University of Wisconsin-Madison

Cooperative Institute for Meteorological Satellite Studies (CIMSS)

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

Cooperative Agreement Annual Report

for the period
1 October 2009 to 30 September 2010
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National Oceanic and Atmospheric Administration (NOAA)

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

1 October 2009 to 30 September 2010

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Director, CIMSS

Thomas Achtor
Executive Director, Editor

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

1 October 2009 to 30 September 2010

Steven Ackerman Director, CIMSS
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I. Director's Executive Summary

The National Oceanic and Atmospheric Administration (NOAA) and the University of Wisconsin-Madison (UW-Madison) have collaborated for over three decades in satellite meteorology and remote sensing research. This collaborative relationship between NOAA and the UW-Madison, which led to the establishment of the Cooperative Institute for Meteorological Satellite Studies (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 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 NOAA/NESDIS' Advanced Satellite Product Branch (ASPB) stationed at Madison. This collaboration is expanding through the inclusion of a scientist from the National Climate Data Center, joining the NOAA 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 which 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 papers with NOAA co-authors, indicating the strong collaborations. 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.

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. For example, the UW-CIMSS group proposed further refinement and validation the experimental University of Wisconsin-Madison Convective Initiation (UWCI) decision support algorithm. This year the UWCI decision support product was distributed to the NOAA Satellite Applications Branch (SAB), the Storm Prediction Center (SPC) during the Hazardous Weather Testbed (HWT) Spring Experiment in 2009, and via AWIPS to various National Weather Service Forecast Offices (NWSFOs). CIMSS scientists continue to explore innovative methods for improving estimates of tropical cyclone (TC) intensity from GOES observations. The supported experimental Advanced Dvorak Technique (ADT) upgrades are being implemented into the operational ADT algorithm at NESDIS-SAB via a GPSDI grant that is in place. GIMPAP also supported the real-time implementation of GOES-R ABI cloud property retrieval algorithms on current GOES imager data. CIMSS also has a strong partnership with NOAA in the GOES-R program. CIMSS is very active in the GOES-R Algorithm Working Group (AWG) activities, developing algorithms and writing Algorithm Theoretical Basis Documents (ATBDs) for various required products. As one example, we are developing sea and lake ice property retrieval algorithms for the GOES-R ABI instrument, which will enable ice monitoring of the Great Lakes. As part of AWG effort, CIMSS continues to develop proxy data sets and model outputs that support a broad range of AWG activities. Some of CIMSS' capability to support NOAA needs through these simulations result from leveraging non-NOAA computer resources to undertake weather simulations at appropriate GOES-R simulated temporal and spatial scales.

NOAA has begun to develop consensus prototype algorithms for GOES-R using its AWGs. The Cloud Application Team at ASPB/CIMSS has developed a prototype system for testing algorithms applied to geostationary imager data (GEOCAT). GEOCAT processes geostationary imager data from the current GOES, the Spinning Enhanced Visible Infrared Imager (SEVIRI), and the Multifunctional Transport Satellite (MTSAT). This tool is used to develop and test various products. For example, an ASPB/CIMSS team developed a 4-channel (0.65, 3.9, 11, 12/13.3-μm) approach for detecting volcanic ash and a bi-spectral (11 and 12/13.3-μm) approach for retrieving ash height and ash mass loading.

For many years GOES-East/-West were the only operational environmental geostationary platforms with fire monitoring capabilities. Now observations are also available from Meteosat-8/-9, making fire detection a global product. CIMSS has successfully used these global satellite data products for real-time fire monitoring, trend analyses and applications in data assimilation and long-range transport. The latest version of the WF_ABBA has enabled processing of all data from the supported satellites with minimal latency. The GOES-E/-W fire products continue to be used in climate change analyses, emissions assessment and modeling, air quality applications, and aerosol transport models.

CIMSS is internationally recognized for its tropical cyclone (TC) research, with the development of the program going back to the early 1980s. The primary objectives of the research and development have focused on new approaches for analyzing TCs using the latest in satellite sensor technologies, computer-based methods, and display capabilities, with the goal of increasing our knowledge about these storms and improving forecasts. Many of these products, distributed through web pages, support decision making and their utility has been demonstrated through various comments on its use by tropical storm forecasters. The following is a recent example of the value of this CIMSS derived product (with bold face added for emphasis):

HURRICANE IGOR SPECIAL DISCUSSION NUMBER 18
NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL AL112010
130 PM AST SUN SEP 12 2010

SATELLITE IMAGERY AND THE UW-CIMSS ADVANCED DVORAK TECHNIQUE INDICATE THAT IGOR HAS CONTINUED TO RAPIDLY INTENSIFY AND IS NOW A CATEGORY FOUR HURRICANE. THE VISIBLE AND BD-CURVE INFRARED ENHANCEMENT PICTURES REVEAL A CLEAR 20 NMI DIAMETER EYE WITH A SURROUNDING INTENSE INNER CORE RING OF -80 DEGREE CELSIUS CLOUD TOP TEMPERATURES. THE OFFICIAL INTENSITY FORECAST HAS BEEN MODIFIED TO INDICATE SOME ADDITIONAL INTENSIFICATION DURING THE NEXT 3 DAYS AND THEN SHOWS A SLIGHT DECREASE AT DAYS 4 AND 5. ALSO...FLUCTUATIONS IN STRENGTH DUE TO EYEWALL REPLACEMENT CYCLES ARE POSSIBLE...BUT THERE IS LITTLE SKILL IN FORECASTING THE TIMING OF THESE CYCLES.

THE WIND RADII FORECAST HAS ALSO BEEN ADJUSTED TO ACCOUNT FOR THE INCREASE IN THE INTENSITY. THE OFFICIAL NHC TRACK FORECAST REMAINS UNCHANGED FROM THE PREVIOUS ADVISORY.

FORECAST POSITIONS AND MAX WINDS

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INITIAL      12/1830Z 17.7N  46.1W   115 KT
 12HR VT     13/0000Z 17.8N  47.5W   125 KT
 24HR VT     13/1200Z 18.0N  49.8W   125 KT
 36HR VT     14/0000Z 18.4N  51.8W   125 KT
 48HR VT     14/1200Z 19.0N  53.6W   130 KT
 72HR VT     15/1200Z 20.7N  56.7W   130 KT
 96HR VT     16/1200Z 22.6N  59.6W   125 KT
120HR VT     17/1200Z 24.5N  62.5W   125 KT
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$$
FORECASTER ROBERTS/BRENNAN

Our expertise in supporting and improving weather forecasting extends to other storms systems as well as tropical storms. CIMSS researchers seek to provide forecasters with new tools to help identify areas of convective destabilization 3-6 hours in advance of storm development, using observations from geostationary satellites. The NearCasting system uses a trajectory-based approach which preserves large gradients and maxima and minima observed in the GOES data, as well as using successive temporal data insertions, to revalidate/revise previous projections every hour.

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 developing new applications making use of NOAA satellites. This strong collaboration throughout our history as yielded a strong national and international reputation for UW-Madison as developers of new methods for analyzing satellite observations. For example, CIMSS is developing new approaches to detect turbulence and convective initiation using geostationary observations. CIMSS current operational GOES sounding products are limited to clear skies only, and CIMSS continues to conduct research to expand the GOES sounding coverage into cloudy skies.

CIMSS continues to support NOAA's goal for future GOES advanced infrared sounding requirements and definition. Our research continues to demonstrate the needs and value of an advanced sounder in geostationary orbit. We continue to develop algorithms for better soundings by combing geo and leo satellite observations. Since ABI has high temporal and spatial resolution while CrIS has high vertical resolution, the objective for combining ABI/CrIS is to maintain GOES-R high temporal and spatial resolution, include CrIS high spectral resolution, and transfer the positive impacts from CrIS high spectral resolution to later times. Research on the combined retrieval method is currently being developed using the GOES Sounder and NASA/AIRS. 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, such NPP/JPSS. We support calibration/validation activities, and cloud and sounding algorithm work. ASPB/CIMSS scientists are actively involved in developing and evaluating algorithms for the 22-band Visible/Infrared Imager/Radiometer Suite (VIIRS). Data from VIIRS will be used to operationally generate a suite of products for NOAA. As an example project, ASPB/CIMSS scientists are assessing the VIIRS cloud algorithms using collocated CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) observations and MODIS proxy radiance and geo-location data as input. This assessment is made possible by leveraging the SSEC Atmospheric Product Evaluation And Test Element (PEATE) processing system.

CIMSS is active in the international effort to calibrate the world's environmental satellites: Global Space-based Intercalibration System (GSICS). In collaboration with ASPB, CIMSS participated in the intercalibration of the GOES-15 Imager with IASI (Infrared-Atmospheric Sounding Interferometer). CIMSS scientists are working with STAR scientists on applying similar methods to the GOES sounder. 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/SSEC are also actively engaged in assessment of the capabilities of the CrIS, through analysis of the Flight Model 1 thermal vacuum tests and the development of calibration/validation approaches.

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, CLAVR-X (The Extended Clouds from AVHRR processing system), HIRS and MODIS. 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.

CIMSS and SSEC have long had an international reputation for producing outstanding visualization tools. This excellence continues with the development of McIDAS-V, an interactive visualization and data analysis system capable of integrating satellite observations and model simulations. The McIDAS-V software to supporting both the GOES-R and the NPP/JPSS data analysis and visualization programs. The first version of this open source, freely available software is publically available.

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 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. Two graduate students and one post doc participated in the CoRP 2010 symposium held at Colorado State University's CIRA. This past year Chian-Yi Liu finished his PhD on "The upper tropospheric storm-scale signature from hyperspectral infrared soundings." The work demonstrated the utility of soundings of the upper troposphere in understanding heavy precipitation weather events.

NOAA grants to CIMSS also supported undergraduate student research projects. For example, Luke Schiferl was an AOS undergraduate who conducted research on the Great Lake cloudiness; he is now attending CSU as a graduate student.

We work in collaboration with NOAA and other cooperative institutes in developing training resources for NOAA. These activities are in strong support of the GOES Users Subcommittee on Training, Education and Outreach recommendation to develop training and education resources to recruit, expand and maintain a skilled workforce. 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. To date, a total of 15 VISIT modules have been developed at CIMSS, which have been delivered via "live" instructor-led lessons as well as via recorded audio lessons that can be viewed at any time. The freely available VISITView software (also developed at CIMSS) continues to evolve as feedback is received from the user community.

To increase the applicability of VISIT training sessions to NWS forecasters, CIMSS staff succeeded in implementing the Advanced Weather Interactive Processing System (AWIPS) on site in 2005. AWIPS is the primary tool employed in NWS field offices for assessing atmospheric observations and datasets during forecast preparation and product issuance. With real-time data, VISIT instructors at CIMSS can find and add new examples of operational satellite data in AWIPS to their lessons instantly. To further learning using real time situations, CIMSS developed the CIMSS Satellite Blog [http://cimss.ssec.wisc.edu/goes/blog]. As one example, on the day that GOES-13 replaced GOES-12 as the operational GOES-East satellite, a blog post was added to the "Training" category which discussed how the new GOES-13 visible channel was different from that on GOES-12, requiring the use of a different default enhancement for optimal viewing of GOES-13 visible imagery. Presently, the CIMSS Satellite Blog contains nearly 700 posts, covering 38 different categories. CIMSS has also invested in infrastructure to hold weather briefings, science team meetings and visitor meetings that focus on using the analysis and visualization technologies, the CIMSS Analysis and Visualization Environment (CAVE), which includes high-tech graphics and dynamical weather displays on state-of-the-art monitors.

We continue to provide outreach to pre-college (K-12) education. As an example, CIMSS continues to host middle and high school science teachers from around the country. This NOAA-supported event covers topics of weather and climate and global climate change with an effort to support teaching and learning related to the 2007 Intergovernmental Panel on Climate Change (IPCC) Summary for Policy Makers. We continue to maintain, update and distribute the CIMSS *Satellite Meteorology for Grades 7-12* as a CD and an on-line course. Updated course CDs are freely distributed at events like the Education Symposium at the 2010 AMS Conference and meetings of the Federation of Earth Science Information Partners (ESIP). A highlight of teacher and student visits is our 3-foot Magic Planet spherical display system, with animations that demonstrate how scientists and forecasters utilize satellite imagery to monitor weather and climate.

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. The CIMSS mission includes three goals:

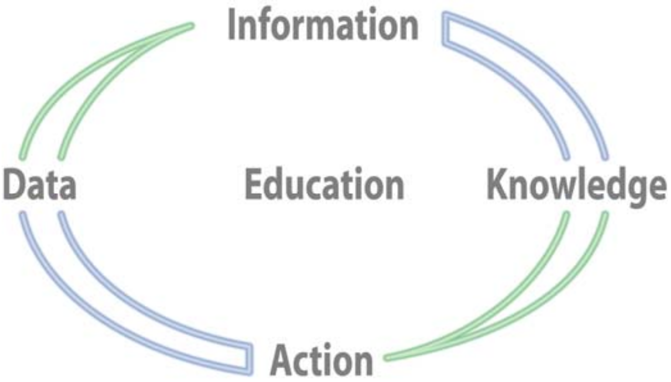
- Foster collaborative research among NOAA, NASA, and the University in those aspects of atmospheric and earth system science that exploit the use of satellite technology;
- Serve as a center at which scientists and engineers working on problems of mutual interest can focus on satellite-related research 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. Weather Nowcasting and Forecasting
2. Clouds, Aerosols and Radiation
3. Global Hydrological Cycle
4. Environmental Trends
5. Climate
6. Education, Training 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 come to realize 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 and ourselves.



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

CIMSS plays a unique role to NOAA as a non-profit partner, advisor, consultant and link to UW-Madison students and researchers. As a long-term partner of NOAA, CIMSS helps to serve as part of the NESDIS corporate memory, particularly when government staff change positions and roles. For example, original CIMSS/SSEC staff associated with GOES VAS (the first geostationary sounding instrument) and GOES-8/12 design, testing, and checkout are now assisting with similar activities in GOES-R. On the polar orbiting satellite side, our decades long work with the TOVS and ATOVS sounders and the aircraft HIS (High spectral resolution Interferometer Sounder) and scanning-HIS are aiding in the development of applications for the 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. 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.

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 13 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.

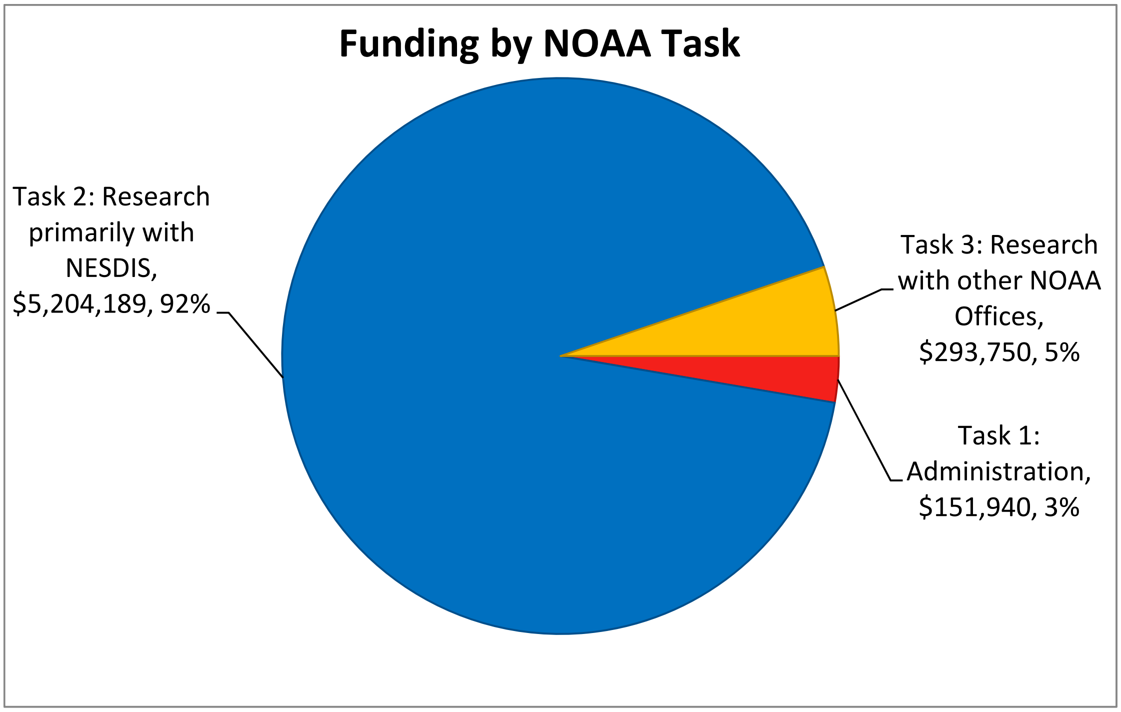
3. NOAA funding to CIMSS in FY2010, summarized by Task, NOAA Strategic Goal and CIMSS Research/Education Theme

In FY2010, funding to CIMSS through this Cooperative Agreement totaled approximately $5.65M. 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 FY2010 funds provided to CIMSS under the Cooperative Agreement that ended on 30 June 2010. Other FY2010 funds were provided to CIMSS under a new Cooperative Agreement that started on 1 July 2010. These funds are not reported here.

Funding by NOAA task

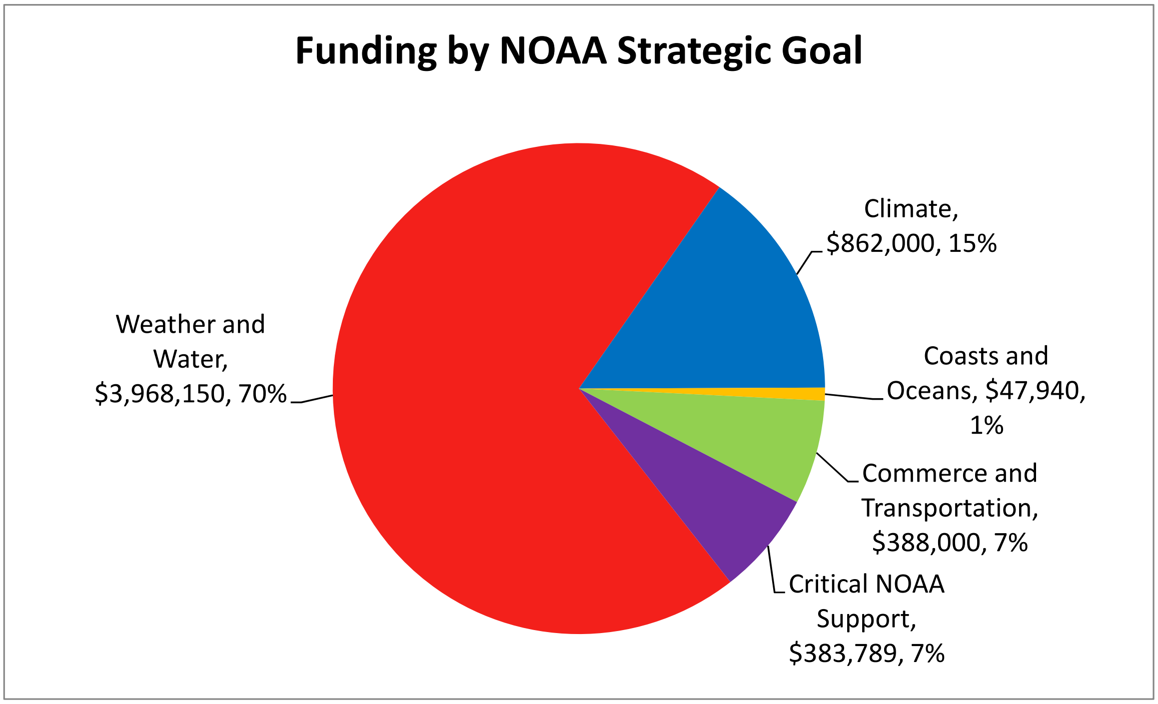
CIMSS Task	Funding in dollars	Percentage
Task 1: Administration	$ 151,940	2.6%
Task 2: Research primarily with NESDIS	$ 5,204,189	92.2%
Task 3: Research with other NOAA Offices	$ 293,750	5.2%
	$ 5,649,879	

- Note: Task 3 funds are primarily those projects conducted in collaboration with scientists and forecasters in the NOAA National Weather Service (NWS).



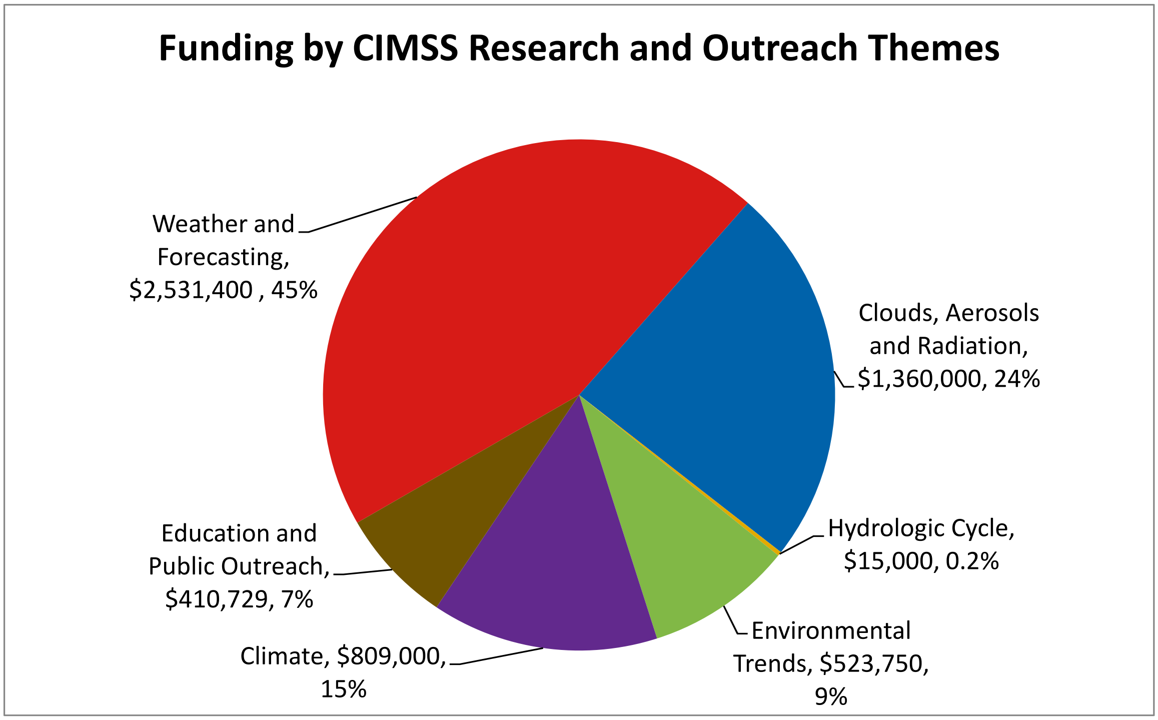
Funding by NOAA Strategic Goal

NOAA Strategic Goal	Funding in dollars	Percentage
Weather and Water	$ 3,968,150	70.1%
Climate	$ 862,000	15.3%
Coasts and Oceans	$ 47,940	0.9%
Commerce and Transportation	$ 388,000	6.9%
Critical NOAA Support	$ 383,789	6.8%
	$ 5,649,879	



Funding by CIMSS Research and Outreach Themes

CIMSS Theme	Funding in dollars	Percentage
Weather and Forecasting	$ 2,531,400	44.8%
Clouds, Aerosols and Radiation	$ 1,360,000	24.1%
Hydrologic Cycle	$ 15,000	0.2%
Environmental Trends	$ 523,750	9.3%
Climate	$809,000	14.3%
Education and Public Outreach	$410,729	7.3%
	$ 5,649,879	



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 May 2007. Current Board of Directors members include:

Martin Cadwallader, Chair	Dean, UW-Madison Graduate School
Steven A. Ackerman	Director, CIMSS, UW-Madison
Henry E. Revercomb	Director, SSEC, UW-Madison
Jonathan Martin	Chair, Dept. of Atm. and Oceanic Sciences, UW-Madison
Mary Kicza	Asst. Admin. for Satellite & Information Svcs., NOAA/NESDIS
Alfred Powell	Director, Ctr. for Satellite Appl. and Research, NOAA/NESDIS
Jeff Key	Chief, Advanced Satellite Products Branch, NOAA/NESDIS
Jack Kaye	Associate Director for Research, NASA
Franco Einaudi	Dir., Earth-Sun Expl. Div., NASA Goddard Space Flight Center (retired)
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, UW-Madison Engineering
Annemarie Schneider	Professor, UW-Madison, SAGE
Ralf Bennartz	Professor, UW Department of Atmospheric and Oceanic Sciences
Graeme Stephens	Professor, Dept. of Atmospheric Science, Colorado State Univ.
Bob Ellingson	Professor, Dept. of Earth, Ocean, and Atm. Science, Florida State University
Steve Goodman	GOES-R Senior Scientist, GOES-R Program Office
Ingrid Guch	Chief, Atmospheric Res. and Appl. Div., 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 Base (Task I)

Task Leaders: Steven Ackerman, Thomas Achtor
CIMSS Support Staff: Maria Vasys, Leanne Avila, Wenhua Wu, Jenny Hackel
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- 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

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 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 allows users to access CIMSS research projects via three paths: alphabetically, by observing platform and by CIMSS research theme.

CIMSS Task I funding was used to support staff work to document the work that Hal Woolf contributed to the international community. With the unexpected passing of Hal Woolf, it was realized that he provided many services to people in NOAA, the US and around the world, including upgrades to the International ATOVS Processing Package, radiative transfer fast model coefficients, and various types of satellite observational data. The servers Hal kept active were not well documented, so a small team of CIMSS staff designed and implemented a plan to document what Hal did for the community and move the data to a new server. This work has maintained the contributions Hal made to our global weather satellite community.

CIMSS Task I funds partially supported the expanded development of the PDA Animated Weather (PAW) project. The creation of satellite and other meteorological products for smart phones has been a great success in terms of the number of web site hits (see http://www.ssec.wisc.edu/data/paw/). Over the road truckers and many others have sent email thanking the CIMSS developer, Russ Dengel, for making these data and images available.

NOAA provided support for the International (A)TOVS Working Group's conference, ITSC-17, help in April 2010 in Monterey, CA. This funding helps with administrative details in preparation of the conference, web site maintenance and post-conference publications.

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 scientists.

CIMSS Task I funding also provide support for two graduate students, Caitlin Hart and Mark Kulie, as they fulfilled their academic course obligations and decided on their research thesis topics.

NOAA/NESDIS/STAR also provides funds for graduate students to attend the annual Cooperative Research Symposium, held at one of the NESDIS Cooperative Institutes each year. This funding supported three CIMSS students to attend the 2010 meeting in Fort Collin, CO (CIRA).

2. GIMPAP (GOES Improved Measurements and Product Assurance Program)

2.1. Validation and Improvement of Convective Nowcasting Products

Task Leaders: Justin Sieglaff, Lee Cronce
NOAA Collaborator: Robert Rabin
NOAA Strategic Goals:

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

CIMSS Research Themes:

- Weather, Nowcasting and Forecasting

Proposed Work

The UW-CIMSS Satellite Nowcasting Aviation Applications (SNAAP) group proposed further refinement and validation the experimental University of Wisconsin-Madison Convective Initiation (UWCI) decision support algorithm. This year the UWCI decision support product was distributed to the NOAA Satellite Applications Branch (SAB), the Storm Prediction Center (SPC) during the Hazardous Weather Testbed (HWT) Spring Experiment in 2009, and via AWIPS to various National Weather Service Forecast Offices (NWSFOs) through GIMPAP and GOES-R Proving Ground resources.

The UWCI algorithm exploits high temporal (5-15 min) and high spatial resolution (1-4 km) geostationary satellite observations of cumulus clouds, as they evolve from an immature "fair-weather" state into a mature thunderstorm. Roberts and Rutledge (2003) show that monitoring GOES IR window (10.7 μm) brightness temperatures (BTs) and their time trends is important for providing better nowcasts of convective storm initiation. Specifically, they show that isolating cumulus clouds with IR window BTs that have recently dropped below 273 K and 15-min cloud-top cooling rates of -8 K or less can provide 30 minute lead time in forecasting convective initiation (CI) over the use of WSR-88D radar observations alone. The term "convective initiation" refers to the transition of a convectively induced radar reflectivity echo from below to above 35 dBz.

Regarding UWCI algorithm refinement, the current research path is to use cloud products (cloud type/phase) that are or will be operational via GEOCAT and retire the daytime-only University of Alabama-Huntsville (UAH) statistically based unsupervised clustering convective cloud mask method, which highly relies on visual texturing. The new cloud products have several advantages, 1) physically based on cloud microphysical properties, 2) provide 24 hour cloud properties, 3) use operational data streams, 4) algorithm logic is applicable to all geostationary sensors although optimal results are obtained when more radiative information is present (SEVIRI vs. GOES) and higher temporal resolution is available. We have conducted research with MSG SEVIRI imagery toward the use of an IR-only cloud microphysical type product to identify newly developing convective storms. This cloud type product serves as a surrogate to a daytime-only satellite VIS+IR convective cloud mask that has been developed at UAH. The use of an IR-only cloud microphysical type product will extend nowcasting capability to the nighttime hours. Research has shown that monitoring the cloud phase (type) transition from liquid and supercooled water to thick ice cloud tops is a key indicator of convective initiation that we can exploit from satellite observations. We are using the GEOCAT framework to produce the cloud-top type product, which allows for flexibility in the spectral channels used as input to the algorithm. We plan to examine the impact of reducing the spectral information supplied to the algorithm on the resulting convective cooling rate product, as GOES has far fewer IR channels than MSG SEVIRI. This work should help us to understand the feasibility of using cloud phase (type) information from current GOES in the nowcast process.

Towards product validation, research is being conducted to evaluate the accuracy and lead-time provided by the UWCI box-averaged cloud-top cooling rate and convective initiation nowcast products relative to National Lightning Detection Network (NLDN) cloud-to-ground lightning data. Initial validation plans involved the use of WSR-88D radar reflectivity, but further investigation of digital radar datasets distributed by Unidata showed significant issues with ground clutter that would adversely impact objective radar recognition of CI. Radar echo movement and areal expansion are also complicating factors that can cause problems in separating new convective initiation signals from existing echo development. NLDN data, on the other hand, provides a binary yes/no lightning detection, which can be gridded and processed to identify the first occurrence of lightning over a selected grid point (i.e., “lightning initiation”). Several GOES cases have been selected and processed for validation.

This work supports NOAA mission goals for commerce, transportation, weather, and water. This information is valuable decision support guidance for NWS forecasters, NESDIS SAB hydrology, and the general aviation community.

Summary of Accomplishments and Findings

The main focus of this research was to streamline an algorithm, data access, and temporal latency to provide a near real-time convective initiation decision support product to the SPC HWT experiment conducted in April – June 2009 and perform a validation of the products. The UWCI (University of Wisconsin-Madison Convective Initiation) algorithm was refined from a daytime only algorithm to day/night independent algorithm for use with GOES or SEVIRI data.

The refined UWCI algorithm can be broken into two main components, a box-averaged BT cooling rate and cloud microphysical information from an improved method of the Pavolonis et al. (JAM, 2005) cloud typing algorithm. The box averaged 10.7 micron channel BT cooling rate identifies areas of rapidly cooling clouds between consecutive GOES scans. Pixels with sufficiently negative box average cooling rates signify significant vertical cloud growth and lateral expansion associated with newly developing convective clouds. In areas of sufficiently large box averaged cloud top cooling, transitions from water phase cloud to supercooled, mixed phase, and thick ice (as identified by the ABI/GOES Cloud Type product) signify when newly developing convective clouds are beginning to enter precipitation and/or lightning producing period of the storm life cycle.

The cooling information and cloud top microphysical information is combined to form the UWCI product. The UWCI product is spilt into three categories, which are intended to reflect large to small lightning/significant precipitation lead-times and correspondingly higher to lower false alarm rates. Category ‘1’ of the UWCI represents sufficiently cooling warm liquid water clouds. There is a significant lead-time for lightning initiation/significant precipitation for category 1. However, since not every vertically growing water cloud will produce a mature thunderstorm, this category will have the largest false alarm rate. As storms continue to grow vertically, the cloud tops begin to fall below freezing and transition to supercooled water and mixed phase types. Category '2' of the UWCI consists of sufficiently cooling supercooled/mixed phase clouds. The category 2 pixels have smaller lead-time than category '1', but also have a lower false alarm rate. This result is expected since category '2' storms are more mature than category '1' storms with colder cloud-top BT. Category '3' of the UWCI consists of sufficiently cooling clouds that exhibit cloud type transitions to thick ice. Thick ice cloud type transitions become more likely with decreased window brightness temperature and must occur at BT below the homogenous freezing point (233K or -40C). Since the category 3 storms are closest to reaching maturity, the lead-time is lowest of the three categories but also have lower false alarm rates, equal to the category 2 storms.

The UWCI products that were provided to operational centers (SAB, SPC, and NWSFOs) in near real-time include: 1) 60-minute accumulated cloud-top cooling rate, 2) 60-minute accumulated convective initiation nowcasts, 3) instantaneous cloud-top cooling rate, and 4) instantaneous convective initiation nowcast. Figure 2.1.1 shows an example of GOES imager UW-CIMSS Convective Initiation (UWCI) nowcast within N-AWIPS. GOES imager convective initiation nowcast from June 17, 2009 of GOES-12 Imager-derived Cloud Top Cooling (CTC) at 1545 UTC (upper left panel) and 1610 UTC (upper right panel). The radar image at the time of the 1545 CI nowcast indicates no precipitation reflectivity (middle left panel), the first satellite-based cloud-top cooling rate at 1545 UTC proceeded NEXRAD radar based convective initiation signal by 32 minutes indicated by first radar echo at 1617 UTC middle right panel. At 1826 UTC the radar image (bottom panel) shows a severe tornadic thunderstorm along the Kansas/Nebraska border.

