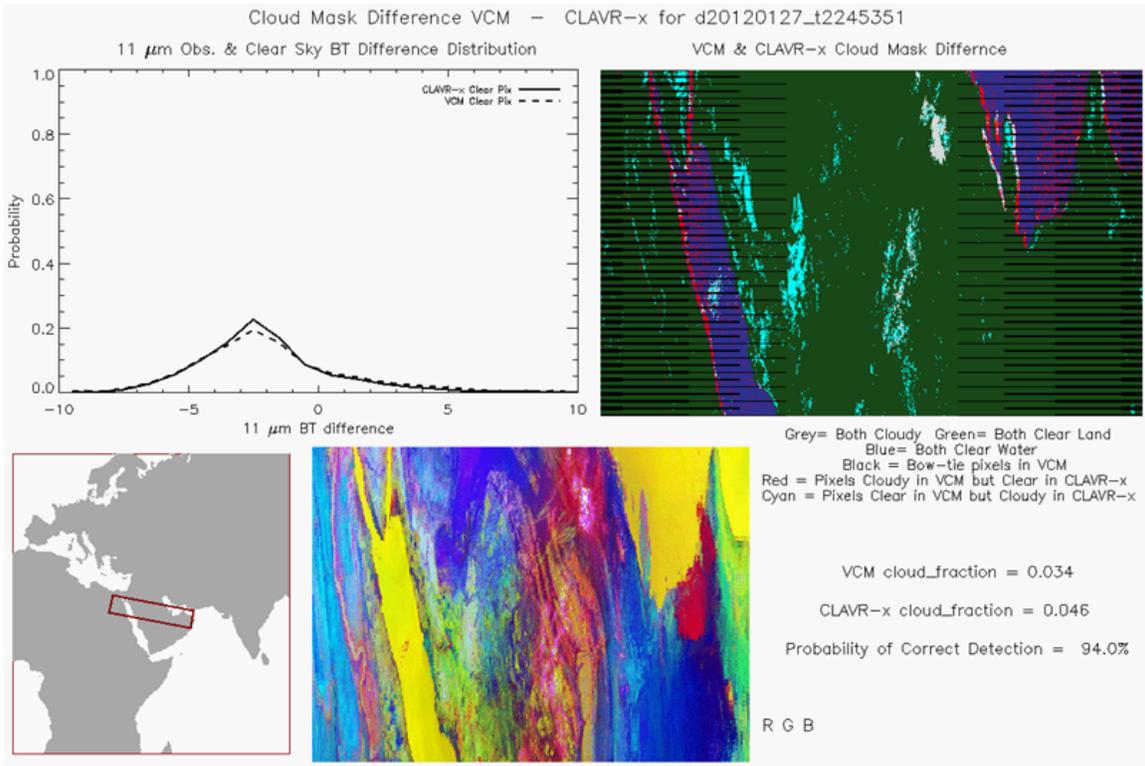
Figure 21.1. Comparison between the VIIRS cloud mask (VCM) and a cloud mask produced in CLAVR-x over the Arabian peninsula, showing geo-location errors leading to false cloudiness along some coastlines.
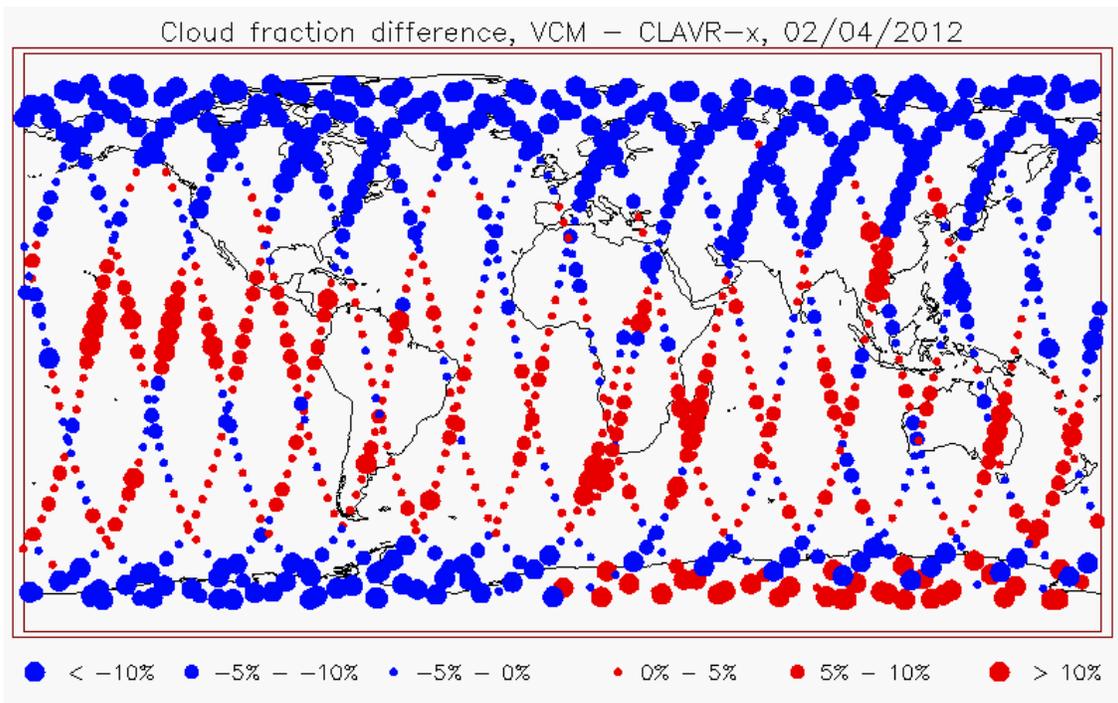
Figure 21.2. Global comparison between VIIRS cloud mask and a cloud mask produced in CLAVR-x.

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

CIMSS Task Leader: Yinghui Liu
CIMSS Support Scientist: Xuanji Wang
NOAA Collaborator: Jeffrey R. Key
NOAA Long Term Goals
- Climate Adaptation and Mitigation
- Weather-Ready Nation

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

CIMSS Research Themes
- Satellite Meteorology Research and Applications

Proposed Work

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. CIMSS scientists 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

This report covers the period from 1 April 2011 to 31 March 2012. 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 initial comparisons of these IPs and EDRs with other data sets. 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:
- VIIRS SDRs, IPs, and EDRs have been retrieved from GRAVITE based on time, location;
- VIIRS SDRs, IPs, and EDRs were processed and matched with collocated MODIS ice surface temperature, NCEP reanalysis surface air temperature, SSM/I sea ice

concentration products. VIIRS ice surface temperature (IST) and MODIS IST product are re-gridded to 1 km EASE-Grid; VIIRS ice concentration and SSM/I ice concentration product are re-gridded to 25 km EASE-Grid for quantitative calibration and validation. Figure 22.1 shows the re-gridded IST and ice concentration over the Arctic on March 7, 2012;

- Comparisons of collocated VIIRS ice surface temperature with MODIS ice surface temperature product and NCEP surface air temperature show that VIIRS ice surface temperature are in general agreement with other two products in spatial distributions over both Arctic and Antarctic. VIIRS and MODIS show more spatial detail than that of NCEP. The overall bias of VIIRS and MODIS IST is -1.06 K, with precision 1.72 K. The Arctic (Antarctic) bias is -1.11 K (-0.54 K) with a precision of 1.64 K (2.30 K);
- The cloud cover products from VIIRS and MODIS show non-negligible differences;
- Preliminary comparisons of VIIRS ice concentration with SSM/I sea ice concentration show general agreement over both the Arctic and Antarctic. The overall bias is 9.27%, with precision 20.60%. The VIIRS ice concentration retrieval performance is better over regions with higher ice concentration than over regions with lower ice concentration;
- Preliminary examination of VIIRS ice age product by using the LANDWEB browser show that most of the high Arctic ocean area has nearly no ice age data, though there are ice surface temperature data for those missing ice age data areas. The LANDWEB personnel are investigating the issue, but it may be a simple as not including nighttime data in the browse imagery; and
- Some incorrect ice age classifications have been found during the Antarctic summer. Since there is no ground truth data for the ice age product, we plan to use proxy data derived from other algorithms to do more validation work.

Publications and Conference Reports

Liu, Y., J. R. Key, Z. Liu, X. Wang, and S. J. Vavrus (2012), A cloudier Arctic expected with diminishing sea ice. *Geophys. Res. Lett.*, **39**, L05705, doi:10.1029/2012GL051251.

Wang, X., J. Key, Y. Liu, Arctic Climate Change: Trends in Surface, Cloud, Radiation, and Sea Ice Properties from Satellite Data (Talk), 2012 IPY Conference: From Knowledge To Action, April 22-27, 2012, Montreal, Canada.

Wang, X., J. Key, Y. Liu, Arctic Sea Ice Changes, Interactions, and Feedbacks on the Arctic Climate during the Satellite Era (Invited talk), 2011 AGU Fall Meeting, 5-9 December 2011, San Francisco California, USA.

Liu, Y., J. Key, X. Wang, Understanding the interactions and feedbacks between Arctic sea ice, clouds, and the atmosphere from satellite observations, (keynote talk), 2011 EUMESAT meteorological satellite conference, September 5-9, 2011, Oslo, Norway.

Wang, X., J. Key, Y. Liu, Arctic Sea Ice Properties and Changes from Satellite Data over the Period 1982-2010 (Talk), 2011 EUMETSAT Meteorological Satellite Conference, 5-9 September 2011, Oslo, Norway.

Wang, X., J. R. Key, and Y. Liu, 2010: A thermodynamic model for estimating sea and lake ice thickness with optical satellite data. *J. Geophys. Res.*, **115**, C12035, 14 PP., 2010, doi:10.1029/2009JC005857.
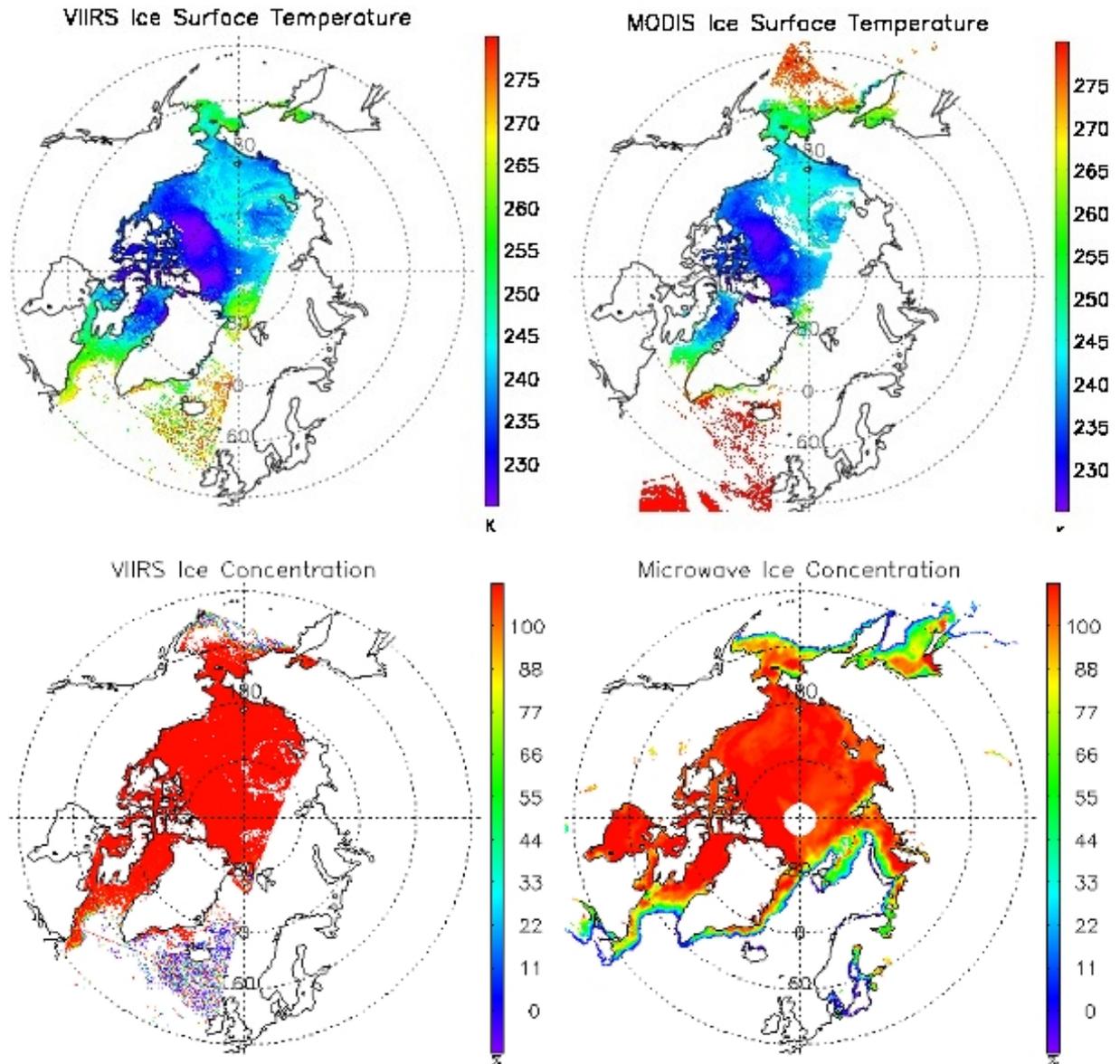
Figure 22.1. Ice surface temperature from VIIRS (upper left), MODIS (upper right) in 1 km EASE-Grid; Ice concentration from VIIRS (lower left), and SSM/I (lower right) in 25 km EASE-Grid over Arctic on March 7, 2012.

Liu, Y., J. R. Key, and X. Wang, 2009: The influence of changes in sea ice concentration and cloud cover on recent Arctic surface temperature trends. *Geophys. Res. Lett.*, **36**, L20710, doi:10.1029/2009GL040708.

Fernandes, R., H. Zhao, X. Wang, J. R. Key, X. Qu, and A. Hall, 2009: Controls on Northern Hemisphere snow albedo feedback quantified using satellite Earth observations. *Geophys. Res. Lett.*, **36**, L21702, doi:10.1029/2009GL040057.

23. Research Tasks in Support of the Suomi NPP/JPSS Program

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

CIMSS Task Leaders: Hank Revercomb, Dave Tobin
CIMSS Support Scientists: Fred Best, Bob Knuteson, Joe Taylor, Lori Borg, Dan Deslover
NOAA Collaborator: Yong Han
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

Proposed Work
The University of Wisconsin-Madison (UW) Space Science and Engineering Center (SSEC) has proposed to support a broad scope of activities aimed at providing the government with expertise in specific technical areas related to the JPSS mission. The general purpose of this work is to provide expertise that: (1) reduces schedule, cost, and performance risk; (2) helps assess performance of industry; (3) points to feasible observing system improvements; and (4) leads to increased positive impact of JPSS goals, by making use of the broad experience in instrument design, testing, algorithms, and science gained from previous and ongoing UW SSEC research activities.

Summary of Accomplishments and Findings
Our efforts for this period of performance have been devoted to preparing for and performing our various cal/val tasks for characterization, refinement, and reporting of the CrIS SDRs in the Early Checkout Cal/Val phase. These tasks include a range of post-launch assessment/validation efforts including "quick look" type analyses and assessments performed very early after launch as well as more accurate and detailed analyses performed later in the evaluation period. Our cal/val tasks are:

1. Internal consistency checks on Radiometric Calibration
2. Radiometric Non-linearity Evaluation
3. Radiometric Noise assessment
4. Variable artifact assessment using Principle Component Analysis
5. Early broadband comparisons with GOES and other GEOs
6. Clear sky Observed minus Calculated Analysis
7. Internal Consistency checks on spectral self-apodization correction and resampling
8. Analysis of non-uniform scene effects on the ILS

9. SDR evaluations using SNO comparisons with IASI and AIRS
10. CrIS/VIIRS Radiance Comparisons
11. ICT Environmental Model Evaluation and Refinement
12. In-orbit RU Estimation

We have recently completed the Early Checkout portion of each of these tasks, and reported on our findings at daily and weekly CrIS Cal/Cal team telecons and at the 04 April CrIS SDR Product Review meeting. These efforts are reflected in the v33 CrIS Engineering Packet which was uploaded to the sensor on April 11. These efforts are all aimed at characterizing and optimizing the radiometric and spectral calibration of the sensor, and on noise performance. Examples of the major results of this work are shown in Figures 23.1.1 through 23.1.4. Most recently we discovered a problem with the radiometric calibration of CrIS that has an interferometer sweep direction dependence, diagnosed the source of this problem (the on-board numerical filter), helped to simulate the effects of uploading an improved numerical filter, and have validated the improved calibration of the sensor following the upload of a new filter on April 18 (Figure 23.1.5) which precedes declaration of "beta" status of the CrIS SDRs. In summary, at the end of the Early Checkout phase, we have completed all of our Early Checkout phase efforts and find the radiometric and spectral performance of CrIS to be excellent.