In addition, the NOAA Aviation Weather Center and Meteorological Space Group (Houston, TX) has also requested the AWIPS datafeed. Since this proposal was introduced last year, the SPC and GOES-R Proving Ground expressed strong interest in the UWCI algorithm. GOES-R Proving Ground resources have allowed UW-CIMSS to take the GIMPAP developed algorithm and work closely with operational forecasters. This work in turn provided us with a list of improvements to implement from in-field operational feedback.

The focus during the second half of FY2009 was implementing improvements from interactions with forecasters at the SPC HWT. The improvements have been completed and an algorithm validation as also been completed. For the validation, lightning initiation (LI) derived from the National Lightning Detection Network CG strikes served as a proxy for convective initiation. The validation consisted of manually tracking clouds through space and time using GOES-12 IR-window imagery to determine: 1) the LI POD, which is defined as the number of LI events within the validation period that were correctly nowcast by the UWCI algorithm and 2) the UWCI nowcast FAR, which is defined as the number of UWCI nowcasts that were not associated with an LI event. The study was focused on the Storm Prediction Center severe storm risk areas for 23 convective days over the Southern and Central Plains during the spring and summer of 2008 and 2009. A total of 260 LI events occurred within the SPC slight risk or greater validation domain and a total of 288 UWCI nowcasts were made within the domain. The mean POD is 55.4% and the mean FAR is 26.0%. Analysis of the outlying days with POD/FAR above or below one standard deviation of the respective mean reveals that the UWCI algorithm performs 1) better in certain regimes such as with storms developing in previously clear to partly cloudy skies and with storm development along sharp boundaries and 2) poorer in other regimes such as scenes covered with mid-level cloud layers, cirrus shields, existing convective anvils, and fast cloud motion. The analysis showed the "pre-CI cloud growth" nowcast category offers the largest lead-times of the three nowcast categories, but also has a highest FAR. The "CI likely" and "CI occurring" nowcast categories show progressively shorter lead-times, respectively. The lead-times grow shorter with the CI Likely and CI

Occurring categories since these nowcasts are capturing developing convection further along in the development process lifecycle, but have equally low FAR. Further details are included in the journal article that will be submitted in February 2010.

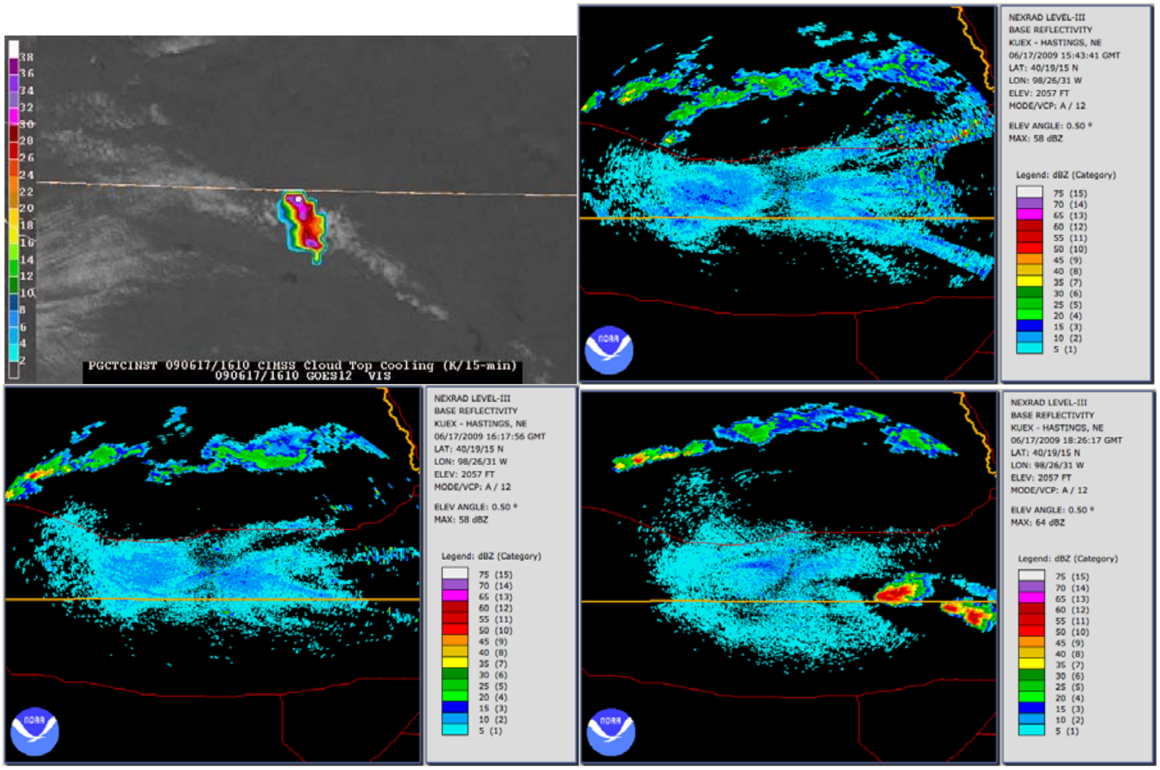


Figure 2.1.1. GOES imager convective initiation nowcast from June 17, 2009 of GOES-12 Imager-derived Cloud Top Cooling (CTC) at 1545 UTC (upper left panel), 1610 UTC (upper right panel). The radar images at the time of the 1545 CI nowcast (middle left), 1617 UTC (middle, right and,1826 UTC (bottom panel).

In addition to the UWCI algorithm, a blended RUC+GOES sounder stability product has been developed along with an objective infrared overshooting top algorithm. The UW-CIMSS research team is integrating these new techniques into a common processing scheme to provide end-to-end satellite convective decision support aids. SPC and SAB have expressed interest in both new products and they will be introduced at the SPC HWT Spring 2010 experiment. We have coordinated with the Cooperative Institute for Mesoscale Meteorology Studies in Norman, Oklahoma. A collaborative effort is underway to dovetail satellite derived convective properties into WDSS-II which currently focuses on radar signal object tracking.

Publications and Conference Reports

Bedka, K. M., J. Brunner, R. Dworak, W. Feltz, J. Otkin, and Thomas Greenwald, 2009: Objective Satellite-Based Overshooting Top Detection Using Infrared Window Channel Brightness Temperature Gradients. Accepted for publication within *Journal of Applied Meteorology and Climatology*.

Sieglaff, J.M., L.M. Cronce, K.M. Bedka, W.F. Feltz, and M.J. Pavolonis, 2010: Nowcasting Convective Storm Initiation Using Satellite-Based Box-Averaged Cloud-top Cooling and Microphysical Phase Trends. To be submitted to *Journal of Applied Meteorology and Climatology*, February 2010.

2.2. Intercalibration

Task Leader: Mat Gunshor
NOAA Collaborator: Tim Schmit
NOAA Strategic Goals:

- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Clouds, Aerosols and Radiation

Proposed Work

The purpose of the intercalibration project is to compare select infrared channels on geostationary instruments (GOES, Meteosat, etc.) using those obtained from polar-orbiting instruments (NOAA /AVHRR and HIRS, EOS/AIRS, EUMETSAT/IASI). Multiple comparisons are made at the geostationary sub-satellite points yielding an average brightness temperature difference between the geostationary imager and the polar orbiter.

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 World Weather Watch (WWW) Global Observing System (GOS) and Global Earth Observing System of Systems (GEOSS). This project supports NOAA's efforts with GSICS and also the NOAA Mission Goals of Climate and Weather and Water.

This proposal covers research into new and improved methods, diagnosing calibration-related problems on various instruments, ongoing inter-calibration between various geostationary imagers (domestic and international) and AIRS, IASI, AVHRR, and HIRS, and the analysis and presentation of results.

Specific tasks proposed for 2009-10 included:

- CIMSS will further assess the current AIRS spectral gap-filling method.
- CIMSS will continue to contribute to NOAA's cal/val efforts especially in terms of cooperating with the international GSICS and our partners on that committee.
- Intercalibration using IASI will become more commonplace and an assessment of the recent calibration accuracy of operational GEOs using IASI will be presented.
- We will continue to work with NOAA scientists on issues affecting the GOES-13 Imager 13.3 micrometer band.
- Maintenance of GEO SRFs will continue. CIMSS provides radiance to brightness temperature conversion coefficients to McIDAS for new instruments. These SRFs are also used in fast forward models (CRTM, PFAAST) as well as for intercalibration.

Summary, Findings, and Task Progress

The assessment of the AIRS spectral gap-filling method was concluded in the first half of 2009 and was covered in the first semi-annual report. The conclusion was that CIMSS should adopt the changes applied to the original CIMSS gap-filling method by GSICS colleagues at the Japanese Meteorological Agency (JMA).

CIMSS has continued to contribute to NOAA's cal/val efforts by maintaining communications with our GSICS partners. GSICS members maintain contact through an e-mail distribution list which helps members keep up with work being done in other member-states. There is currently an ATBD being drafted.

Intercalibration with IASI continues to grow. Most recently, CIMSS used IASI to do an assessment of the calibration accuracy of the Chinese operational geostationary imagers FY-2C and FY-2D. A presentation was made to the Director of China's National Satellite Meteorological Center (NSMC) during a November 2009 visit to CIMSS; the presentation covered an overview of intercalibration activities at CIMSS and focused on the comparisons of IASI to the FY-2C and FY-2D imagers.

The GOES-13 Imager 13.3 micrometer band spectral response function (SRF) issue was settled in the first half of 2009 and was covered in the first semi-annual report. The new SRF for that band should be implemented operationally by users. GOES-13 is scheduled to become the operational GOES-East on April 14, 2010. The official GOES SRFs were acquired from the Office of Satellite Operations (OSO) and then are detector-averaged by CIMSS. The ASPB/CIMSS Calibration Web page was updated with the new GOES-13 SRFs, Planck Function coefficients (for conversion from radiance to brightness temperature), bandwidth information, and plots. http://cimss.ssec.wisc.edu/goes/calibration/

The transmittance coefficient files for the fast forward model used in GOES product generation were updated for GOES-O (now GOES-14) and GOES-P. In addition the new GOES-13 Imager 13.3 micrometer band SRF was used in these new coefficient files as well. These files are generated at CIMSS and used operationally by NOAA in the generation of GOES products.

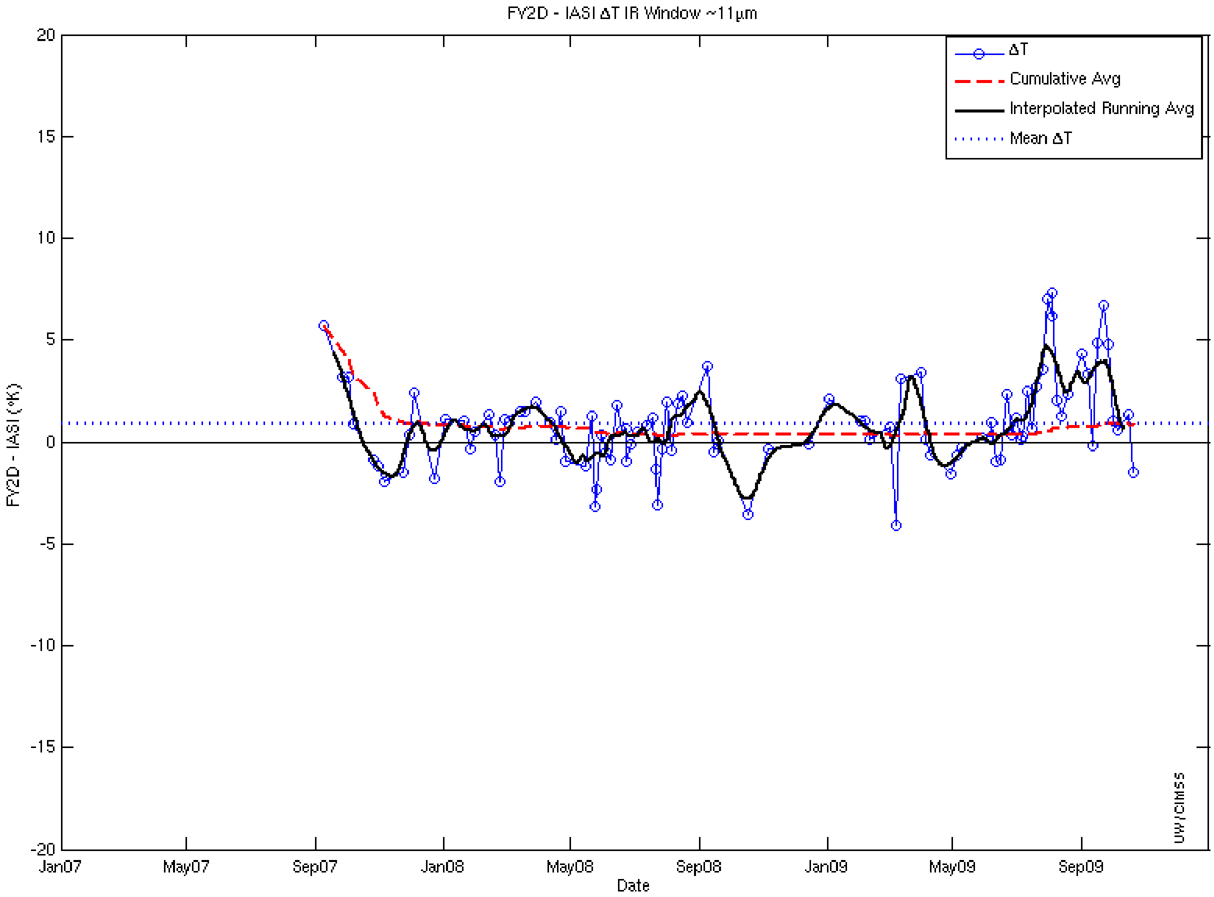


Figure 2.2.1. FY-2D IR Window band (~11 micrometer) intercalibration time series results in comparisons with IASI. While the differences can range in values as different as 5K, the mean difference over the time period for 98 cases is 0.9 K with a standard deviation bout the mean of 2.2 K.

Operational Transition/Importance to NOAA/GOES

Intercalibration is not an operational product, however what can be learned and applied from calibration related topics can have a positive impact on the accuracy of many GOES operational products. When an instrument is poorly calibrated, such as was the case with GOES-13's 13.3 micrometer band, it is possible to get that problem fixed (especially if the problem is discovered before the instrument becomes operational, as is the case with GOES-13). Calibration can have a profound effect on numerous operational products such as the assignment of heights to GOES winds and cloud top heights in this case. Maintaining spectral response functions for various users also has importance to NOAA operations mostly through the generation of fast forward model transmittance coefficient files. Other users also depend on the accuracy of radiance to brightness temperature conversions done in software such as McIDAS. The scientists that maintain PFAAST/PLOD rely on CIMSS to provide up-to-date spectral response functions to varying degrees. CIMSS collaborates with CRTM scientists, especially when anomalies are found (such as the as of yet unexplained, regularly spaced discontinuities found in several of the SRFs for GOES-O and –P) and PFAAST is generated at CIMSS and relies solely on CIMSS personnel to obtain, average, and maintain a library of up-to-date SRFs in order to generate transmittance coefficient files. PFAAST (sometimes known as PLOD) transmittance coefficient files are provided by CIMSS to NOAA operations for use in the generation of GOES products.

Publications and Conference Reports

A poster was presented at the 6th GOES User's Conference. "Intercalibration of GOES Imagers with high spectral resolution data" by Mathew M. Gunshor, Timothy J. Schmit, David C. Tobin, and W. Paul Menzel presented a retrospective analysis of GOES-IASI comparisons since 2007. Using the entire IASI data record to that point in comparisons with GOES-10, GOES-11, GOES-12, and GOES-13 were presented. In addition, preliminary results from the GOES-14 science checkout were included. The conference was held in Madison, WI from 3-5 November, 2009.

CIMSS was invited to give a presentation at the AIRS Science Team meeting held in October of 2009. Robert Knuteson attended the meeting and presented "Intercalibration of broadband geostationary imagers using AIRS" by Mathew M. Gunshor, Timothy J. Schmit, David C. Tobin, and W. Paul Menzel. The AIRS Science Team meeting was held in Greenbelt, MD from 13-16, October 2009.

A poster was prepared for the 6th Annual Symposium on Future National Operational Environmental Satellite Systems-NPOESS and GOES-R for the 2010 AMS Annual Meeting, 19-21 January 2010 in Atlanta, GA. The poster, "Intercalibration activities at CIMSS in preparation for the GOES-R era" by Mathew M. Gunshor, Timothy J. Schmit, David C. Tobin, and W. Paul Menzel contains a summary of intercalibration activities using IASI and GOES.

2.3. Using Quantitative GOES Imager Cloud Products to Study Convective Storm Evolution

Task Leader: Justin Sieglaff
CIMSS Support Scientist: Cory Calvert
NOAA Collaborators: Andy Heidinger, Mike Pavolonis
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:

- Weather, Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Project Summary and Motivation

In FY07, GIMPAP funded the real-time implementation of GOES-R ABI cloud property retrieval algorithms on current GOES imager data. The cloud products generated are cloud type (phase included), height, emissivity, optical depth, microphysics (e.g., particle size), and liquid/ice water paths. The algorithms are the GOES-NOP version of the GOES-R ABI algorithms developed by the Algorithm Working Group (AWG) Cloud Application Team. We seek to explore the utility of these cloud properties for studying convective storm evolution. Specifically, we will address the following questions:

- Can the observed temporal and spatial evolution of cloud properties be mapped into useful metrics of convective storm evolution?
- Do cloud properties form a superior basis for convective initiation studies compared to raw channel observations?

The GOES NOP Imagers are capable of making many of the same products that will be generated by the GOES-R ABI, albeit with reduced accuracy. Previous funding has enabled the generation of real-time cloud properties, which were not previously generated by NESDIS. The generation of GOES cloud properties, however, does not guarantee that they will be used. The goal of this project is to extract information from the cloud properties that can potentially be used by forecasters to make short-term predictions on convective storm evolution, throughout the storm's lifecycle. Demonstrating the utility of retrieved cloud properties in diagnosing convection may also lead to other advanced applications, which will increase the demand for cloud products now and into the GOES-R era.

Accomplishments

Our main accomplishments during this period are:

- Continued to explore how infrared cloud microphysical information can be used to study and assess deep convective cloud systems.
- Began implementing automated object tracking software (Warning Decision Support System – Integrated Information (WDSS-II)) on our cloud property defined convective cloud objects.
- Made improvements in the cloud phase/type algorithm, which led to improvements in making short-term predictions on convective initiation (see Feltz et al. GIMPAP and GOES-R Proving Ground convective initiation work).

As noted in previous reports, the presence of small ice crystals near the top of deep convective cloud systems may precede a severe weather event. Infrared measurements can be used to study and monitor deep convection at all times of the day. Deriving cloud microphysical information from infrared measurements, however, is limited in that the effective transmittance (combined effects of transmission and reflection) of the cloud layer must be large enough to detect, since it is the difference in effective transmittance between two infrared channels that contains the cloud microphysical information. The more closely a cloud approximates a blackbody, the less information on cloud microphysics that can be inferred from infrared measurements. Near-infrared derived particle size information is primarily derived from reflected solar radiation and, hence, does not have the same limitations as the infrared with regards to the transmission of radiation near cloud top. Thus, it is instructive to compare near-infrared and infrared derived effective particle radii for deep convective clouds to determine if infrared measurements can be used to derive effective particle radii consistent with the near-infrared.

A pixel-to-pixel comparison of a near-infrared derived effective particle radius (r_{eff}) and an infrared derived r_{eff} is complicated by the fact that valid infrared retrievals of r_{eff} are not always possible for reasons described above, and the radiative transfer processes at work differ between the near-infrared and infrared. Differing radiative transfer processes cause the measured radiation to be a function of the bulk microphysical properties of a different volume of cloud. In lieu of a pixel-to-pixel comparison, we analyzed effective particle radius information for over 500 deep convective cloud objects. A cloud object is defined as a collection of spatially connected pixels that meet a certain criteria (ice clouds with an 11-μm emissivity > 0.95 in this case). For each deep convective cloud object, the distribution of r_{eff} from the near-infrared retrievals and the distribution of r_{eff} from the infrared retrievals were analyzed.

Figure 2.3.1 shows the histogram of the minimum value of r_{reff} in each cloud object from the infrared retrieval as well as the histograms of the minimum and maximum values of r_{eff} in each cloud object from the near-infrared retrieval. The maximum value of r_{eff} is not shown for the infrared retrievals since effective particle radius values above about 40 μm cannot reliably be retrieved from infrared measurements even under the best circumstances. As expected, Figure 2.3.1 indicates significant differences, although there are some important similarities. For instance, of the 17 cloud objects that the near-infrared retrieval indicates are dominated by small particles (maximum $r_{eff} < 15$ μm), the infrared retrievals depict the presence of small particles ($r_{eff} < 15$ μm) for 16 of those objects. Further, of the 69 cloud objects that the near-infrared retrieval indicates are dominated by larger ice crystals (minimum $r_{eff} >$ 20 μm), the infrared retrieval depicts larger particles for 42 of those objects (minimum $r_{eff} > 20$ μm). Overall, more really small r_{eff} are indicated by the infrared measurements, which is expected given that the near-infrared solution space is ambiguous at smaller r_{eff}, while the opposite is true of the infrared retrieval solution space. The near-infrared retrievals may also be influenced by larger ice crystals present at greater depths from the cloud top, which do not influence the infrared measurements. The most important result is that 95% of the small particle dominated cloud objects (given by the near-infrared) contained pixels with an effective cloud transmittance large enough to perform an infrared retrieval, which means that the infrared retrievals can reliably be used in an operational severe weather decision support system.

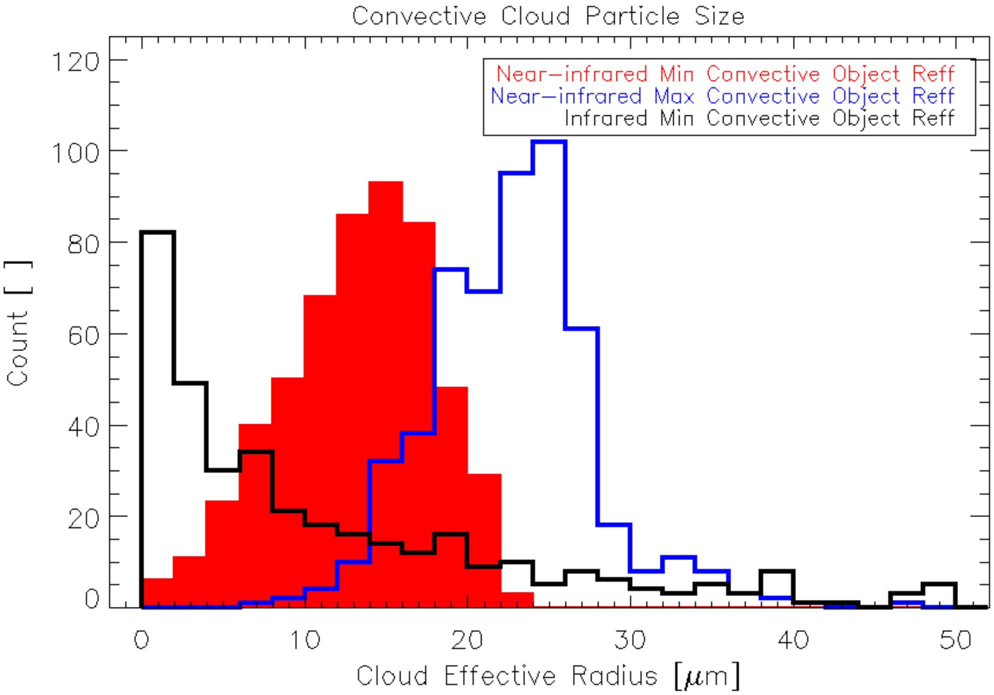


Figure 2.3.1. The histogram of the minimum value of effective particle radius (r_{reff}) in 541 deep convective cloud objects from an infrared retrieval as well as the histograms of the minimum and maximum values of r_{eff} in each cloud object from a near-infrared retrieval.

During this period we also began implementing automated object tracking software (Warning Decision Support System – Integrated Information (WDSS-II)) on our cloud property defined convective cloud objects. WDSS-II will allow us to more quickly and objectively analyze the change in the cloud properties of convective cloud objects over time compared to manual analysis. A preliminary time series of the maximum value (within an object) of a cloud emissivity parameter is shown in Figure 2.3.2 for two storms. We will refine and improve our usage of WDSS-II in FY10.

Operational Transition/Importance to NOAA/GOES

The science developed under this project will be incorporated into an existing convective weather decision support system developed at the University of Wisconsin (the Feltz et al. group plan on seeking funding to transfer this system to NESDIS operations by ~FY12). In the past year, cloud phase information from our algorithms has already been incorporated into this system with great success. The cloud phase information is critical in that it is used to determine the growth stage of cumulus clouds. Along these same lines, we plan on working with the Feltz et al. group to incorporate more sophisticated usage of the GOES Imager quantitative cloud products into their system.

Publications and Conference Reports

Pavolonis, M. J., 2009: The Temporal and Radiometric Evolution of Mid-latitude Deep Convection Observed by Satellites, Seminar at University of Wisconsin-Madison (Department of Atmospheric and Oceanic Sciences).

Pavolonis, M. J., 2009: Advances in extracting cloud composition information from spaceborne infrared radiances: A robust alternative to brightness temperatures. Part I: Theory, Submitted to *J Appl. Meteor. and Climatology* (November 2009).

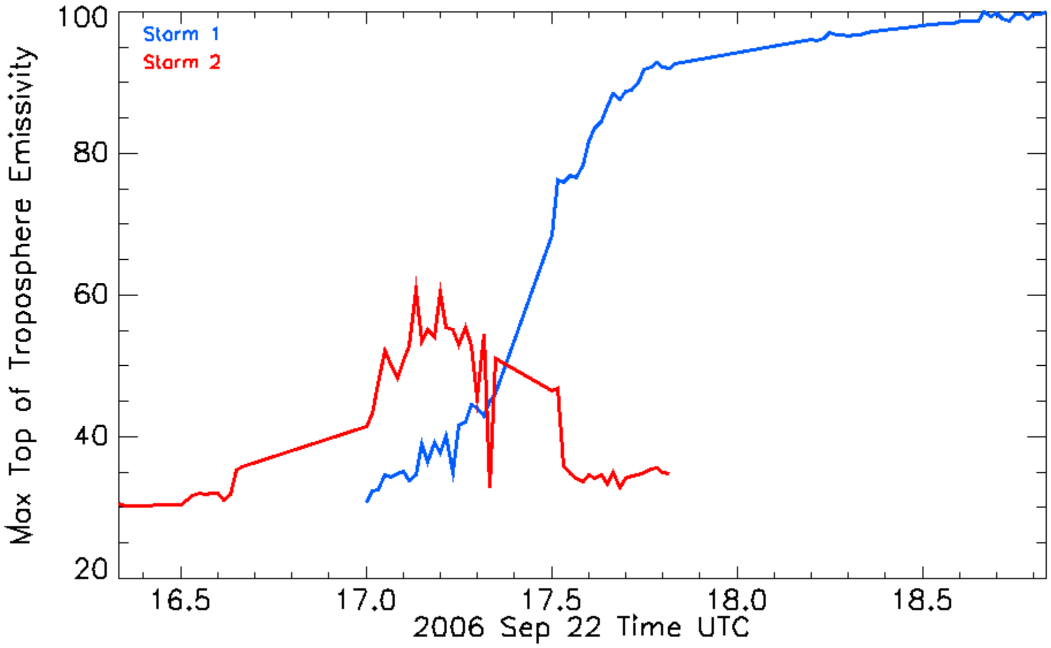


Figure 2.3.2. Example convective cloud object statistical time series generated using WDSS-II object tracking software for two convective cloud objects on September 22, 2006. The red line shows a weak storm and the blue line shows a strong storm.

2.4. Analysis and Application of GOES IR Imagery Toward Improving Hurricane Intensity Change Prediction

Task Leader: Chris Rozoff
NOAA Collaborator: Jim Kossin
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:

- Weather, Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Project Summary and Motivation

GOES infrared (IR) imagery and environmental and tropical cyclone (TC) data from the Statistical Hurricane Prediction Scheme (SHIPS) developmental dataset were used to derive information that can be incorporated into statistical forecast schemes for TC rapid intensification (RI). Here, RI has been defined by intensification thresholds of 25, 30, and 35 kt per 24 h. We have developed Bayes and logistic probabilistic models that can be used as additional RI forecast resources complementing the existing operational "SHIPS-RII" scheme (Kaplan et al. 2010) at the National Hurricane Center (NHC).

Improving the forecasting skill of TC intensity changes, particularly RI, continues to be a primary goal of NOAA. One of the greatest threats to coastal communities and marine interests is a poorly forecasted RI event in a TC. Our current forecasting skill of RI, while improving, is still not satisfactory. This study, which incorporates widely available environmental variables and GOES information about storm structure into a statistical predictive scheme, has the potential to further improve operational forecasting.

Accomplishments

Two statistical models were developed for the RI thresholds of 25, 30, and 35 kt per 24 h. One scheme is an empirical Bayesian probability model (described in Kossin and Sitkowski 2009), and the other is based on logistic regression. The Bayesian model utilizes class-conditional probability density functions for the environmental and satellite-based features (constructed during the “training” of the model). The logistic regression equation fitted to the data is given as follows:

$$p = \frac{1}{1 + \exp(-b_0 - b_1 x_1 - \ldots - b_n x_n)},$$

where p is the predicted probability of RI for a pre-defined intensification threshold (i.e., 25, 30, or 35 kt per 24 h), (x_1, x_2, …, x_n) are the predictors, and (b_0, b_1, …, b_n) are the fitted coefficients obtained through an iterative least squares approach. Although both models use similar features, they provide independent information, and cross-validated skill improves when the two models are averaged into a consensus forecast.

The lists of optimal predictors vary for each probabilistic model and between the North Atlantic and Eastern North Pacific Ocean basins. Nonetheless, the environmental and satellite predictors used in each instance provide a consistent picture. Namely, RI is more likely over a warmer ocean surface, in a moister atmosphere with lower vertical wind shear, and with favorable outflow divergence aloft. In addition, RI is more likely when the storm is already intensifying and when GOES-IR imagery suggests a more symmetric and convectively active storm. More specific details on the predictors are provided in Rozoff and Kossin (2010).

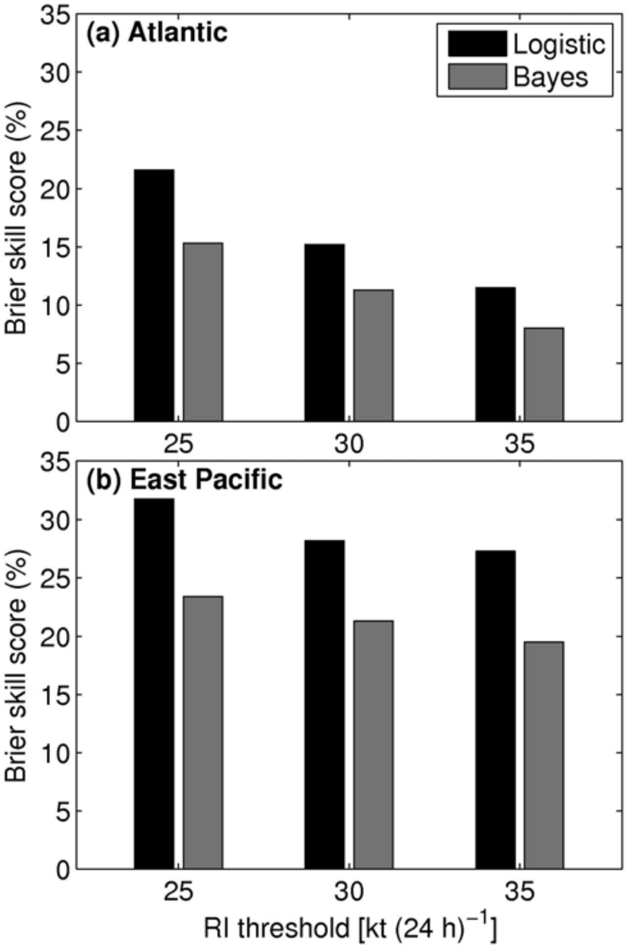


Figure 2.4.1. The Brier skill scores (%) determined from leave-one-year-out cross-validation (1995-2009) for the logistic (black) and Bayes (dark gray) probabilistic schemes over the (a) North Atlantic and (b) eastern North Pacific Ocean basins and for the RI thresholds of 25-, 30-, and 35-kt per 24 h. The sample sizes are $N = 2572$ for the North Atlantic and $N = 2614$ for the eastern North Pacific.

Both the logistic and Bayes probabilistic models possess skill in predicting RI for the years evaluated (1995-2009). This can be shown through leave-one-season-out cross validation. Figure 2.4.1 provides an overview of the Brier skill score (BSS) for each model, RI threshold, and ocean basin. In both basins, the logistic model provides higher BSS values than the Bayesian model for all RI thresholds. In the Atlantic, BSS ranges from 11.5 to 21.6 % (8.0 to 15.3 %) for the logistic (Bayesian) model. In the eastern North Pacific, BSS ranges from 27.3 to 31.8 % (19.5 to 23.4 %) for the logistic (Bayesian) model. Higher forecast skill was found in the eastern North Pacific as compared to the North Atlantic in the SHIPS-RII model as well (Kaplan et al. 2010).

Given the multiple statistical techniques to forecast RI, it is of interest to explore whether an ensemble mean probability of RI may offer superior forecast skill. To this end, the logistic and Bayesian models were utilized to construct ensemble mean probabilities of RI. The probabilities of RI from the SHIPS-RII described in Kaplan et al. (2010) and also trained with the SHIPS developmental dataset over the years 1995-2009 were also available, so SHIPS-RII was used in the ensemble mean.

Dependent testing was used to assess the performance of each scheme against one another and the ensemble mean. In other words, individual 6-hourly forecasts were made for each tropical cyclone over the 1995-2009 timeframe in each ocean basin. Such dependent testing is used since independent testing, such as leave-one-season-out cross validation, would require deriving new SHIPS-RII parameters for assessing the forecasts of each seasonal subsample, whereas dependent testing merely requires the easily obtainable SHIPS-RII probabilities for each individual forecast.

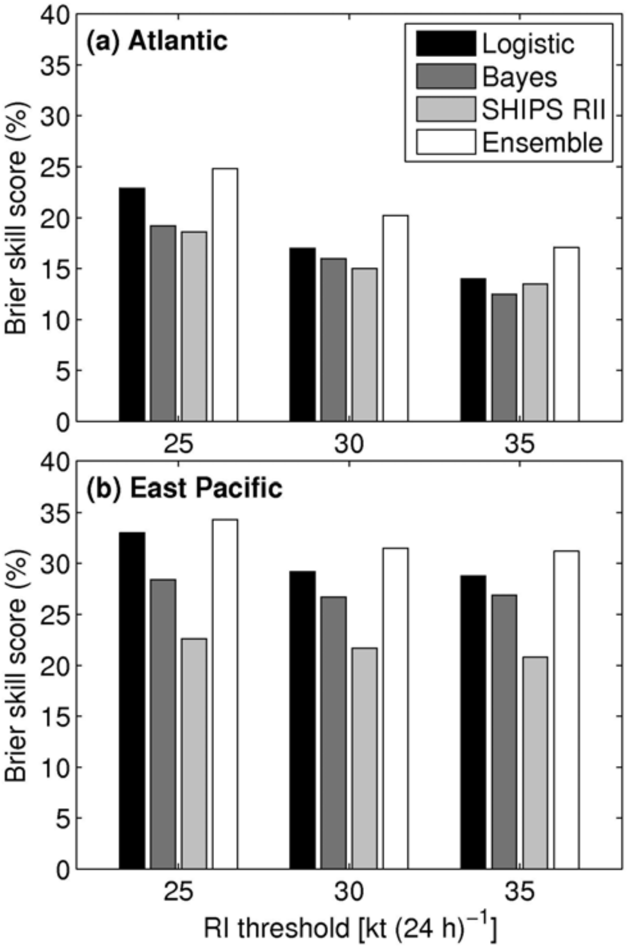


Figure 2.4.2. The Brier skill scores (%) determined from dependent testing (1995-2009) for the logistic (black), Bayes (dark gray), SHIPS-RII (gray), and consensus (light gray) schemes over the (a) North Atlantic and (b) eastern North Pacific Ocean basins and for the RI thresholds of 25, 30, and 35-kt per 24 h.

Figure 2.4.2 shows the BSS values for each model and their ensemble mean forecast. Much like in the independent testing results shown above, the logistic scheme possesses the highest forecast skill when subjected to dependent testing. Nonetheless, all three statistical models are certainly competitive and possess forecast skill for all RI thresholds and for each ocean basin. Despite the slightly higher skill level ascribed to the logistic model, the ensemble mean always performs best. In the North Atlantic (eastern North Pacific), the BSS of the ensemble mean is, on average, 2.1% (2.0%) higher than the BSS of the logistic model. The relative value of the ensemble mean is greatest when there is less disparity in BSS between individual models.

Operational Transition/Importance to NOAA/GOES

We have submitted a proposal to NOAA's Joint Hurricane Testbed (JHT) to incorporate our statistical RI schemes into operations at forecast centers such as the NHC.

Publications

Rozoff, C. M., and J. P. Kossin, 2010: New probabilistic forecast models for the prediction of tropical cyclone rapid intensification. *Wea. Forecasting*, to be submitted.

References

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.

Kossin, J. P., and M. Sitkowski, 2009: An objective model for identifying secondary eyewall formation in hurricanes. Mon. Wea. Rev., 137, 876-892.

2.5. GOES Single Field of View (SFOV) Cloudy Sounding Product Development

Task Leader: Jun Li
CIMSS Support Scientists: Zhenglong Li, Jim Nelson
NOAA CollaboratoR: Tim Schmit
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:

- Weather, Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Proposed Work

Operational GOES sounder clear sky products have been developed (Ma et al., 1999), and the algorithm has been improved for the legacy GOES soundings (Li et al., 2008). However, only clear observations are currently processed. Development of products (soundings, total precipitable water - TPW, lifted index - LI) in cloudy regions is very important for severe storm nowcasting. The proposed work includes the development of an algorithm to derive atmospheric temperature and moisture profiles in some cloudy situations (focus on thin or low clouds). Radiosondes and ground-based TPW measurements are used to evaluate the algorithm and to validate the product under cloudy situations.

Summary of Accomplishments and Findings

More validation on cloudy SFOV soundings has been performed. Radiosonde observation (RAOB) data set from August 2006 to May 2007, collected at ARM Southern Great Plains (SGP) site are used for primary validation. In addition, the conventional RAOB measurements over the continental United States (CONUS) from January 2007 to November 2008 are also used. The results from both datasets are very similar, under thin cloudy conditions, GOES Sounder improves the moisture GFS forecast in the upper troposphere, while in the middle troposphere, the improvements are small with respect to RH, but substantial with respect to mixing ratio. In the lower troposphere, the improvements become more substantial, especially with respect to the mixing ratio. In the case of low clouds, the largest improvements are in the upper troposphere too. And the improvements become less significant in the lower troposphere, as the impact by clouds becomes more significant.

The GOES single field-of-view cloudy sounding algorithm has also been evaluated with collocated CALIPSO data. Since the algorithm retrieves atmospheric profile and cloud-top height (CTH) simultaneously, we can also validate the algorithm by comparing GOES CTH with the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) measurements. The GOES cloudy sounding algorithm provides also reasonable CTH in cloudy skies according to the comparisons.

We have studied the application of the GOES cloudy sounding research product in convective storm nowcasting. Typical cases are used in our study. We found that the GOES cloudy sounding retrievals show earlier warning in terms of low values of LI than the two model forecasts (GFS and RUC), indicating the importance of expanding the GOES soundings into cloudy skies.

Operational Transition Activities

Besides the cloudy sounding algorithm development and evolution, we are also working on the operational transition of the improved GOES sounding algorithm through collaboration with FPDT (forecast product development team) at STAR/NESDIS. Currently the improved algorithm in clear skies has been used in the CIMSS routine process, implementation issues have been cleaned up recently. Routine evaluation of the improved algorithm is ongoing. Figure 2.5.1 shows one example of real time evaluation of GOES sounding retrievals – the old (left panel) versus new (right) versions. RAOBs over CONUS are used in the real time evaluation. The new version has been delivered to FPDT for operation transition. We plan to transit the cloudy sounding algorithm into operation as well through PSDI.

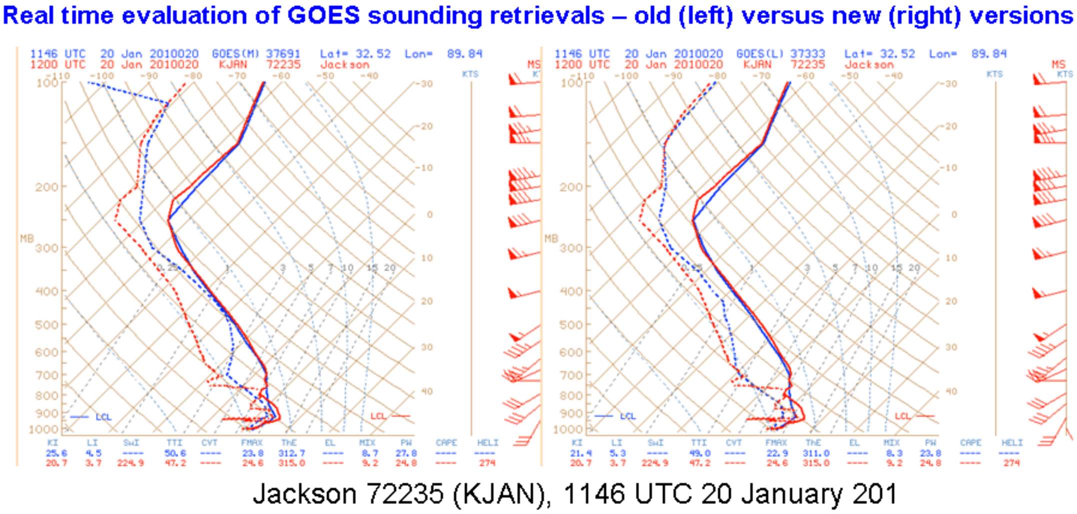


Figure 2.5.1. Real time comparison between RAOBs and GOES sounding retrievals – the old (left panel) versus new (right) versions. The Jackson radiosonde (red lines) is used as an example.

Publications

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

Li, Z., 2009: Improvements and applications of atmospheric soundings from geostationary platform, Ph.D. dissertation, University of Wisconsin-Madison. Pp134.

2.6. Automated Volcanic Ash Detection and Volcanic Cloud Height and Mass Loading Retrievals from the GOES Imager

Task Leader: Justin Sieglaff
CIMSS Support Scientist: Andrew Parker
NOAA Collaborator: Mike Pavolonis
NOAA Strategic Goals:

- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes:

- Weather, Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Proposed Work

With the advent of the GOES-R Algorithm Working Groups, NOAA has begun to develop consensus prototype algorithms for GOES-R. In particular, the Cloud Application Team has developed a prototype system for testing algorithms applied to geostationary imager data (GEOCAT). GEOCAT can process geostationary imager data from the Geostationary Operational Environmental Satellite (GOES), the Spinning Enhanced Visible Infrared Imager (SEVIRI), and the Multifunctional Transport Satellite (MTSAT). The GOES-R volcanic ash products (detection, height, and mass loading) can, in fact, be produced from the current GOES imagers, albeit with reduced accuracy. These quantitative products would greatly benefit current operations. All volcanic ash products in operations today are imagery based and qualitative, and, as such, do not offer information on mass loading or height. The height and mass loading information are important, since they can be used to initialize dispersion models. Therefore, in this project, we plan on capitalizing on our GOES-R algorithm development experience in an effort to develop quantitative products for the current GOES imagers. Since the current GOES imagers lack a key channel (8.5 micron) used in the GOES-R algorithm, we need to make modifications to our approach.

Summary of Accomplishments and Findings

We have developed a 4-channel (0.65, 3.9, 11, 12/13.3-μm) approach for detecting volcanic ash and a bi-spectral (11 and 12/13.3-μm) approach for retrieving ash height and ash mass loading (mass per unit area). These quantitative retrievals are unique because similar products are not currently produced in operations. Instead, volcanic ash forecasters rely manual imagery analysis.
The focus during the second half of FY 2009 was to ensure the ash detection and retrieval algorithms can perform well in absence of the 12 μm channel since GOES-12 and higher numbered satellites do not have the 12 μm channel, but rather a 13.3 μm channel. The significance of the 13.3 μm channel versus the 12 μm channel is the 13.3μm channel is not a window channel, rather it lies within CO_2 absorption region. In absence of CO_2 absorption, the 13.3 μm channel is actually a better channel to pair with the 11μm channel than the 12 μm channel. This combination is preferable because the difference in absorption due to ash particles is larger with the 11 and 13 μm pair than the 11 and 12 μm pair. However, the CO_2 absorption poses significant challenges for ash detection. The peak of the CO_2 weighting function is approximately 850 hPa, which makes low-level ash plumes more difficult to detect.

Current operational volcanic ash detection relies heavily on the 11-12 μm brightness temperature difference (BTD). As demonstrated in previous reports, our research utilizes an alternative measurement space using absorption optical depth ratios (Beta ratios) opposed to BTDs alone. The beta ratio approach accounts for differences in surface emissivity and clear sky gaseous absorption, which allows the cloud-top microphysical signal to be isolated. The beta ratio approach is even more important when considering the 13.3 μm channel on GOES-12 and higher satellites.

The Moderate-resolution Imaging Spectroradiometer (MODIS) has the 11, 12, and 13.3 µm channels. The use of MODIS data allows for a demonstration of the difference between the 11 and 12 µm and 11 and 13.3 µm channel pairs, serving as a proxy for GOES-11 and GOES-12+, respectively. One benefit of using MODIS is the viewing geometry is the same for all channels and spectral response functions are well known. Figure 2.6.1 shows a false color image of a volcanic ash plume over the Atlantic Ocean as viewed by MODIS-Aqua on 05 May 2008 at 0315 UTC. The volcanic ash plume is indicated by pink colors within the RGB image and is also circled.

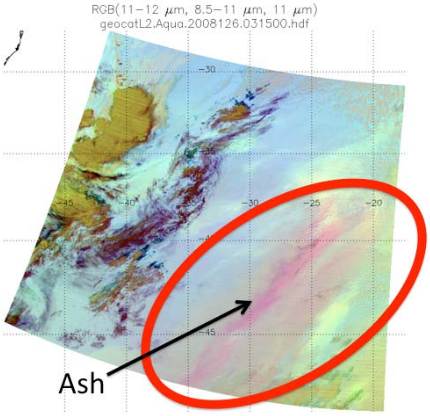


Figure 2.6.1. A false color composite of an ash plume from the Chaiten Volcano (Chile) over the Atlantic Ocean from 5 May 2008 at 0315 UTC using MODIS.

The ash plume shown in Figure 2.6.1 is depicted rather well by negative 11 - 12 BTDs (red circle, Figure 2.6.2a), however, areas of meteorological cloud also have negative 11 - 12 BTDs (yellow and purple circles, Figure 2.6.2a). The ash plume is considerably more ambiguous in the 11 - 13 BTD (Figure 2.6.2b.) than the 11 - 12 BTD. In this case the ash plume has 11 - 13 BTDs in the 10.0 – 17.0 K range (red circle, Figure 2.6.2b). Meteorological clouds have a wide variety of 11 - 13 BTDs, ranging from similar values as the ash cloud in the yellow and purple circles to values near zero in the high convective clouds in the northwestern portion of the image. The 11 - 13 BTD largely depicts a measure of cloud height due to differing weighting function peak heights between the 11 and 13.3 µm channels. The 11 and 12 µm have similar peaking weighting functions at the surface, while the 13.3 µm channel weighting function peaks in the lower to middle troposphere. As a result, low to mid-level clouds have large to moderate 11 - 13 BTDs. For thick high clouds the 11 - 12 and 11 - 13 BTDs converge to similar values (near zero) because these clouds reside above weighting function peaks for all 3 channels and are optically thick. A BTD only approach for automated ash detection with the 11 and 13.3 µm channel pair is not optimal, if not impossible.

The beta ratio measurement space provides a means for ash detection with both the 11 and 12 µm channel pair and 11 and 13.3 µm channel pair. The 12/11 beta ratios are typically less than 1.0 for ash clouds as predicted by single scatter theory (shown in previous reports). In the example case, the ash plume has 12/11 beta ratios between 0.50 and 0.90 (Figure 2.6.2c). The 13.3/11 beta ratios behave in a similar manner as the 12/11 beta ratios, but typically have even smaller values for ash clouds due a greater difference between absorption of ash particles between 11 and 13.3 µm than 11 and 12 µm. In this example, the ash plume has 13/11 beta ratios from near zero to 0.60 (Figure 2.6.2d). Within both the 12/11 and 13/11 beta ratio plots, the ash plume has smaller beta values than meteorological clouds within the yellow circle and the high convective clouds over the northwestern portion of the image. This distinction was not evident with the BTDs. However, the beta ratio space is not a perfect solution, as areas of ambiguous beta ratios still exist between ash and meteorological cloud (purple circles).

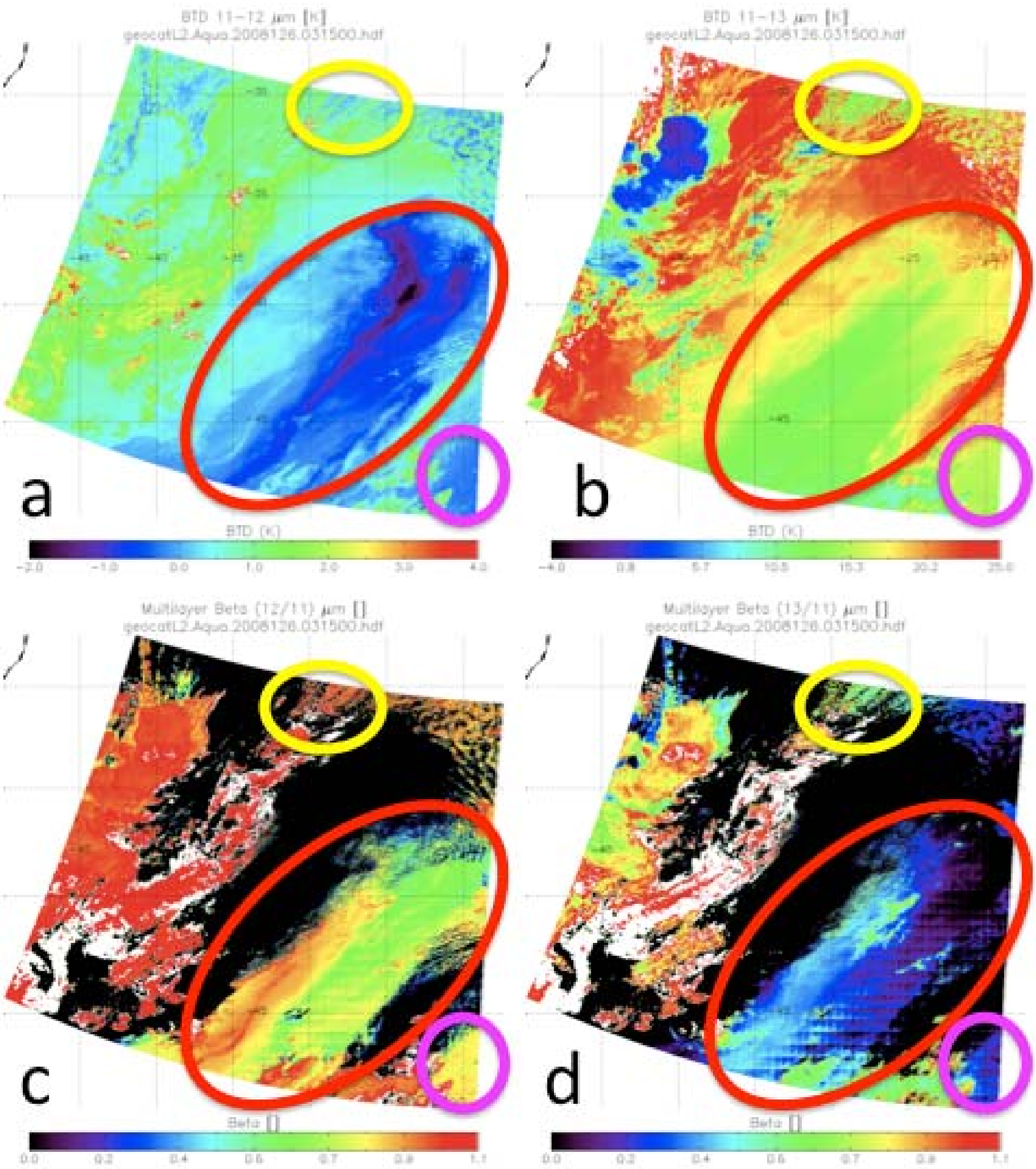


Figure 2.6.2. a) BTD 11 -12 µm from MODIS-AQUA 05 May 2008 at 0315 UTC. b) BTD 11-13.3 µm. c) Beta ratio (12/11). d) Beta ratio (13.3/11). The ash plume is circled in red. The yellow circles highlight areas where the ash plume and meteorological cloud have similar BTD values, but the beta ratios are lower for ash cloud and higher for meteorological cloud. The purple circles highlight areas where the ash plume and meteorological cloud have similar BTD values and similar beta ratios.

As was shown in previous reports, even after including additional GOES spectral channels (e.g., visible and shortwave IR window) there is always some ambiguity between ash and certain meteorological cloud pixels when the pixels are treated individually. The FY 2010 work will make use of sophisticated spatial metrics, namely cloud objects to distinguish ash clouds from meteorological clouds. The approach will utilize statistics derived from cloud objects for many spectral combinations including beta ratios.

Publications and Conference Reports

Pavolonis, M. J., J. Sieglaff, and A. Parker, 2009: New Automated Methods for Detecting Volcanic Ash and Retrieving It's Macro- and Micro-physical Properties. Oral presentation at 2009, AGU Annual Meeting.

Pavolonis, M. J. and J. Sieglaff, 2009: New Automated Methods for Detecting Volcanic Ash and Retrieving Its Properties from Infrared Radiances. Oral presentation at 2009 AMS Annual Meeting.

Pavolonis, M. J., 2009: Advances in Determining Cloud Composition from Infrared Radiances. Invited presentation at the Optical Society of America Hyperspectral Imaging and Sounding of the Environment Conference.

Pavolonis, M. J. and J. Sieglaff, 2009: Quantitative Volcanic Ash Remote Sensing at NOAA/NESDIS/STAR. Oral briefing at NWS and USGS in Anchorage, AK.

Pavolonis, M. J, 2009: Quantitative Volcanic Ash Remote Sensing at GOES-R Proving Ground Meeting. Oral briefing, Fairbanks/Anchorage, AK.

Pavolonis, M. J., 2009: Advances in extracting cloud composition information from spaceborne infrared radiances: A robust alternative to brightness temperatures. Part I: Theory. Submitted to *J Appl. Meteor. and Climatology* (November, 2009).

Pavolonis, M. J., 2009: 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 Appl. Meteor. and Climatology*.

2.7. Global Geostationary Fire Monitoring and Applications

Task Leader: Chris Schmidt

CIMSS Support Scientists: Jason Brunner, Elaine Prins, Jay Hoffman, and Joleen Feltz

NOAA Collaborators: Robert Rabin (NOAA/NSSL), Phillip Bothwell (NOAA/NWS/SPC), Ivan Csiszar (NOAA/NESDIS/STAR), Shobha Kondragunta (NOAA/NESDIS/STAR)

Other Collaborators: NRL-Monterey/FNMOC, EPA, USFS, hazards monitoring/assessments, global climate change modelers, trace gas/aerosol transport modelers, transportation, air quality agencies.

NOAA Strategic Goals Addressed:

- 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:

- Clouds, aerosols, and radiation
- Environmental trends
- Climate

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, and future instruments (INSAT-3D, COMS, etc.) this capability is now global. The WF_ABBA has been recently upgraded to Version 6.5

(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, 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 must be developed to characterize and integrate the data. This work supports U.S. and international efforts (IGOS GOFC/GOLD, CGMS, CEOS Constellation Concept) and the GEO 2006 Work Plan (DI-06-13, DI-06-09). Version 6.5 of the WF_ABBA tracks metadata regarding clear fields of view and satellite scan coverage, allowing trend analyses to be corrected for clouds and the satellite scanning schedule.

Preliminary studies indicate that time series of GOES Rapid Scan Operations (RSO) fire parameters along with ancillary information may provide enhanced information for fire weather applications. This work was started in FY07 with analyses of several case studies.

To accomplish these goals CIMSS will expand the GOES WF_ABBA trend analysis to extend around the globe, not just the Western Hemisphere. CIMSS will collaborate with the atmospheric modeling community to integrate and assimilate “global” geostationary WF_ABBA fire products into aerosol/trace gas transport models and collaborate with Dr. R. Rabin (NOAA/NSSL) and Dr. P. Bothwell (NOAA/NWS, Storm Prediction Center) on applications of RSO GOES fire products for early detection of wildfires and agricultural burning and diurnal monitoring of fire variability for fire weather forecasting. We will continue to work with GEOSS, GTOS GOFC/GOLD, CEOS, and CGMS to foster the development and implementation of a global geostationary fire monitoring network with international involvement. This aspect of the work at CIMSS has been an important GIMPAP task for the last few years and played a role in the push to create a virtual global constellation for fire detection utilizing the WF_ABBA as the common algorithm across fire-detection capable platforms.

Summary of Accomplishments and Findings
The GOES WF_ABBA v65 trend analysis is being expanded to extend around the globe and now includes Met-9 over Africa and Europe and also MTSAT-1R over Asia and Australia. The Western Hemisphere through 2009 is also included, providing nearly complete global coverage by the WF_ABBA. Figure 2.7.1 shows a graph of GOES East WF_ABBA v65 annual fire detections over South America for 1997-2009. The most active fire year for South America was in 2007 where nearly 850,000 processed fire detections occurred. Other active fire years occurred in 1997 and 1998. The least active fire years were in 2000, 2008, and 2009. Only around 450,000 processed fire detections occurred in these years. 2007 had nearly twice as many processed fire detections compared to 2008 or 2009. As prices for soy and cattle surged in 2007, deforestation and soybean production and associated burning also soared in states along the southern and eastern perimeters of the Amazon (Mato Grosso, Para, Tocantins, Amazonas). In 2008 the WF_ABBA observed below average burning most likely associated with regulatory changes, increased enforcement, and reductions in grain prices. Additionally, increased cloud coverage and changes to satellite scanning schedules may have played a role, and that will be examined as trend analyses proceed. Overall, a steady downward trend in the number of processed fire detections has occurred over South America since 2004 (besides 2007).

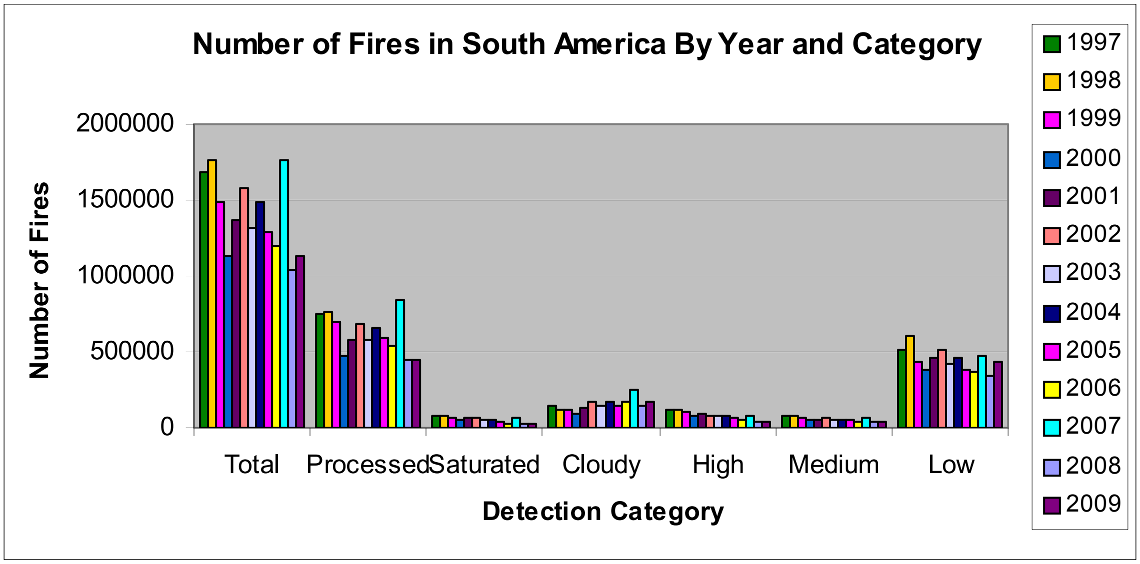


Figure 2.7.1. GOES East WF_ABBA v65 annual fire detections over South America for 1997-2009.

The WF_ABBA (version 6.5.006) was modified to process GOES-15 and MTSAT-2 data. In addition updates were made to reflect changes in the 3.9 micron saturation temperature for GOES-11, -12, and -13. The GOES-15 WF_ABBA was executed on diurnal imagery collected in August and the code performed as expected. Figure 2.7.2 shows an example of the GOES-15 WF_ABBA fire mask at 1745 UTC on 20 August 2010. Evaluation of the MTSAT-2 WF_ABBA fire product during July and August 2010 indicate that performance is similar to MTSAT-1R. The MTSAT-2 3.9 micron saturation threshold of ~320.0 K is similar to MTSAT-1R and hinders fire detection and characterization. This is especially evident over Australia where large areas are saturated within several hours of local noon. The updated global WF_ABBA (version 6.5.006) is currently being transferred to NESDIS operations.

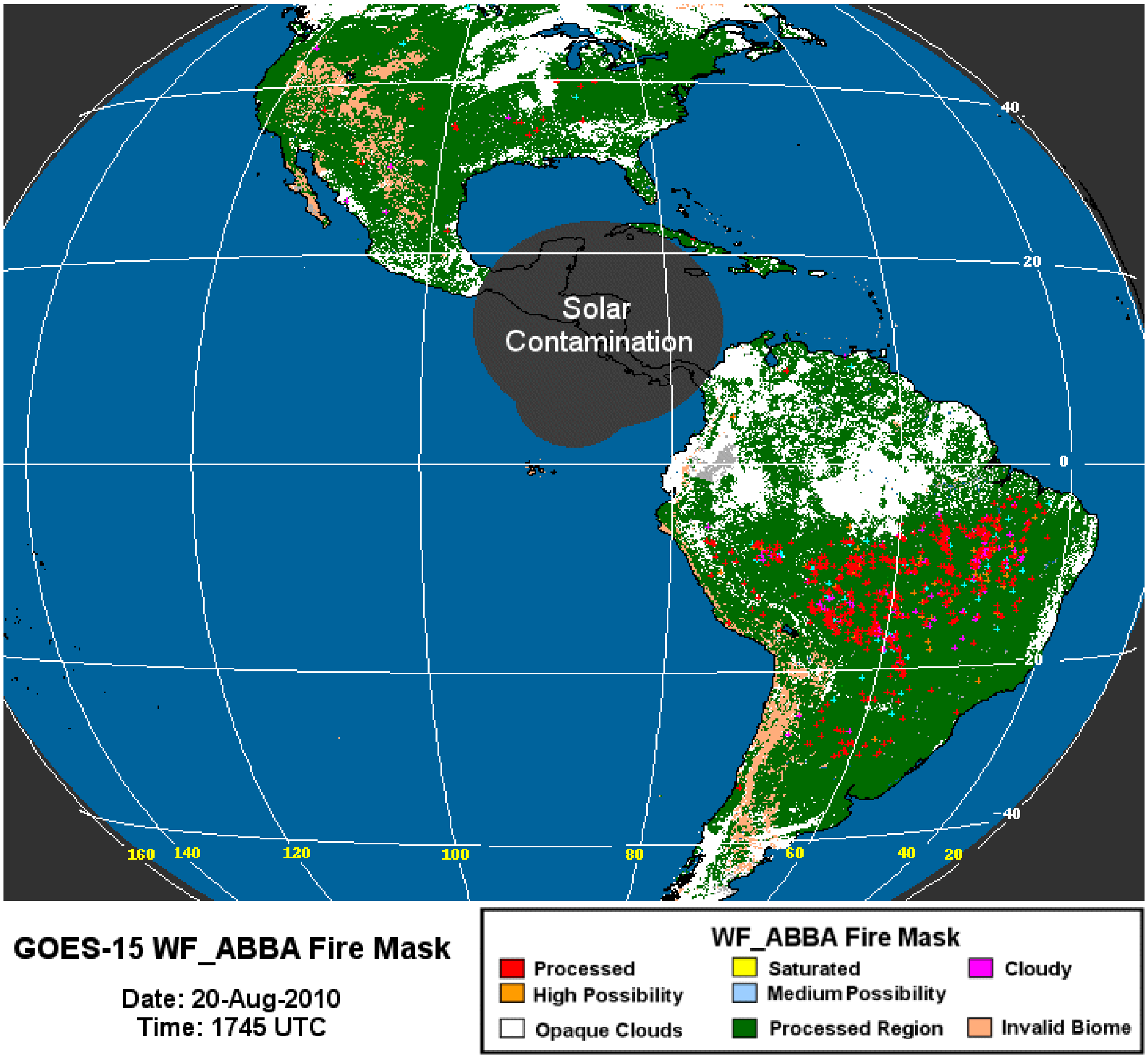


Figure 2.7.2. GOES-15 WF_ABBA fire mask at 1745 UTC on 20 August 2010.

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 the user community to help to ensure proper applications of geostationary satellite derived fire products 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 continues to support international satellite fire monitoring efforts by being actively involved in GEOSS, GTOS GOFC/GOLD, CEOS, and CGMS activities. This includes involvement in international planning committees, workshops and technology transfer to global partners in Europe, Africa, Asia, Australia, etc. Currently global geostationary fire monitoring is being considered as a CEOS Constellation Concept. Figure 2.7.3 shows Meteosat-9 WF_ABBA Version 6.5 fire pixels for 2009, including only the processed (re) and saturated (yellow) fire categories.

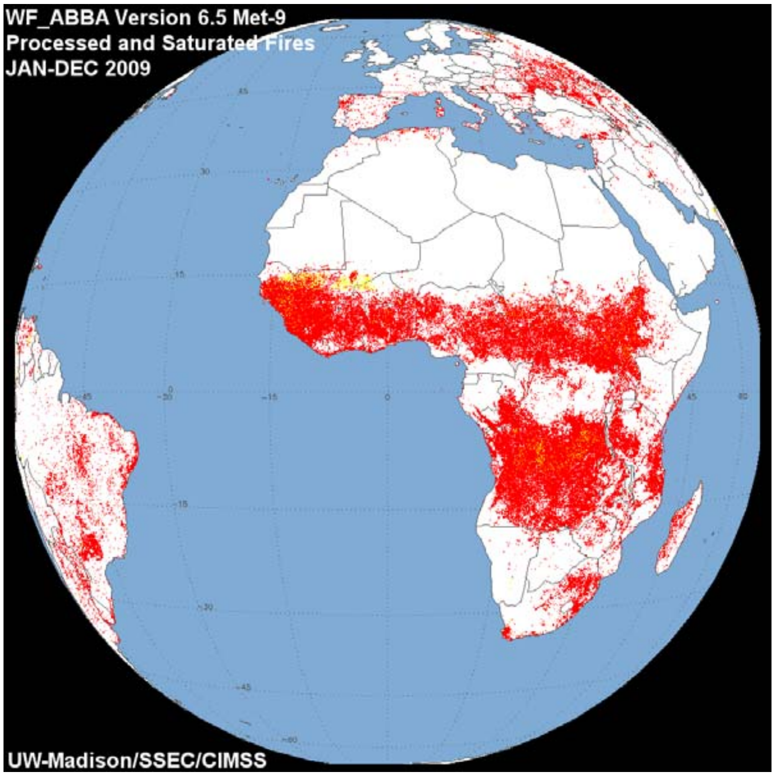


Figure 2.7.3. Meteosat-9 WF_ABBA Version 6.5 detected fire pixels for 2009. Red indicates processed fires, which have instantaneous fire size, temperature, and fire radiative power associated with them. Yellow indicated saturated fire pixels.