We are now continuing these efforts into the Extended Cal/Val phase, focusing on lower level radiometric calibration and other issues that have been discovered during the Early Checkout phase that are part of our planned work. Also, we have recently become involved in efforts to prepare of FM2 (JPSS1) sensor TVAC level testing.
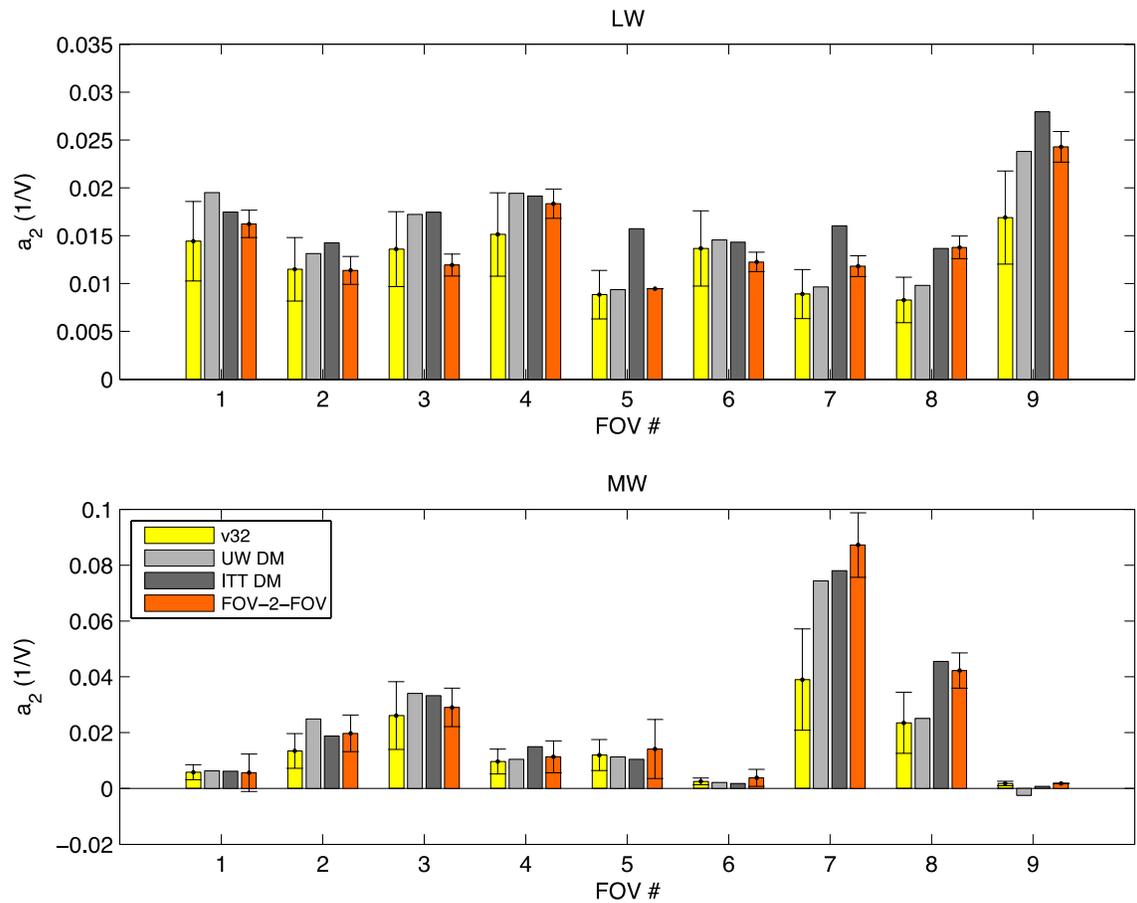
Figure 23.1.1. CrIS radiometric nonlinearity correction coefficients, a_2, determined during thermal vacuum testing (yellow), from in-orbit Diagnostic Mode data and analysis (by UW, light grey, and ITT/Exelis, dark grey), and from in-orbit FOV-2-FOV consistency analysis (orange). The CrIS longwave and midwave bands exhibit quadratic nonlinearity and this accounts for a significant portion of the CrIS Radiometric Uncertainty. To reduce the overall Radiometric Uncertainty and to create optimal agreement between the nine CrIS FOVs in each band, we have performed analyses to determine the optimal a_2 values. At-launch a_2 values were determined from thermal vacuum testing (v32 Eng. Packet, yellow) and the refined values were determined from FOV-2-FOV Earth view analysis (v33 Eng. Packet, orange).
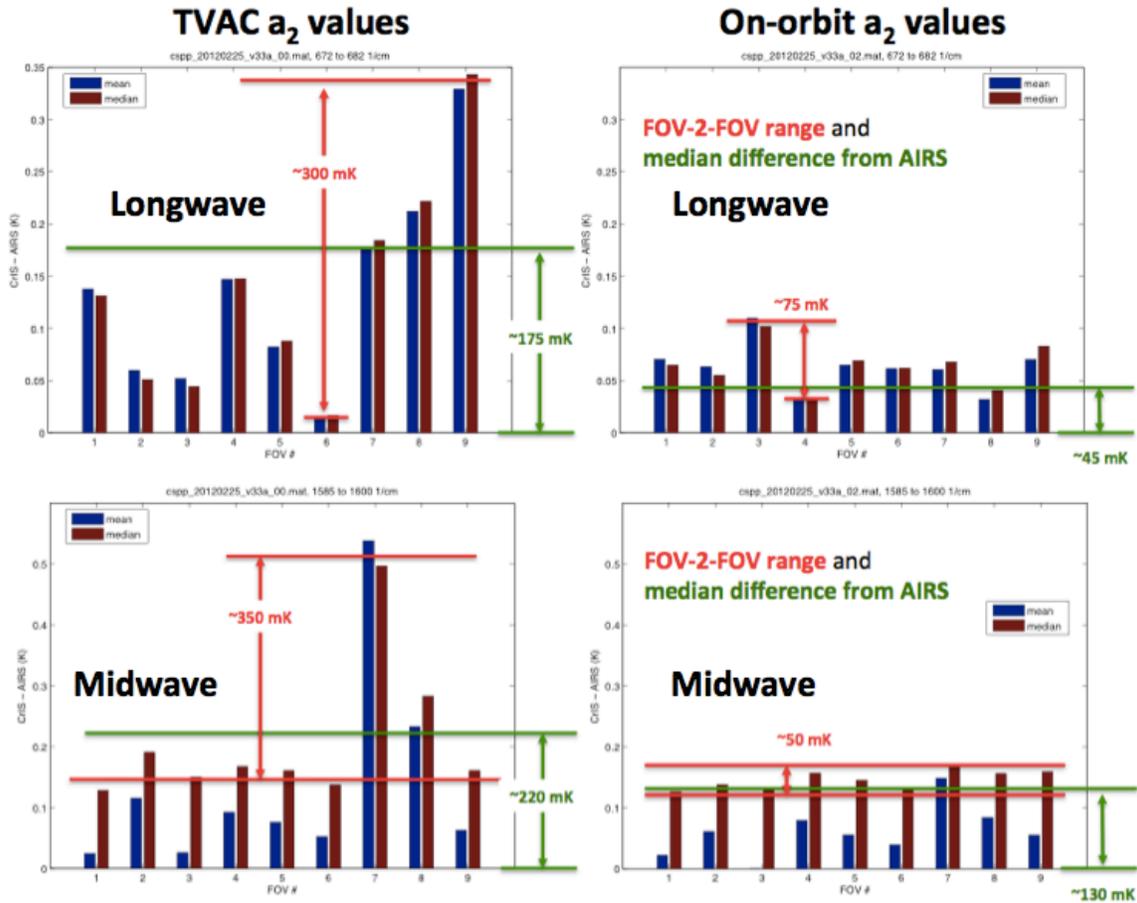
Figure 23.1.2. Example comparisons of CrIS and AIRS radiances (expressed in brightness temperature) using ~4800 SNOs collected on 25 February, for wavenumber regions which are most sensitive to the CrIS radiometric nonlinearity corrections. The left hand panels show comparisons using the at-launch (v32 Eng. Packet) a_2 nonlinearity correction coefficents, while the right hand panels show comparisons using the refined a_2 values (v33 Eng. Packet). The top panels are for the Longwave CO_2 region, and the bottom panels are for the Midwave water vapor region. With the refined a_2 values, the FOV-2-FOV agreement and overall agreement with AIRS is significantly improved.
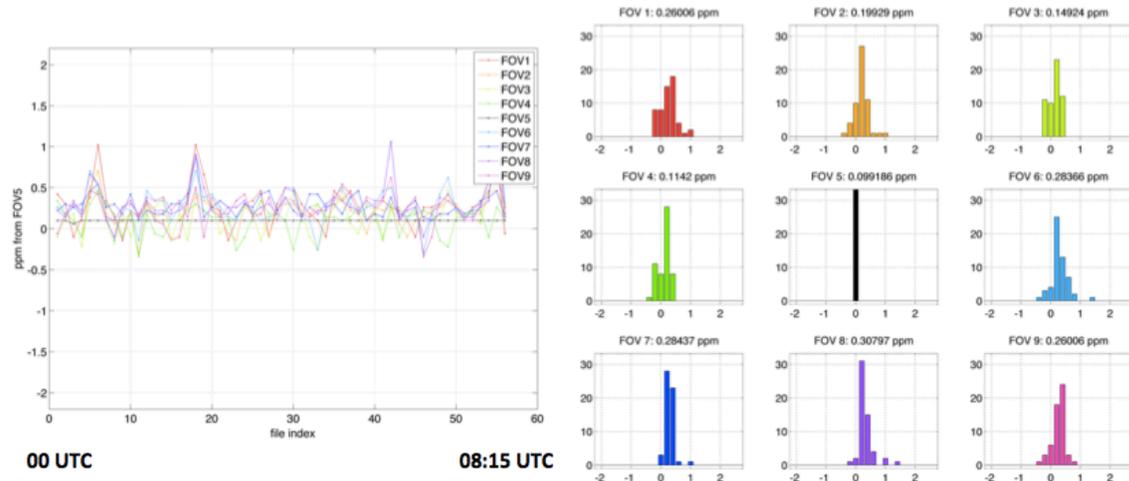
Figure 23.1.3. The results of an example analysis of inter-FOV spectral calibration analysis, for data following a sensor/platform warm-up/cool-down event on 24/25 March. As part of the CrIS spectral characterization and ILS parameter refinement in the Early Cal/Val phase, we have contributed a unique analysis technique and results for determining the inter-FOV spectral calibration for all three spectral bands, including the lower resolution shortwave band. This analysis and results are reflected in the FOV positions in the v33 Eng. Packet. In this figure, the left hand plot shows a time series of inter-fov spectral shifts from the center FOV5 in parts per million (ppm), and the right hand panels show a histogram of the shifts for each FOV. This shows excellent spectral performance of the sensor as well as the ability to characterize this performance with this technique, with inter-FOV spectral shifts less than a few tenths ppm.
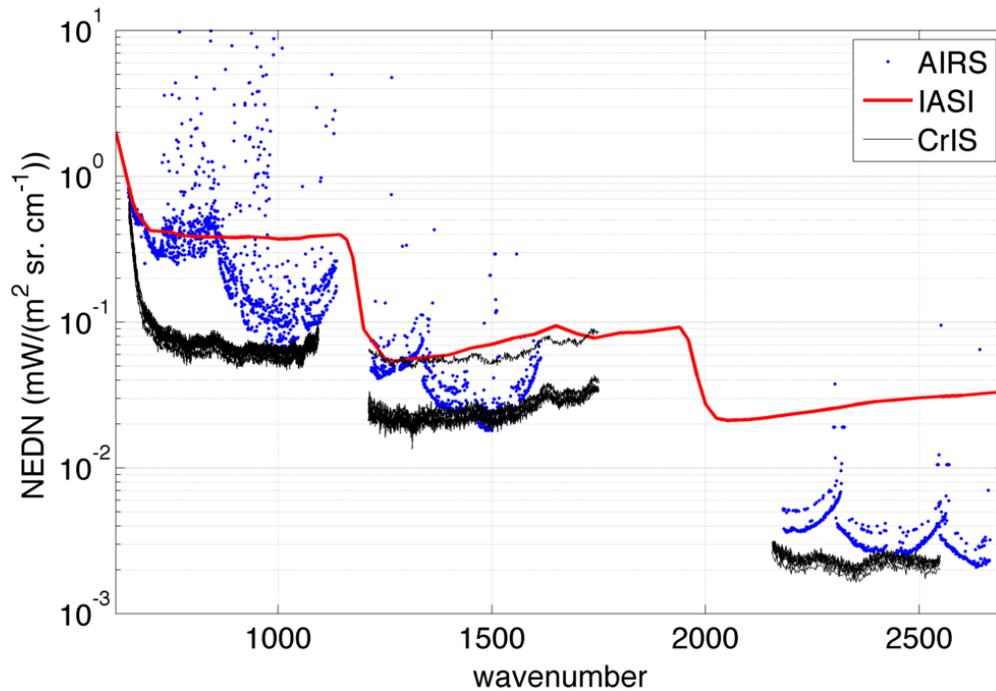
Figure 23.1.4. CrIS in-flight noise performance (black) as compared to the noise performance of AIRS (blue) and IASI (red). (Noise is shown here for each sensor for their native spectral resolutions and FOV sizes). This CrIS random noise estimate was produced from analysis of ensembles of ICT and Space view data collected on 21 January. Spectrally correlated noise is very small and difficult to estimate. As expected, the noise performance of CrIS is very good. It is lower than AIRS and IASI by roughly a factor of 5 in the longwave region, slightly better than AIRS in the midwave region, and also slightly better than AIRS (and significantly better than IASI) in the shortwave region.
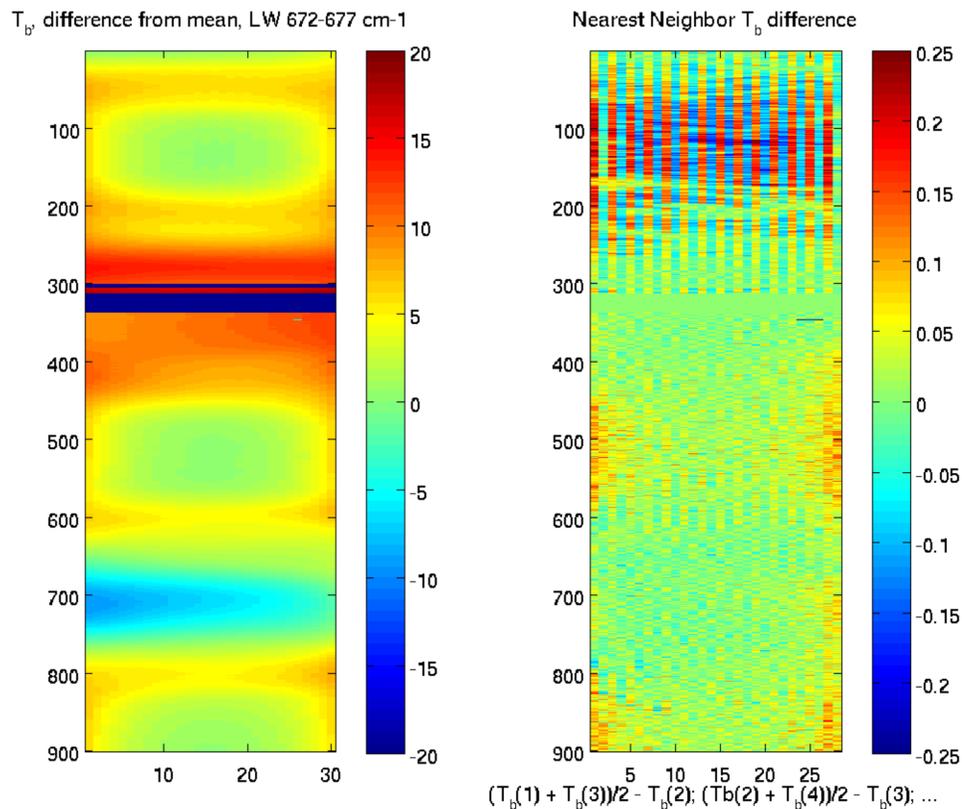
Figure 23.1.5. The left hand panel shows a cross section of brightness temperature variations in the longwave CO_2 (672-677) spectral region with 30 cross track FORs and time increasing from y-axis indices 0 to 900. The right hand panel shows the difference between adjacent FORs in each scan line, and in the upper portion of the figure clearly shows a FOR (interferometer sweep direction) dependent bias in the radiometric calibration. This "striping" effect has largest brightness temperature biases in this spectral region. At 16:15 on April 18 (approximately scan line 300 in these figures), the new on-board FIR filter was uploaded, greatly reducing the size of this effect.

Reports, Publications, Conference Presentations

14 presentations on our Cal/Val efforts and findings to the JPSS CrIS Cal/Val team between January 24 and April 11, primarily at the Wednesday CrIS Cal/Val telecons.

Monthly reports on our JPSS CrIS Cal/Val team efforts/results.

Hank Revercomb, Dave Tobin, Bob Knuteson, Dan Deslover, Joe Taylor, Graeme Martin, Ray Garcia, Lori Borg, "New Results from the Cross-track Infrared Sounder (CrIS) on NPP, Part 1", The 18th International TOVS Study Conference (ITSC-18), Toulouse, France, 21-27 March 2012. http://cimss.ssec.wisc.edu/itwg/itsc/itsc18/program/files/ITSC-18-Revercomb-Toulouse-21Mar12-f.pdf

Dave Tobin, Hank Revercomb, Bob Knuteson, Dan Deslover, Joe Taylor, Graeme Martin, Ray Garcia, Lori Borg, "New Results from the Cross-track Infrared Sounder (CrIS) on NPP, Part 2",

The 18th International TOVS Study Conference (ITSC-18), Toulouse, France, 21-27 March 2012.

23.2 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

Proposed Work
This task supports expert participation in VIIRS pre- and post-launch performance evaluation:
 1. Spectral characterization of the NPP VIIRS sensor including analysis of all pre-launch spectral measurements and post-launch spectral performance evaluation:
    • Complete the Government team Spacecraft Level RSR analysis,
    • Assess Northrop Grumman's (NG) NPP VIIRS at-launch RSR product, and
    • Evaluate spectral performance in the Early On-orbit Checkout (EOC) and prepare for the follow-on Intensive Cal/Val (ICV) phase;
 2. Support VIIRS SDR preparation for NPP launch readiness:
    • Build software tools necessary for Government team implementation of the NG Cal/Val Task Network, and
    • Participate in VIIRS SDR Cal/Val Rehearsals;
 3. Support VIIRS post-launch Cal/Val assessment:
    • Implement VIIRS Cal/Val tasks assigned to UW-Madison;
    • Review VIIRS performance through VIIRS imagery inspection using McIDAS to identify, isolate and characterize anomalous performance in all VIIRS bands; and
 4. Participation on VIIRS SDR team and in all associated activities.

Summary of Accomplishments and Findings
The reporting period includes the final preparations for the October 2011 launch of NPP into the post-launch checkout period of VIIRS on NPP. Over this reporting period, Dan LaPorte and Chris Moeller participated in the completion of NPP VIIRS pre-launch readiness leading to launch, and the Early On-orbit Checkout (EOC) period. Participation on the VIIRS SDR team was also supported during this funding cycle.

NPP VIIRS Relative Spectral Response Characterization
 • Spacecraft Level Relative Spectral Response - The Government team review of spacecraft level RSR was completed and RSR for all detectors of all VisNIR "M" and "I" bands was released to the VIIRS user community in May-June 2011. The RSR files along with README and other background information are posted at https://cs.star.nesdis.noaa.gov/NCC/SpectralResponseVIIRS. The RSR files have been made available with "sensor order" and "product order" detector numbering. The Government team spacecraft level RSR were adopted by Northrop Grumman into the October 2011 NG VIIRS RSR product.

- At-Launch RSR Characterization - The NPP VIIRS RSR have been measured multiple times and independently analyzed by both the NG and Government teams. NG delivered at-launch LUTs based upon the NG December 2010 RSR product release. The December 2010 RSR for VIIRS VisNIR bands was based largely upon a preliminary release of the spacecraft level RSR. After a detailed review by the Government team, the October 2011 band averaged NG RSR product release has been deemed appropriate to represent the NPP VIIRS at-launch RSR characterization. The SDR RSR LUT is in process of being updated with the NG October 2011 RSR product.
- The Government team RSR, an alternative high quality RSR available to the science community, has been compared to the NG October 2011 RSR and agrees closely but not exactly with the NG RSR primarily due to analysis differences that only affect the RSR at low response levels. As the accepted RSR for populating at-launch SDR and EDR LUTs, the Government team is recommending that the community apply NG's October 2011 band averaged RSR product to support SDR and EDR product algorithm development and evaluation. However, the Government team RSR will remain available to the community for their investigative interests, and may evolve if new understanding of VIIRS spectral performance is revealed in the post-launch era of NPP.
- A VIIRS RSR Overview document providing insight and recommendations on the development and use of all generations of NPP VIIRS RSR has been released by the Government team. The document is intended to help users of these products understand the strategy and strengths of each RSR data set and therefore guide their use. The document is available along with the Government team and NG RSRs at https://cs.star.nesdis.noaa.gov/NCC/SpectralResponseVIIRS.

VIIRS SDR Preparation for NPP Launch Readiness
- Tools have been developed to support cal/val tasks RAD-01 (out-of-band spectral), RAD-04 (RVS), RAD-12A (VIIRS-CrIS), and RAD12-B (VIIRS-IASI). Aircraft based tasks RAD-18, RAD-20, and RAD-21 were not funded during this cycle.
- UW-Madison participated in the July 2011 VIIRS SDR Cal/Val Rehearsal, pulling data products from GRAVITE, and successfully generating the RAD-12A Cal/Val product.
- During the July rehearsal, issues were revealed in using multiple GTP threads to pull data from GRAVITE. UW-Madison has adjusted its strategy for pulling data from GRAVITE. GRAVITE represents a backup source of VIIRS SDR data; the primary source remains SD3E.

VIIRS Post-Launch Cal/Val Assessment
- On-orbit gain monitoring and a subsequent deep dive investigation has revealed that the reflectance of four mirrors in the VIIRS RTA is subject to degradation with time due to tungsten contamination. The reflectance degradation is largest in the near infrared and SWIR spectral regions; VIIRS bands M7, I2 and M8 are most affected with bands M6 and M9 less affected. The degradation modulates the spectral response of these bands. This behavior is being monitored and continues under review for impact on SDR. If appropriate based upon radiometric impact, the VIIRS RSR for these bands will be updated to represent the response modulation.
- Early VIIRS data inspection has demonstrated high quality performance in many VIIRS bands. Ghosting and cross talk signatures are not present in reviews of high contrast scenes. Minor detector and mirror side striping is present, most notably in visible bands in sun glint regions. This performance surpasses that of early MODIS data.

- Band M6 is experiencing analogue saturation for high signal (e.g., clouds) earth scenes. The saturation causes the digital scale to fold over, creating ambiguity in interpreting M6 reflectances. A mitigation strategy is sought in the form of a data quality flag.
- RAD-12A has been implemented to assess VIIRS post-launch in-band spectral radiance performance for bands M13, M15, and M16. The VIIRS-CrIS comparisons for Jan 21, 2012 demonstrate good pre-Beta SDR performance with biases near zero and no indication of scene dependence of the biases.
- VIIRS-CrIS comparisons have been used to assess VIIRS RVS influence in VIIRS SDR (RAD-04). Early findings show that VIIRS HAM RVS is well characterized with no meaningful scan angle dependence in the VIIRS-CrIS biases.
- RAD-12B has been implemented to assess VIIRS post-launch in-band + out-of-band spectral performance. The VIIRS-IASI SNO data base is being built up to establish a large data sample (about 300 SNOs within +/- 10 minute window per month). Early findings have indicated that VIIRS SDR pre-Beta performance is encouraging with biases close to zero for M12 – M16 (Figure 23.2.1).

VIIRS SDR Team Participation
- Weekly SDR Team telecons have been conducted during the majority of the cycle. UW-Madison has presented on VIIRS SDR performance and has participated in reviews of performance evaluations presented by other elements of the SDR Team.
- UW-Madison is participating in SDR Technical Team telecons that are conducted multiple times per week, presenting on our investigations into SDR performance and reviewing investigations by other elements of the team in this tabletop format.

Publications and Conference Reports
DeLuccia, F., B. Guenther, C. Moeller, and X. Xiong, NPP VIIRS Pre-launch Performance and SDR Validation. IGARSS 2011, July 24-29, 2011, Vancouver, Canada.

Moeller, C., J. McIntire, T. Schwarting, D. Moyer, VIIRS F1 "Best Estimate" Relative Spectral Response Characterization by the Government Team. EOS XVI, SPIE, August 21-25, 2011, San Diego, CA.

Schwarting, T., C. Moeller, D. Moyer, J. Costa, S. Brown, K. Lykke, R. Barnes, B. Guenther, J. Xiong, J. Butler, VIIRS F1 VisNIR Effective RSR Measurement and Impact to VIIRS Calibrated Radiances. Calcon 2011 conference, August 29 – September 1, 2011, Logan, UT.
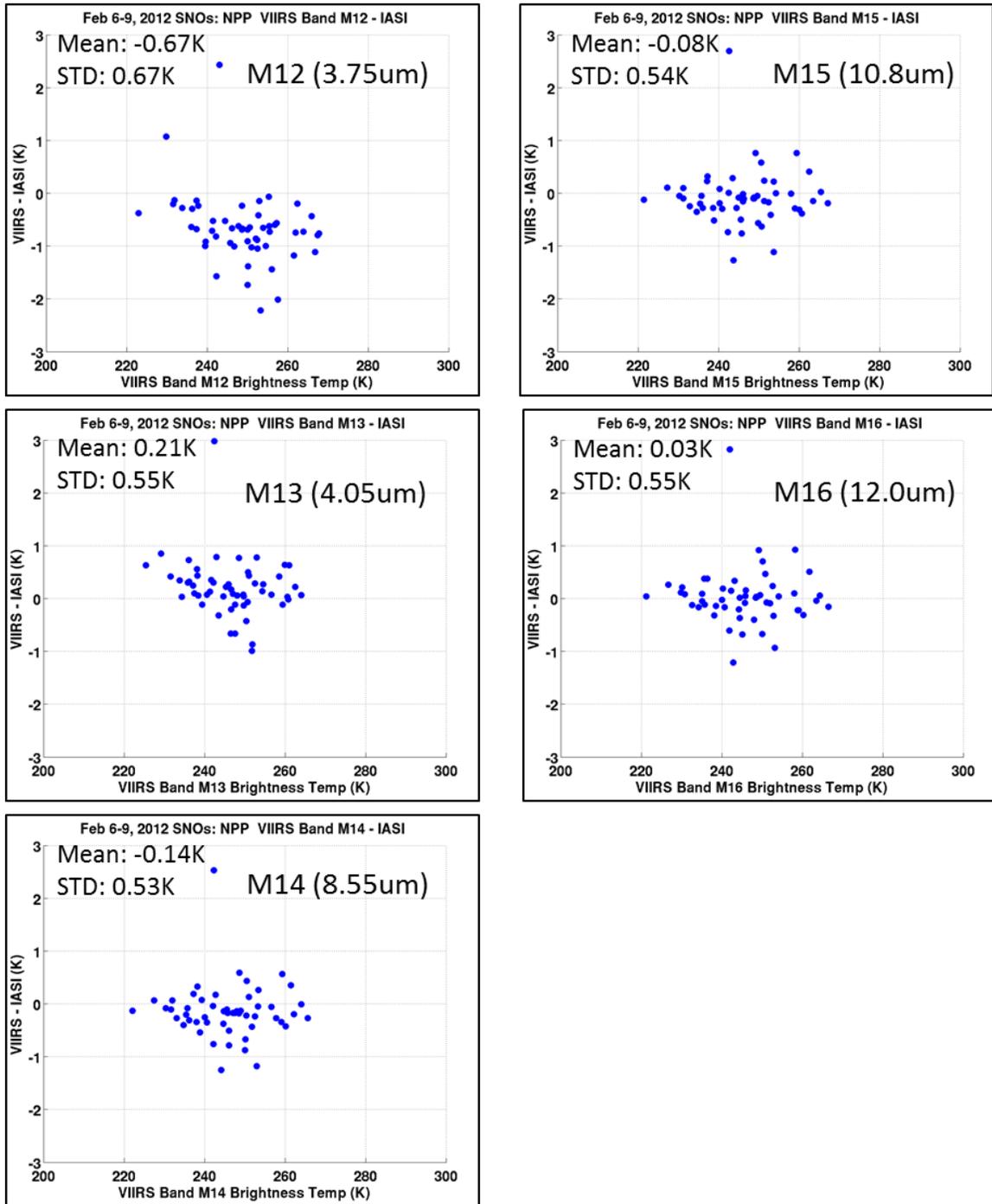
Figure 23.2.1. Calibration comparison of pre-Beta designation NPP VIIRS and Metop-A IASI instruments using simultaneous nadir overpasses (SNOs) from Feb 6-9, 2012. SNOs within +/- 10 minutes are collected to evaluate VIIRS radiance calibration against IASI. These early VIIRS SDR results are favorable, showing biases near to zero for all bands and without any apparent scene temperature dependence.

23.3 CrIMSS EDR Cal/Val: ARM Site Support

CIMSS Task Leader: Dave Tobin
CIMSS Support Scientists: Lori Borg, Robert Knuteson
NOAA Collaborator: Chris Barnet
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

Proposed Work
The proposed work is designed to prepare for and 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. Previously for AIRS and IASI, best estimates of the atmospheric state and surface properties at the satellite overpass times were produced via a 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. We have proposed to continue these activities to provide validation of the NPP soundings.

Summary of Accomplishments and Findings
This year, we have continued to plan and coordinate the ARM site efforts for CrIMSS EDR validation. Currently, we are planning to conduct the 2012 validation efforts in July, August, and September. We have also worked with the GRUAN community to develop these types of validation methodologies at other ground truth sites.

References
Tobin D. C., H. E. Revercomb, R. O. Knuteson, B. M. Lesht, L. L. Strow, S. E. Hannon, W. F. Feltz, L. A. Moy, E. J. Fetzer, 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.

23.4 CrIMSS Post Launch EDR Assessment

CIMSS Task Leader: Robert Knuteson
CIMSS Support Scientists: Michelle Feltz, Jacola Roman
NOAA Collaborator: Chris Barnet
NOAA Long Term Goals
- Climate Adaptation and Mitigation
- Weather-Ready Nation

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

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

Proposed Work

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 data set 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.

Total Column Water Vapor Validation using MWR and GPS stations

We have published detailed analyses 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. We are developing methods for CrIMSS validation of total water vapor that take into account the station elevation in regional assessments.

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 new Raman Lidar has been installed at the DOE ARM site in Darwin, Australia which will be incorporated into the validation of CrIMSS in subsequent years. 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 can also be used to validate the CrIMSS 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 performance is degraded but the GPS occultation profile is considered to have excellent absolute accuracy. Methods to validation the CrIMSS temperature profiles will be developed to complement the radiosondes at the ARM sites in particular.

Summary of Accomplishments and Findings

CrIMSS products were not yet available during this project time period. In preparation for these data, we developed the matchup tools for CrIMSS and validation products. For the comparison of COSMIC RO and AIRS IR temperature profiles, we found that a one hour time difference between GPS RO and the IR profile measurement provided adequate yield with sufficient accuracy to characterize bias and RMS errors for 20 degree latitude zones. When GPS RO horizontal averaging was applied to the AIRS Level 2 granule matchups, improved agreement was obtained compared to using the closest AIRS IR profile. Daily zonal statistics were found to provide a useful measure of AIRS retrieval performance. We anticipate that monthly time series for latitude zones can be used to monitor CrIMSS retrieval performance. This study showed RMS error is between 1.5 K and about 2 K for the 300 mb to 30 mb altitude range for all latitude zones. Above this range, the COSMIC RO profiles appear to have much higher vertical resolution than the AIRS IR profiles. Below this range, the COSMIC RO profiles become strongly contaminated by water vapor in the occultation ray path. The height of this effect is latitude dependent. These results are in qualitative agreement with results of Yunck et al. (2009). Future work includes the application of the AIRS temperature averaging kernel to the COSMIC minus AIRS profile differences to remove vertical structure higher than the theoretical AIRS resolution. Application of this method to CrIMSS EDR products is in progress. Figure 23.4.1 illustrates the matchup profiles between AIRS and COSMIC for the Darwin ARM site. Note the deviation of the GPS dry temperature from the AIRS IR retrieval below about 400 mb. Note also the AIRS IR profile error at the tropopause and in the lower stratosphere due to a relative lack of vertical resolving power in that region. The results are very encouraging for the use of COSMIC data in CRIMSS temperature validation near the tropopause.