Publications and Conference Reports

Brioude, J., O. R. Cooper, G. Feingold, M. Trainer, S. R. Freitas, D. Kowal, J. K. Ayers, E. Prins, P. Minnis, S. A. McKeen, G. J. Frost, and E. -Y. Hsie1, 2009: Effect of biomass burning on marine stratocumulus clouds off the California coast. *ACPD*, **9** (4**)**, 14529 – 14570.

Brunner, J. C., C. C. Schmidt, R. M. Rabin, E. M. Prins, J. M. Feltz, J. P. Hoffman, and P. D. Bothwell, 2010: The development of a Western Hemisphere trend analysis of fires and United States fire potential product from version 6.5 WF_ABBA data. 17th Conference on Satellite Meteorology and Oceanography. Annapolis, MD. September 2010, Amer. Meteor. Soc., P4.16.

Reid, J. S., E. J. Hyer, E. M. Prins, D. L. Westphal, J. Zhang, J. Wang, S. A. Christopher, C. A. Curtis, C. C. Schmidt, D. P. Eleuterio, and J. Hoffman, 2009: Global monitoring and forecasting of biomass-burning smoke: Description and lessons from the Fire Locating and Modeling of Burning Emissions (FLAMBE) program. Accepted for publication in *IEEE Journal of Selected Topics in Earth Observations and Remote Sensing*.

Prins, E. M., C. C. Schmidt, J. C. Brunner, J. P. Hoffman, S. S. Lindstrom, and J. M. Feltz, 2010: The global geostationary Wildfire ABBA fire monitoring network. 17th Conference on Satellite Meteorology and Oceanography, Annapolis, MD, September 2010, Amer. Meteor. Soc., P9.13.

2.8. GOES Tropical Cyclone Applications Research

Task Leader: Chris Velden

CIMSS Collaborators: Tim Olander, Derrick Herndon, Dave Stettner

NOAA Strategic Goals:

- Serve society's needs for weather and water

CIMSS Research Themes:

- Weather, Nowcasting and Forecasting

Background and Motivation

This research is being conducted to help advance GOES-derived products as applied to Tropical Cyclones (TCs). The research strategies proposed are novel, and promise to improve on the product quality, and utilization. The tasks build on a long and successful GIMPAP TC research program at CIMSS. Both the operational and research communities have frequently cited the importance of GOES products developed by CIMSS under NOAA GIMPAP support. We use this feedback as motivation to continue to innovate and advance GOES product development towards TC applications.

Primary Accomplishments

Proposal Task 1: Continue the exploration of new and innovative methods for integration into the Advanced Dvorak Technique (ADT) to improve estimates of tropical cyclone (TC) intensity from GOES.

To accomplish this task, we employ three approaches:

1) Explore the integration of other GOES channels. The current algorithm version only employs the GOES IR-Window channel imagery.

We have concluded our initial study to explore a scheme that uses pixel-differencing between collocated/coincident IR-W and WV channels to denote strong eyewall convection, to assess if there might be useful information for the ADT. A briefing on the method and preliminary findings were summarized in a prior report. We have written up the results, and the paper just appeared in the December 2009 issue of Weather and Forecasting, presenting a quantitative analysis showing the potential of this approach. The IRWV data appears to provide a more decisive correlative element for TC intensity than achieved with the IR aveT_b values alone; we will investigate this area further for possible applications to the ADT in a follow-on GIMPAP proposal that was accepted for funding in FY 2010-11.

2) Analyze and mitigate known biases in the ADT estimates. Primary example: ADT has difficulty with emerging EYE scenes.

An important ADT issue has been addressed that focuses on emerging eye cases, where the ADT plateaus at an intensity that has been shown to be too weak because the eye cannot be resolved adequately in the IR due to cirrus debris. Our mitigation strategy involved the incorporation of polar-orbiting microwave data to discern EYE scene types during obscuration in the IR. The microwave views through this debris to denote eye structure, and we have tested new logic to over-ride the ADT IR-based scene typing if an eye is observed in the microwave data. Experimentation with this approach commenced on real time cases in 2008. Our final validation assessment was conducted during this reporting period. From these results, the scheme is indeed very successful in lowering the errors associated with the ADT estimates as is indicated in both the hPa and Dvorak T-number metrics of performance. Transition of this modification into the NESDIS operational ADT code is now underway under PSDI funding.

3) Explore extending the ADT scope of operations to pre-Depression, Subtropical, and Extratropical Transition stages. The current version only operates on purely tropical systems of at least Depression strength.

No efforts on this approach were conducted during this reporting period.

Proposal Task 2: Continue the development and evaluation of a new TC intensity estimation algorithm called SATCON, which yields a weighted consensus estimate of TC intensity from multiple satellite sources (incl. GOES/ADT).

The CIMSS TC group continues to explore an integrated approach to satellite-based TC intensity estimation through a weighted consensus of satellite-based ADT, and AMSU methods derived at CIMSS and at CIRA. The approach (SATCON) has first identified the strengths and weaknesses of each individual method, which is then used to assign weights towards a consensus algorithm designed to better estimate TC intensity. An updated statistical analysis (see previous report) reveals the approach is superior to the independent algorithms evaluated alone. The cross-platform approach uses information derived from the estimate methods (i.e., CLW, AMSUB 89 GHz, ADT Eye temps and RMW) to make intensity adjustments to the individual member values. Once these adjustments are made, we then apply the consensus weighting scheme. This approach has resulted in an improvement in skill compared to simply weighting the members with no adjustments, or with just a simple un-weighted consensus.

The primary research on the SATCON algorithm during this period was the implementation of the microwave-based ADT, replacing the previous ADT (IR-only) member in the SATCON algorithm. Re-processing of cases from 2005 to present is underway and expected to yield sufficient cases for a re-derivation of the SATCON weighting scheme. We will test the new SATCON weighting scheme in near real time during the upcoming 2010 hurricane season, and will re-evaluate it after the season for potential transition into NESDIS-SAB operations via a PSDI proposal.

Proposal Task 3: As part of public outreach and improving user utilization of GOES data, we have set up an on-line archive of GOES derived products developed and processed by the CIMSS TC group over the past decade.

GOES datasets and products are continuously requested and provided to the user community for expanding scientific research on TCs. As reported earlier, we had completed the transfer of historical datasets on archive tapes to an on-line storage facility towards the development of an on-line GOES TC product archive. Data and products from over 10 years of tapes have been uploaded to the on-line archive site. The first phase of a graphical user interface has been designed for outside requesters of the GOES TC products, and has completed beta testing. The on-line archive site is now active to the outside user community, and has already been accessed by over 100 user requests at the time of this writing. Users are able to find products using searches based on date or tropical cyclone names. Comments from users have been very positive. Requests have been filled for users around the globe, including U.S. government and educational institutions. Researchers are now able to get very large quantities of data on their own, in a very short period of time. The site can be found at:

http://tropic.ssec.wisc.edu/archive/

Operational Transition Activities

Proposal Task 1: The experimental ADT upgrades are being implemented into the operational ADT algorithm at NESDIS-SAB via a GPSDI grant that is in place. The upgrades are also part of the ADT code deliveries within the milestones of the GOES-R/AWG program.

Proposal Task 2: The SATCON algorithm is being evaluated in tandem with analysts at NESDIS SAB, NWS/NHC, and JTWC during the 2010 tropical cyclone season. After that evaluation is completed, a decision will be made on operational transition through PSDI or JHT funding mechanisms.

Publications

Olander, T. and C. Velden, 2009: Tropical cyclone convection and intensity analysis using differenced Infrared and water vapor imagery. *Weather and Forecasting,* **24***, 1558-1572*.

2.9. GOES Atmospheric Motion Vectors (AMV) Research

Task Leader: Chris Velden
CIMSS Collaborators: Steve Wanzong, Howard Berger
NOAA Strategic Goals:

- Serve society's needs for weather and water

CIMSS Research Themes:

- Weather, Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Background and Motivation

The CIMSS automated satellite-derived winds tracking algorithm is continuously evolving. In order to advance the software package, new science and research ideas need to be developed and tested at CIMSS in collaboration with winds research collaborators at NOAA/NESDIS and elsewhere. Innovations in the CIMSS automated wind derivation techniques and its applications often lead to improved wind information from GOES for operational and research use.

This research is being conducted to help mitigate the existing limitations of the GOES Atmospheric Motion Vectors (AMV) product; directed at the two key areas of vector height assignment and quality confidence. The research strategies proposed are novel, and promise to improve on the product quality. AMVs are a fundamental variable observable from GOES, and can have a high impact in NWP data assimilation and prognoses. The two key outstanding issues of vector height assignment and quality confidence are what we aim to address in this research. The tasks build on a long and successful GIMPAP AMV research program at CIMSS. Both the national and international met communities have frequently cited the importance of GOES AMV products developed by CIMSS under NOAA GIMPAP support. We use feedback as motivation to continue to search out ways to improve GOES AMV product development.

Primary Accomplishments

Proposal Task 1: Continue the exploration of new and improved techniques for GOES AMV height assignments (largest source of vector RMSE).

To accomplish this task we continue research on GOES AMV representation in terms of the *layer* being tracked. The goal is to move away from the traditional *level* height assignment. The results presented in previous reports are quite encouraging to lower vector RMSE. An example is shown in Figure 2.9.1 below. This work was published in the March 2009 volume of the Journal of Applied Meteorology.

Proposal Task 2: Continue the evaluation of improved quality indicators (QIs) for GOES AMVs; specifically, to further the testing and assessment of the newly-developed "Expected Error" QI. The significance is: 1) Potential to improve AMV data assimilation, and 2) Potential to replace the cumbersome Auto Editor in the NESDIS operational AMV production algorithm.

Good progress and final statistical results were shown in the previous reporting period. Results of considering the EE in tandem with the QI were promising, with the primary goal of developing a quality control scheme involving the EE that varies as a function of AMV speed in order to prevent the unwanted removal of high-speed AMVs. Our recommendations for this approach have been passed to NOAA/NESDIS/STAR.

This work should benefit data assimilation. The results have been discussed with data assimilation experts from NWP centers, and CIMSS is now providing the layer-mean information as an attachment to the AMV data records that is being sent to selected NWP centers interested in the data monitoring and assimilation assessment.

Operational Transition Activities

Proposal Task 1: The AMV layer-mean height parameter has transition potential. However, this transition potential will depend on the NWP follow-up and user request.

Proposal Task 2: The log-EE QI parameter is being included into the GOES-R AMV processing package as part of the GOES-RRR and AWG programs. In this sense, it is being transitioned. The method may also be considered by NESDIS STAR for transition and integration into the existing GOES AMV processing algorithm.

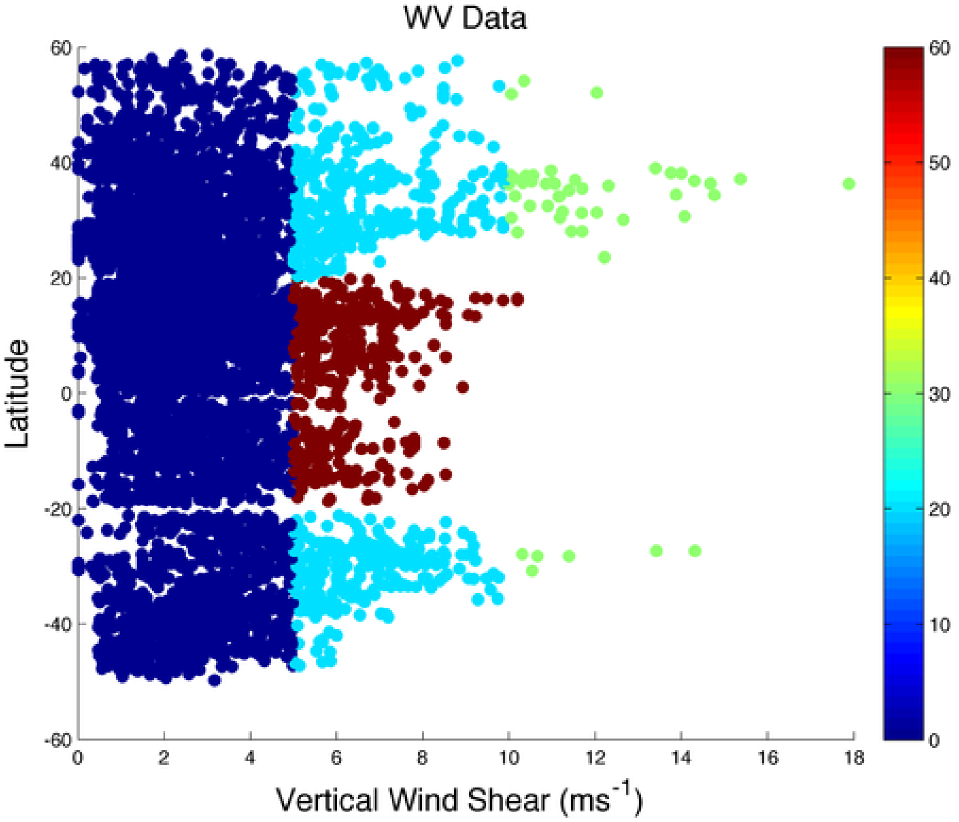


Figure 2.9.1. Based on a statistical study in (Velden and Bedka, 2009), assigning AMVs to a tropospheric layer of finite thickness (hPa), rather than a single level, for their height attribution has been shown to reduce vector errors as compared to collocated RAOBS. Based on this study, in the example above a day's worth of GOES WV AMVs have been assigned to layer thicknesses based on their local latitude and vertical wind shear regime (taken from the Navy NOGAPS model). The colors in the scatter plot represent the assigned layer of best fit thickness (hPa). For higher shear regimes, the AMVs are best represented by a deeper tropospheric layer, with slightly thicker layers assigned to vectors in the deep tropics.

2.10. Using AWIPS to Expand Usage of GOES Imagery and Products (including those from the GOES Sounder) in NWS Forecast Offices

Task Leaders: Scott Bachmeier, Jordan Gerth
NOAA Collaborator: Gary Wade
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
- Education, Training and Outreach

Project Summary and Motivation

The Advanced Weather Interactive Processing System (AWIPS) is the primary tool used by National Weather Service (NWS) meteorologists for viewing current weather information, such as satellite imagery, model output, and observations, pertinent to forecast preparation. Until recent work was done, previously supported by GIMPAP, AWIPS could only be run at NWS Forecast Offices (FOs) due to its complex infrastructure. It was difficult for research institutes to create training modules in which AWIPS was employed, which diminished their practical value to field meteorologists. Furthermore, there was no way to provide additional data which sampled cutting-edge research in progress, and could add value to the forecast process. The potential strongly continues for the further creation and deployment of experimental satellite imagery and products into AWIPS, particularly from the Geostationary Operational Environmental Satellite (GOES) Sounder, that can enhance operations at National Weather Service offices nationwide. Subsequent training modules can provide a meaningful demonstration of such imagery in AWIPS to forecasters. Current non-operational GOES Imager and GOES Sounder products from CIMSS/SSEC, undergoing evaluation at NWS Forecast Offices, have shown some positive results to date, and the interest remains.

Although GOES-R will not have an improved hyper-spectral interferometer sounder, the Advanced Baseline Imager (ABI) on GOES-R will provide some assortment of multi-spectral channels, capable of generating some sounding-like integrated quantities (such as total moisture or bulk stability). As the current, limited filter-wheel GOES Sounder products have a similar information content to proposed GOES-R products (also referred to as "Sounder legacy products"), improvement of the application of current geo sounder products (and eventual incorporation into AWIPS) meshes well with preparations for GOES-R data and products. Furthermore, as the GOES-R data stream is anticipated to be available no earlier than after 2015, and current GOES Sounders may continue operating for years after the GOES-R launch, it remains practical and expedient to continue to exploit the limited sounder on the current GOES as best as is possible.

Transitioning cutting-edge research to the operational environment through AWIPS maximizes the benefits to all cooperating NOAA employees and team members by:

1. Increasing the dialogue between researchers and forecasters so that scientists can tailor their research to meet the changing needs of field meteorologists, and forecasters can provide critical feedback to scientists before products are implemented operationally;
2. Encouraging the use of current Geostationary (GOES) and Polar-orbiting Operational Environmental Satellites (POES) in new ways;
3. Providing a forum to answer questions from the field and provide meaningful training exercises to assure appropriate and maintained use of satellite data as a fundamental part of the forecast process;
4. Expanding the applications for satellite data;

5. Saving bandwidth on existing product delivery infrastructure through assuring forecasters only have the best, most pertinent imagery and products available; and
6. Introducing researchers to AWIPS.

This effort supports the NOAA Mission Goal of: “serving society’s needs for weather and water information,” in line with the NOAA cross-cutting priority of: development and distribution of “sound, reliable state-of-the-art research.”

Accomplishments

- Regular, periodic visits to the NWS FO in Sullivan, WI (MKX) were provided by J. Gerth, on a monthly basis throughout the period, to insure that the FO staff were aware of the latest CIMSS products available on AWIPS, to make sure that the AWIPS data transfers were smoothly occurring as expected, and to gain feedback from forecasters. As noted in the previous 6 month period report, larger group visits between CIMSS staff and NWS-MKX staff did occur on 27 Jan 2009 as well as on 17 Feb 2009. (Although no group visits with NWS-MKX are currently planned for 2010, there are plans being arranged for individual CIMSS staffers to participate in routinely spending a shift at NWS-MKX during the late spring and summer of 2010, typically providing for, on a one-or two- day a week basis, close interaction and mutual learning between forecasters and developers.)
- 15 live tele-training sessions were presented during the latter half of 2009, of the following VISIT (Virtual Institute for Satellite Integration Training) lessons, which address the use of GOES imagery in the forecast process: “Basic Satellite Principles,” “Water Vapor Imagery and Potential Vorticity Analysis,” “Interpreting Satellite Signatures,” “The Enhanced-V: A Satellite Indicator of Severe Weather,” “Mesoscale Convective Vorticies,” and “TROWAL Identification.” These VISIT lessons were done with a variety of NWS Forecast Offices.
- 56 new GOES-related “mini-cases,” with many typically showing displays from AWIPS, were added to the CIMSS Satellite Blog during the Jul-Dec 2009 period [http://cimss.ssec.wisc.edu/goes/blog]. {See Figures 2.10.1 and 2.10.2.}
- 47 new NWS AFDs (Area Forecast Discussions), mentioning either CRAS and/or MODIS products (as provided in AWIPS by CIMSS) were noted during this period. CRAS, the CIMSS Regional Assimilation System, utilizes GOES Sounder products (of moisture and cloud) to provide the best initial conditions as well as effectively preserving that unique information through its future time steps as the forecasts are generated. GOES Sounder products are also an essential input to the “dynamic nearcasting” system of Petersen and Aune, which will be part of the new product suite discussed and evaluated during the day visits to NWS-MKX during the spring and summer of 2010.

Operational Transition/Importance to NOAA/GOES

As already described in the Project Summary and Motivation section above, the GOES-R ABI will provide a small variety of multi-spectral channels, capable of generating some sounding-like integrated quantities (often referred to as the “legacy Sounder products”). As the current GOES (limited filter wheel) Sounder products have a similar information content to proposed GOES-R products, research and development for improvement of current geo sounder products mesh well with preparations for GOES-R legacy Sounder products. And, as the GOES-R data stream is anticipated to be available no earlier than after 2015, it continues now to remain most practical and expedient to continue to exploit the limited sounder on the current GOES as best as is possible, and via the most appropriate means of distribution, currently for the NWS, being AWIPS. Thus, on-going assessment of the newly implemented and routinely generated Li et al. (2008)-based GOES Sounder algorithm continues, as the suite of new Li-based Derived Product Imagery (DPI) is planned, next, to be provided to the CIMSS AWIPS. This new version has appeared more consistent, being smoother and much less prone to showing extreme values of moisture or instability, as often has been observed with the older, but still operational, algorithm, being that of Ma et al. (1999). [This development and promotion of the newer GOES Sounder Products within AWIPS is increasingly falling under the efforts of the GOES-R Proving Ground, while promotion of GOES Sounder Products themselves relies on the success of the GIMPAP funded effort to develop a cloudy retrieval as well as to intrinsically improve the traditional physical retrieval.]

Publications and Conference Reports

A poster presentation was provided by G. S. Wade, at the 6th GOES Users Conference, in Madison, WI on 04 Nov 2009, entitled: "Insuring incorporation of improvements to the GOES Sounder vertical profile retrieval algorithm into NOAA/NESDIS operations" by Wade, G. S., Z. Li, J. P. Nelson, J. Li, and T. J. Schmit. This display discussed evaluations of the on-going implementation of the latest version of the retrieval algorithm, which, when satisfactory, will be further evaluated by provision from CIMSS, to select NWS offices, via the AWIPS data stream feed provided by this project. The poster is available at: ftp://ftp.ssec.wisc.edu/pub/garyw/GUCposter-InsureGSndrImprov-GSW-20091102.ppt. {An example of the real-time comparisons being done to verify and evaluate the implementation of the new Li et al. (2008) version of the GOES Sounder retrieval algorithm is shown in Figure 2.10.3. Provision to AWIPS of the Li-based GOES products can not be done until satisfactorily demonstrated to be no worse than the previous Ma et al. (1999) version.}

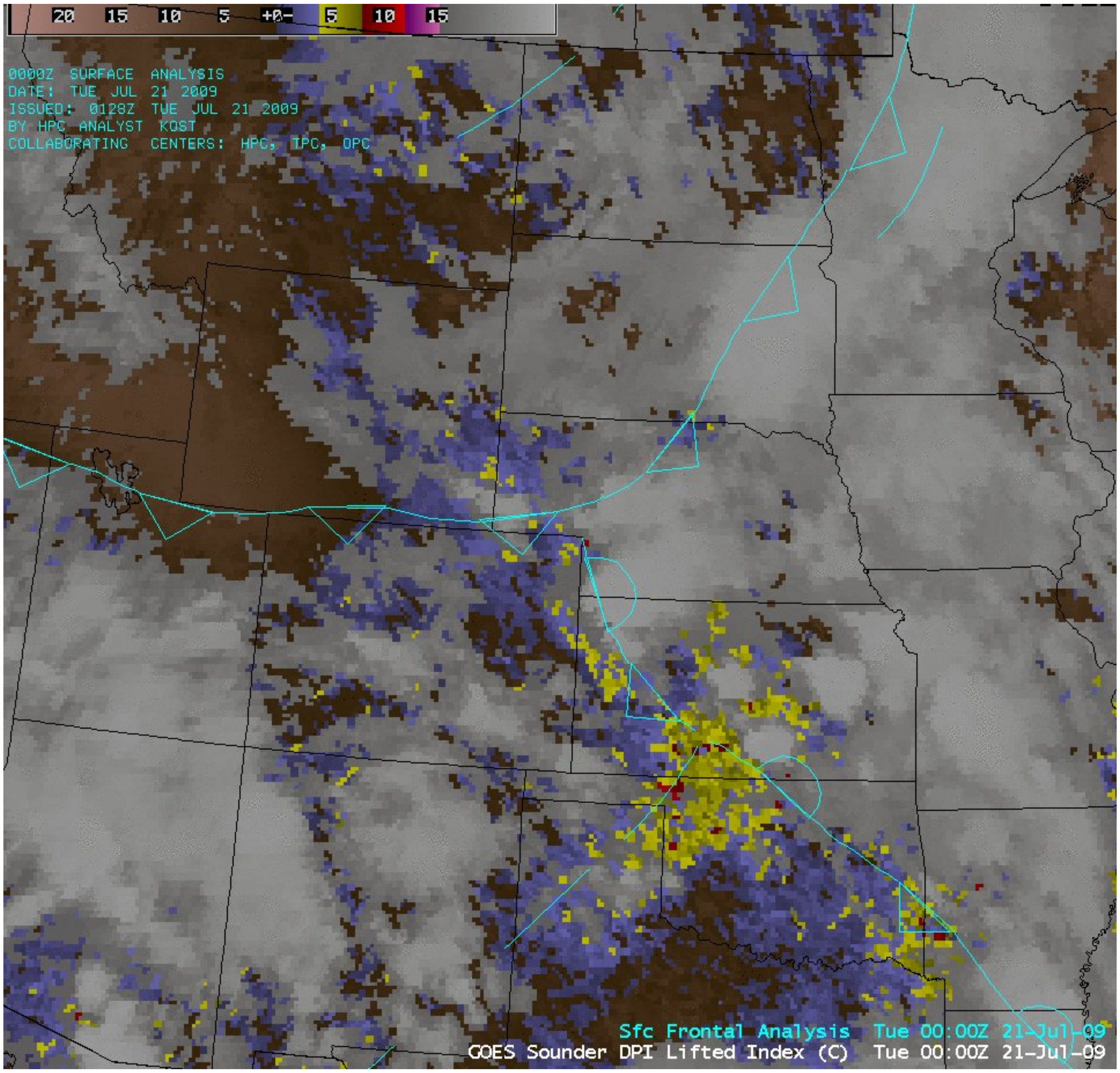


Figure 2.10.1. As shown on the CIMSS Satellite Blog, GOES Sounder LI (lifted index) DPI are included in the discussion about the severe weather on 20-21 Jul 2009 over the US central High Plains. Favorable instability, for severe convection, is evident over far northern Oklahoma and across Kansas in the LI DPI, on AWIPS, at 00 UT on 21 Jul 2009. Although not sufficient in itself to provide a complete forecast, the LI DPI (and its trend and location) can be a corroborating, or a challenging, input factor to the forecast process. A few tornadoes, along with numerous reports of large hail, were observed across far western Kansas; a number of severe hail and wind reports were also noted throughout southeast central Kansas.

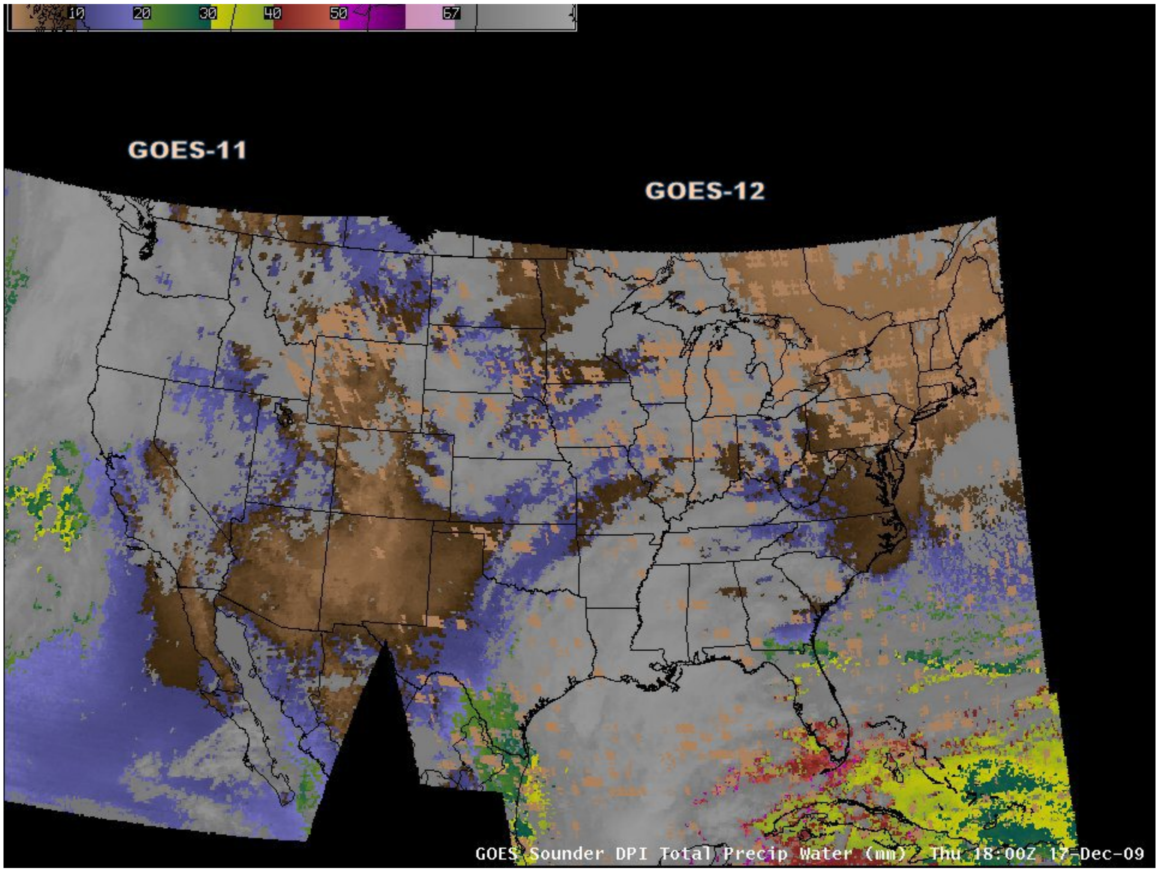


Figure 2.10.2. As shown on the CIMSS Satellite Blog, when satellite instrument performance issues become relevant (in this case, the GOES-12 Sounder continued to suffer from increasing significant noise problems during the fall of 2009), sample problem imagery on AWIPS is identified and shown, and the users are alerted to the difficulties. Small, incorrect, irregular patches (in light tan, i.e., very dry air) are evident in the GOES Sounder TPW (total precipitable water) DPI, for 18 UT on 17 Dec 2009, across the GOES-12 sector (east half of the composite image), due to increasingly bad data in the GOES-12 Sounder short wave CO2 spectral bands. Otherwise, rather moist air (30-40mm+) is seen around Cuba, the Bahamas, and Florida, as well as, across to the far western Gulf of Mexico; dry air (<5-10mm) dominates over the northeast US and southeast Canada, as well as, along the Rockies and into the southwest US.

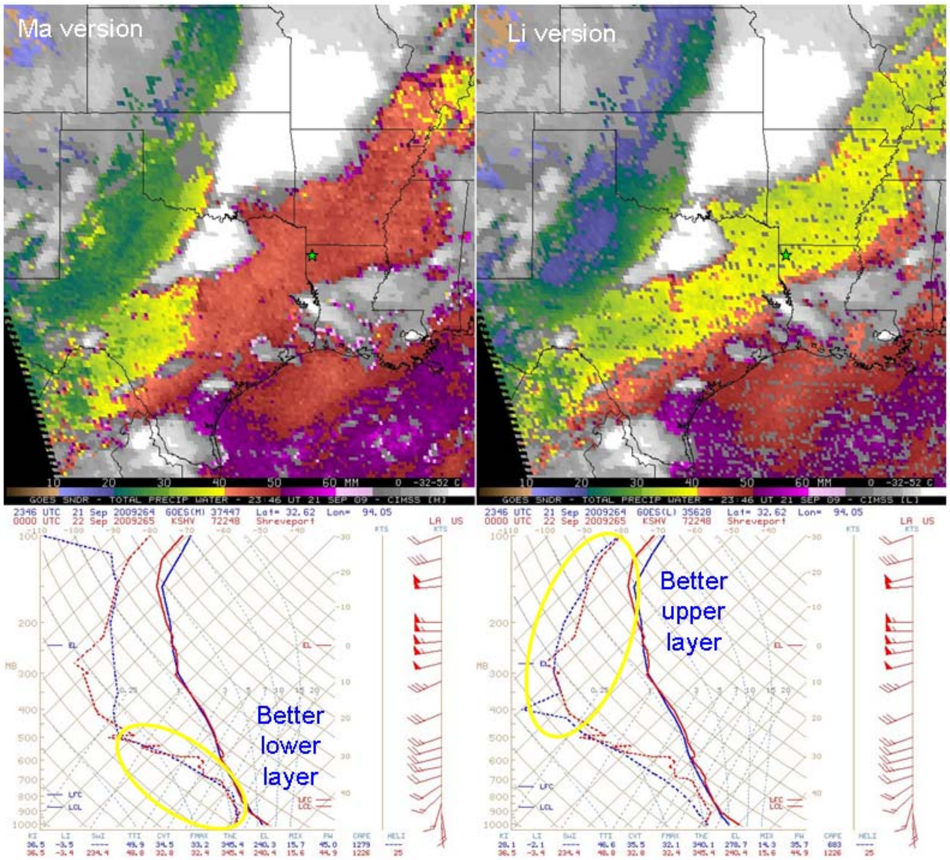


Figure 2.10.3. Comparison is shown between results from the (left) older “Ma” version and the (right) newer “Li” version of the GOES Sounder retrieval algorithm for nominally 00 UT on 22 Sep 2009, with DPI of TPW on top, and with skew-T/log-P comparisons with the co-located Shreveport, LA radiosonde, on the bottom. The Ma version typically is seen as too moist (with problematic extremes in the past), while the Li version often seems to run dry. This example illustrates how the Ma version has tended to do better at low levels, while the Li version handled upper levels better. (It also is evident, by the shot noise, that the Li version is more sensitive to the noise difficulties now occurring with some GOES-12 Sounder bands.)