AIRS.2010.08.18.044
C004.2010.229.18.57.G21
twpsondewnpnC3.b1.20100818.000600
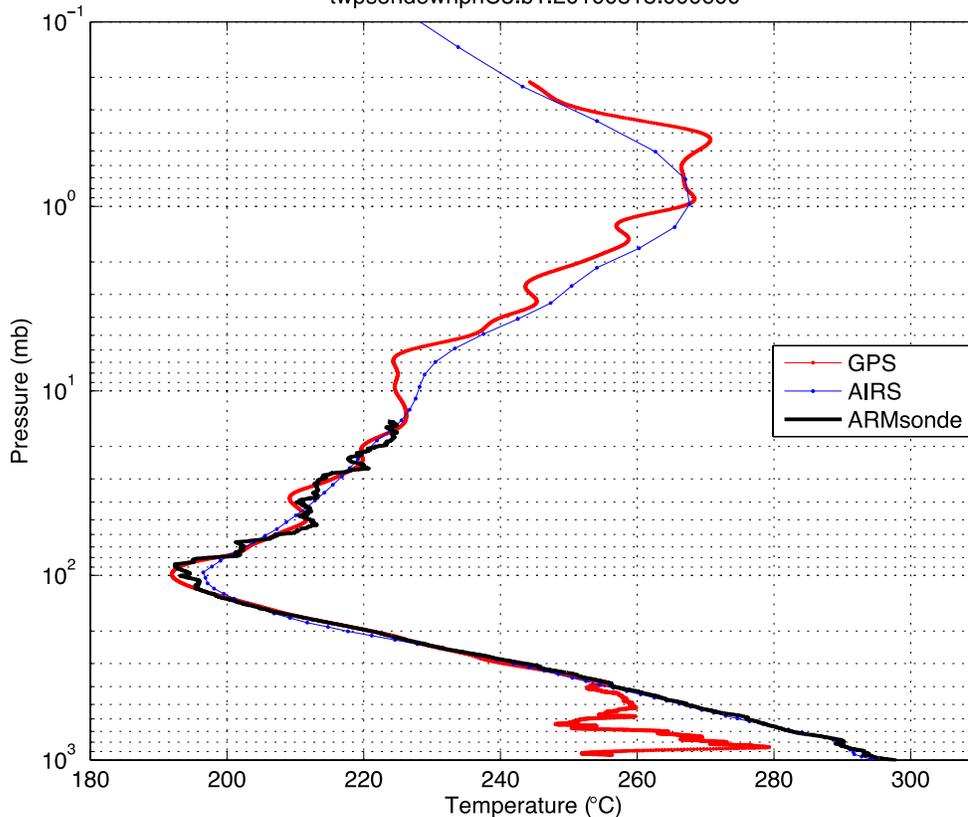
Figure 23.4.1. Example matchup between GPS RO, AIRS IR, and Vaisala radiosonde.

Publications and Conference Reports

UW/CIMSS presented two poster papers at the AMS 2012 annual meeting conference in the Eighth Annual Symposium on Future Operational Environmental Satellite Systems:

Michelle Feltz, CIMSS/Univ. of Wisconsin, Madison, WI; and R. Knuteson, D. Tobin, S. Ackerman, H. Revercomb, and A. Reale, Methodology for the Validation of Temperature Profile Environmental Data Records (EDRs) From the Cross-Track Infrared Microwave Sounding Suite (CrIMSS): Experience with GPS Radio Occultation From COSMIC
http://ams.confex.com/ams/92Annual/webprogram/Paper200494.html

Robert Knuteson, CIMSS/Univ. of Wisconsin, Madison, WI; and D. Tobin, A. Sorce, J. Roman, S. Ackerman, H. Revercomb, and D. D. Turner, Methodology for the Validation of Water Vapor Profile Environmental Data Records (EDRs) From the Cross-Track Infrared Microwave Sounding Suite (CrIMSS): Experience with the DOE ARM Water Vapor Raman Lidar
http://ams.confex.com/ams/92Annual/webprogram/Paper200492.html

23.5 NPP-VIIRS Evaluation Using Satellite Observations

CIMSS Task Leader: Robert Holz
CIMSS Support Scientists: Min Oo and Fred Nagle
NOAA Collaborator: Andrew Heidinger
NOAA Long Term Goals
- Climate Adaptation and Mitigation
- Weather-Ready Nation

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

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

Proposed Work

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

Summary of Accomplishments and Findings

Clouds

The primary instrument for clouds on NPP is VIIRS. VIIRS is multispectral visible and IR imager similar to MODIS. To evaluate the VIIRS retrievals we are using tools developed by both the GOES-R collocation project and the NASA atmospheric PEATE. The NASA A-Train satellite system provides our primary source of the evaluations products with a focus on MODIS, CALIOP, and CloudSat. An example of the VIIRS cloud top height retrieval compared to CALIOP is presented in Figure 23.5.1. For optical thick high clouds, the VIIRS retrieval performs as expected however there are significant differences that needs to be addressed. For low clouds, VIIRS overestimates the cloud top heights by 1-2 km. This bias results from incorrectly handling the near surface temperature inversion. The overestimation also happens for clouds near the tropopause between -47 -46 Latitude in Figure 23.5.1. A global gridded image of the VIIRS and MODIS cloud top height retrieval is presented in Figure 23.5.2.

In Figure 23.5.2, the color scales are identical for MODIS and VIIRS. Notice the significant differences in cloud top pressure retrievals given that both observations are from the same day and nearly the same time. Compared to MODIS, VIIRS overestimates the cloud top heights for low clouds and underestimates the high cloud retrievals, which is consistent with the granule results compared to CALIOP in Figure 23.5.1.
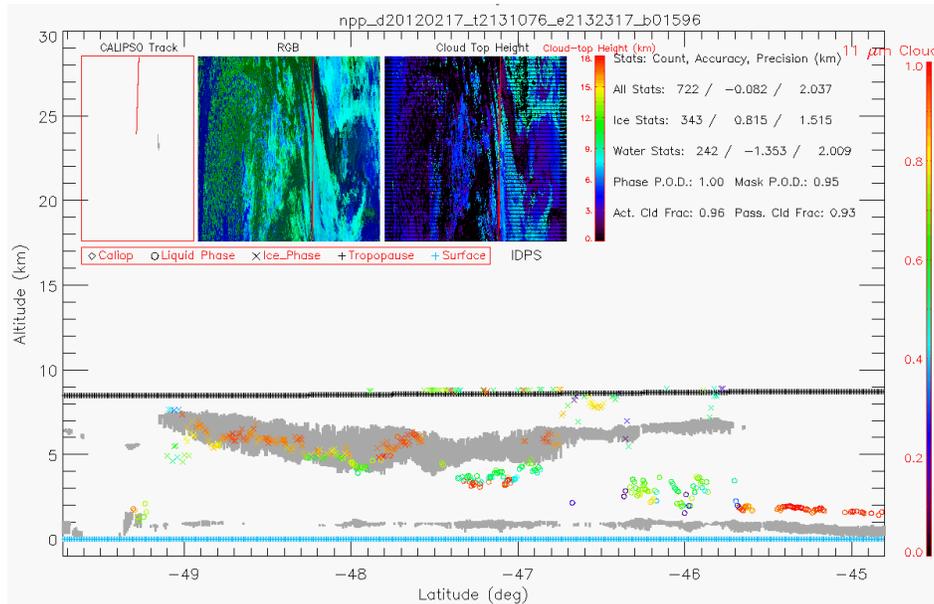
Figure 23.5.1. VIIRS cloud top height granule for February 17th 2012 on the top of the figure. The bottom figure overlays the VIIRS cloud top height on a CALIOP attenuated backscatter profile.
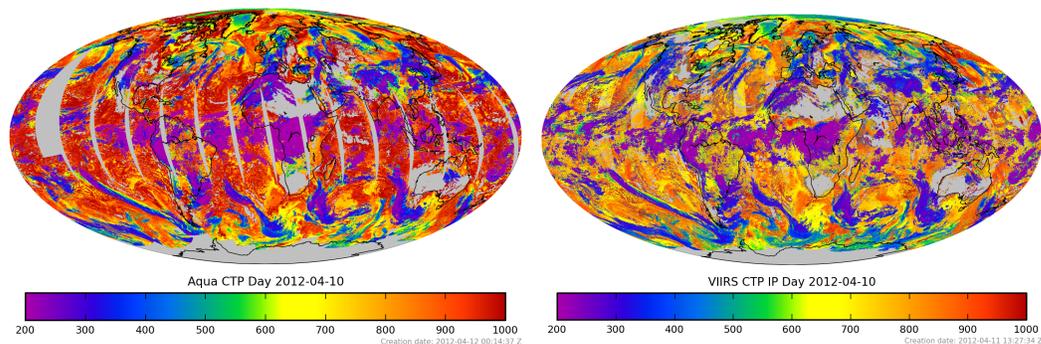
Figure 23.5.2. Global gridded CTP retrievals for MODIS Aqua (left figure) and VIIRS (right figure). The color scales are identical for each image.

In summary, the cloud top height/pressure example presented provides an example of the types evaluation being conducted as part of this project. We are in the process of evaluating all VIIRS cloud using the methodology presented for CTH and CTP. Although not presented in this report, we are finding significant anomalies other VIIRS cloud products that we are communicating to the JPSS management.

24. Research Tasks in Support of a Suomi NPP / JPSS Field Campaign

24.1 UW Scanning HIS Participation in the 2012 NPP/JPSS field campaign

CIMSS Task Leaders: Dave Tobin, Hank Revercomb
CIMSS Support Scientists: Fred Best, Joe Taylor, Robert Knuteson
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

Proposed Work

The proposed work is to participate with the Scanning-HIS aircraft sensor in an NPP aircraft cal/val campaign, with emphasis on the validation of CrIS SDRs. Efforts include preparation of the Scanning-HIS for deployment, participation in campaign planning, in-field campaign efforts, production of calibrated/geolocated Scanning-HIS spectral radiances, and validation analyses of the CrIS SDRs.

Summary of Accomplishments and Findings

The 2012 field campaign is being planned for the Fall of 2012. We are helping to coordinate the campaign and will participate in the campaign this Fall.

References

E.g., Smith, W. et al., Joint Airborne IASI Validation Experiment (JAIVEx) - An Overview of the US component and capabilities, Joint 2007 EUMETSAT Meteorological Satellite & 15th AMS Satellite Meteorology and Oceanography Conference, Amsterdam, The Netherlands 24 – 28 September 2007.

24.2 Integration of HSRL into the SSEC Mobile Laboratory

CIMSS Task Leader: Ed Eloranta
NOAA Long Term Goals
- Climate Adaptation and Mitigation
- Weather-Ready Nation

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

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

Proposed Work

In order for the High Spectral Resolution LIDAR (HSRL) to participate in mobile field experiments, it must be installed into a field deployment unit. Previous LIDAR systems developed at UW-Madison were installed in a fully dedicated semi trailer. The latest HSRL unit has the physical and performance characteristics that will allow for installation into our existing Winnebago mobile laboratory. To achieve this integration several modifications must be made to

the Winnebago in order to safely and securely deploy the system in this vehicle.

Summary of Accomplishments and Findings

Following a deployment of the Winnebago mobile laboratory in fall 2011 it was determined that the useful life of the Winnebago vehicle was ending. SSEC has made the decision to construct a new mobile laboratory built from the ground up that will house SSEC instruments, including the HSRL. The funding for this project is being held until the basic mobile unit construction is complete and the integration of the HSRL can being.

24.3 High Latitude Proving Ground

CIMSS Task Leaders: Allen Huang, Liam Gumley, Kathleen Strabala

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

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

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

Proposed Work
We proposed to conduct proving ground activities in support of US agencies (in particular the National Weather Service) for early and optimal uses of NPP/JPSS data and products at high latitudes.

Summary of Accomplishments and Findings
Building on the success of the polar products in AWIPS work at CIMSS, the JPSS High Latitude Proving Ground aims to provide NPP/JPSS products to the National Weather Service as a means to improve local forecasts. The first step in this process is the development of a portable tool that can reproject and reformat the VIIRS Science Data Records (SDRs) into a netCDF file that can be displayed within the Advanced Weather Interactive Processing System I (AWIPS I) that is used as the visualization and analysis tool at all US National Weather Service (NWS) Forecast offices. Data that are acquired directly from the satellite via a local antenna is the optimal source for this effort, because the data can be gathered, processed and distributed rapidly. This process has already been demonstrated successfully by providing Aqua and Terra MODIS products in AWIPS from data acquired from CIMSS as part of the GOES-R Proving Ground. CIMSS is now providing MODIS products to 57 different forecast offices in the lower 48 states. The improved spatial resolution and new spectral bands of VIIRS (such as the day/night band), mean that these data will be even more valuable to forecasters, especially in the high latitudes where there are more frequent polar overpasses, and where data from the geostationary satellites are less useful because of the large viewing angles.

CIMSS has completed the initial testing of the tool using data overpasses from the NPP Atmospheres Product Evaluation and Test Element (PEATE) covering Alaska. The data quality is

very high and displays nicely in AWIPS using the CIMSS created AWIPS menus and enhancements. Figure 24.3.1 shows an example data set of VIIRS displayed in AWIPS from 25 February 2012. The initial version of the tool will include reprojection and reformatting of 4 VIIRS I-Bands (.640 micron (band I3), 1.61 micron (Band I3), 3.74 micron (Band I4) and 11.4 micron (Band I5)) as well as the Day/Night Band (DNB). It will also include the 11 micron minus 4 micron brightness temperature difference, that is often referred to as the Fog Product.

The portability of the tool means that it can be installed on standard Linux 64 bit operating systems. This capability also means that it can be used in CONUS, using the CIMSS antenna acquired antenna data to test the direct broadcast CSPP SDR product generation and distribution to forecast offices, as well as to other sites such as Hawaii.

Plans have been made to visit Alaska in May 2012 in order to assist in the installation and distribution of NPP VIIRS data to the NWS. Working with Tom Heinrichs and his team at GINA in Fairbanks, the plan includes training NWS forecasters in Fairbanks and Anchorage on how to use the direct broadcast data to support operational forecasts.
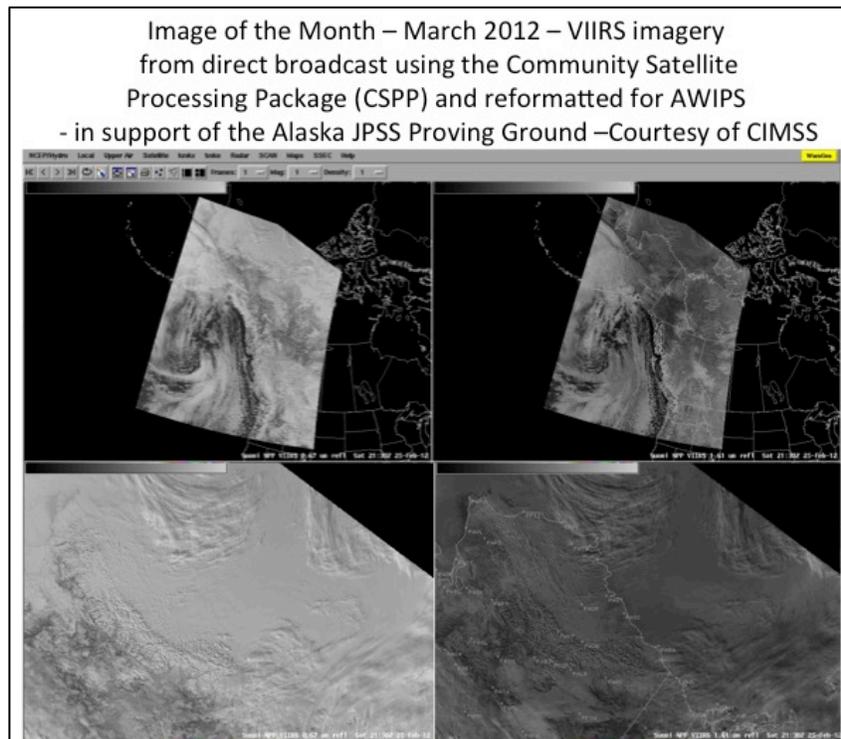
Figure 24.3.1. Example of VIIRS data as displayed in AWIPS I over Alaska. The data were reprojected and reformatted using the CIMSS VIIRS to AWIPS tool. Displayed are the VIIRS I-Band .64 micron reflectances (left panel) and the 1.61 micron reflectances (right panels). This figure was part of the Image of the Month as distributed by the JPSS Program Scientist, Dr. Mitch Goldberg.

24.4 McIDAS-V Support for Suomi NPP / JPSS

CIMSS Task Leader: Thomas Achtor
CIMSS Support Scientists: Tom Rink, Tommy Jasmin
NOAA Collaborators: Don Hillger (NESDIS/STAR Imagery Applications Team
**   Lead), Michael Denning (NOAA Satellite Operations Facility, Suitland, MD)**
NOAA Long Term Goals
- Climate Adaptation and Mitigation
- Weather-Ready Nation
- NOAA Enterprise Objectives

NOAA Strategic Goals
- Serve society's needs for weather and water information
- Understand climate variability and change
- Provide critical support for the NOAA mission

CIMSS Research Themes
- Satellite Meteorology Research and Applications
- Satellite Sensors and Techniques
- VIIRS Cloud Property Research

Proposed Work
A key milestone for McIDAS-V in 2012 is to release a stable, supported new version with full support for all Suomi NPP instruments. Following this release (a goal of the 2nd quarter of 2012) CIMSS will expand general JPSS support to improve ease-of-use, and provide key additional functionality, including:

1. Insure a mechanism is in place to properly calibrate all instrument data in such a way users need not be concerned or aware of by default. VIIRS has had degradation issues since launch, and debate continues on how to validate delivered data. Whatever decisions are made, McIDAS-V has to seamlessly present properly calibrated data to its end users;

2. The present JPSS data selection mechanism in McIDAS-V allows multiple-selection of actual granules direct from the file system. This user interface is limited by the fact that JPSS granules are relatively small (86 second duration VIIRS granules) and by the fact that each spectral channel is stored in a separate file. We will develop a graphical user interface to simplify discovery and selection of data, presenting a view organized by orbit, instruments, and products;

3. McIDAS-V should provide an option, integrated into the GUI, to re-grid VIIRS data to handle the bow-tie deletion artifact. As a result of the new mechanism employed by VIIRS to maintain consistent spatial resolution from nadir to limb, the underlying data structure removes redundant pixel values on successive scans. The resulting imagery, when displayed using the default McIDAS-V sampling and object model, appears as though there may be missing data near the limb of each granule. Based on user response, we are adding an option to re-grid VIIRS data by varying amounts to partially or entirely remove this visual artifact;

4. Several users have expressed a desire to run various analyses on JPSS data in McIDAS-V, and have the capability to write these processed data to disk in a more generally usable, intermediate format such as satellite-CF compliant NetCDF. We want to leverage the Java NetCDF library and add this capability; and

5. The NESDIS/STAR Imagery and Visualization Team has specific JPSS support needs, including the ability to batch run various processing algorithms, and to produce RGB composite imagery. We wish to provide the necessary functionality via the McIDAS-V Jython scripting interface, which is currently under development. VIIRS RGB support is

nearly complete, implemented as a McIDAS-V plug-in. This plug-in would go through formal testing and be made available for download to all users via the McIDAS-V plug-in Web repository.
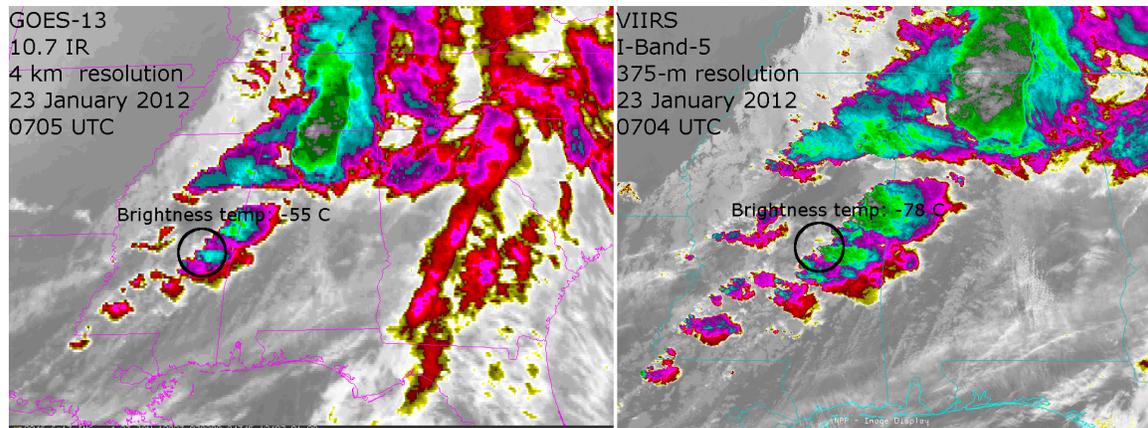
Figure 24.4.1. High spatial resolution thermal band (I-Band 5, 375 m resolution) on VIIRS captures cloud structure not detectable from GOES. In this case, cloud-top temperature difference over 20 deg C.

Summary of Accomplishments and Findings

Going back to 2010, CIMSS management had the foresight to direct the McIDAS-V development team to begin preparing for the launch of NPP. Anticipating desire from scientists, researchers, forecasters, and others to begin working with the enormous amount and variety of critical scientific data as soon as available, CIMSS began adding support for this complex data model to McIDAS-V.

Utilizing simulated data developed and distributed by a NOAA computing facility known as the Government Resource for Algorithm Verification, Independent Testing, and Evaluation (GRAVITE), CIMSS was able to add visualization and analysis capabilities to McIDAS-V for the Visible/ Infrared Imager Radiometer Suite (VIIRS), the Advanced Technology Microwave Sounder (ATMS), and the Cross-track Infrared Sounder (CrIS), and the Ozone Mapping and Profiler Suite (OMPS) (examples Fig. 24.4.1 and 24.4.2).

CIMSS leveraged previous work done for McIDAS-V to support hyperspectral data. This very novel functionality allows scientists to interrogate hyperspectral satellite data in very useful ways. For example, all 717 longwave CrIS channels can be easily manipulated bi-directionally in two display windows. Another clever innovation for NPP support was the development of a Granule Aggregator, which allows users to select and display an arbitrary set of contiguous granules. Once loaded, the full McIDAS-V capabilities are available, including subsetting, reprojecting, applying formulas, etc.

CIMSS was one of the first organizations worldwide to visualize and analyze both the simulated GRAVITE data, and the post-launch, live Suomi NPP data. CIMSS also provided critical pre-launch feedback to correct errors in the NPP data model, in the NPP product profiles, and in documentation. Fueled only by very minimal funding sources, CIMSS played a vital role in a mutually beneficial feedback cycle among the various agencies supporting NPP pre-launch – a collaboration which has certainly been a key factor in this successful first JPSS mission.
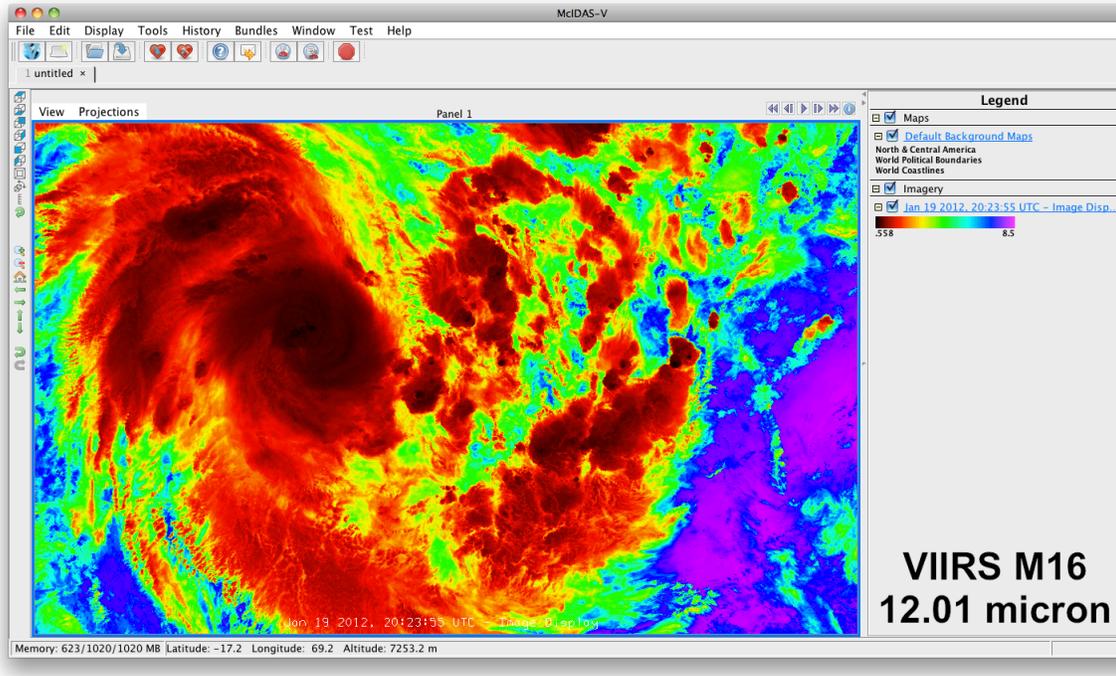
Figure 24.4.2. Tropical Cyclone Ethyl, visualized in McIDAS-V utilizing VIIRS M-Band 16 on January 19, 2012.

Publications and Conference Reports

Jasmin, Tommy; Dave Santek, Tom Rink, Thomas Achtor, and Tom Whittaker: Using the McIDAS-V scientific data software system to visualize and analyze NPP data. 2011 EUMETSAT Meteorological Satellite Conference, 5-9 September 2011, Oslo, Norway.

Rink, Thomas D.; Jasmin, T. and Achtor, T.: McIDAS-V: Visualization and analysis capabilities for JPSS. Annual Symposium on Future Operational Environmental Satellite Systems, 8th, New Orleans, LA, 22-26 January 2012. American Meteorological Society, Boston, MA, 2012.

Rink, Thomas; Jasmin, T. and Achtor, T.: Engineering support for JPSS instruments and data formats in McIDAS-V. Annual Symposium on Future Operational Environmental Satellite Systems, 8th, New Orleans, LA, 22-26 January 2012. American Meteorological Society, Boston, MA, 2012.

25. 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
NOAA Collaborator: Paul Meade
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

Proposed Work

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, and
- Developing an output product aggregation capability for ADL.

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

SSEC released ADL 3.0 to the user community in July 2011. ADL 3.1 followed in October 2011. The releases were available in two formats: (a) source code as delivered by Raytheon, with explicit instructions developed by SSEC for installing prerequisite packages and building the software, and (b) a 64-bit Linux virtual appliance where all prerequisites are installed and ADL is built and ready to run. SSEC also released the first version of the ShellB3 Python library for working with ADL executable and data files.

SSEC continued to develop and refine the ADL Web site for documentation and user instructions and the ADL Forum for user interaction. The Web site is available at:

https://jpss-adl-wiki.ssec.wisc.edu

and includes information on ADL Software and Downloads, Installation Instructions, Scripts and Helper Applications, ADL Virtual Appliance, HOWTOs, Add-Ons, and a link to the ADL help desk email address. The Web site also contains links to the ADL ancillary data Web site.

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 ShellB3 Python scripting environment released by SSEC provides a portable pre-built library of read-to-run utility scripts for assisting with common tasks in ADL, including:
- Reading and writing HDF5 and BLOB files,
- Converting native ancillary data formats (e.g., GRIB) to BLOB format,

- BLOB read-write access (big and little endian),
- ASC metadata manipulation,
- Ancillary data gridding and granulation, and
- HDF5 file comparisons (e.g., for comparing output files from different versions of a retrieval algorithm).

SSEC developed and is operating a real-time ancillary data ingest and distribution site to provide a one-stop shop for ADL users top obtain the ancillary data needed to run SDR and EDR algorithms in ADL. The Web site is available at

http://jpssdb.ssec.wisc.edu/ancillary/

Files distributed include:
- GFS model NPP 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, and
- TLE internal text and ascii files.

SSEC developed scripts for ADL to automatically identify and download ancillary files matching a given date/time. The scripts search a local ancillary directory for files, and they are not found, they are downloaded from the SSEC site. GFS forecast files used for near real-time NPP data processing, and GDAS analysis files are used for historical and non real-time data.

SSEC developed Python scripts to transform native format ancillary data to the binary format required internally by ADL. Script functions include:
- Read GRIB data sets using pygrib,
- Resampled and transform NCEP GRIB data sets to match CDFCB spec,
- Ingest global gridded NCEP data sets, and
- Ingest Navy Aerosol Model global gridded data set.

Extensive validation of the ancillary data produced by the SSEC scripts was done to ensure that the products were compatible with the ancillary data created by IDPS. Note that the ancillary data preprocessing tools in IDPS are not yet available in ADL (they are planned to be available in ADL 4.0). SSEC's approach has been to create work-alike, but necessarily identical, versions of the ancillary data used in IDPS (examples Fig. 25.1 and 25.2).

Publications and Conference Reports
SSEC participated in the ADL workshop held at NASA GSFC in January, 2012. Status of the ADL effort at UW/SSEC was presented by Scott Mindock.

ADL : 4d87b80f-6275d-0a4f18da-57dc83f6.VIIRS-GridIP-VIIRS-Nbar-Ndvi-Mod-Gran
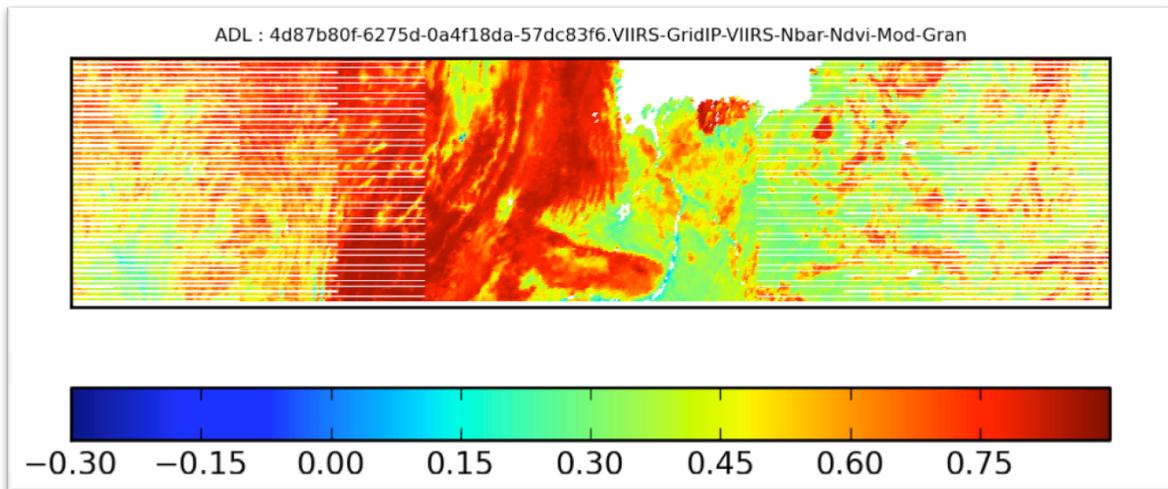
Figure 25.1: NDVI ancillary data processed in IDPS.

Local : 4ef0bb8d-8ede9-c2938b6d-c85df967.VIIRS-GridIP-VIIRS-Nbar-Ndvi-Mod-Gran
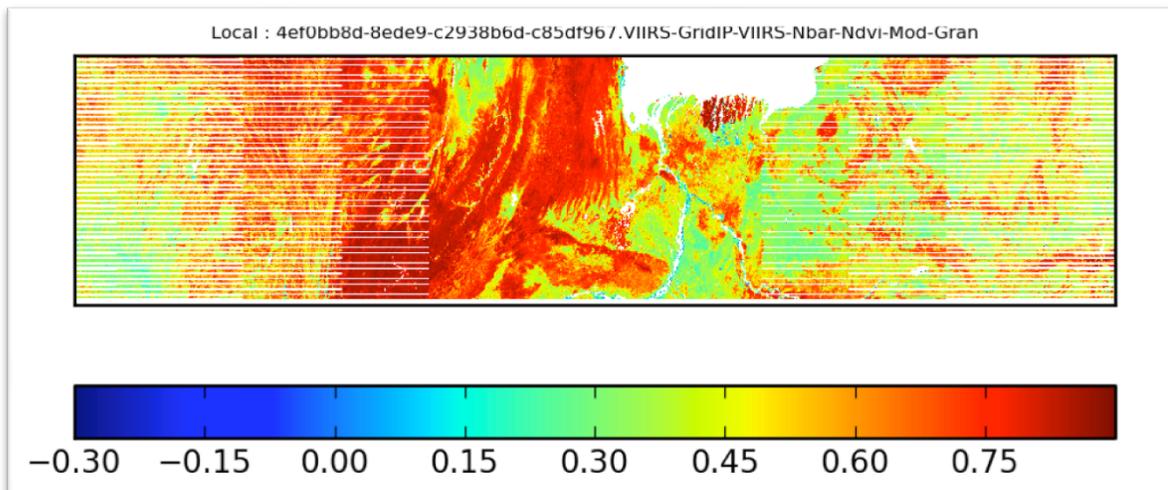
Figure 25.2: NDVI ancillary data processed in ADL using scripts developed at SSEC.

26. Integration of NPP Algorithms into JPSS Proving Ground

CIMSS Task Leaders: Liam Gumley, Allen Huang
**CIMSS Support Scientists: Scott Mindock, Ray Garcia, Graeme Martin, Geoff
    Cureton, Kathy Strabala, Elisabeth Weisz, Nadia Smith**
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

Proposed Work

SSEC team proposes to develop a NPP/JPSS component of the Community Satellite Processing Package (CSPP) for direct broadcast users that will transform VIIRS, CrIS, and ATMS RDRs to SDRs and create selected EDRs optimized for real-time processing and regional applications within six months after the launch of the NPP spacecraft. CSPP-NPP/JPSS will have the following features:

- 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 78/Vista/XP 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;
- Allow the end user to add customer user-developed algorithms;
- Provide products optimized for NWS which are AWIPS and/or NOAA NextGen compatible;
- Provide value-added products for end users that are not part of the JPSS operational suite, such as images in KML format for Google Earth; Night Fog Detection; Volcanic Ash; and Aviation Safety products; and
- Utilize GPU-based High-Performance Computing (HPC) technology to reduce the latency of CSPP-NPP/JPSS product generation for time-critical regional applications.