3. CIMSS Support for Polar & Geostationary Satellite Science Topics (P & G PSDI)

3.1. Operational Implementation of the CIMSS Advanced Dvorak Technique (ADT)

Task Leaders: Tim Olander, 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. The algorithm runs in a completely automated fashion through the use of a series of scripts to process IR satellite imagery and collect needed auxiliary data to generate output products. As previously reported, the ADT has been migrated to the operational framework environment at NOAA's Satellite Analysis Branch (SAB) through collaborative efforts by scientists and programmers at CIMSS and NOAA. During this reporting period, the primary focus has been on 1) derivation of an algorithm verification suite of programs/scripts to evaluate the accuracy of the ADT versus several "ground truth" sources, and 2) evaluation of new Version 8.1.1 utilizing the performance verification suite. ADT v8.1.1 includes innovative techniques to utilize auxiliary passive microwave (PMW) information to augment the ADT IR-based analysis in situations where the ADT has historically had trouble deriving accurate intensity estimates; the period just prior to eye formation when the TC center is shielded by cirrus overcast.

Summary of Accomplishments and Findings

Version 7.2.3 of the ADT was released to SAB in 2008 and was declared fully operational by NOAA/OSDPD in April of 2009. Due to a NOAA freeze on any software updates, this version is still the current version being utilized by NOAA/SAB during 2010. A new version of the ADT (Version 8.1.1) has been implemented at CIMSS for testing on 2010 cases, with SAB using the results provided from this version for its own verification to assess the improvements of v8.1.1 over v7.2.3. In order to automate the verification process for the ADT algorithm, a suite of programs and LINUX shell scripts have been created to derive various statistical parameters to verify the accuracy of the ADT versus SAB Dvorak estimates, NHC "Best Track" data, and/or aircraft reconnaissance in situ intensity information. This process had been conducted manually by NOAA/SAB scientists using Microsoft Excel spreadsheets, but it was very labor intensive. An automated approach was derived at CIMSS to mimic the Excel spreadsheet methodology in order to expedite the verification process. This verification suite has been utilized during the 2010 season for all global storms (including the Atlantic, East Pacific, West Pacific, Indian Ocean, and South Pacific) with results posted on a Web site for NOAA/SAB scientists to verify the performance of the verification suite against those produced using the Excel methodology. It is expected this new code will be migrated to NOAA/SAB machines once the NESDIS software freeze has been lifted.

During this reporting period, CIMSS scientists also aided SAB programmers on adding the relevant microwave data streams locally and interfaces necessary for v8.1.1 to operate when the freeze is lifted.

Publications and Conference Reports

Sears, J., T. Olander, and C. Velden, 2010: Recent Statistical Analysis of the Advanced Dvorak Technique (ADT), 29th AMS Hurricanes and Tropical Meteorology Conference, Tucson, AZ, May 10-14.

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.

3.2. GOES-14 and 15 Checkout & Data Analysis

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:

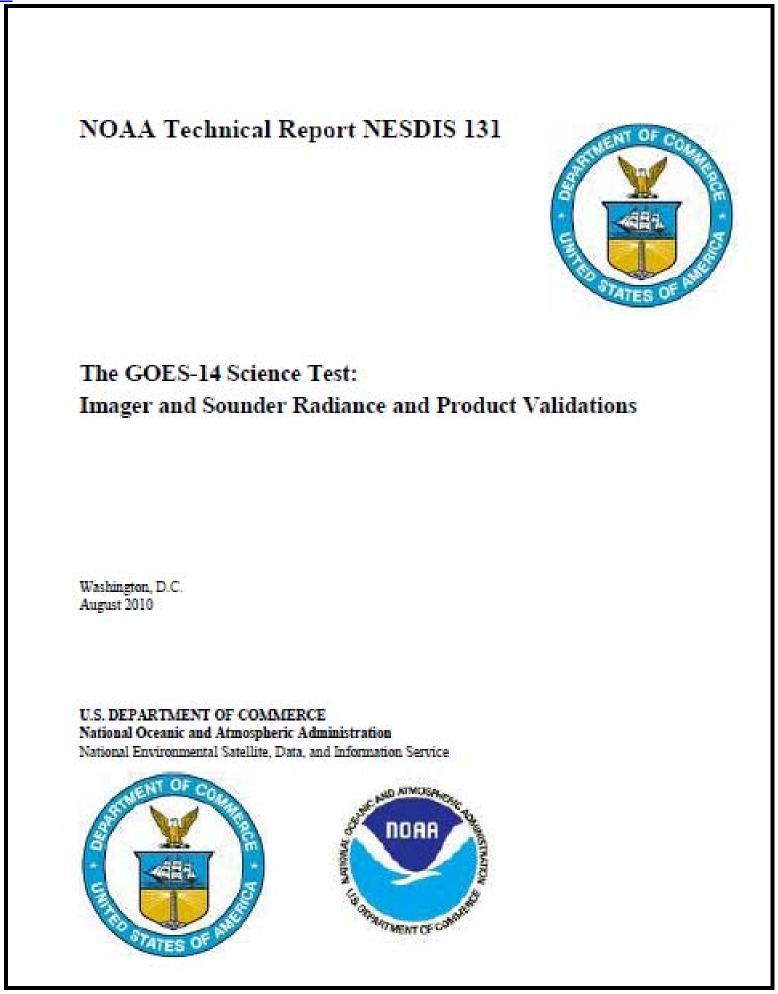
- Comparison of observed clear-sky brightness temperatures with current operational GOES satellites and NOAA polar-orbiting platforms. The purpose is to determine if pre-flight spectral response information and weighting functions are in need of adjustment.
- Acquisition and archive of the GOES-14 & -15 GVAR data during the NOAA Science tests.
- 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.
- 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 3.2.1) 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 3.2.1. 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 3.2.2). 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.

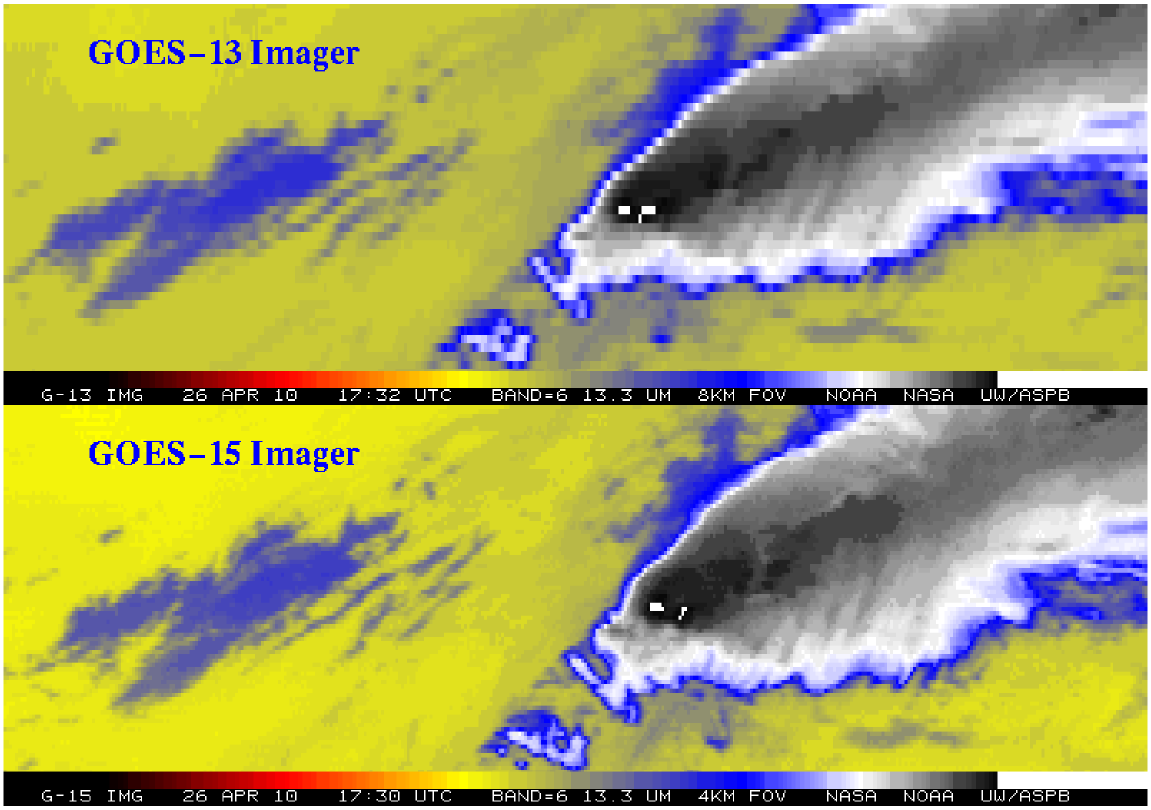


Figure 3.2.2. A comparison of GOES-13(8 km Instantaneous Geometric Field of View) and GOES-15 (4 km) Imager Band 6 (13.3µm) on 26 April 2010. Note the 'cleaner' image from GOES-15.

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 randomly 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 3.2.1). 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 3.2.1. 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 v.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.

4. Ground Systems Research

4.1. Support for CIMSS Satellite Validation Infrastructure

Task Leader: Wayne Feltz
CIMSS Support Scientists: Erik Olson, Bruce Flynn, Joe Garcia
NOAA Collaborators: Brad Pierce, Tim Schmit
NOAA Strategic Goals

- Serve society's needs for weather and water information

CIMSS Research Themes

- Weather Nowcasting and Forecasting

Proposed Work

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

SSEC/CIMSS recently acquired a 14-channel microwave profiler (22-60 GHz) and a high frequency 90/150 GHz microwave radiometer, greatly expanding our remote sensing capabilities to measure temperature, water vapor, and cloud properties from our rooftop and mobile weather laboratory. This new acquisition complements the Atmospheric Emitted Radiance Interferometer (AERI) that routinely measures the downwelling infrared radiance at high spectral resolution, providing accurate temperature and moisture retrievals of the lower troposphere every 10 minutes (or higher temporal resolution). SSEC is currently building a High Spectral Resolution Lidar (HSRL) with support from NSF funding that will provide continuous retrievals of cloud and aerosol properties. These four remote sensing instrument systems are housed in a SSEC rooftop laboratory and are also available for deployment in the field.

Other existing SSEC/CIMSS rooftop instrumentation includes a Vaisala RS-92 GPS capable rawinsonde launch and receiver system, a Multi-Filter Rotating Shadowband Radiometer (MFRSR) providing solar derived aerosol optical depth, a Total Sky Imager (TSI) providing cloud fraction and daytime sky imagery, a Vaisala ceilometer for cloud base height measurements, a standard surface meteorological tower, GPS total precipitable water receiver, a rooftop camera, longwave broadband flux instrumentation and a lake buoy with meteorological instrumentation.

We plan to incrementally update our data from these instruments as they are made available.

Once fully integrated, this instrument suite will allow for atmospheric monitoring of temperature/moisture profiles, integrated water vapor, atmospheric stability, liquid water path, aerosol optical depth, total cloud fraction, cloud phase, and cloud extinction profiles useful for ongoing GOES and POES satellite product validation efforts. Both our fixed rooftop site and our mobile laboratory are excellent observation and validation facilities that will greatly benefit NOAA programs.

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

Summary of Accomplishments and Findings

With this resource, SSEC has developed the Ground-based Atmospheric Monitoring Instrument Suite (GAMIS) that collects, archives, and displays near-realtime data from various instruments on SSEC rooftop and lake Mendota buoy.

A diagram of GAMIS data flow is shown in Figure 4.1.1 essentially showing data flowing from rooftop instruments to various computing nodes, archival system, and quicklook pages.

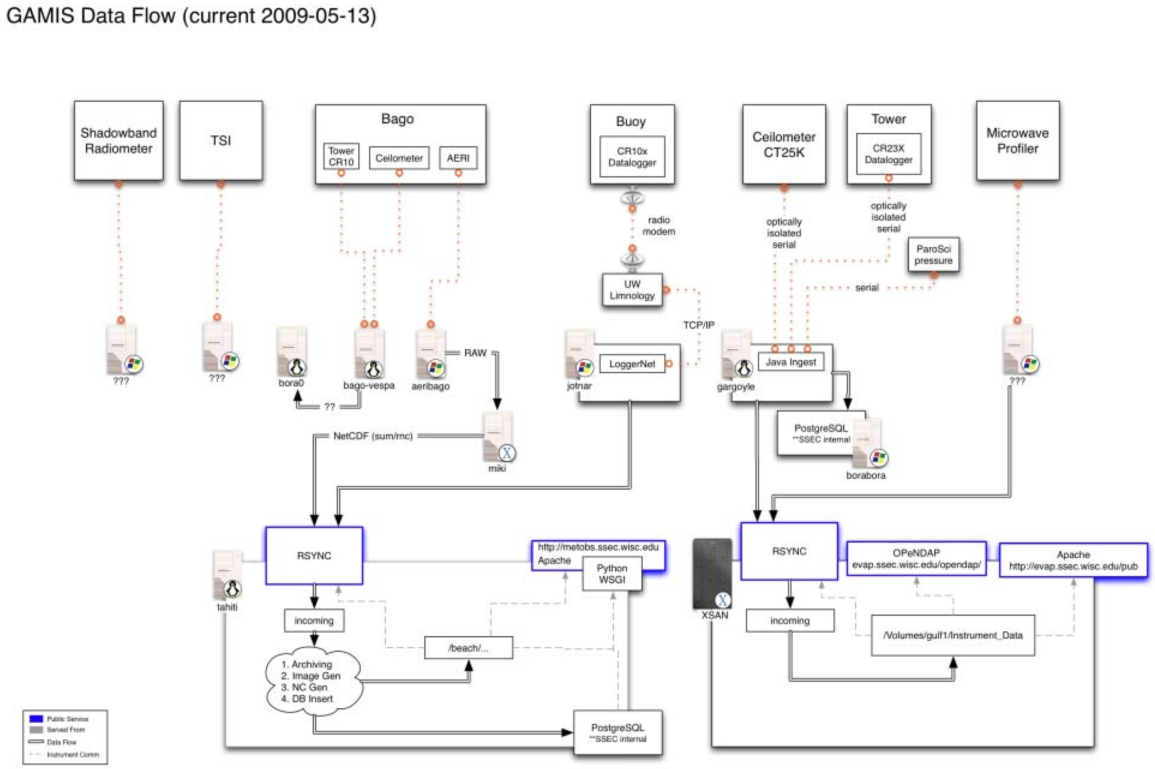
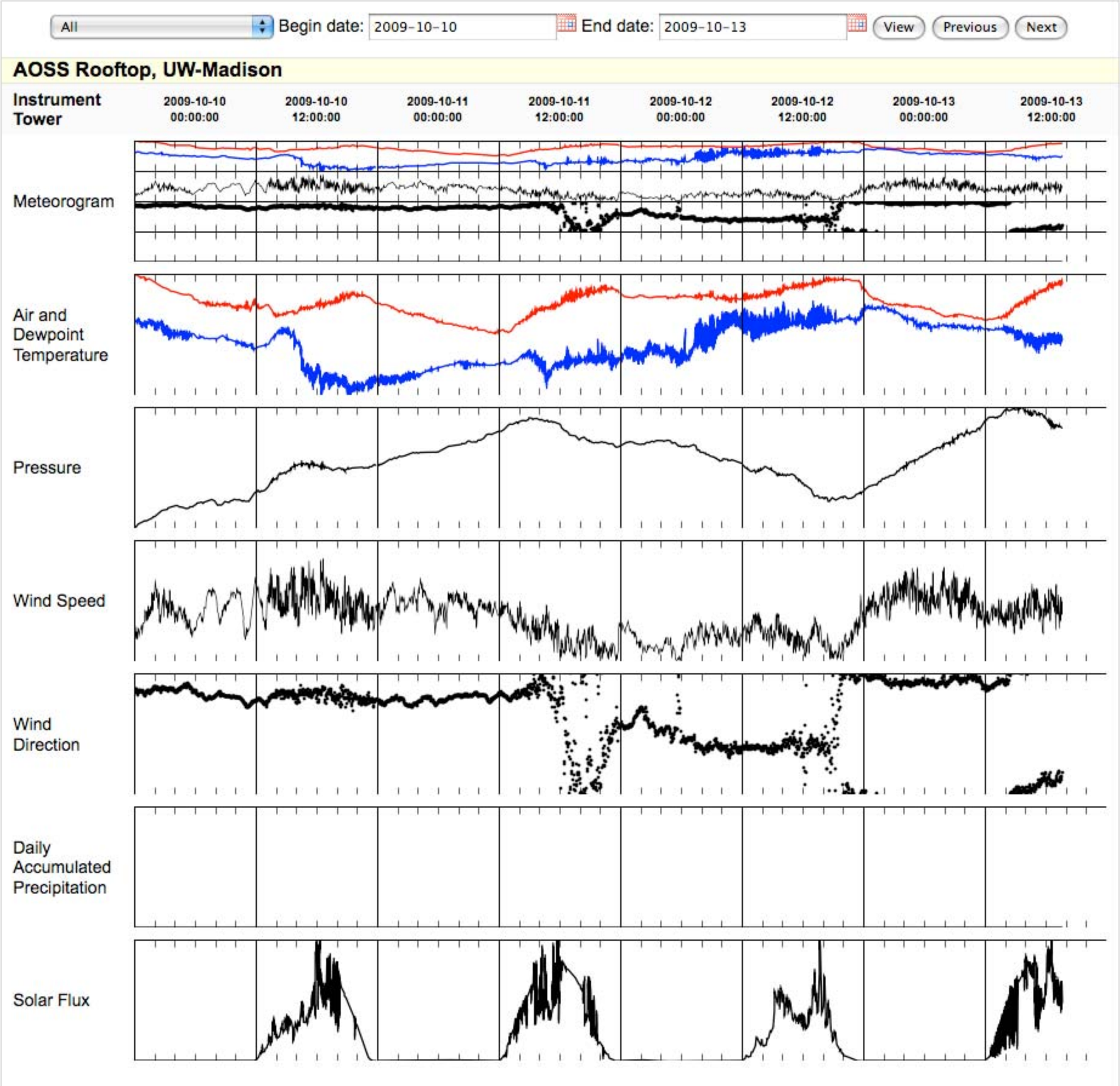


Figure 4.1.1. A diagram indicating GAMIS flow of data from instruments to computer servers, archival system, and final display.

A near real-time quicklook interface (Figure 4.1.2) for rooftop data and buoy (Figure 4.1.3) has been developed at:

http://metobs.ssec.wisc.edu/quicklooks/

The datasets are collected in a central location, convert all data files to NetCDF, and reformatted to achieve Climate and Forecast (CF) netCDF compliance. A Vaisala Ceilometer, lake buoy, AERI and microwave data have been added to archive and new datastreams are pending. In 2010, three rooftop atmospheric monitoring cameras have been installed on roof allowing access to real-time (Figure 4.1.4) and archived movies of weather events. This information is key when selecting certain validation criteria days for satellite and ground-based product cross reference.


All
Begin date: 2009-10-10
End date: 2009-10-13

AOSS Rooftop, UW-Madison

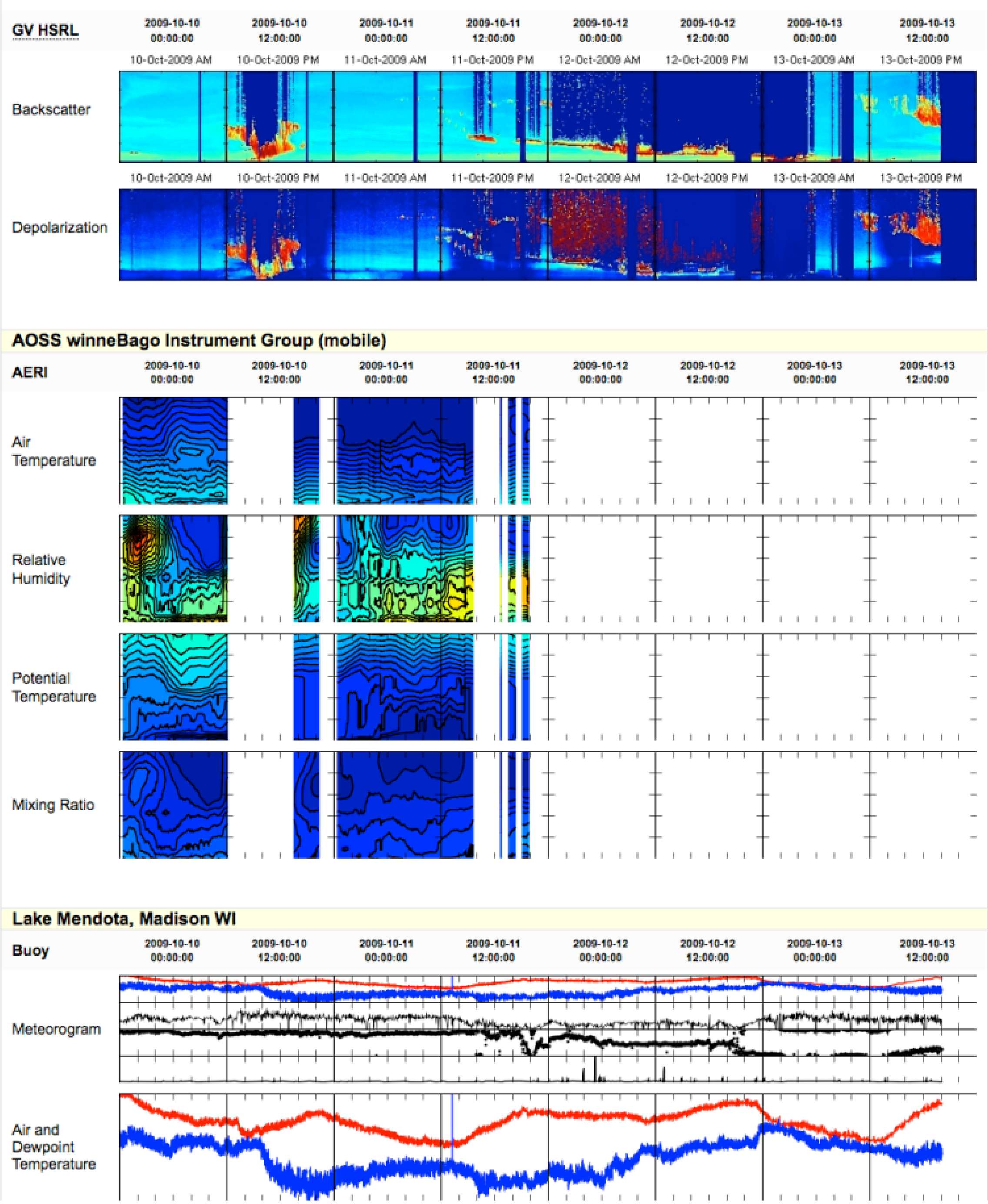
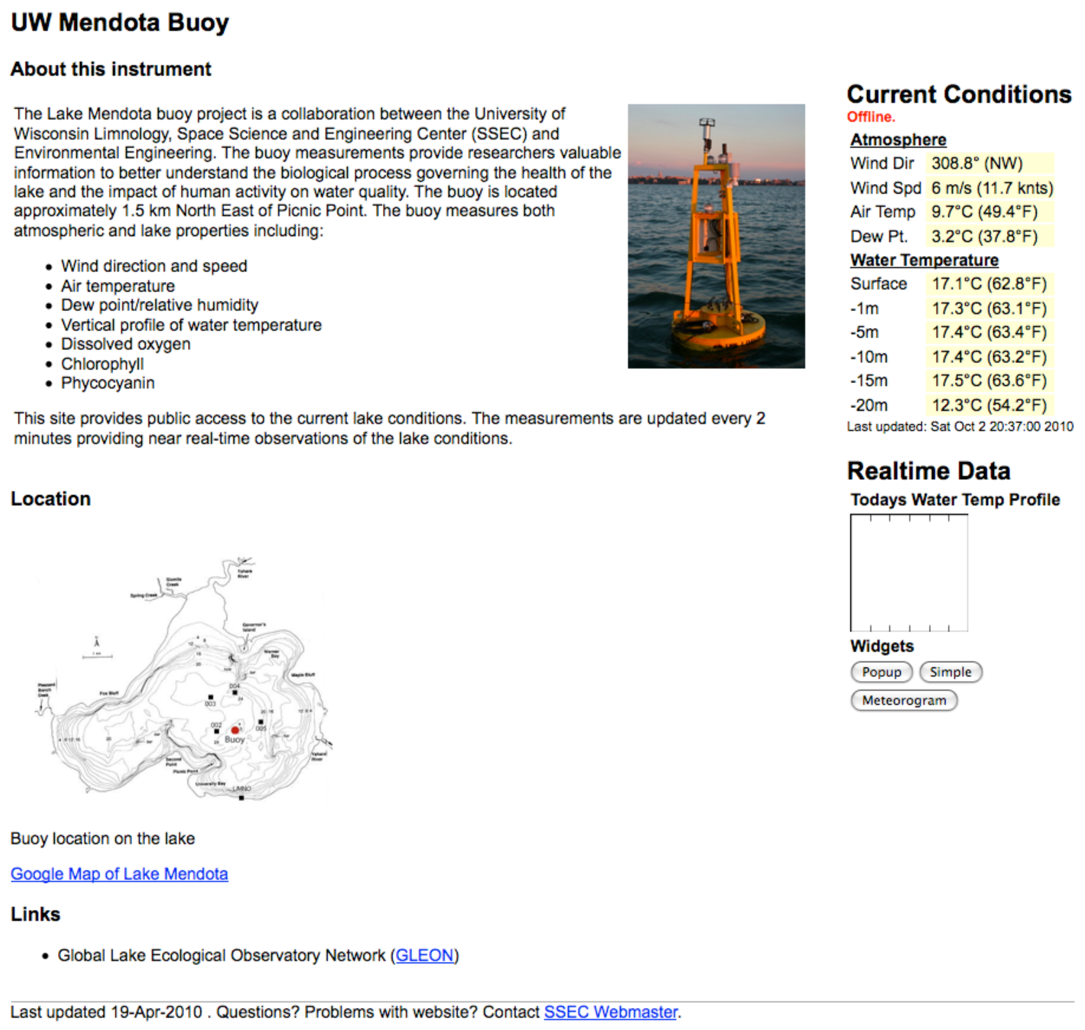


Figure 4.1.2. Example of quicklook interface to AOSS rooftop data.



UW Mendota Buoy

About this instrument

The Lake Mendota buoy project is a collaboration between the University of Wisconsin Limnology, Space Science and Engineering Center (SSEC) and Environmental Engineering. The buoy measurements provide researchers valuable information to better understand the biological process governing the health of the lake and the impact of human activity on water quality. The buoy is located approximately 1.5 km North East of Picnic Point. The buoy measures both atmospheric and lake properties including:

- Wind direction and speed
- Air temperature
- Dew point/relative humidity
- Vertical profile of water temperature
- Dissolved oxygen
- Chlorophyll
- Phycocyanin

This site provides public access to the current lake conditions. The measurements are updated every 2 minutes providing near real-time observations of the lake conditions.

Current Conditions

Offline.

Atmosphere	
Wind Dir	308.8° (NW)
Wind Spd	6 m/s (11.7 knts)
Air Temp	9.7°C (49.4°F)
Dew Pt.	3.2°C (37.8°F)
Water Temperature	
Surface	17.1°C (62.8°F)
-1m	17.3°C (63.1°F)
-5m	17.4°C (63.4°F)
-10m	17.4°C (63.2°F)
-15m	17.5°C (63.6°F)
-20m	12.3°C (54.2°F)

Last updated: Sat Oct 2 20:37:00 2010

Realtime Data

Todays Water Temp Profile

Widgets

Location

Buoy location on the lake

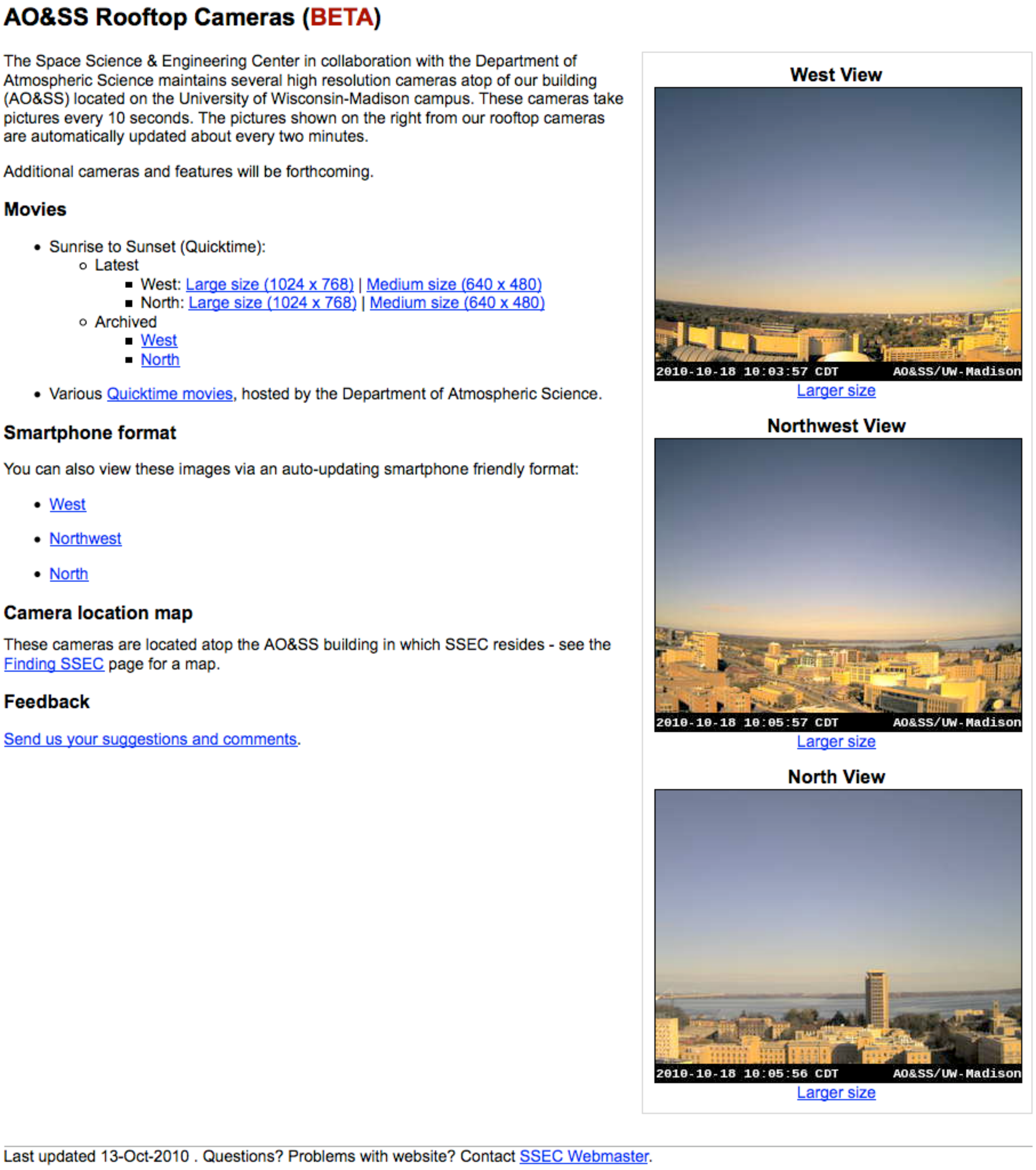
Google Map of Lake Mendota

Links

- Global Lake Ecological Observatory Network (GLEON)

Last updated 19-Apr-2010 . Questions? Problems with website? Contact SSEC Webmaster.

Figure 4.1.3. Example of Lake Mendota Buoy quicklook interface.



AO&SS Rooftop Cameras (BETA)

The Space Science & Engineering Center in collaboration with the Department of Atmospheric Science maintains several high resolution cameras atop of our building (AO&SS) located on the University of Wisconsin-Madison campus. These cameras take pictures every 10 seconds. The pictures shown on the right from our rooftop cameras are automatically updated about every two minutes.

Additional cameras and features will be forthcoming.

Movies

- Sunrise to Sunset (Quicktime):
  - Latest
    - West: Large size (1024 x 768) | Medium size (640 x 480)
    - North: Large size (1024 x 768) | Medium size (640 x 480)
  - Archived
    - West
    - North
- Various Quicktime movies, hosted by the Department of Atmospheric Science.

Smartphone format

You can also view these images via an auto-updating smartphone friendly format:

- West
- Northwest
- North

Camera location map

These cameras are located atop the AO&SS building in which SSEC resides - see the Finding SSEC page for a map.

Feedback

Send us your suggestions and comments.

West View

Larger size

Northwest View

Larger size

North View

Larger size

Last updated 13-Oct-2010 . Questions? Problems with website? Contact SSEC Webmaster.

Figure 4.1.4. Example of AOSS west, northwest, and north facing cameras recently installed on building rooftop.

This project will be folded into two other research programs in support of satellite validation as NOAA Ground-systems funding will be depleted after this year.

4.2. A Dedicated Processing System for the Infusion of Satellite Products in AWIPS

Task Leaders: Scott Bachmeier, Jordan Gerth

NOAA Collaborators: Robert Aune, Gary Wade

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

This project is to continue the CIMSS effort to accelerate the infusion of satellite-based products into the National Weather Service (NWS) Advanced Weather Interactive Processing System (AWIPS), which is the primary operational government weather analysis and forecasting system, and eventually, into the NWS forecast process. A variety of unique, real-time satellite datasets from CIMSS are routinely generated and injected into the local AWIPS data stream, including imagery and products from GOES (Geostationary Operational Environmental Satellite), MODIS (MODerate resolution Imaging Spectroradiometer), POES (Polar Operational Environmental Satellite) AVHRR (Advanced very High Resolution Radiometer), and the CRAS (CIMSS Regional Assimilation System) forecast model. The AWIPS environment, in the actualization of the Weather Event Simulator (WES), is also critically used for NWS training, where unique CIMSS satellite case studies may be re-played. To provide robust, timely, dependable CIMSS data products to the AWIPS users, CIMSS will:

- Operate, maintain, and upgrade (as needed) a dedicated processing machine for development of AWIPS related products. Critical needs would be in response to upgrades required by transition to AWIPS II (now scheduled for September 2011);
- Upgrade AWIPS "client" computers to handle new capabilities required by the move towards AWIPS II as well as for improvements in display, through-put, and increased data volumes; and
- Continue to develop and expand documentation of the CIMSS AWIPS environment (for establishing a corporate knowledge basis to ensure future operation of the system).