Summary of Accomplishments and Findings

The CSPP software for Suomi NPP is based on the Algorithm Development Library (ADL) developed by Raytheon and the JPSS project, which 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."

The first beta version of the CSPP software for transforming VIIRS, CrIS, and ATMS RDRs to SDRs was released to external testers on Dec 21, 2011 (less than two months after the launch of Suomi NPP). Agencies involved in the beta test process included UKMO, Meteo-France, EUMETSAT, CMA, FMI, SMHI, DWD, CONABIO, INPE, ACRES, GINA, SeaSpace, and ScanEx. All testers submitted reports indicating that the software worked as expected using global data from Suomi NPP.

The second beta release of the CSPP RDR to SDR software occurred on March 1, 2012. This version included the following changes and enhancements:
- Compiler optimizations were enabled to improve runtime performance,

- Dynamic ancillary files are now downloaded automatically as needed,
- SDR output files now contain the N_GEO_Ref attribute,
- Execution scripts now include enhanced error checking and logging,
- Updated calibration lookup tables have been installed for VIIRS, and
- Test data from 2012/02/14 with all VIIRS channels activated are now available.

Science data direct broadcast from Suomi NPP started on Feb 23, 2012. SSEC received the pass using our 2.4-meter X/L-band antenna system, but we were unable to process it immediately because of errors in the RDR format created by the RT-STPS 5.1 application created by the Direct Readout Laboratory at NASA/GSFC. SSEC immediately began a detailed investigation of the RT-STPS RDR creation code, and started to fix a number or problems in the way CCSDS packets were tagged and stored in the RDR files. By March 1, SSEC was able to process DB data from Suomi NPP in-house, and by March 8, SSEC was ready to distribute a DB-compatible version of the CSPP RDR to SDR code to beta testers.

On March 8, SSEC released the third beta test version of the CSPP RDR to SDR packages for Suomi NPP, including a set of patches developed at SSEC to remedy the problems in the RT-STPS code responsible for creating the RDR HDF5 files. At this time, SSEC also released a set of scripts for creating remapped VIIRS images in IDL. On March 9, SSEC received an email from the Finnish Met. Institute including a VIIRS images created from DB data at FMI on March 9 (see Figure 26.1 and 26.2).

On March 16, SSEC released the final beta version of the CSPP RDR to SDR packages for Suomi NPP to the beta test team. The final beta version included the following changes:
- The VIIRS SDR software will now attempt to process all available granules in a direct broadcast pass, instead of automatically skipping the first and last granules. This method will improve the yield of granules processed, however some granules will contain missing data;
- A problem in the VIIRS SDR processing script that caused the processing to exit during post-processing has been fixed;
- A new script for comparing VIIRS test output to reference output is included;
- A new script for creating quick-look images from VIIRS M-band SDR files is included;
- The ATMS SDR software has been updated with improved calibration lookup tables and tested on direct broadcast data; and
- Instructions for installing and patching RT-STPS v5.1a are now include in the documentation.

The first public release CSPP software for processing data received via direct broadcast from Suomi NPP occurred on April 4, 2012. Software packages for transforming VIIRS and ATMS Raw Data Record (RDR, or Level 0) products to Sensor Data Record (SDR, or Level 1) products on 64-bit Intel Linux computers were included, and software for transforming CrIS RDRs to SDRs will be available in a few weeks when the CrIS calibration parameters stabilize.

The CSPP VIIRS and ATMS SDR version 1.0 distribution includes pre-built binary executable files, static support data files, test data for verification of a successful local installation, and documentation. Source code for the VIIRS and ATMS SDR algorithms is available separately as part of the complete ADL distribution available from SSEC. System requirements for the CSPP VIIRS and ATMS SDR version 1.0 software are as follows:
- Intel or AMD CPU,
- 16 GB RAM,

- Red Hat Enterprise Linux 5.5 64-bit (or other compatible 64-bit Linux distribution),
- 100 GB disk space, and
- Internet connection (for downloading the packages and the dynamic ancillary data).

Important Disclaimer: CSPP is providing Suomi NPP processing functionality using preliminary algorithms and data to prepare users for real-time direct broadcast applications. Official algorithms are pending and the Suomi NPP calibration/validation checkout has not been completed.

Upcoming releases of CSPP will include:
- VIIRS lookup table automated updates;
- CrIS RDR to SDR;
- CrIS Dual-Regression Single FOV Temperature, Moisture, and Cloud Retrievals;
- VIIRS Cloud Mask, Active Fires, Cloud Top Properties, Cloud Optical Properties, and Aerosol Optical Thickness EDRs; and
- AVHRR (POES and Metop) Cloud and Land Surface Retrievals.
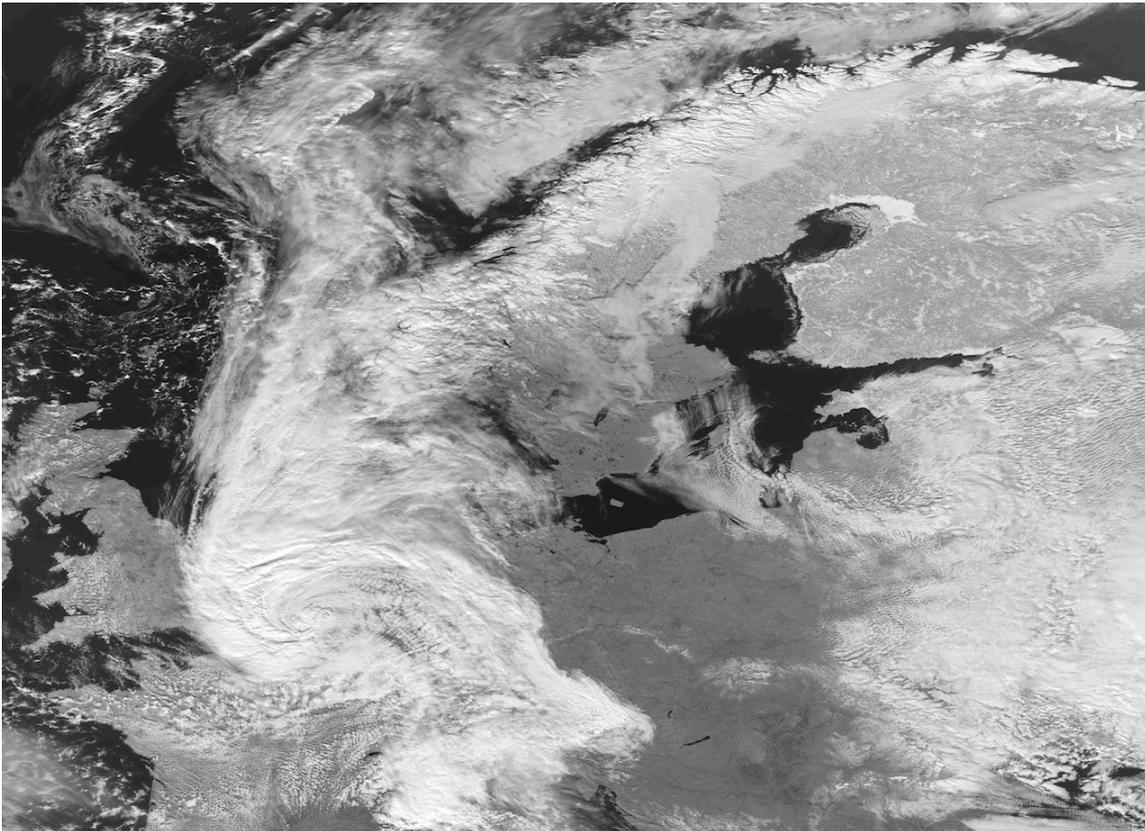
Figure 26.1. First VIIRS data received by FMI and processed by CSPP (2012/03/09).
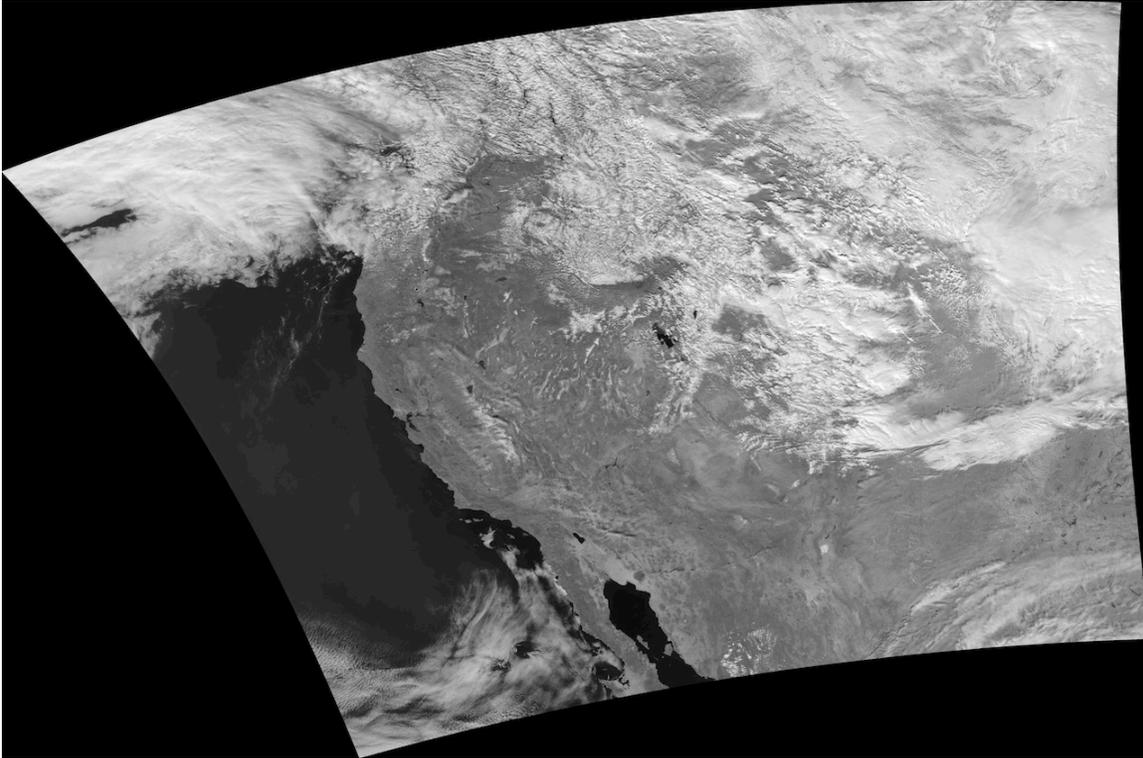
Figure 26.2. First VIIRS data received at SSEC and processed using CSPP (2012/02/23)

27. Development of Data Assimilation Capabilities for SEVIRI Volcanic Ash retrievals

CIMSS Task Leader: Todd Schaack
NOAA Collaborator: R. Bradley Pierce
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

Proposed Work

The proposed activities focus on development of assimilation capabilities to improve volcanic ash forecasting. The WRF-CHEM (Grell et al., 2005) regional air quality model is used to conduct the volcanic ash forecast studies. A 4-bin WRF-CHEM volcanic ash module developed by George Grell at Earth System Research Laboratory (ESRL) and Martin Stuefer at the University of Alaska, Fairbanks (UAF) is used in forecasting volcanic ash. The NOAA Operational Gridpoint Statistical Interpolation (GSI) scheme (Wu et al., 2002) is used for assimilation of SEVIRI volcanic ash retrievals within WRF-CHEM. The impact of assimilation of SEVIRI ash

retrievals is evaluated through comparisons with CALIPSO, EARLINET lidar and AERONET measurements of the April 2010 Eyjafjallajökull eruption in southern Iceland.

Summary of Accomplishments and Findings

The volcanic ash version of WRF-CHEM has been ported to the NESDIS Super Computer for Satellite Simulation and Data Assimilation Studies (S4) located at UW-Madison and baseline (no SEVIRI assimilation) forecasting experiments were conducted for the period from April 15 through April 19, 2010. The baseline experiments were verified through comparisons with the original UAF forecasts. The WRF-CHEM IR aerosol extinction calculation was updated to include realistic optical properties for volcanic ash and the baseline experiments were compared with SEVIRI 11 micron (IR) volcanic ash Aerosol Optical Depth (AOD) retrievals (Pavolonis et al., 2006) and found to significantly underestimate IR AOD relative to SEVIRI. The GSI was modified for SEVIRI IR total column AOD assimilation following the approach used to assimilate Ozone Monitoring System (OMI) total column ozone.

One of the largest uncertainties in forecasting volcanic ash is the initial injection height which results in uncertainties in ash mass since it is estimated from the injection height. For low eruption heights (~5 km) a 500 meter offset in the height changes the total mass estimate by almost 60% (Martin Stuefer, personnel communication). To generate realistic background errors for the GSI volcanic ash assimilation we computed differences (for the same forecast length) between two forecast experiments with different injection heights (+/- 20% of the baseline injection height) and then followed the NMC method approach to generate estimates of error covariances and horizontal and vertical length scales for use within GSI. Figure 27.1 shows the 11 micron AOD from the baseline and GSI/SEVIRI assimilation experiments at 08Z on April 17, 2010. The GSI/SEVIRI assimilation experiment shows a broader volcanic ash plume extending from Iceland to Norway and significantly larger IR AOD values over Europe.
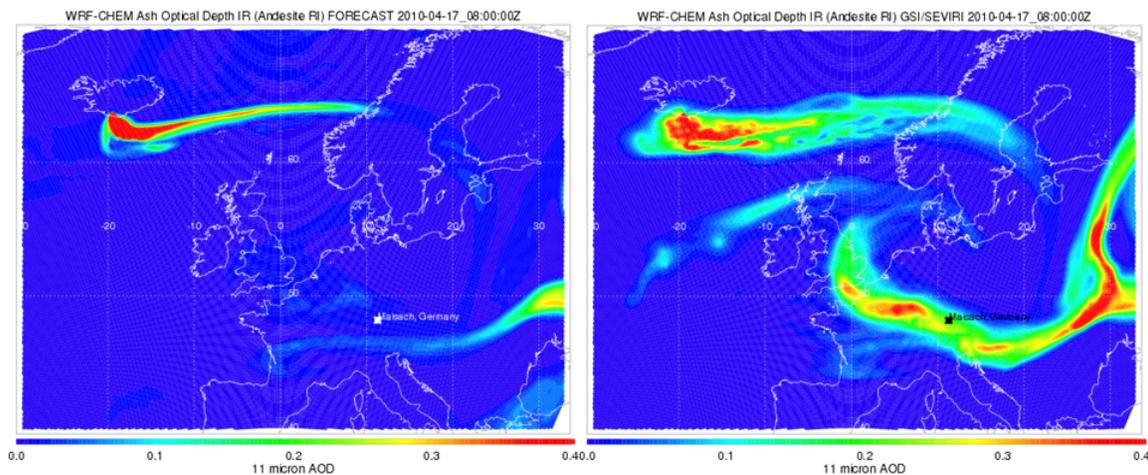
Figure 27.1. Forecasted (left) and GSI/SEVIRI assimilation (right) 11 micron volcanic ash Optical Depths at 08Z on April 17, 2010. The location of the ground based lidar in Maisach, Germany is indicated by an (*).

Ground based lidar systems in Maisach, Germany observed the volcanic ash plume between 17Z on April 16 and 17Z on April 17. Figure 27.2 shows time-height cross sections of the observed aerosol backscatter along with volcanic ash mass predictions from the baseline and GSI/SEVIRI assimilation experiments. The plume is first observed just after 17Z on April 16 at 6km and

gradually descends to below 2 km by 17Z on April 17, 2010. Gasteiger et al. (2011) estimated maximum volcanic ash mass concentrations of 1,100 mgm^{-3} (650 to 1,800 mgm^{-3}) at an altitude of 2.2km at 08Z on April 17, 2010. The observed aerosol backscatter below 2km is associated with urban haze. The GSI/SEVIRI assimilation experiment shows significantly higher ash mass concentrations in the vicinity of the observed plume while both the baseline and GSI/SEVIRI assimilation experiments show a volcanic ash plume with mass concentrations in excess of 1,000 mgm^{-3} near 10km that is not observed. Maximum volcanic ash mass concentrations near the vicinity of the observed plume reached 3,226 mgm^{-3} over Maisach, Germany in the GSI/SEVIRI assimilation experiment and only 155 mgm^{-3} in the baseline experiment. Assimilation of SEVIRI volcanic ash retrievals results in improved agreement with observationally based ash concentration estimates with ash concentrations approaching the levels used by the London Volcanic Ash Advisory Centre (VAAC) to designate "No Fly Zones" (above 4,000 mgm^{-3}) (EU, 2010).