Summary of Accomplishments and Findings

Overall, the CIMSS AWIPS infrastructure continued to operate dependably, and provided timely and unique satellite products to a number of NWS users. Evidence of this effective AWIPS product distribution capability was clearly demonstrated by the widespread use of CIMSS AWIPS data during 2010. CIMSS imagery and products now flow to all six NWS regional headquarters sites using the Local Data Manager (see Figure 4.2.1). In addition, AWIPS infusion played a role in other CIMSS research to operations demonstrations, including: participation in the GOES-R Proving Ground portion of the Storm Prediction Center (SPC) "Spring Experiment" which evaluated a GOES Convective Initiation product; completion of a spring-summer assessment of GOES Convective Initiation and GOES Sounder Nowcasting products at the local Milwaukee-Sullivan NWS office (MKX); and, continued regular and frequent inclusion of CIMSS AWIPS displays in the popular CIMSS Satellite Blog [http://cimss.ssec.wisc.edu/goes/blog/].

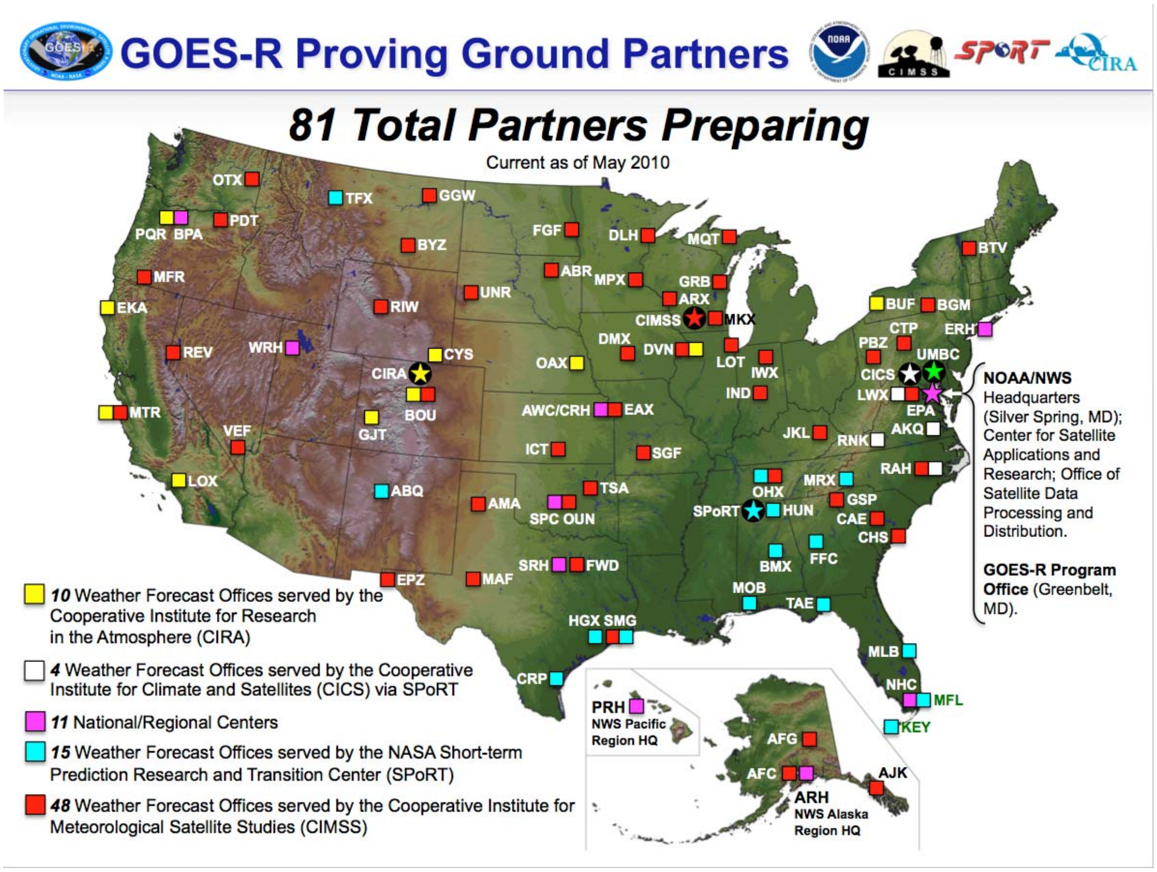


Figure 4.2.1. Display of NWS offices (as of May 2010) acting as partners in the GOES-R Proving Ground, in preparation for effective use of GOES-R data coming later in mid decade.

Developing a research-grade AWIPS network at a non-NOAA facility is a lasting accomplishment which has impacted and enhanced numerous projects at CIMSS since 2005. Research to operations activities involving AWIPS continue to accelerate. Through ground systems and other funding to perform this work and maintain the system, CIMSS continues to add configurations to AWIPS which expand the number of display-ready datasets, including numerous experimental satellite products which are made available to NWS users. Within the past year, CIMSS worked with NESDIS to parallel the operational creation of GOES Ingest and NOAAPORT Interface (GINI) formatted POES AVHRR channels and deliver this NOAAPORT-approved data to select field sites. Due to bandwidth deficiencies between NESDIS and the Satellite Broadcast Network (SBN) Control Facility (NCF), NESDIS was unable deliver POES AVHRR data to NWS field sites for several years.

Recent additions to the AWIPS network at CIMSS include twin NWS-specified Hewlett-Packard (HP) Z800 workstations with NVIDIA Quadro FX1800 graphics card capable of running AWIPS II, which will be used by Scott Lindstrom, a VISIT trainer at CIMSS, as well as Gary Wade and Robert Aune. This new hardware replaces existing AWIPS hardware which was outdated, susceptible to failure, and limited software performance. Continuity of internal AWIPS service during the nationwide transition to AWIPS II in 2011 is of utmost importance to CIMSS' continuing work with product development and dissemination, training, and transition to operations activities.

OCONUS NWS field offices and other NOAA-supported agencies which are not serviced with NOAAnet connectivity are considering the CIMSS approach to build a prototype "AWIPS in a box" system for their operations.

Current plans are to add a NWS-specified HP DL380 G7 High Performance server to CIMSS' failover-ready triplet of AWIPS ingest, processing, and product preparation servers in preparation for AWIPS II. In part to due adequate and well-supported hardware, there were no major disturbances which significantly impacted server uptime during the previous year.

Over the same period, the number of operationally-oriented products developed and transmitted to the field has grown significantly with the addition of numerous products created using Clouds from AVHRR Extended (CLAVR-X), NOAA's operational cloud processing system.

For all new products which are developed for AWIPS, additional work is required to prepare the internal CIMSS AWIPS to accept the additional images. This work is then documented and made available to NWS field office users such that it is possible for them to access and display the data quickly using the instructions. The in-house AWIPS facilitates this process, as well as troubleshooting and support field site systems.

CIMSS has taken a leadership role in working with the NWS Office of Science and Technology (OST) to establish Technical Interchange Meetings (TIMs) with AWIPS developer and contractor Raytheon. These TIMs provide absolutely critical and time-saving information about how the next generation of software works and the additional capabilities and benefits that are available to the user and developer. AWIPS II represents an end-to-end overhaul of the display, data processing, and storage architecture compared to the legacy AWIPS. CIMSS is also a part of the National Core Local Applications Development Team (NCLADT) and Governance Tiger Team.

CIMSS is actively working in AWIPS II development and is prepared to transition all current, legacy AWIPS ready experimental imagery and products to an AWIPS II accepted format such that field sites which transition to AWIPS II do not experience an interruption in their feed of experimental satellite products.

CIMSS is also experimenting with other technologies which may support NWS operations, including the use of a touchscreen overlay fitted on situational awareness displays for aiding weather briefings and interactive demonstrations of AWIPS.

Publications and Conference Reports

Gerth, J. J., 2010: AWIPS-II and GOES-R: When Updated Information Processing Systems and New Satellites Meet, *National Weather Association 35th Annual Meeting*—General Session XI, 06 Oct 2010, Tucson, Arizona.

5. GOES-R Risk Reduction

5.1. Study of the Efficient and Effective Assimilation of GOES-R Temporal/Spatial Measurement Information

Task Leaders: Jason Otkin, Allen Huang
CIMSS Support Scientist: Will Lewis
NOAA Strategic Goals:

1. Serve society's needs for weather and water

CIMSS Research Themes:

- Weather Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Proposed Work

The primary goals of this project are to develop the necessary infrastructure to perform high-resolution data assimilation studies and to evaluate how the assimilation of ABI infrared brightness temperatures impacts the accuracy of atmospheric analyses and affects the skill of short-range numerical model forecasts.

Summary of Accomplishments and Findings

During the past year, a manuscript describing results from a regional OSSE case study was submitted to and accepted for publication in the *Journal of Geophysical Research*. The study examined how the assimilation of ABI brightness temperatures for both clear and cloudy sky conditions impacts the accuracy of atmospheric analyses within an Ensemble Kalman filter data assimilation system. Four assimilation experiments and a control case without assimilation were performed. Both clear and cloudy-sky ABI 8.5 μm (band 11) brightness temperatures were assimilated during the B11-ALL case whereas only the clear-sky observations were assimilated during the B11-CLEAR case. Simulated conventional observations were assimilated during the CONV case. Finally, all of the conventional observations and 8.5 μm brightness temperatures were assimilated during the CONV-B11 case. The observations for each assimilation case were assimilated once per hour during a 12-hr period.

Overall, the assimilation results showed that the 8.5 μm brightness temperatures had a large positive impact on the simulated cloud field with the best results achieved when both clear and cloudy sky observations were assimilated. Figure 5.1.1 shows the simulated 11.2 μm brightness temperatures from the assimilation experiments and the truth simulation. As expected, the largest errors occur during the control case (Figures 5.1.1e-h) since the lack of assimilation allows the ensemble spread to steadily increase, which manifests itself as more extensive cloud cover by 00 UTC. Comparison of the B11-ALL (Figures 5.1.1i-l) and B11-CLEAR (Figures 5.1.1m-p) images reveals that the infrared brightness temperatures have a larger impact on the analysis when both clear and cloudy sky observations are assimilated. For instance, though both cases contain fewer erroneous clouds over the southern portion of the domain due to the influence of the clear-sky observations, the cloudy observations were also able to correctly modify the cloud field associated with the extratropical cyclone. The impact of the cloudy brightness temperatures is already evident after the first assimilation cycle by the narrower axis of the coldest cloud tops over the northwestern corner of the domain and the warmer brightness temperatures over Minnesota and Wisconsin (Figures. 5.1.1e, i). Cloudy brightness temperature assimilation also resulted in a more accurate representation of the upper level cloud cover that developed over central Texas by 00 UTC (Figures. 5.1.1h, l). The conventional observations had a larger impact on these cloud features (Figures. 5.1.1q-t) than the B11-CLEAR case but not as large as the B11-ALL case. These observations also had a smaller influence than the 8.5 μm brightness temperatures over the southern portion of the domain where more extensive cloud cover developed by 00 UTC.

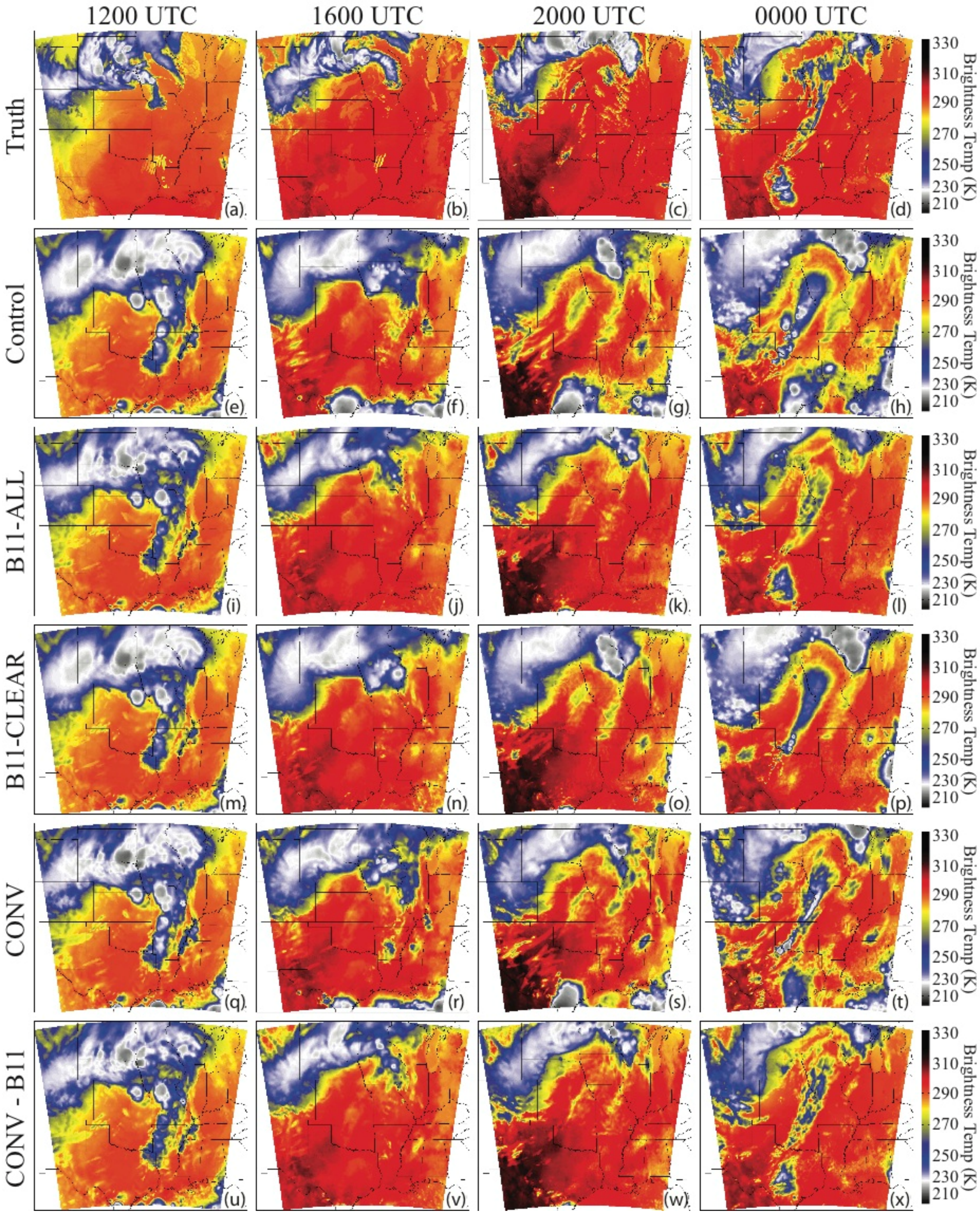


Figure 5.1.1. Simulated ABI 11.2 μm brightness temperatures (K) valid at 1200, 1600, and 2000 UTC on 04 June 2005 and 0000 UTC on 05 June 2005. Results are shown for the (a-d) truth and (e-h) control simulations and the (i-l) B11-ALL, (m-p) B11-CLEAR, (q-t) CONV, and (u-x) CONV-B11 assimilation experiments. The simulated brightness temperatures for each assimilation experiment were computed using data from the posterior ensemble mean.

A second regional OSSE study is currently underway for a case containing several mid-latitude cyclones and associated cloud features that occurred across the U.S. during 07-08 January 2008. Numerous assimilation experiments employing different combinations of conventional and ABI brightness temperature observations were performed to explore the sensitivity of the analysis accuracy to the brightness temperature observation error used during the assimilation step. Various options were explored, including the use of constant errors for both clear and cloudy-sky observations as well as using variable errors that are a function of cloud top pressure, cloud optical depth, or cloud water path for the cloudy observations. The observation error was set to 7.5, 10, 15, or 20K for the constant error cases while the errors increased linearly from 7.5 to 15K with increasing or decreasing cloud top pressure, cloud water path, or cloud optical depth for the variable error cases. For the variable error cases, the analysis accuracy was similar to the benchmark case using a constant 10K observation error. This result is somewhat surprising since it is not unreasonable to expect that the ability of an infrared observation to improve the analysis is at least partially dependent upon the observed cloud height and optical depth. Additional experiments employing non-linear error functions or different minimum and maximum error values are necessary, however, to fully explore this issue. For the clear sky only assimilation cases, the analysis accuracy varied slightly when different observation errors were used, with the best results achieved with a 10K observation error. The errors were slightly smaller for cloud-affected fields such as total cloud condensate when a smaller error was used, however, these improvements were offset by larger errors in the temperature, moisture, and wind fields. Lastly, for the combined clear and cloudy-sky brightness temperature assimilation cases, the analysis accuracy varied greatly when different error values were used for the cloudy-sky observations. Overall, the accuracy steadily improved for both thermodynamic and cloud-affected fields as the cloudy observation error was increased from 7.5 to 20K. In most cases, however, the accuracy was slightly degraded compared to the clear-sky only assimilation cases, especially for statistics computed with respect to the clear grid points in the truth simulation. The underlying causes of the strong sensitivity to the cloudy observation error are currently being explored.

Publications and Conference Reports

Otkin, J. A., 2010: Clear and cloudy-sky infrared brightness temperature assimilation using an ensemble Kalman filter. *J. Geophys Res.*, **115**, D19207, doi:10.1029/2009JD013759.

Otkin, J. A., 2010: The relative impact of clear and cloudy sky infrared brightness temperatures within an ensemble data assimilation system. 17th Conference on Satellite Meteorology and Oceanography, Annapolis, MD.

Otkin, J. A., and W. E. Lewis, 2010: Assimilation of simulated ABI infrared brightness temperatures using an ensemble Kalman filter data assimilation system. 11th Annual WRF User's Workshop, Boulder, CO.

Otkin, J. A., and W. E. Lewis, 2010: Assimilation of simulated ABI infrared brightness temperatures using an ensemble Kalman filter. The 4th Ensemble Data Assimilation Workshop, Renssellaerville, NY.

Otkin, J. A., and W. E. Lewis, 2010: Assimilation of simulated infrared brightness temperatures as part of an OSSE employing the Ensemble Kalman Filter. 14th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface, Atlanta, GA.

5.2. Hurricane Wind Structure and Secondary Eyewall Formation

Task Leader: Chris Rozoff
NOAA Collaborator: Jim Kossin
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

Proposed Work

Eyewall replacement cycles (ERCs) are fairly common in more intense tropical cyclones (TCs). In a typical ERC, an outer eyewall forms outside of the TC's primary eyewall, which often leads to a temporary weakening of the maximum winds but also a widening of the damaging low-level winds. Yet, there are predictability limits in properly capturing the timing of ERCs which eludes forecasters on important questions of intensity change and wind structure evolution.

The focus of this project has been to utilize existing GOES infrared (IR) imagery and synthetic ABI imagery to improve the predictability of concentric eyewall formation. In addition, a central focus of this project has been on the role of diabatic heating in initiating ERCs. To this end, we have developed empirical forecast models trained on environmental parameters and GOES-IR imagery to improve prediction of secondary eyewall formation (SEF) (e.g., Kossin and Sitkowski 2009), we have studied multi-spectral products derived from synthetic ABI data from both MSG-SEVIRI data and high-resolution simulations of TCs with ERCs, and we have investigated the role of diabatic heating in SEF in the simulations.

Summary of Accomplishments and Findings

Analysis of Synthetic ABI Derived from MSG-SEVIRI Data

We have investigated a synthetic ABI dataset derived from MSG-SEVIRI of North Atlantic Hurricane Helene (2006). The bi-spectral technique of Olander and Velden (2009), which provides a depiction of TC inner-core structure based on a function of the difference field of GOES water vapor (WV) (6.5 μm) and IR (10.7 μm) brightness temperatures (T_b), has shown great potential in detecting intense convection in TCs and, to a more reliable degree than individual GOES channels, it depicts precipitation structures that are best displayed in passive microwave imagery. Since the temporal resolution of microwave data is inadequate for many forecasting applications, the enhanced precipitation signatures that may be found in multi-spectral GOES imagery may greatly improve forecasting and nowcasting. As such, the increased spectral resolution of ABI has been exploited to create similar difference fields to explore the internal structure of Hurricane Helene. Because of the marked ABI weighting function differences between any of WV and IR channels, we have found that a number of enhanced bi-spectral fields offer a better glimpse of strong, deep convective activity in Helene. In particular, differences between the 10.35 mm and any of the WV bands (6.19, 6.95, or 7.34 μm), using the difference formula from Olander and Velden (2009), $T_{b,IR}$-$T_{b,WV}$- exp(1 - $T_{b,IR}$-$T_{b,WV}$), we find the following results: all three difference fields can distinguish vigorous convection, particularly in the trainband region and the 6.95-10.35 μm bi-spectral field provides the best relative emphasis in active convection outside of the primary eyewall. However, thick cirrus clouds can still obscure some of the inner core structure in any of the bi-spectral channels.

Analysis of Synthetic ABI Derived from WRF

Analysis of synthetic ABI data from an idealized, full-physics WRF simulation (1-km horizontal grid spacing) of concentric eyewalls has been conducted, with particular focus on how multi-spectral fields can distinguish important structural features related to SEF. In the model data, the enhanced IR-WV channels are particularly successful in depicting outer eyewall structure. Just one of the bi-spectral enhancement examples is shown in Figure 5.2.1a (10.35 μm and 6.19 μm T_b), although the other IR-WV differences provide very similar results. Figure 5.2.1b shows the corresponding low-level rain-rate. It should be noted the outward tilt of the eyewalls cause the apparent differences in the diameters of the eyewalls between each panel, but both clearly indicate the double eyewall structure. Thus, with the observational and modeling results, it is suggested there may be increased ability in detecting secondary eyewall formation normally obscured in individual GOES IR and WV imagery when using multi-spectral techniques.

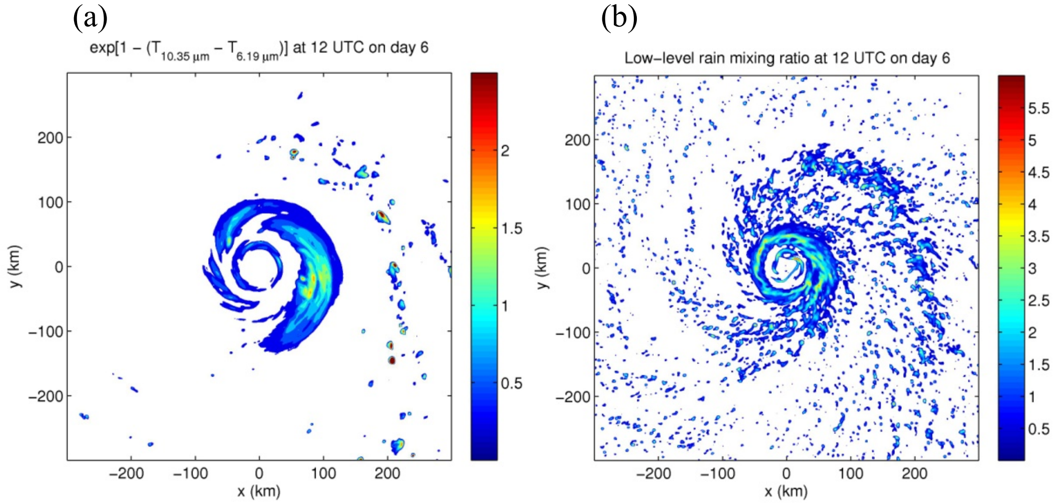


Figure 5.2.1. (a) An exponential enhancement of the difference between 10.35 μm and 6.19 μm Td (K) and (b) low-level rain mixing ratio (g kg^{-1}) 132 h into the simulation.

Theoretical Progress on Secondary Eyewall Formation

In or high-resolution numerical simulations of ERCs, we have investigated the physical relationships between latent heating and SEF. Using absolute angular momentum (AAM) budgets, potential vorticity (PV) budgets, and an idealized balanced vortex model, connections between latent heating and the vortex response have been elucidated. For example, Figure 5.2.2 shows the results of a successfully balanced AAM budget for an hour-long period near the early stages of SEF. AAM has substantially increased throughout the troposphere in the region, r = 80 – 150 km. This region is an area dominated by concentrated rainband activity and latent heating that is strong enough to project onto the axisymmetric mean. Asymmetric perturbations from the axisymmetric mean (mostly wavenumber 1) do play a smaller role in this region, particularly at lower levels in the troposphere, although the increase in AAM is predominantly brought into being by the axisymmetric transverse circulation. A PV budget offers similar insight and emphasizes the important role of diabatic heating in the generation of the outer eyewall.

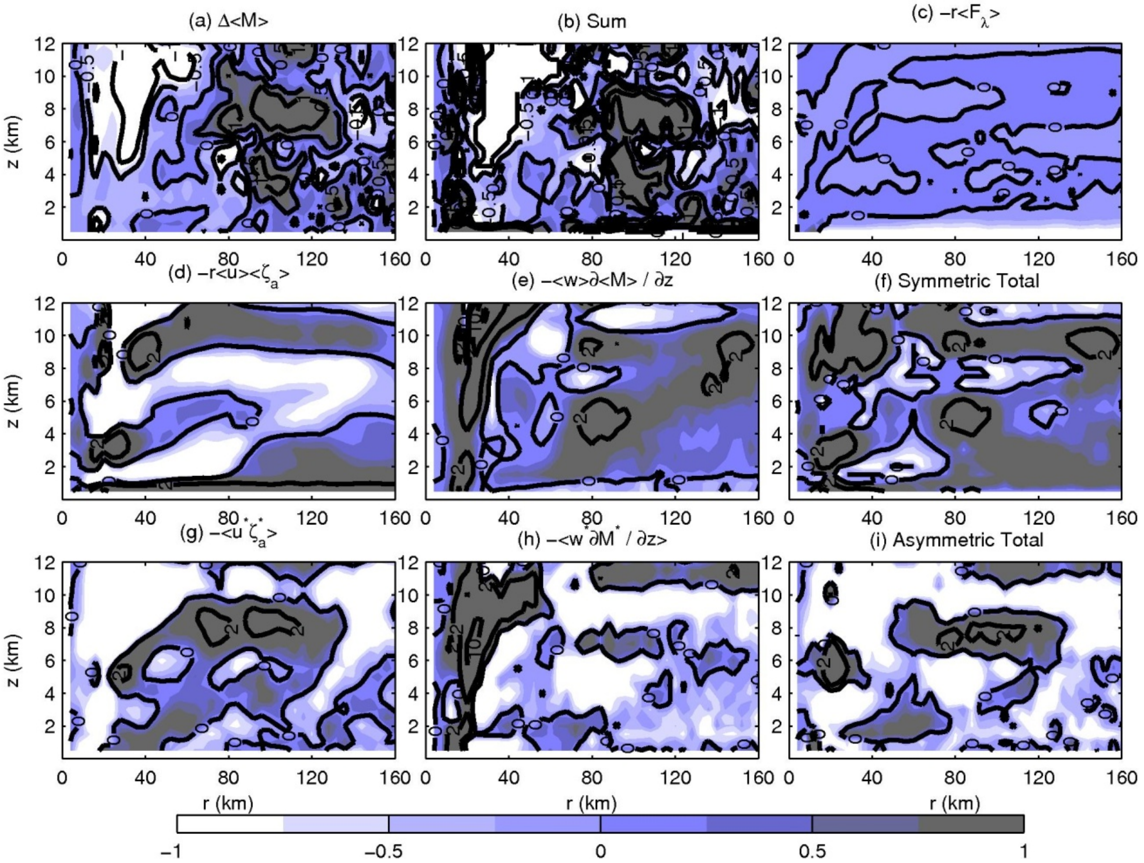


Figure 5.2.2. Various terms of an AAM budget for an hour period on the fifth day of simulation. The above radius-height panels show (a) actual change in azimuthal average (brackets represents an azimuthal average) AAM in the model simulation, (b) the sum of the terms in the AAM budget equation, (c) the total frictional contribution to (b), the mean (d) radial and (e) vertical advection contributions to (b), (f) the total symmetric contribution (c+d+e) to (b), the asymmetric (g) radial and (h) vertical advection components of (b), and (i) the total asymmetric contribution (g+h) to (b). AAM changes are expressed in units of 10^5 m^2 s^{-1} h^{-1}.

Not only does latent heating drive the secondary circulation to expand the wind field, a balanced vortex model (more details in Rozoff et al., 2010) suggest that SEF can be partially captured by balanced vortex dynamics and that inertial stability plays a key role in the genesis process. Figure 5.2.3 shows an example of a balanced vortex model successfully reproducing the secondary circulation only prescribing the WRF model's axisymmetric diabatic heating rate and tangential wind field. This provides confidence in the balanced vortex model to describe some of the fundamental physics of SEF. In the balanced framework, it is seen that as inertial stability increases with an expanding wind field, latent heating becomes increasingly effective at generating an outer wind maximum and a secondary eyewall. These results suggest that more accurate detection of latent heating structures in tropical cyclones provides better confidence in accurately gauging the current and future behavior of tropical cyclone structure and intensity change.

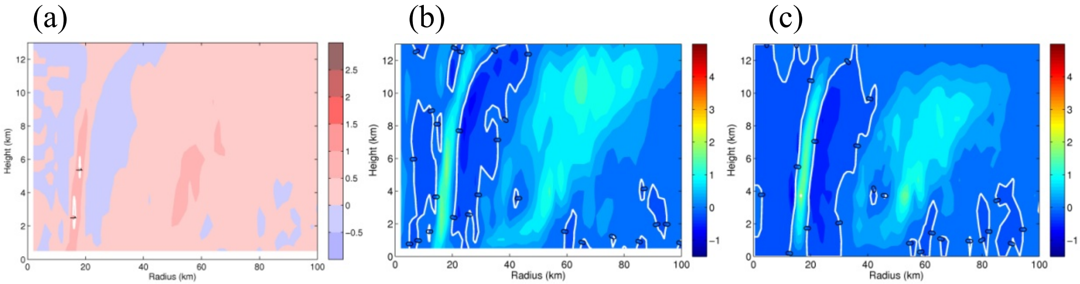


Figure 5.2.3. (a) WRF axisymmetric diabatic heating (10^{-2} K s^{-1}) prescribed to the balanced vortex model, the WRF axisymmetric vertical motion (m s^{-1}), and the balanced model diagnosed vertical motion field (m s^{-1}) near the time of SEF.

Publications and Conference Reports

Rozoff, C. M., J. P. Kossin, D. S. Nolan, F. Zhang, and J. Fang, 2010: Dynamical mechanisms for secondary eyewall formation in a high-resolution simulation of an intense tropical cyclone. *Mon. Wea. Rev.*, to be submitted.

Rozoff, C. M., J. P. Kossin, D. S. Nolan, F. Zhang, and J. Fang, 2010: Dynamical mechanisms for secondary eyewall formation: Insights from a cloud-resolving tropical cyclone model. 29th Conference on Hurricanes and Tropical Meteorology, Tucson, AZ, May 10-14.

References

Kossin, J. P., and M. Sitkowski, 2009: An objective model for identifying secondary eyewall formation in hurricanes. Mon. Wea. Rev., 137, 876—892.

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.

5.3. GOES-R Risk Reduction Study - GEO/LEO Synergy for Sounding

Task Leader: Jun Li
CIMSS Support Scientists: Elisabeth Weisz, Zhenglong Li, Zhigang Yao, Jim Nelson
NOAA Collaborator: Timothy J. Schmit
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

- Weather Nowcasting and Forecasting

Proposed Work

Since the Advanced Baseline Imager (ABI) - instead of a hyperspectral IR sounder on the GOES satellite - is used to provide the current GOES Sounder legacy atmospheric profile (LAP) product, it is very important to combine high temporal ABI and hyperspectral IR data from low earth orbiter (LEO) satellites for improved soundings. The proposed work for FY2010 includes refining CHISR (CIMSS Hyperspectral Infrared Sounding Retrieval) algorithm to include IASI, using AIRS and GOES Sounder for GEO/LEO algorithm development, and developing algorithm for GEO IR radiance bias estimate using LEO (AIRS/IASI). In addition, ABI time continuity for sounding improvement will also be investigated.

Summary of Accomplishments and Findings

LEO Single Field-of-view (SFOV) Advanced IR Sounding Retrieval Algorithm Refined and Improved

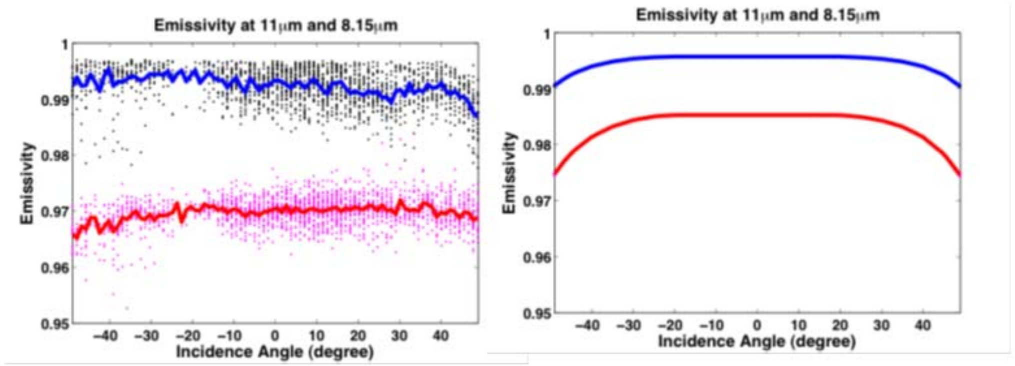
AIRS and IASI single field-of-view (SFOV) cloudy sounding retrieval algorithm has been improved for LEO/GEO combination. A dual regression algorithm has been developed to accurately retrieve sounding profiles as well as cloud parameters (e.g. cloud top pressure) from hyper-spectral infrared radiances under cloudy skies at SFOV resolution. Two sets of eigenvector regression relations, trained for clear and cloudy conditions respectively, are computed from a global training database. The clear regression coefficients are calculated from the original training database plus the same profiles but with isothermal/saturated conditions below specified cloud top pressures from 100 to 900 mbar. Cloudy regression coefficients are computed from a cloudy database (representing variety of cloud height, cloud optical thickness, and cloud particle size) for eight overlapping cloud top categories (from 100 to 900 mbar with a 200 mbar range each). Then applying these two sets of regression coefficients to real observations (e.g., AIRS), and two sets of retrievals are obtained. The cloud level is determined as that level where the clear-trained and cloudy-trained profiles start to deviate from each other (i.e., the clear-trained gets systematically colder than the cloudy one). Above the clouds the clear-trained profile and below the cloud level the cloudy-trained profile is retained. This algorithm provides AIRS and IASI SFOV soundings in both clear and cloudy skies with good accuracy when compared with the ECMWF analysis data.