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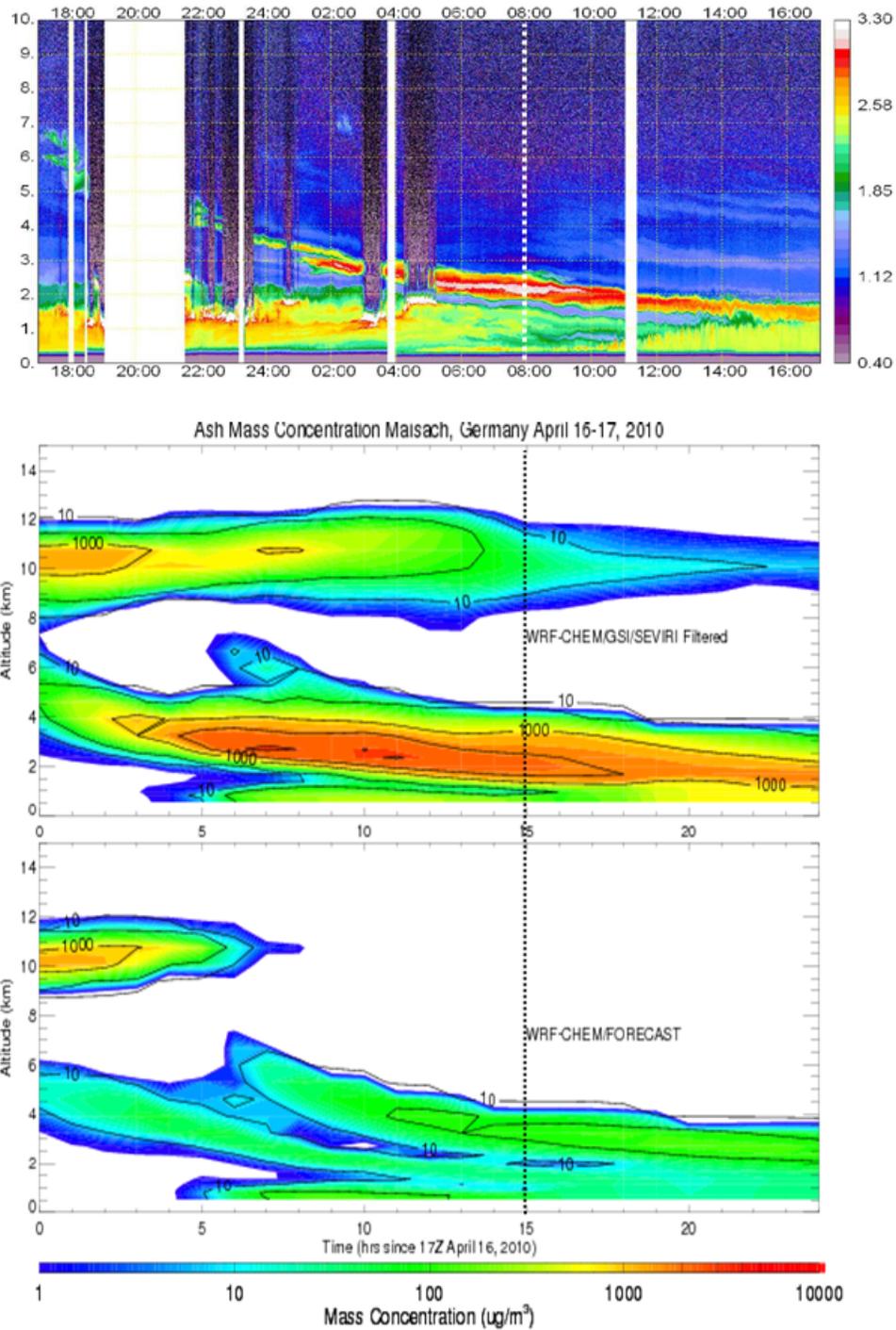
Figure 27.2. The upper panel shows the logarithm of range-corrected aerosol backscatter at 1064 nm over Maisach from 16 April 2010 17:00 UTC to 17 April 2010 17:00 UTC (reproduced from Gasteiger et al., 2011). The middle panel shows time height cross sections of the logarithm of volcanic ash mass concentration (μgm^{-3}) from WRF-CHEM GSI/SEVIRI experiment and the lower panel shows volcanic ash mass concentrations from the baseline experiment.

Appendix 1: List of Awards to Staff Members

2012

Christopher Velden: UW Chancellor's Award for Excellence in Research: Independent
Investigator
Graeme Martin and Dave Tobin: Individual "Best Poster" awards at the International TOVS
Study Conference (ITSC-18) in Toulouse, France.

2011

James Kossin: NOAA Office of Oceanic and Atmospheric Research's Gold Medal for
excellence in research and data stewardship leading to a more confident assessment of the
influence of human-induced climate change on hurricanes.
Timothy Schmit: Department of Commerce Silver Medal "For revolutionizing NOAA Science
Tests for geostationary satellites, significantly reducing the likelihood of a single satellite
configuration."
**Scott Bachmeier, Wayne Feltz, Mathew Gunshor, James Nelson, Christopher Schmidt,
Anthony Schreiner, Justin Sieglaff, David Stettner, William Straka III, Christopher
Velden, and Steven Wanzong**: NOAA-CIMSS Collaboration Award "For working with
NOAA in revolutionizing NOAA Science Tests for geostationary satellites, significantly
reducing the likelihood of a single satellite configuration"
Tim Schmit: The T. Theodore Fujita Research Achievement Award from the National Weather
Association (NWA) "for excellence in promoting and extending the use of satellite data
within the operational community currently and in the future"
Steven Ackerman: Elected Fellow of the Wisconsin Academy of Sciences, Arts and Letters
Jordan Gerth: Wisconsin Space Grant Consortium Graduate Fellowship Award
Andrew Heidinger: NOAA Employee of the Month for the first delivery of an externally-
generated climate data record to NCDC as part of their CDR program
Justin Sieglaff: NOAA-CIMSS Collaboration Award "For providing near real-time volcanic ash
information in the critical period following the eruption of the Eyjaafjallajokull volcano"
William Straka III: NOAA-CIMSS Collaboration Award "For developing an enhanced
production system for satellite-based real-time radiation data from NOAA's operational
geostationary satellites"

2010

Thomas Achtor and Wayne Feltz: 2010 University of Wisconsin Police Department
Community Service Award for Providing Weather Forecasts for Special Events in Camp
Randall Stadium
Steven Ackerman: NASA Exceptional Public Service Medal
Steven Ackerman and Tom Whittaker: Finalist in NSF International Science and Engineering
Visualization Challenge
Scott Bachmeier: NOAA Team Member of the Month for his efforts to improve public
awareness of NOAA satellite applications, both for the general public and for NOAA
Kaba Bah: Best Poster Presentation at the 35th National Weather Association Annual Meeting
for "Preparation for use of the GOES-R Advance Baseline Imager (ABI)"
Jordan Gerth: Wisconsin Space Grant Consortium Graduate Fellowship Award
Andrew Heidinger: Department of Commerce Bronze Medal: "For developing an enhanced
production system for satellite-based, real-time radiation data from NOAA's operational
geostationary satellites"

Michael Pavolonis: Department of Commerce Bronze Medal: "For providing near real-time volcanic ash information in the critical period following the eruption of the Eyjafjallajökull volcano"

Appendix 2: Publications Summary

A full listing of CIMSS publications can be found starting in Appendix 6.

The tables below indicate the number of reviewed and non-reviewed papers on which CIMSS and ASPB scientists were first author (Table 1) or contributors (Table 2). Another column showing lead authors and collaborations with NOAA scientists outside of ASPB is included this year. Note that data for 2012 is incomplete.

A separate listing of publications of the Advanced Satellite Products Lab (ASPB) is available at: http://library.ssec.wisc.edu/resources/aspb/aspb.php .

Table 1. Peer Reviewed and Non Peer Reviewed journal articles having CIMSS, ASPB, NOAA or Other lead authors, 2010-2012.*

	Inst Lead			ASPB Lead			NOAA Lead			Other Lead		
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012*
Peer Reviewed	17	21	6	5	0	1	4	4	1	32	33	7
Non Peer Reviewed	3	0	0	0	0	0	0	0	0	1	1	0

*2012 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, 2010-2012.*

	Institute Co-Author			ASPB Co-Author			NOAA Co-Author		
	2010	2011	2012*	2010	2011	2012	2010	2011	2012*
Peer Reviewed	82	82	20	19	14	3	20	47	6
Non Peer Reviewed	6	0	0	1	0	0	0	0	0

*2012 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 1995-2012.
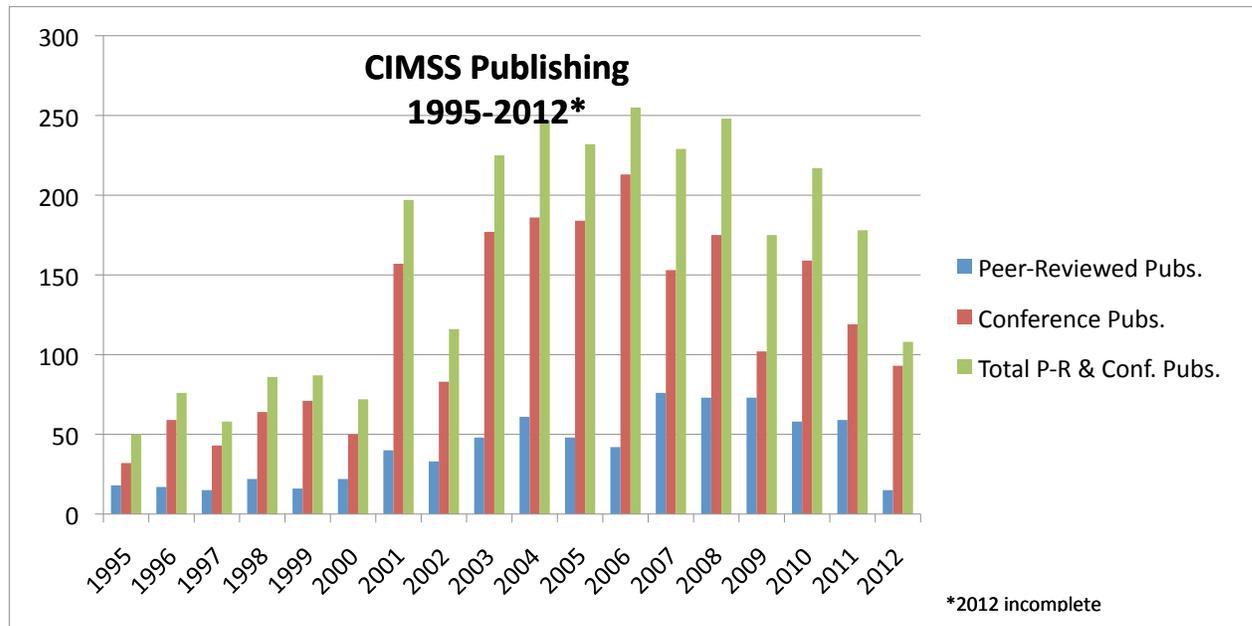
CIMSS Publishing 1995-2012*

*2012 incomplete

*2012 incomplete: does not include forthcoming papers or papers submitted for publication.

Appendix 3: Employee Information

CIMSS Staff and Student Hours on NOAA Cooperative Agreement Projects

Below is a listing of all CIMSS staff members who charged more than 5% of their time to the CIMSS-NOAA Cooperative Agreement projects during the period 1 April 2011 through 31 March 2012. A total of 52 staff members charged 50% of their time or greater to these projects. A total of 119 staff members charged 5% of their time or greater to these projects.

	Name:	Total Hours	Percent
1	Jung, Jim	1,750	100.0%
2	Brunner, Jason	1,732	99.0%
3	Liu, Yinghui	1,699	97.1%
4	Lee, Yong-Keun	1,696	96.9%
5	Mindock, Scott	1,643	93.9%
6	Li, Zhenglong	1,635	93.4%
7	Lenzen, Allen	1,598	91.3%
8	Martin, Graeme	1,565	89.4%
9	Wanzong, Steven	1,526	87.2%
10	Straka, William	1,492	85.3%
11	Gunshor, Mathew	1,483	84.7%
12	Nelson, James III	1,464	83.7%
13	Foster, Mike	1,458	83.3%

14	Hoffman, Jay	1,458	83.3%
15	Bachmeier, Anthony	1,456	83.2%
16	Wang, Jun	1,384	79.1%
17	Calvert, Corey	1,372	78.4%
18	Sieglaff, Justin	1,366	78.1%
19	Li, Jinlong	1,360	77.7%
20	Zheng, Jing	1,344	76.8%
21	Monette, Sarah	1,318	75.3%
22	Botambekov, Denis	1,312	75.0%
23	Vasys, Egle	1,302	74.4%
24	Moeller, Christopher	1,299	74.2%
25	Wang, Xuanji	1,297	74.1%
26	Dworak, Richard	1,293	73.9%
27	Hartung, Daniel	1,292	73.8%
28	Huang, Bormin	1,286	73.5%
29	Mielikainen, Jarno	1,274	72.8%
30	Schiffer, Eva	1,273	72.7%
31	Bah, Momodou	1,268	72.5%
32	Tobin, David	1,232	70.4%
33	Olander, Timothy	1,229	70.2%
34	Wimmers, Anthony	1,228	70.2%
35	Walther, Andi	1,152	65.8%
36	Rink, Thomas	1,124	64.2%
37	Stettner, David	1,111	63.5%
38	Cronce, Lee	1,085	62.0%
39	Schaack, Todd	1,052	60.1%
40	Feltz, Wayne	1,028	58.7%
41	Gerth, Jordan	1,013	57.9%
42	Borg, Lori	998	57.0%
43	Garcia, Raymond	996	56.9%
44	Zhang, Hong	970	55.4%
45	Hart, Caitlin	968	55.3%
46	Knuteson, Robert	964	55.1%
47	Oo, Min Min	963	55.0%
48	Smith, Nadia	955	54.6%
49	Cintineo, John	916	52.3%
50	Schmidt, Christopher	906	51.8%
51	Borbas, Eva	904	51.7%
52	Greenwald, Thomas	886	50.6%
53	Huang, Hung-Lung	847	48.4%
54	Lindstrom, Scott	816	46.6%
55	Cureton, Geoffrey	800	45.7%
56	DeSlover, Daniel	798	45.6%
57	Line, William	795	45.4%
58	Garms, Elise	790	45.1%
59	Strabala, Kathleen	784	44.8%
60	Gumley, Liam	752	43.0%
61	Avila, Leanne	738	42.2%
62	Schreiner, Anthony	738	42.2%
63	Velden, Christopher	717	41.0%
64	Holz, Robert	716	40.9%
65	Davies, James	700	40.0%

66	Park, Chang Hwan	695	39.7%
67	Feltz, Michelle	685	39.1%
68	Gravelle, Chad	684	39.1%
69	Feltz, Joleen	646	36.9%
70	Frey, Richard	644	36.8%
71	Rozoff, Christopher	640	36.6%
72	Nebuda, Sharon	629	35.9%
73	Satria, Muhammad	609	34.8%
74	Li, Yue	604	34.5%
75	Weisz, Elisabeth	596	34.1%
76	Roman, Jocola	594	33.9%
77	Li, Jun	577	33.0%
78	Jasmin, Tommy	574	32.8%
79	Wang, Pei	566	32.3%
80	Otkin, Jason	565	32.3%
81	Smalley, Mark	518	29.6%
82	Dengel, Russell	514	29.4%
83	Lewis, William	480	27.4%
84	Wu, Xianyun	408	23.3%
85	Revercomb, Henry	402	23.0%
86	Petersen, Ralph	394	22.5%
87	Beavers, Jonathan	388	22.2%
88	Nagle, Frederick	386	22.1%
89	Stroik, Jesse	370	21.1%
90	Quinn, Greg	368	21.0%
91	Gjermo, Britta	362	20.7%
92	Smith, William, Sr	338	19.3%
93	Olson, Erik	330	18.9%
94	Moeller, SzuChia	325	18.6%
95	Achtor, Thomas	314	17.9%
96	Hoover, Brett	313	17.9%
97	Whittaker, Thomas	273	15.6%
98	Kuehn, Ralph	268	15.3%
99	Hudson, Rebecca	262	15.0%
100	Lim, Agnes	248	14.2%
101	Bearson, Nicholas	247	14.1%
102	Kwon, Eun-Han	240	13.7%
103	Pi, Hsuan-Yun	238	13.6%
104	Menzel, Wolfgang	229	13.1%
105	Hiley, Michael	225	12.9%
106	Taylor, Joseph	218	12.5%
107	Santek, David	214	12.2%
108	Molling, Christine	213	12.2%
109	Nolin, Scott	193	11.0%
110	Ackerman, Steven	165	9.4%
111	Hoese, Dave	160	9.1%
112	Rowley, Charles	157	9.0%
113	Lalande, John	153	8.7%
114	Vinson, Kenneth	150	8.6%
115	Pasowicz, Daniel	145	8.3%
116	Baum, Bryan	138	7.9%
117	Bellon, Willard	132	7.5%
118	Plokhenko, Youri	112	6.4%

119   **Antonelli, Paolo**   110   6.3%

Research Topics of Current CIMSS Graduate Students and Post-Doctors

NOAA Funded Graduate Students
Jordan Gerth
M.S. Thesis title: "Improving Cloud and Moisture Representation by Assimilating GOES Sounder Products into Numerical Weather Prediction Initial Conditions" This study clarifies the impact of observations, in the form of retrievals, from the Geostationary Operational Environmental Satellite (GOES) Sounder on 12, 24, and 36-hour WRF model forecasts of precipitable water, low-level relative humidity, precipitation, and sky cover. Two experimental analyses are built from a CIMSS Regional Assimilation System (CRAS) pre-forecast spin-up. The CRAS assimilates precipitable water and cloud products derived from the GOES Sounder. An experimentation period between late September and early October 2011 found that the majority of impact in the experimental simulations compared to the control is recognized in the total precipitable water field over the first 12 hours. In some cases, this resulted in an improved precipitation forecast.