Combining GEO High Spatial Resolution ABI and LEO Advanced IR Soundings for Better Atmospheric Temperature and Moisture Profiles

We continue to develop algorithm for better soundings from combined ABI and CrIS using GOES Sounder and AIRS as proxy. Since ABI has high temporal and spatial resolution while CrIS has high vertical resolution, the objective for combining ABI/CrIS is to maintain GOES-R high temporal and spatial resolution, include CrIS high spectral resolution, and transfer the positive impacts from CrIS high spectral resolution to later times. Away from sink or source, moisture is a conservative variable and time continuity could be applied, methodology is being developed for LEO/GEO combination, the new feature of the method is to identify the height above which the GEO time continuity will be applied. By identifying the height, the moisture information from AIRS or previous retrieval above the height can be used as first guess for the GOES Sounder physical retrieval. The "height" is defined a pressure level above which a GOES Sounder channel is not seeing the surface, therefore each GOES channel corresponds to one height.

Emissivity Impact on LEO Advanced IR Sounding Retrieval Studied

An accurate land surface emissivity (LSE) is critical for the retrieval of atmospheric temperature and moisture profiles along with land surface temperature from the LEO hyperspectral IR sounder or GOES-R ABI IR radiances, it is also critical to assimilating the IR radiances in numerical weather prediction (NWP) models over land. To investigate the impact of different LSE datasets on the hyperspectral IR SFOV sounding retrievals, experiments are conducted by using a one-dimensional variational (1DVAR) retrieval algorithm with constant emissivity, the emissivity dataset from the IASI, and the CIMSS baseline fit dataset (BLF) for AIRS granules with significant clear footprints. The comparisons reveal that the emissivity from the IASI could obtain the best agreement between the retrieval results and ECMWF analysis, whereas the constant emissivity gets the worst results. The results also confirm that the simultaneous retrieval of atmospheric profile and surface parameters could reduce the dependence of sounding on the emissivity choice and finally improve the sounding accuracy over land. Additionally, emissivity angle dependence is investigated with AIRS radiance measurements. The retrieved emissivity spectra from AIRS over ocean reveal weak angle dependence, which is consistent with that from an ocean emissivity model (see Figure 5.3.1).



(a): retrieved emissivity (b): calculated from emissivity model

Figure 5.3.1. The retrieved emissivity versus the incidence angles (black: emissivity at 11 µm; blue: mean emissivity at 11 µm for each angle; pink: emissivity at 8.15 µm; red: mean emissivity at 8.15 µm for each angle) over ocean for Granule 046 on 03 September 2008.

Identifying GEO Radiance Biases Using LEO Advanced IR Radiances

One of the bias sources for GEO radiance is the spectral response function (SRF) shifting, as the instrument ages. These biases must be corrected before any applications. The hyperspectral instruments, such as AIRS and IASI, and in future CrIS, are well calibrated to evaluate and quantify the GOES Sounder and in future GOES-R ABI radiances. The hyperspectral IR radiance measurements are convolved with the GOES Sounder SRF in this study, and the convolved IR radiance measurements are considered bias free. Due to the viewing angle difference between GEO and LEO, we have developed a method to identify GOES Sounder radiance biases by quantifying the radiance differences due to angle difference, in such a way, the GEO radiance bias can be estimated in all angles in clear skies. We have applied this method to process GOES Sounder with AIRS and IASI radiance measurements. Overall, AIRS finds similar GOES-12 Sounder radiance biases as IASI. Similar as other study, channel 15 has the largest radiance bias (around 5 K), and channel 5 has about 2 K bias. For other channels, the small differences are probably due to the different observation times of AIRS and IASI. For channel 12, the averaged bias from AIRS is about 1 K, and almost 0 from IASI. Part of the reason for this difference is the spectral gap of AIRS in the water vapor absorption region. This methodology can be applied to process GOES-R ABI.

LEO/GEO Synergy Study Using Time Continuity

The ABI has temporal resolution better than 15 minutes and a decent spatial resolution of 2 km at nadir for IR bands, but has a very limited spectral resolution. On the other hand, AIRS, IASI and in future CrIS are hyperspectral sounders with a low temporal resolution and coarser spatial resolution (12 ~ 14 km at nadir). The AIRS/GOES-12 Sounder synergy study explores the possibility of combining GEO/LEO to improve the soundings. This study is based on the concept of time continuity, with the assumption that the atmosphere should remain stable or change smoothly in a short period of time. Two methods are used to conduct the time continuity. In the first method, the radiance biases are assumed unchanged where the concept of time continuity stands. At the starting time, the radiance biases can be estimated with AIRS measurements, and the same radiance biases are applied to later times. In the second method, the retrieval from previous hour is used as the first guess for the current retrieval. It is known that the GOES Sounder has limited capability to capture the temperature changes and the moisture changes in the lower atmosphere. Therefore, in the second method, only the previous moisture retrievals in the middle and upper troposphere are used as the first guess for current retrieval. GOES-12 Sounder measurements collocated with in-situ measurements at ARM at Southern Great Plain (SGP) are used to demonstrate the concept. At the starting time at 12 UTC on 03 August 2008, the radiosonde observations (RAOBs) are used to simulate the AIRS retrievals. The retrieval using time continuity is allowed to run for 24 hours. Every 6 hours, the results are compared with RAOBs. Together with the GOES/AIRS synergy results, the GOES sounding retrievals using GFS forecast as background (GOES alone) is included for comparison.

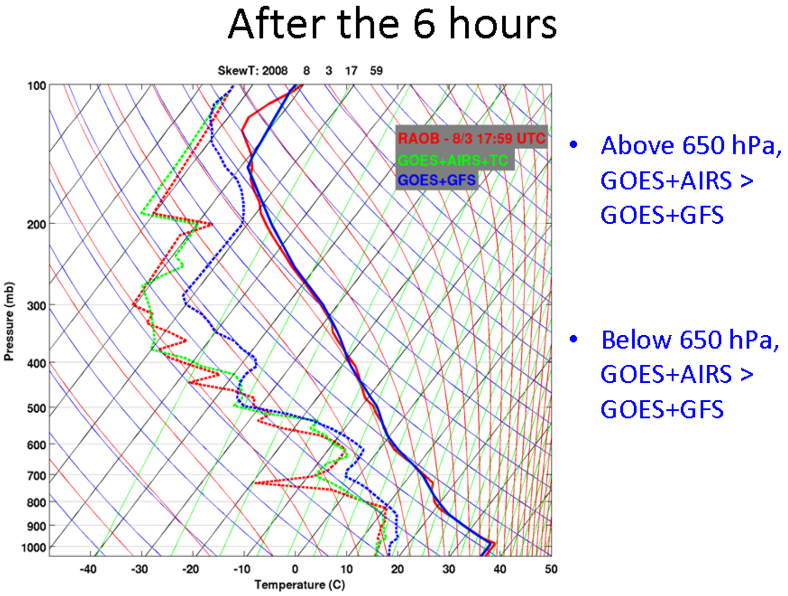


Figure 5.3.2. Dewpoint temperature retrievals (dash lines) from GOES+AIRS and GOES+GFS 6 hours after AIRS data are used, along with a radiosonde observation.

In Figure 5.3.2, after the first 6 hours, the GOES/AIRS synergy captures the moisture profile well, much better than the GOES alone (GOES+GFS). After the second 6 hours (not shown), the GOES/AIRS synergy captures the moisture profile in the middle and upper troposphere well, slightly better than GOES alone. Through time continuity, GOES/AIRS synergy is able to provide quality moisture information in the middle and upper troposphere, which is very important for improving the weather forecasting. The methods developed can be used to process GOES-R ABI and JPSS (Joint Polar Satellite System) hyperspectral IR data for better soundings.

Publications

Li, Z., J. Li, X. Jin, T. J. Schmit, E. Borbas, and M. Goldberg, 2010: An objective methodology for infrared land surface emissivity evaluation, Journal of Geophysical Research (in press).

Yao, Z., Jun Li and Jinlong Li, 2010: Land surface emissivity impact on advanced infrared soundings, Journal of Applied Meteorology and Climate (submitted).

Yao, Z., J. Li, E. Weisz, C. Liu, 2010: Improving Cloud Top Height Retrieval from Hyperspectral Infrared Sounder Radiances, Journal of Atmospheric and Oceanic Technology (submitted).

5.4. Nearcasts - Filling the Gap Between Observations and NWP Using Dynamic Projections of GOES Moisture Products

Task Leader: Ralph Petersen
CIMSS Support Scientist: Tom Rink
NOAA Collaborator: Robert Aune
NOAA Strategic Goals:

- Serve society's needs for weather and water

CIMSS Research Themes:

- Weather Nowcasting and Forecasting

Proposed Work

The overall goal of this project has been to provide forecasters with new tools to help identify areas of convective destabilization 3-6 hours in advance of storm development using products from current and future Geostationary Satellites. The NearCasting system uses a trajectory-based approach which preserves large gradients and maxima and minima observed in the GOES data, as well as using successive temporal data insertions, to revalidate/revise previous projections every hour. Because the basic system development has reached sufficient maturity, the broad objective for 2010 was directed at performing product and display improvement and real-time testing in selected NWS/WFOs.

Summary of Accomplishments and Findings

The majority of the effort during the past year has focused on extending real-time testing and subjective evaluation of the NearCast products, including a variety of additional case studies using both GOES and SEVIRI data. Output from the real-time NearCasting system has been expanded to include two layers of Equivalent Potential Temperature and from those derived Convective Instability. Other indicators of potential for other hazardous weather events (e.g., LI, CAPE, etc.) are being evaluated in the off-line, developmental version of the system. Work during the past year has concentrated both on useful delivery of real-time products and scientific expansion of the products. Notable accomplishments include: 1) providing NearCast products in real-time; 2) expanding the number and combinations of output parameters; and 3) enhancing the output graphics to be more useful to forecasts.

Tests Using SEVERI Data

Experiments were run using data from SEVIRI retrievals as a surrogate for future GOES-R ABI retrievals. NearCasts were run for an un-forecasted F-2 tornado event in southern Poland. Here was a case of isolated severe summer-time convective when conventional NWP products gave no indication that convection was likely, much less to provide guidance as to the location and timing of the events. Although there were repeated instances during the day when convective clouds attempted to form over much of the area, the problem for forecasts was to determine which of these clouds would grow rapidly and when. In addition to using a wider variety of stability parameters than is done in the real-time system, the developmental system was also used to supply data to McIDAS-V for display and parameter development, as well as to glean a better understanding of the evolution of the local environment prior to storm formation.

Although neither the temperature nor moisture NearCasts alone provided sufficient information to isolate the region of greatest total thermal energy content of the low-level pre-storm environment, this was accomplished by computing the Equivalent Potential Temperature (θ_e). The source of the thermal energy for the tornadic storm becomes readily apparent. As shown in the top row of Figure 5.4.1, the area of highest θ_e is initially located southwest of the later storm formation. This area moves east-north-eastward over the next 6 hours, just passing the tornadic formation area.

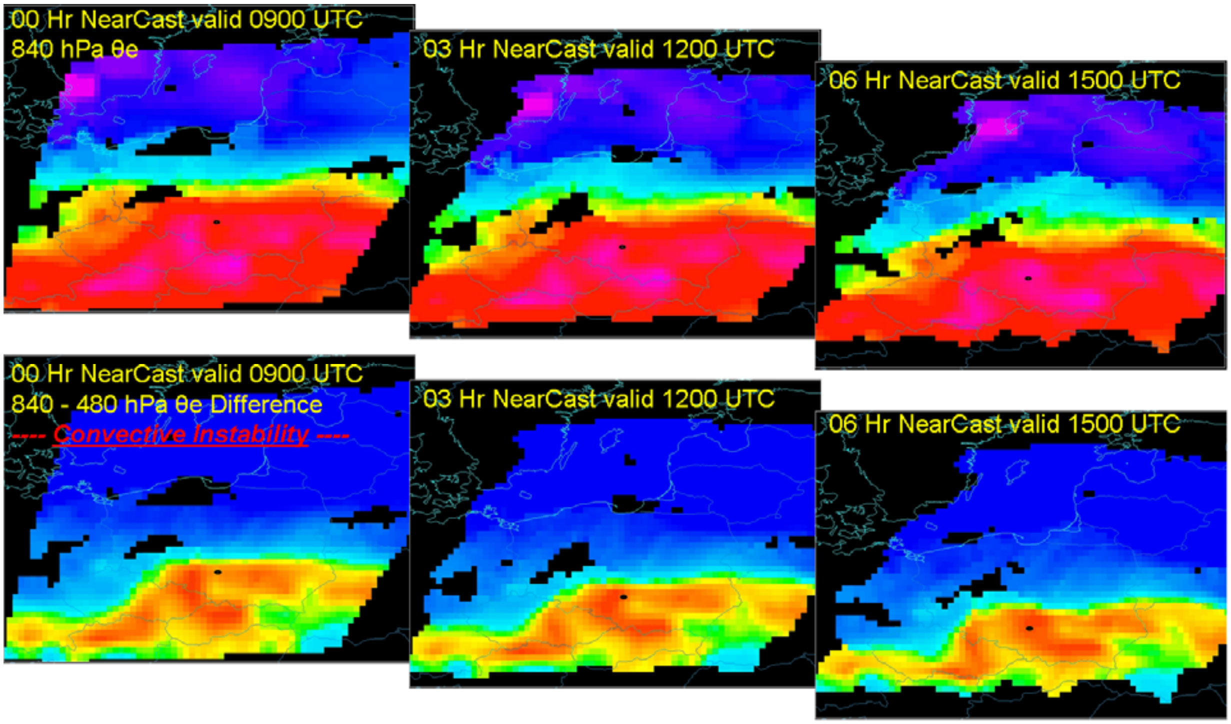


Figure 5.4.1. 840 hPa Equivalent Potential Temperature (θ_e) in top row and vertical difference of θ_e between layers centered at 840 hPa and 480 hPa in bottom row. Largest values of θ_e difference indicate regions of Convective Instability (red areas). Site of tornado shortly after 1500 UTC marked.

Although the low-level θ_e distribution indicates the regions of greatest thermal support, they alone do not answer the question of where this low-level energy is likely to be released quickly if sufficient lifting is present, as is areas along the surface front. To address this question, the difference can be computed between the low- and mid-level θ_e fields to determine the Convective Instability. In this case, the mid-level θ_e fields showed large south-to north gradients. The differential movement of the low-level θ_e under the more west-north-westerly and more rapidly moving mid-level fields produces a distinct pattern of Convective Instability that changes shape and intensity over time, reaching a maximum at the time and location of the rapid tornadic storm formation.

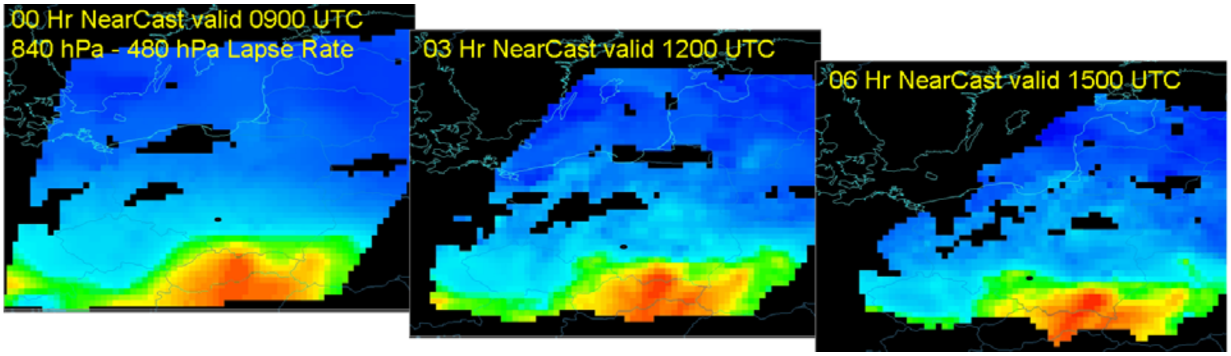


Figure 5.4.2. Same as Figure 5.4.1, except for 840-480 hPa lapse rate (red indicates weak lapse rates-large decrease of temperature with height).

Additional information about the timing of the release of the convective instability is also contained in the SEVIRI data. By studying the evolution of the 840-480 hPa vertical lapse rate in the area of the storm formation in Figure 5.4.2, it becomes apparent that the movement of a small pocket of warm air near 480 hPa initially west-north-west of the tornadic storm formation increases mid-level stability in that area in first the 4 hours, acting as a cap to vertical storm growth. This result is consistent with the inability of cumulus clouds that formed earlier in this area to grow. In the last 1-2 hours, however, the static stability decreases rapidly as cold air infiltrates aloft. In addition, the temperature NearCasts show the surface front just at the location of the tornado intensified during the period, potentially contributing to the lifting required to release the Convective Instability.

The use of the display tool available in McIDAS-V also allows users to view the various different NearCasting products to be combined in physically meaningful combinations. As shown in Figure 5.4.3, two of the major ingredients for rapid development and continued support of severe convection are 1) the development of convective instability (θ_e decreasing with height or increasing with pressure) and 2) an abundant supply of total low-level thermal support. This can be depicted by the product of the two fields, which further focuses forecaster attention on the areas of greatest threat.

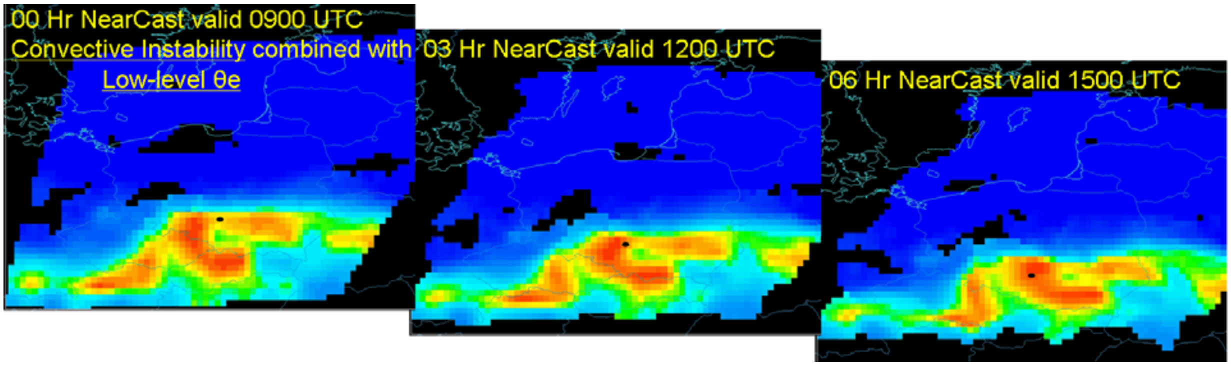


Figure 5.4.3. Same as Figure 5.4.2, except for product of 840 hPa Equivalent Potential Temperature (θ_e) and vertical difference of θ_e between layers centered at 840 hPa and 480 hPa. Largest values indicate regions of combined Convective Instability and large total low-level thermal energy (red areas).

Summary

Tests results presented here show the utility of a simplified Lagrangian model to project GOES and SEVIRI soundings into the near future to augment conventional NWP output and help isolate areas that are becoming convectively unstable 3-6 hours in advance. The results show that: 1) The GOES DPI NearCasts are useful in detecting the pre-convective environment for hazardous weather in many US cases, 2) Projections of GOES Temperature Soundings provide additional information, further enhancing the moisture signal for detecting Convective Potential when using θ_e, 3) - Tests with SEVIRI retrieval were positive, and 4) Combined display of multiple physical meaning parameters that can be observed well by SEVIRI and GOES provide enhanced information and guidance fore operational forecasters.

Publications and Conference Reports

Aune, R., R. Petersen, 2010: Using the GOES sounder to NearCast severe convection. IGARS Meeting, Hawaii.

Petersen, R., R. Aune, 2010: Optimizing the impact of GOES sounder products in very-short-range forecasts – Recent Results and Future Plans. AMS Satellite Conference, Annapolis, MD.

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

5.5. ABI Proxy Data Studies: Regional Assimilation of SEVIRI Total Column Ozone

Task Leader: Todd Schaack
NOAA Collaborator: Brad Pierce
NOAA Strategic Goals:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Weather Nowcasting and Forecasting Research

Proposed Work

This project uses the WRF-CHEM regional chemical model coupled to the Real-time Air Quality Model (RAQMS) global chemical analyses to evaluate the impacts of GOES-R ABI-like Total Column Ozone (TCO) retrievals on Air Quality (AQ) forecasts. Spinning Enhanced Visible and Infrared Imager (SEVIRI) measurements are used as ABI proxy data. The proposed work requires the adaptation and use of WRF-CHEM, the NOAA Grid point Statistical Interpolation (GSI) system, the Community Radiative Transfer Model (CRTM) and RAQMS. The research is focused on the period of August 2006.

Summary of Accomplishments and Findings

The GSI/WRF-CHEM SEVIRI ozone assimilation capabilities were tested on the newly installed computational nodes of the CIMSS computing cluster and a number of issues were identified with the MPI environment. Working closely with the CIMSS Technical Computing staff to rectify issues with the new computing nodes on the CIMSS cluster we found that running GSI/WRF-CHEM within the CIMSS computing environment would not be an efficient use of computing resources. We ported the GSI/WRF-CHEM assimilation system onto the cobalt computer at the National Center for Supercomputing Applications (NCSA) so that the WRF-CHEM SEVIRI ozone assimilation could be completed. Improved background error statistics were developed based on RAQMS ozone forecasts using the NMC method (Parrish and Derber, 1992). This development was necessary since the operational GSI relies on GFS based background error covariance statistics which do not include any representation of tropospheric photochemical sources and sinks.

Results of the GSI/WRF-CHEM SEVIRI TCO assimilation experiments were compared to SHADOZ (Thompson et al., 2003) ozonesonde measurements. WRF-CHEM no assimilation/no lightning NOx comparisons showed large (up to 75%) low biases near 300mb. Introduction of lightning NOx parameterizations compensates for this low bias but introduces high biases near 100mb. Assimilation of SEVIRI TCO within GSI/WRF-CHEM tends to reduce the high biases at 100mb but also slightly increases low biases at 300mb relative to the lightning NOx experiments (Figure 5.5.1). Vertically integrated biases are reduced from 10% to 4.36% with assimilation of SEVIRI TCO using GSI. WRF-CHEM averaged statistics arise due to balance between compensating errors in the lower stratosphere/upper troposphere. Relatively coarse mid and upper tropospheric vertical resolution and underestimates in the depth of convective exchange of low O3 marine boundary layer air may account for compensating errors in WRF-CHEM.

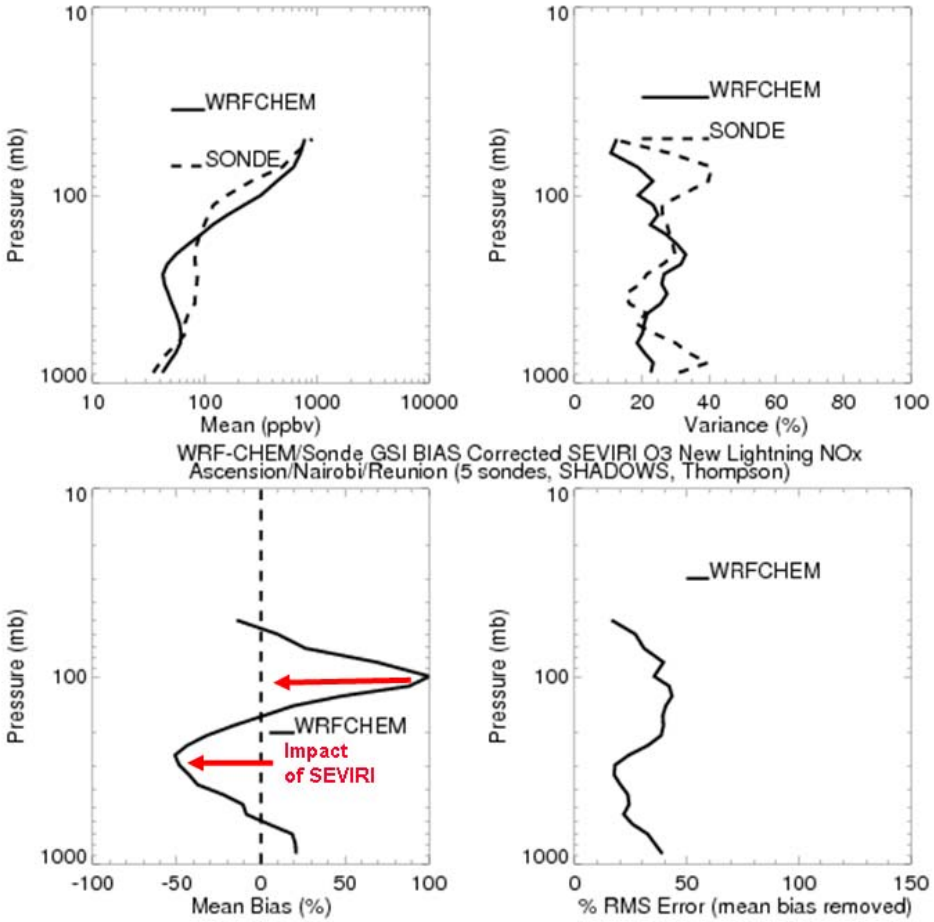


Figure 5.5.1. Comparison between WRF-CHEM Lightning NOx with GSI SEVIRI TCO assimilation experiment and ozonesondes from the SHADOWS network for August 11-24, 2006.

References

Parrish, D. F., and J. C. Derber, 1992: The National Meteorological Center's spectral statistical-interpolation system. *Mon. Wea. Rev.*, **120**, 1747–1763.

Thompson, A.M et al., 2003: Southern Hemisphere Additional Ozonesondes (SHADOZ) 1998-2000 tropical ozone climatology 1. Comparison with Total Ozone Mapping Spectrometer (TOMS) and ground-based measurements. *J. Geophys. Res.*, **108**, No. D2, 8238, doi: 10.1029/2001JD000967

5.6 Data Analysis and Visualization Capabilities

Task Leaders: Tom Rink, Tom Achtor
CIMSS Support Scientists: Jun Li, Ralph Petersen, Tim Schmit
NOAA Collaborators: Tim Schmit
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:

- Weather, Nowcasting and Forecasting

Proposed Work

The continued application of McIDAS-V’s interactive visualization and data analysis/integration capabilities to assist the GEO/LEO Sounding Synergy and NearCasting teams in the research, development and evaluation of their algorithms.

Summary of Accomplishments

Gridded NearCast trajectory field forecasts were converted to standardized NetCDF from text files generate by the model. The standard format can be understood by McIDAS-V without any additional programming to generate displays like those shown in (Figure 5.6.1). Additionally, the self describing format can be used by any software which understands the CF-metadata standards, and the conversion tool can be re-used with new case studies.

The Lagrangian framework NearCast trajectories have been visualized in McIDAS-V (Figure 5.6.1). Here the time evolution of the trajectory location, or parcel path, can be animated over the forecast intervals, and each trajectory is color coded by parameter following the motion. This was accomplished by developing a custom data adapter, or DataSource, and DataControls which describe the manner in which the data is to be displayed. The default data-to-display transforms automatically render the trajectories and set-up the animation. In this case, a new multi-product, multi-coordinate Eulerian/Lagrangian display has been created combining Convective Instability and Isentropic Total Available Moisture trajectories allowing the user to use multiple parameters simultaneously. The trajectories of low-level moisture add information about source regions, while those of low-level TAM better isolate prolonged storms.

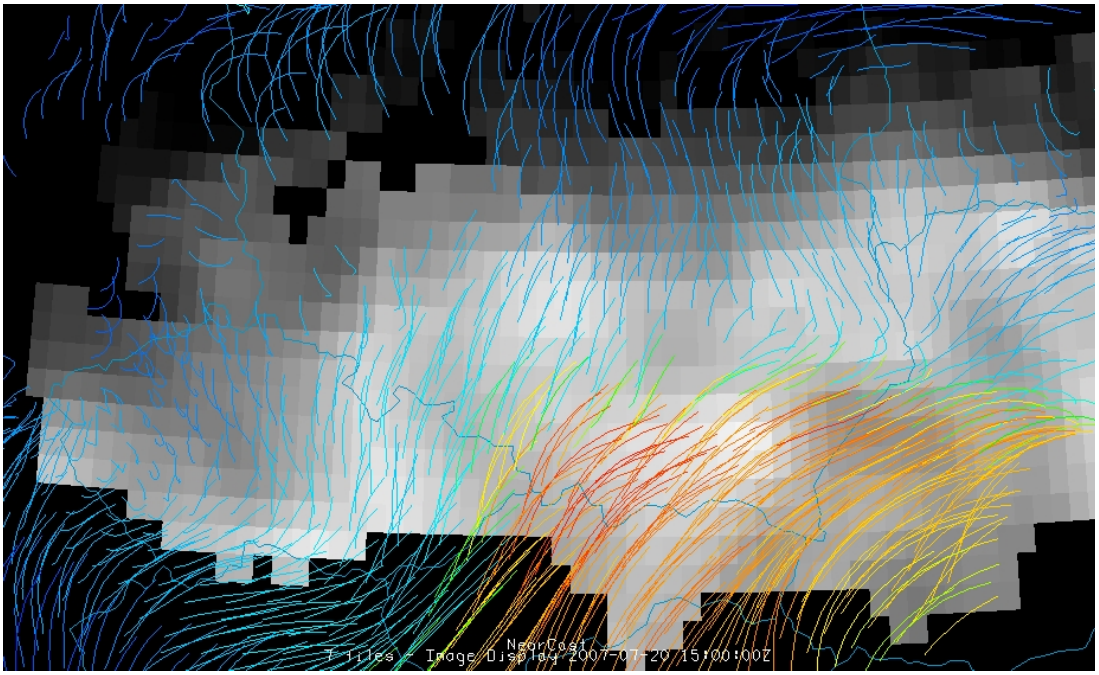


Figure 5.6.1. Multi-Product, Multi-Coordinate Eulerian/Lagrangian display. Convective instability (grey), Trajectories of Total Available Moisture (color).

Successful application of McIDAS-V to enable the GEO/LEO Sounding Synergy team to interactively visualize the 3D structure of retrieval parameters such as water vapor. Work has begun to adapt the results for combined IASI/AIRS and GOES sounder retrieval product to generate displays like that in (Figure 5.6.2), already developed for the high vertical resolution AIRS SFOV retrieval.

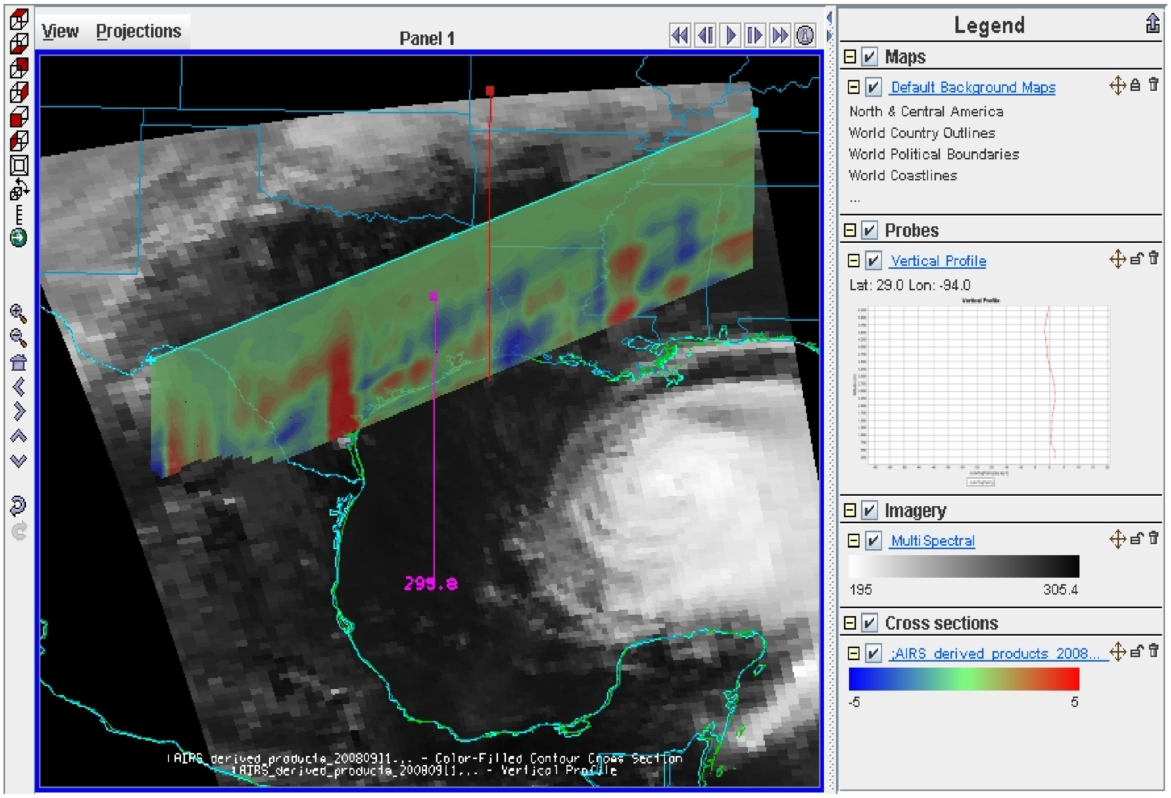


Figure 5.6.2. AIRS L1B window channel (grey-scale) and 2D dragable-in-display slice of ECMWF-AIRS SFOV water-vapor retrieval (color-scale). Values from the slice are re-sampled from the 3D difference field and auto-updated as the slice is dragged in space demonstrating the powerful interactive and data integration capabilities of McIDAS-V.