Caitlin Hart
M.S. Thesis title: "Interpretation of Small Particle Signatures in Satellite Observations of Convective Storms." Strong updrafts in mid-latitude convective storms eject supercooled water droplets into the tropopause and lower stratosphere (Wang, 2003). These droplets flash freeze at very low temperatures, causing them to be significantly smaller than the particles in the glaciated anvil top. Using the Daytime Cloud Optical Microphysical Properties (DCOMP) retrieval (Walther, et al., 2012) applied to GOES-East data, discrete minima are observed in the vicinity of the updraft core of severe thunderstorms in the effective radius retrieval. Several thunderstorms were analysed for small particle signatures, which were compared to 30 dBZ NEXRAD echo to heights. An example from June 27, 2008 over Illinois of an effective radius retrieval using MODIS data indicates several particle signatures that were not observable in GOES retrievals. This example demonstrates the importance of spatial resolution in correctly identifying updraft-related small particle regions.

Erik Janzon
M.S. Thesis title: "Data Assimilation of a Network of Ground-Based Boundary Layer Profilers: Changing the Horizontal Density of the Observations." The OSSE (Observing System Simulation Experiment) was conducted to assess the impact a network of ground-based remote sensing profilers would have when assimilated into a NWP model. Current research using the OSSE dataset has been conducted in order to assess the effect of the assimilation on mid-level frontogenesis during a wintertime convective event.

Agnes Lim
PhD Thesis title: "Study of Convective initiation through Hyperspectral Data and Their Assimilation"
The aim of this study is to improve forecasts of convective initiation through assimilation of AIRS clear and cloud cleared radiances at regional scale scale. It is hoped that by doing so forecasts better predicts summer convective precipitation as well as provides a better thermodynamic understanding of convective initiation.

William Line

M.S. Research topic: The advancement of the CIMSS NearCast model. This model uses GOES temperature and moisture observations to predict convective instability in the near future (0-9 hrs). The model uses gridded wind and height fields that are assigned to each satellite observation. The observations are then projected dynamically forward in time using a lagrangian approach, preserving the actual satellite observations. The near term prediction of convection (and stability) has long been a difficult task, both using information from a data set that is not used in conventional numerical models as well as in providing a practical and potential life-saving tool for forecasters.

Chian-Yi Liu

Ph.D. Thesis title: "Remote Sensing of the Upper Tropospheric State of Storms Using Space-Borne High Spectral Resolution Infrared Measurements". This study addresses the use and handling of clear and cloudy high spectral resolution AIRS IR radiances, and the application of retrieved atmospheric profiles before the genesis of convective storms. The cloud-removal technique, alone with both clear and cloudy sounding retrievals algorithms in AIRS single field-of-view spatial resolution is developed to increase the algorithm capability in pre-storm environment. It is found that a tropospheric low stability is frequently occurred 3- to 6-hour before the convective storm developing, and the use of brightness temperature difference for detecting of tropospheric penetrating convection is effective in detection of deep convection.

Sarah Monette

M.S. Thesis title: "Tropical Applications of a Satellite-based Objective Overshooting Top Detection Algorithm." Research examines operational uses for an objective overshooting top detection algorithm including the employment of an objective overshooting top detection algorithm to various stages of a tropical cyclone, mainly genesis and intensification. In addition, the algorithm has been applied to the likelihood of an airplane experiencing turbulence.

Jacola Roman

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.

Matthew Sitkowski

Ph.D. Thesis title: "Investigation and Prediction of Hurricane Eyewall Replacement Cycles". This study develops a probabilistic model that determines the likelihood of hurricane secondary eyewall formation and subsequent eyewall replacement cycles. The model incorporates environmental and satellite-based features that are used to identify when conditions are favorable for the formation of a secondary eyewall. Flight-level aircraft data are utilized to determine the intensity and structure changes associated with eyewall replacement cycles. In addition, the role of the decaying inner eyewall, or relict inner eyewall circulation, on the evolution of the inner-core structure, intensity, and pressure-wind relationship of the storm near the end of and following an eyewall replacement cycle is examined.

Pei Wang

Ph.D. Research interest is using high spatial and temporal resolution satellite data to understand hurricane evolution. Both WRF/3DVAR and WRF/GSI data assimilation system are used in the research. Hurricane Ike has been simulated with AIRS retrieval data using WRF/3DVAR, and Irene with AMSU-A and AIRS radiance data using WRF/GSI. It is found that AIRS temperature retrieval data has positive impacts on Ike simulation, especially for the results of hurricane track. The AIRS moisture retrieval data has few impacts than temperature data. The further step is to find out the effects of AIRS retrieval data on hurricane Irene using WRF/GSI. The expected year of graduation is about four years.

Students Funded on Projects by Agencies Other than NOAA

Mike Hiley

M.S. Thesis title: "Triple Frequency Radar Reflectivity Signatures of Snow: Observations and Comparisons to Theoretical Ice Particle Scattering Models." This study utilizes aircraft data from the 2003 NASA Wakasa Bay AMSR Precipitation Validation Campaign to reduce uncertainties in the active microwave remote sensing of frozen precipitation. The main goal is to compare the latest theoretical modeling of scattering properties of complex aggregate snowflakes to actual radar reflectivity observations. These new models exhibit a distinct behavior when Ku-Ka band Dual Frequency Ratio (DFR) is compared to Ka-W band DFR. This unique signature leads to the potential for ice habit discrimination when radar observations at all three of these frequencies are available. The Wakasa Bay dataset is particularly applicable to this study because observations at all three frequencies of interest are available from the same aircraft. The initial results provide observational confirmation of the distinct triple frequency behavior of complex aggregate scattering models and provide insight for future single and dual frequency snowfall retrievals.

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

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.

Nate Miller

M.S. Thesis title: "Microwave Radiometer Observations of Surface-Based Inversions above the Greenland Ice Sheet." A pair of Microwave Radiometers (MWRs) covering the spectral range from 22.2 to 150 GHz, are part of an integrated suite of remote sensing instruments deployed to Summit Station in central Greenland by a NSF funded project dubbed ICECAPS. Using calibrated brightness temperatures from the MWRs, retrievals of liquid water path, precipitable water vapor and temperature profiles are collected in this extremely cold and dry environment. Surface based inversions are a predominant feature across the Greenland ice sheet and monthly values of depth, intensity, and occurrence are shown for 2011. The atmospheric state is measured twice daily at Summit via radiosonde sounding, although the advantage of using the MWRs is headlined by their close-to autonomous data collection at high temporal resolution. Within a matter of a few hours the presence of a liquid bearing cloud leads to decay in the strength of the inversion thus changing the stability of the boundary layer. Hence a possible increase in cloud frequency or a change in cloud microphysics above the Greenland ice sheet would further inhibit inversions and lead to changes in the interaction between the atmosphere and ice.

Ilya Razenkov

Ph.D. Research topic: "Atmospheric temperature profile measurements using a University of Wisconsin High Spectral Resolution Lidar." Atmospheric temperature profile measurements using a University of Wisconsin-Madison High Spectral Resolution Lidar are proposed in this study. Doppler broadening of the backscattered light depends on the air temperature and pressure. This effect can be utilized to infer the information about the atmospheric temperature profile. A combination of the narrow bandpass Fabry-Perot etalon and molecular iodine absorption filter can be used to detect the temperature sensitive changes of the lidar returns.

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.

John Sears

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.

Mark Smalley

M.S. Thesis title: "Effects of spectral response function uncertainties on cloud height retrievals using CO2 slicing." The 30 year record of HIRS and MODIS cloud heights has the potential to

create a true cirrus cloud climatology. However, inter-instrument biases in retrieved cloud heights due to differing spectral response functions must be addressed when assessing trends or cycles throughout the cloud height record. To estimate these biases in cloud heights retrieved with CO_2 slicing techniques, cloud heights for HIRS and MODIS instruments have been simulated using high spectral resolution measured radiances from AIRS.

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.

Kenneth Vinson

M.S. Thesis title: "Validation of Methane Products from the Atmospheric infrared Sounder (AIRS) during the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites Mission." There is a great deal of methane stored in the Arctic, mainly in the form of underwater methane clathrate ices and in frozen peat bogs in areas with permafrost. Predicted warming trends may release a large amount of methane from these sinks. Elevated methane release in the Arctic may already be underway. Measurements from polar-orbiting satellites, in-situ stations, and aircraft campaigns will be used to evaluate recent trends in arctic methane release and to help constrain climate model predictions.

Tim Wagner

Ph.D. Thesis title: "A method for retrieving the cumulus entrainment rate from ground-based observations." An algorithm has been developed to retrieve the cumulus entrainment rate from observations taken by the suite of instruments at the ARM Southern Great Plains site. This enables the development of a robust dataset of entrainment rates that is unconstrained by the limitations of aircraft observations. Analysis shows that the entrainment rate tends to increase throughout the day.

Post Doctors funded on NOAA projects
Andi Walther

Post Doctors funded on other projects than NOAA
Muhammad Teguh Satria
Xianyun Wu

CIMSS Students and/or Staff hired by NOAA during this period
none

Appendix 4. Visitors to CIMSS (3 days or longer)

2012 (through 31 March)

He, Julia - CREST
Huff, Roy – University of Hawaii

Ibrahim, Waad - Robert S. McNamara Fellow, sponsored by the World Bank, from
   Brandenburgische Technische Universität, Cottbus, Germany
Li, Hongyi - China Meteorological Agency, China
Liu, Hui - National Satellite Meteorological Center, China
Ponsard, Christelle - EUMETSAT
Soerensen, Anders- EUMETSAT
Van Delst, Paul – NOAA
Xiao, Ziniu - China Meteorological Agency, China
Yan, Quanhua - China Meteorological Agency, China
Zhang, Yong – China Meteorological Agency, China
Zheng, Jing - National Satellite Meteorological Center, China

2011

Azarderakhsh, Marzieh – CREST, City College of New York
Deb, Sanjib - Indian Space Research Organisation, India
Fiorino, Mike – Assimilation and Modeling Branch, NOAA/ESRL/GSD, Boulder, CO
Ganeshan, Manisha – ESSIC, University of Maryland, College Park
Giri, R. K. - India Meteorological Department
Herron-Thorpe, Farren – Engineering Sciences, Laboratory for Atmospheric Research,
   Washington State University
Jones, Thomas – CIMMS, Norman, OK
Kaushik, Nitesh - Indian Space Research Organisation, India
Kerkmann, Jochen Karl - EUMETSAT
Knuth, Shelley – CIRES, University of Colorado at Boulder
Mahakur, Mata - Indian Institute of Tropical Meteorology, Pune, India
McGrath-Spangler, Erica – Department of Atmospheric Science, Colorado State University
Mielikainen, Jarno – Eastern Finland University, Finland
Mitra, Ashim Kumar - India Meteorological Department
Narayanasamy, Puviarasan - India Meteorological Department
Nazari, Rouzbeh – CREST, City College of New York
Norouzi, Hamidreza – CREST, City College of New York
Quan, Xiaojing - China
Padmanbhan, Narayan - Indian Space Research Organisation, India
Sangar, Ghansham - Indian Space Research Organisation, India
Schipper, Jarno – Central Institute for Meteorology and Geodynamics, Austria
Schmidt, K. Sebastian – Laboratory for Atmospheric and Space Physics, University of Colorado
Sedlar, Joe – Swedish Meteorological and Hydrographical Institute
Shukla, Munn - Indian Space Research Organisation, India
Song, Changhe – Xidian University, China
Sukumara Pillai, Indira Rani - National Centre for Medium Range Weather Forecasting, India
Tang, Hong Zhao - China
Veglio, Paolo – University of Basilicata, Italy
Wang, Jun – Hangyang University, South Korea
Yao, Zhigang- Institute of Atmospheric Physics, Chinese Academy of Science, Beijing
Zhang, Yafang - China
Zhang, Yong – National Satellite Meteorological Center, China

Appendix 5. CIMSS Subcontracts Summary

Dr. Ping Yang, Texas A&M University, $30,000, "Development of the optical properties of soot, dust aerosols and ice crystals in support of the GOES-R research project of the Cooperative Institute for Meteorological Studies (CIMSS)"

Appendix 6. CIMSS Peer Reviewed Publications: 2011-2012

2012 Forthcoming Papers

Bikos, D.; Lindsey, D.T.; Otkin, J.A.; Sieglaff, J.; Grasso, L.; Siewart, C.; Correia, J.; Coniglio, M.; Rabin, R.; Kain, J., and Dembek, S. Synthetic satellite imagery for real-time high resolution model evaluation. Weather and Forecasting, 2012, doi: http://dx.doi.org/10.1175/WAF-D-11-00130.1.

Dworak, Richard; Bedka, Kristopher; Brunner, Jason, and Feltz, Wayne. Comparison between GOES-12 overshooting top detections, WSR-88D radar reflectivity and severe storm reports. Weather and Forecasting, 2012, doi: http://dx.doi.org/10.1175/WAF-D-11-00070.1.

Goodman, S. J.; Gurka, J.; DeMaria, M.; Schmit; T.; Jedlovec, G.; Siewert, C.; Feltz, W.; Gerth, J.; Brummer, R.; Miller, S.; Reed, B., and Reynolds, R. The GOES-R Proving Ground: Accelerating user readiness for the next generation geostationary environmental satellite system. Bulletin of the American Meteorological Society, 2012, doi: http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-11-00175.1

Kossin, J.P., and Sitkowski, M. Predicting hurricane intensity and structure changes associated with eyewall replacement cycles. Weather and Forecasting, 2012, doi: http://dx.doi.org/10.1175/WAF-D-11-00106.1.

Lakshmanan, V.; Rabin, R.; Otkin, J.A., and Kain, J.S. Visualizing model data using a fast approximation of a radiative transfer model. Journal of Atmospheric and Oceanic Technology, 2012, doi: http://dx.doi.org/10.1175/JTECH-D-11-00007.1.

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Nigro, Melissa A.; Cassano, John J.; Lazzara, Matthew A., and Keller, Linda M. Case study of a barrier wind corner jet off the coast of the Prince Olav Mountains, Antarctica. Monthly Weather Review, 2012, doi: http://journals.ametsoc.org/doi/pdf/10.1175/MWR-D-11-00261.1.

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(PWV) observations from a network of Global Positioning Satellite (GPS) receivers in the U.S. Great Plains and Midwest. Journal of Climate, 2012, doi: http://journals.ametsoc.org/doi/pdf/10.1175/JCLI-D-11-00570.1.

Walther, Andi and Heidinger, Andrew. Implementation of the Daytime Cloud Optical and Microphysical Properties Algorithm (DCOMP) in PATMOS-x. Journal of Applied Meteorology and Climatology, 2012, doi: http://journals.ametsoc.org/doi/pdf/10.1175/JAMC-D-11-0108.1

Wang, C.; Yang, P.; Platnick, S.; Heidinger, A.K.; Baum, B.A.; Greenwald, T.; Zhang, Z., and Holz, R.E. Retrieval of ice cloud properties from airs observations based on a fast high-spectral resolution radiative transfer model. Journal of Applied Meteorology and Climatology, 2012.

Weisz, Elisabeth; Menzel, W. Paul; Smith, Nadia; Frey, Richard; Borbas, Eva E., and Baum, Bryan A. An approach for improving cirrus cloud top pressure/height estimation by merging high spatial resolution infrared window imager data with high spectral resolution sounder data. Journal of Applied Meteorology and Climatology, 2012, doi: http://dx.doi.org/10.1175/JAMC-D-11-0170.1.

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Appendix 7. CIMSS Conference Papers and Presentations: 2011-2012

2012

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