Conference Reports

EUMETSAT Satellite Conference, McIDAS-V: Advances in Data Analysis and Visualization for Environmental Satellite Data, September 2010, Cordoba, Spain

GOES-R Annual Meeting, An Overview of McIDAS-V Capabilities for GOES-R, July 2010, Madison, WI
AMS, McIDAS-V: A Powerful Data Analysis and Visualization Tool for Multi and Hyper-spectral Environmental Satellite Data, January 2010, Atlanta, GA

AGU, McIDAS-V: A Data Analysis and Visualization Tool for Environmental Satellite and Geophysical Data, December 2009, San Francisco, CA

5.7. GOES-R Education and Public Outreach

Task Leaders: Steve Ackerman, Margaret Mooney
NOAA Collaborators: Tim Schmit, Nina Jackson (Office of Education)
NOAA Strategic Goals:

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

CIMSS scientists regularly participate in student and teacher workshops to facilitate the use of satellite data in education; which includes maintaining and distributing the CIMSS "Satellite Meteorology for Grades 7-12" CD and on-line course (http://cimss.ssec.wisc.edu/satmet/).

CIMSS also has a 3-foot spherical display system and animations demonstrating how scientists and forecasters utilize satellite imagery to monitor weather and climate. Along with displays of geostationary and polar satellites orbiting above real-time weather systems circling the globe, CIMSS has created a simulation of GOES-R data over the western hemisphere. A common sequence presented to visitors involves display and discussion of Explorer VII data (from the 1960s) compared to real-time satellite data followed by the GOES-R simulation data.

Specific workshops and outreach events include:

- WeatherFest booths at annual AMS conferences;
- Teacher Workshops at CIMSS featuring satellite imagery on a 3D spherical display;
- ESIP Teacher workshops;
- Presentations at the Satellite Educators Conference;
- Student workshops at CIMSS each summer featuring activities from the Sat Met course; and
- NSTA Webinar entitled Monitoring Climate Change from Space.

We are also in the process of producing an image that demonstrates future GOES capabilities with the ABI for a planned Science/Art Exhibit titled "Satellites See Wisconsin," slated for display at the Dane County Regional Airport during January - June 2011. The vision of this exhibit is to *enable the public to experience the excitement of learning and discovery that comes with images generated through environmental remote sensing technology.*

5.8. A Blended, Multi-Platform Tropical Cyclone Rapid Intensification Index

Task Leaders: Christopher Rozoff, Christopher Velden
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

Proposed Work

The physical processes associated with rapid intensification (RI, we define as an increase in the analyzed maximum sustained surface wind of at least 25 kt in 24 h) of tropical cyclones (TCs) remain unresolved. Predicting these events is one of the most challenging aspects of intensity forecasting. Improved RI prediction is a top priority at NOAA's NHC and CPHC. The GOES-R GLM and ABI, integrated with other observational platforms, offer a promising advancement in the area of RI prediction. In order to thoroughly investigate multi-platform RI forecast tools, a team consisting of CIMSS, CIRA, NOAA/RAMMB, and NOAA/HRD has been developed. The focus at CIMSS centers on developing predictors from passive microwave (MW) data from low Earth orbiting satellites that can be used to improve empirical forecast algorithms for RI.

Probabilistic RI schemes that incorporate environmental data and GOES-IR imagery such as SHIPS-RII (Kaplan et al., 2010), the Bayes model (Kossin and Sitkowski 2009; Rozoff and Kossin 2010), and the logistic model (Rozoff and Kossin 2010) have greatly improved the prediction of RI. The environmental data, such as the storm's potential intensity, ocean heat content, and vertical wind shear, are crucial in the sense that they largely describe whether the necessary background conditions for tropical cyclone (TC) development exist. GOES-IR based predictors also describe characteristics of the environment such as vertical wind shear and upper level divergence, but are particularly useful since the cloud patterns they capture describe aspects of a TC's internal structure. It is generally believed the phenomenon of RI is strongly tied to the organization of and relationships between the precipitation and potential vorticity structures in the inner-core of a developing TC vortex. Thus, it is not surprising that GOES-IR imagery has added appreciable skill to empirical algorithms of RI prediction. One limitation of GOES-IR imagery is that it cannot often discern inner-core TC structure due to fact that thick cirrus clouds often obscure the internal organization of latent heating. However, MW data sees through overlying cirrus clouds to depict precipitation structures. A primary drawback in using MW imagery is its lower temporal coverage in comparison to GOES-IR imagery, but as seen below, it is believed MW imagery will add skill to the empirical prediction of RI.

In our study, we have proposed to assemble a database of MW imagery from multiple sensors (SSM/I, SSMI/S, TRMM-TMI, AMSR-E, AMSU-B, and WINDSAT) for the period 1995-2008. In this effort, we will develop new or enhance existing RI forecasting algorithms using objectively selected MI predictors that depict inner-core structure (e.g., eye, eyewall, or rainbands). Finally, we will work with HRD to being developing automated MW-based predictors in operational applications.

Summary of Accomplishments and Findings

In this reporting period, the value of MW predictors in the probabilistic prediction of RI has been so far assessed using the logistic scheme. For both the Atlantic and Eastern Pacific, the logistic scheme utilizes the SHIPS-based environmental and GOES-IR predictors described in Rozoff and Kossin (2010) and is further trained on predictors derived from 11-km resolution WINDSAT, 12-km resolution AMSR-E, 8.8-10.2-km resolution TRMM TMI, and 24-km SSM/I 37 GHz brightness temperatures (T_b) for the period of 1995-2008. All SHIPS data are interpolated to times of MW data in our analysis so far, but we are updating this scheme to make forecasts at the synoptic times of 00, 06, 12, and 18 UTC. Also, we are training the Bayes scheme and SHIPS-RII run at NHC on MW predictors.

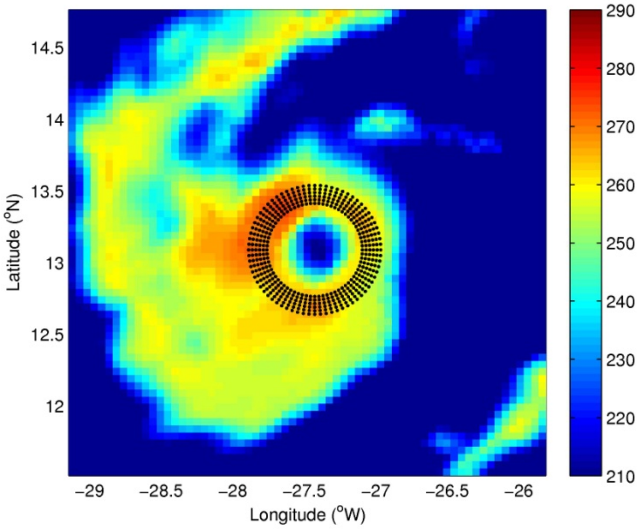


Figure 5.8.1. Rapidly intensifying Atlantic Hurricane Danielle as seen in 37 GHz TRMM-TMI T_b (K) at 1527 UTC 14 August 2004. The ring denotes the region defined to be the eyewall by an automated eyewall detection algorithm (ARCHER).

The many MW predictors that have been evaluated include minimum, average, and maximum T_b for the vertically (V) and horizontally (H) polarized 37 GHz imagery and polarization corrected temperatures (PCT) in regions depicting the eye, eyewall, and general inner- and outer-cores. All center fixes and eyewall/eye definitions used for creating predictors (e.g., Figure 5.8.1) are based on the "Automated Regional Center Hurricane Eye Retrieval" (ARCHER; Wimmers and Velden 2010), which uses a combination of 37 GHz T_b gradients associated with the TC's spiral bands and the potential ring of T_b that often surrounds an existing or developing eye. Table 5.8.1 shows the optimal MW predictors for the logistic scheme in the North Atlantic Ocean.

Figure 5.8.2 shows various skill metrics based on leave-one-year-out cross-validation over the year 1995-2008 for the logistic scheme with and without MW predictors. These skill metrics demonstrate the impact of adding MW predictors to the logistic scheme over the Atlantic. Brier skill score values (Figure 5.8.2a) are enhanced with the inclusion of MW predictors for all RI thresholds and even when we only examine storms of at least 45-kt intensity (orange and red bars) or of at least 60-kt intensity (not shown). False alarm rates range from 0.5 to 3.0% but are not impacted in any consistent way by adding MW predictors. On the other hand, the probability of detection substantially improves when incorporating MW information. Similar improvements are seen in the Eastern Pacific. These improved results are obtained from very simple MW predictors; these predictors are currently being improved to better capture small-scale phenomena.

Table 5.8.1. MW features applied to the logistic model in the North Atlantic.

Feature Description	Preference for RI
Eye/Eyewall average T_b (V pol)	Higher
Eye Radius	Smaller
Eyewall Width	Smaller
Eyewall average T_b (V pol)	Higher
Radius of minimum PCT (r = 30 -130 km)	Smaller
T_b (V pol) Standard Deviation (r = 0 -100 km)	Lower

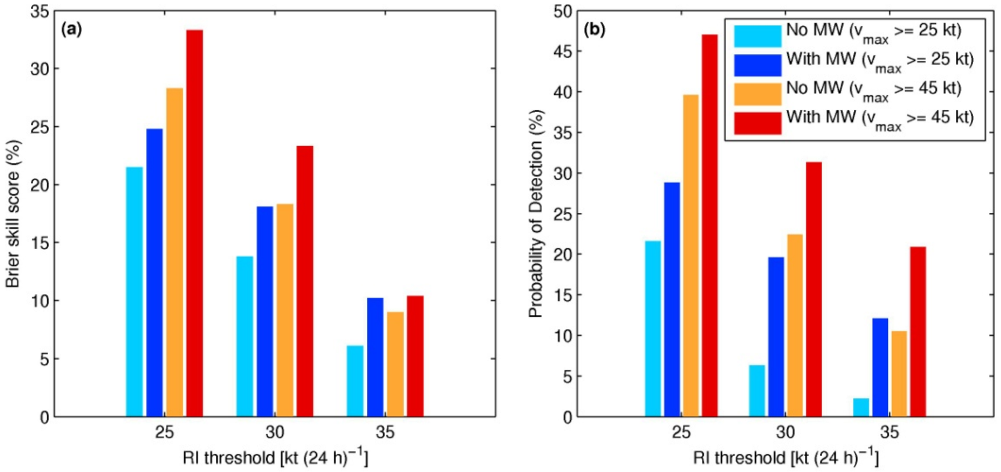


Figure 5.8.2. (a) Brier skill score and (b) probability of detection (based on probability of RI of at least 50 %) values for RI thresholds of 25-, 30-, and 35-kt (24 h)$^{-1}$ for the logistic scheme using no MW predictors (light blue for all TCs; orange for TCs with $v_{\max}$ of at least 45 kt) and including MW predictors (dark blue for all TCs; red for TCs with $v_{\max}$ of at least 45 kt).

Publications

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.

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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.

Kossin, J. P., and M. Sitkowski, 2009: An objective model for identifying secondary eyewall formation in hurricanes. Mon. Wea. Rev., 137, 876—892.

Rozoff, C. M., and J. P. Kossin, 2010: New probabilistic forecast schemes for the prediction of tropical cyclone rapid intensification. Mon. Wea. Rev., to be submitted.

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.

5.9. Combined Geo/Leo High Latitude Atmospheric Motion Vectors

Task Leaders: Matthew Lazzara, Dave Santek, Chris Velden
CIMSS Support Scientists: Nick Bearson, Rich Dworak, Rick Kohrs
NOAA Collaborators: Jeff Key, Jaime Daniels
NOAA Strategic Goals:

- Serve society’s needs for weather and water

CIMSS Research Themes:

- Weather Nowcasting and Forecasting

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 coverage results in a 10 degree gap, which has been noted as a problem by numerical weather prediction (NWP) centers. 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. Therefore, developing novel ways to fill this AMV-void gap is the next logical step toward providing complete wind coverage for the NWP applications. This work will require an Advanced Image Compositing Technique (AICT) designed to blend the data from the many polar and geostationary weather satellites.

The GOES-R Advanced Baseline Imager (ABI) will be a critical component of this composite approach because of the improved spatial resolution over the current GOES imager. This improvement should translate to superior fidelity in the imagery over the critical AMV latitudinal gap (within the longitudinal coverage of the GOES-R series), and improved composite imagery for deriving the AMV fields.

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

The cornerstone of this project is the AICT designed to blend the data from a variety of satellites with differences in calibration, viewing geometry, and temporal offsets. The resulting images are composites of the Geo (GOES, Meteosat, and MTSAT) and Leo satellites (NOAA-15 through NOAA-19 and Metop-A, along with NASA’s Terra and Aqua). The composites are multi-banded files that contain pixel-level quantities that are used in the AICT. The quantities are: Brightness temperature, scan time, pixel distance from the satellite subpoint, pixel area, satellite ID, sensor wavelength, parallax distance, parallax direction. At this time, the final blended satellite images are created by retaining the multi-banded pixel information for the pixel with the best area resolution, that falls within a +/- 15 minute window from the nominal image time. This approach results in composites containing pixels from many different satellites, varying times, different viewing angles, with the best spatial resolution.

The satellite image composites are being routinely generated every 15 minutes for the infrared window channel at 4 km resolution in polar stereographic projection over each pole. To view the composites in real-time with the Man computer Interactive Data Access System (McIDAS)-X or McIDAS-V, the dataset is LEOGEO on the Advanced Abstract Data Distribution Environment (ADDE) server leogeo.ssec.wisc.edu.

The AMVs are generated using three 1/2-hourly composites. However, the composites are generated every 15 minutes in attempt to compensate for the varying geostationary satellite schedules, which does not always give the best coverage in the southern hemisphere. Therefore, the winds processing effectively uses every other composite image, every 15 minutes. The composites are generated 3 hours delayed from real-time, the AMVs are labeled with the middle image time (1/2 hour earlier), and the processing takes about 5 minutes for each pole. So, the north polar winds are completed after a 3:35 hours delay and the south polar winds are completed after a 3:40 hours delay. The winds can be accessed through the same McIDAS ADDE server listed above or via ftp:

ftp://stratus.ssec.wisc.edu/pub/winds/leogeo/

Figures 5.9.1 and 5.9.2 are a depiction of the composite images, over each pole, with wind flags. These images show the wind vectors for a specific time. The three images used to derive winds are combined as red/green/blue depicting features that are tracked in gray areas. The green dots represent potential targets that can't be tracked because the target or search box contains data from more than one satellite. The winds process takes into account the time and parallax information at each pixel, so the tracking can use data from different satellites in the 3 images. However, the target and search box in each individual image must be from a single satellite. These images can be viewed in real-time at:

ftp://ftp.ssec.wisc.edu/pub/ssec/leogeo/	(color composite image)
http://stratus.ssec.wisc.edu/products/rtpolarwinds/	(gray scale image)

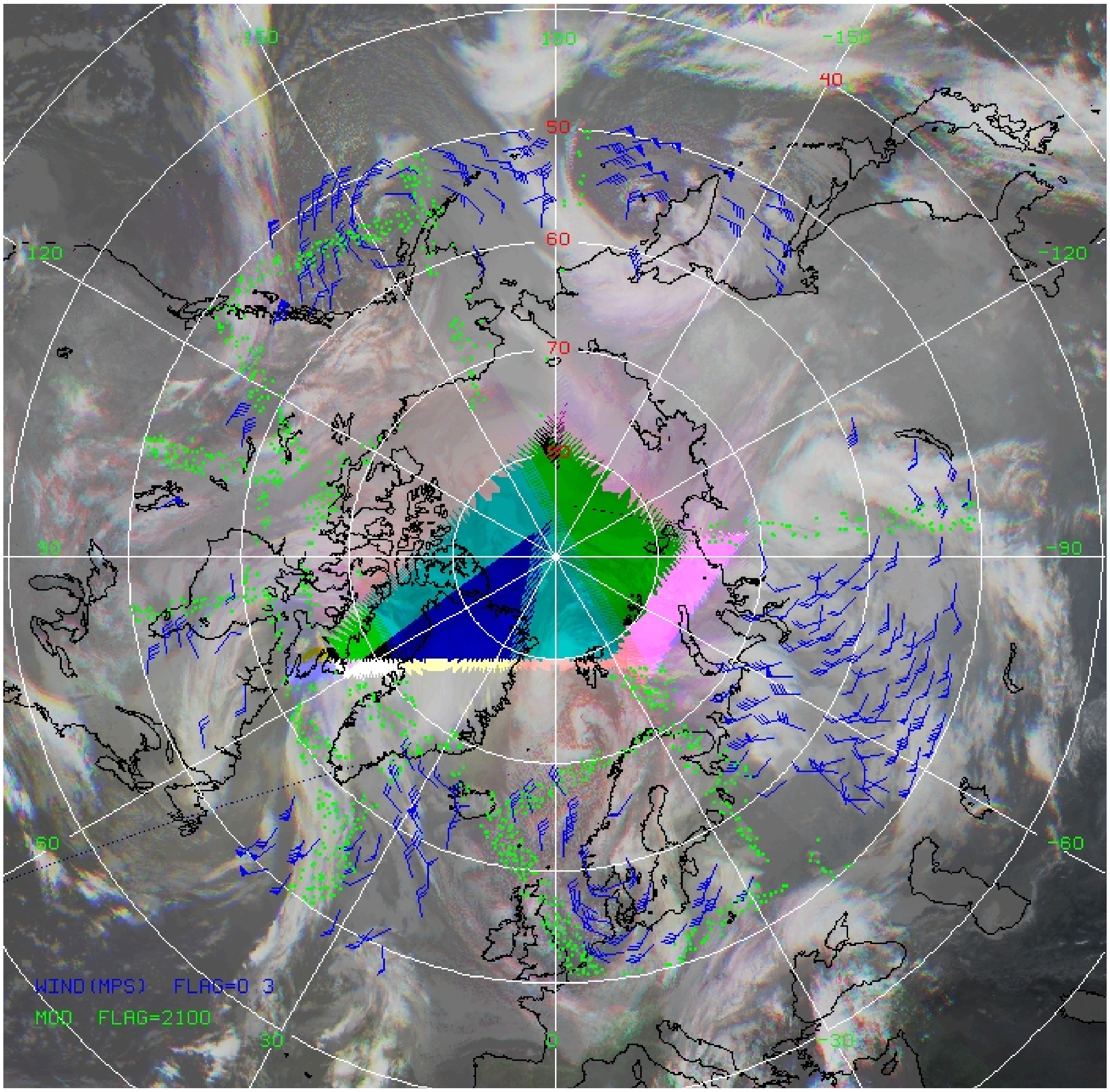

Figure 5.9.1. A north polar Arctic composite from 1115 UTC on 19 October 2010. This infrared image is composed of several images from both geostationary and polar orbiting satellites. Also, the images +/- 30 minutes from this time are included and combined as a red/green/blue composite. Gray represents regions where all 3 images contain data; regions of varying color indicate data only available for one or two images. Green dots represent potential targets that can't be tracked because they are on seams between data from two satellites. The wind vectors are edited winds from tracking cloud features on this image triplet.

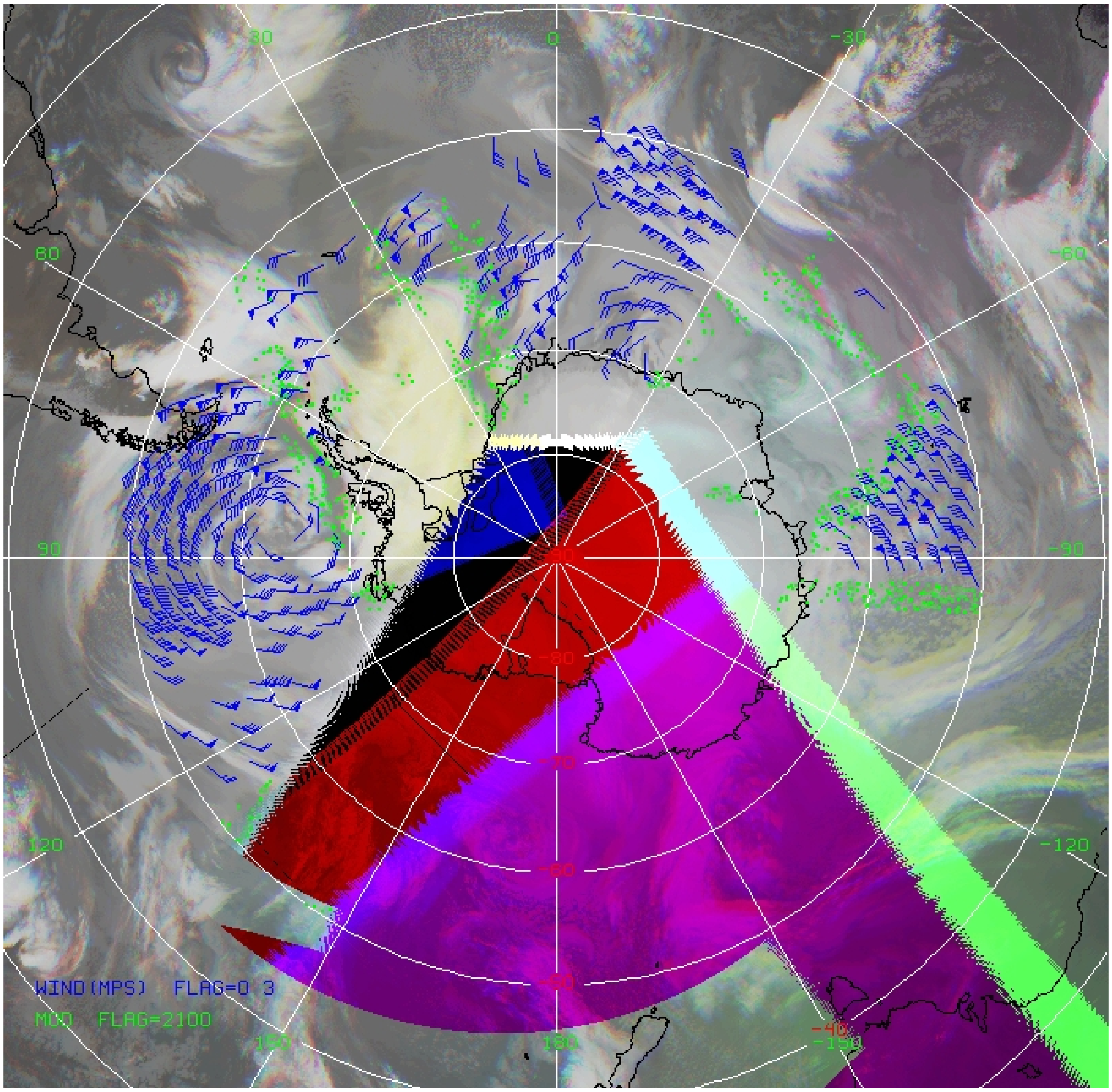

Figure 5.9.2. A south polar Antarctic composite from 1115 UTC on 19 October 2010. See Figure 5.9.1 caption for additional information.

At the end of September 2010, arrangements were initiated to provide the composite AMVs for testing in the US Navy Operational Global Atmospheric Prediction System (NOGAPS) numerical modeling system. There has also been interest expressed by the National Center for Atmospheric Research in using the composite AMVs in the Antarctic Mesoscale Prediction System (AMPS).

Validation efforts have begun to measure the accuracy of the composite AMVs. Traditionally available rawinsonde observations and reports from commercial aircraft in the both the Northern and Southern hemisphere will be the basis of the validation “truth” data set. In addition, aircraft reports from the US Antarctic Program (via LC-130, C-17, etc.) as well as other national Antarctic programs (e.g., British Antarctic Survey) are being pursued for the data sparse Southern Hemisphere. A presentation on this project was given to the 109th New York Air National Guard in Scotia, New York, one of the main contributors to the AIREP reports that will be used to validate the composite AMV observations. Also, this current Antarctic field season provides the opportunity to utilize wind observations from the

Concordiasi field program, as dropsondes measurements are being made from drifting high altitude balloons.

The development of the AICT software, modifications to the current winds software, and the real-time processing environment, were accomplished during this first year.

Publications and Conference Reports

Lazzara, M.A., D.A. Santek, R.A. Kohrs, N.A. Bearson, J. Robaidek, and S.L. Knuth, 2010a: Satellite composites: techniques in combining geostationary and polar orbiting observations. 17th Conference on Satellite Meteorology and Oceanography. American Meteorological Society, Annapolis, MD Sept 27-30, 2010.

Lazzara, M.A., D.A. Santek, R. Dworak, J.R. Key, C.S. Velden, and S. Wanzong, 2010b: High latitude atmospheric motion vectors from combined geostationary and polar orbiting observations. 17th Conference on Satellite Meteorology and Oceanography. American Meteorological Society. Annapolis, MD Sept 27-30, 2010.

Lazzara, M.A., R. Dworak; D.A. Santek, N. Bearson, C.S. Velden, and J.R. Key, 2010c Composite satellite atmospheric motion vectors. In: Antarctic Meteorological Observation, Modeling, and Forecasting Workshop, 5th, Bryd Polar Research Center, Columbus, OH, July 2010 (preprints). Columbus, OH, Ohio State University, Byrd Polar Research Center, pp.18-20.

Lazzara, M.A, R. Dworak, D.A. Santek, C.S. Velden, and J.R. Key, 2010d: High latitude atmospheric motion vectors: Applications for Antarctic and Arctic composite satellite imagery. In: International Winds Workshop, 10th, Tokyo, Japan, 22-28 February 2010. Madison, WI, University of Wisconsin-Madison, Cooperative Institute for Meteorological Satellite Studies (CIMSS).

5.10. Using NearCasts of GOES Sounder Products to Improve Forecasts of High Impact Weather Events

Task Leader: Ralph Petersen
NOAA Collaborator: Bob Aune
NOAA Strategic Goals:

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

Proposed Work

The overall goal of this new project is to test tools designed to allow forecasters that help identify areas of convective destabilization 3-6 hours in advance of storm development using products from current and future GOES satellites. These products are not used in operational NWP. The NearCasting system development has been funding under a separate GOES-RRR task and has been tested at NWS Sullivan. The objective of this task is to provide travel funds to perform additional testing at NCEP Service Centers (specifically SPC). The GOES NearCasting products provide objective examples illustrating the benefits of temporal and spatial improvements available when GOES data are used effectively.

Summary of Accomplishments and Findings

Much of the effort during the early part of the year focused on logistics and preparation for participation in the SPC Spring Exercise in June 2010. The NearCasting tests, which are targeted at improving guidance for the extremely hard-to-forecast cases of isolated severe summertime convection, have been scheduled for mid-June. Travel and logistical arrangements had been made when we were notified that the GRIB-II data that was needed to conduct the tests had not yet received approval for transmission through the SPC firewalls and would not be available for use. Based on this fact, SPC recommended that we postpone our visit until a 'Heavy Precipitation' experiment occurs in Norman and/or the second 'convective season' test planned for spring 2011. As a result, no funds have been expended form this project awaiting rescheduling of testing by SPC.

6. GOES R Algorithm Working Group

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

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

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Weather nowcasting and forecasting
- Clouds, aerosols and radiation

Proposed Work

Our past efforts have focused on generating high-resolution and large-scale WRF model simulations in order to produce high quality simulated ABI proxy data sets for AWG activities. Specific groups that have received these data sets include the GOES-R Proving Ground Program, the Algorithm Integration Team (AIT), the GRAFIIR, and the AWG Sounding, Winds, Clouds, Aviation, Imagery/Visualization teams.

This year's work, while continuing to provide proxy data sets to AWG members and others, has concentrated instead on three main areas:

- Improvement of simulated ABI proxy data sets and related NWP and forward models, especially those relevant to the accurate simulation of various measurement scenarios;
- Validation of simulated ABI proxy data sets; and
- Support for data users.

Summary of Accomplishments and Findings

Improvements to the forward radiative transfer model (FRTM) used to produce simulated ABI proxy data sets from WRF model output involved enhancements to the surface radiative property databases and a move to an entirely new FRTM, i.e., the CRTM, which began during the end of last year's work.

Refinements and enhancements were made to the UW Global IR Land Surface Emissivity Database (or UW Baseline Fit Emissivity Database) (http://cimss.ssec.wisc.edu/iremis/). The database is now available based on the latest Collection 4.1 MODIS MYD11 IR emissivity data between January 2007 and May 2010. (Note, however, that data between 2003 and 2006 are still based on the older Collection 4.0 MODIS data.) The UW database that uses the Collection 4.1 MODIS data also includes a new emissivity flag that better identifies MODIS observations affected by water. This latest database was incorporated into our current FRTM, the CIMSS Fast Solar/IR Radiative Transfer Model (Greenwald et al., 2009).

Validation of the latest UW Global IR Land Surface Emissivity Database was done using SEVIRI data (as simulated GOES-R ABI data) in clear regions for 00 UTC 15 July 2008. SEVIRI brightness temperatures were calculated by RTTOV-9.3 using ECMWF analysis water vapor and temperature profiles. Calculations were done separately assuming a constant surface emissivity of 0.98 and using the UW database. Figure 6.1.1 shows that using the UW database in the forward calculations provides improvement over assuming a constant emissivity for all 8 SEVIRI IR bands. The maximum improvement occurs at 8.7 µm, where the bias and rms error were decreased by 2 K and 1.7 K, respectively.

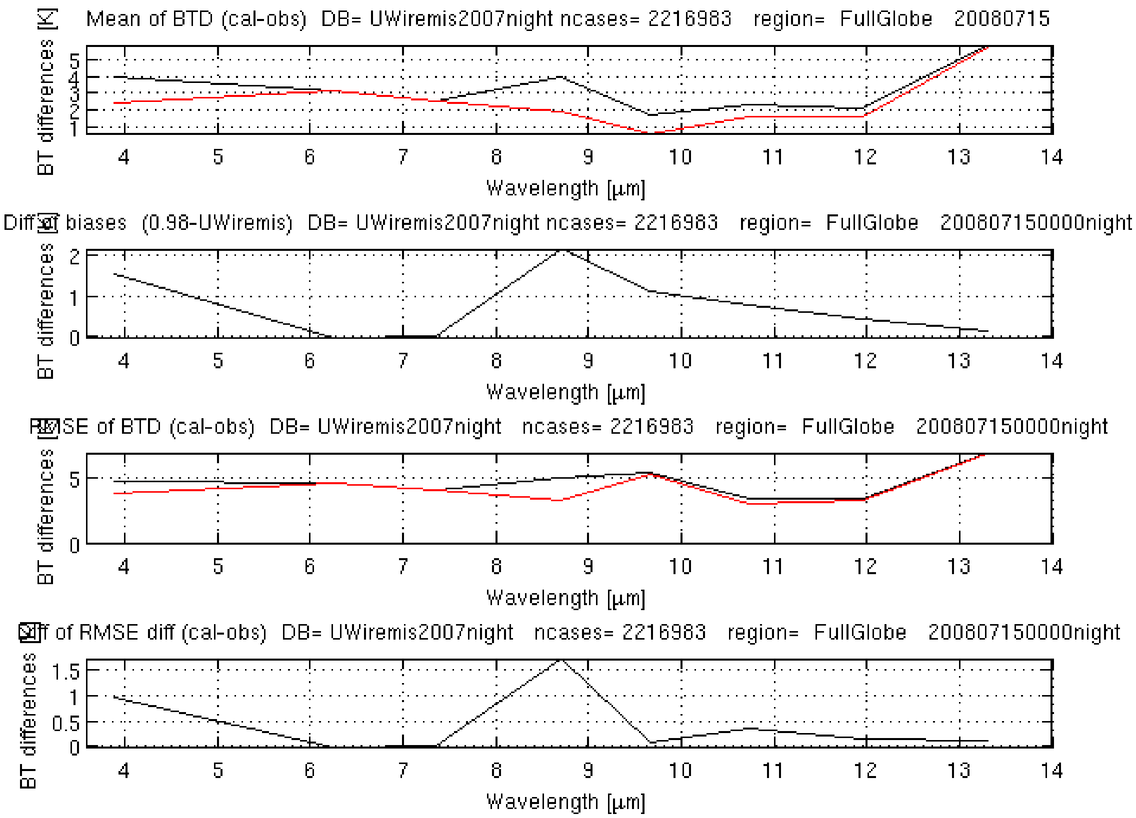

Figure 6.1.1. Top panel: Biases between calculated and observed SEVIRI brightness temperatures for 8 IR bands using the UW emissivity database (red) and assuming a constant emissivity (black). Second panel: Differences between data in top panel. Third panel: rms errors between calculated and observed brightness temperatures. Bottom panel: Differences between rms errors for data in third panel.

Another important surface property database that was improved, which is needed in calculating simulated reflectances/radiances for the ABI solar bands (1-7), was land surface albedo. The initial database used was developed by the MODIS atmosphere science team and produced on a 0.017° grid; however, it did not include snow surfaces or allow for the albedo to vary as a function of solar zenith angle. To address these limitations, we acquired the latest gap-filled land surface albedo database (MCD43DGF; also derived from MODIS data) from Boston University for each of our WRF model simulations. The new database has 1 km resolution, includes snow surfaces, and is actually an albedo model that not only allows for variation with solar zenith angle but also can provide the full bidirectional reflectance distribution function. This latest database will be incorporated into the CIMSS Fast Solar Radiative Transfer Model in the near future.

In addition to the development of enhanced surface property databases, extensive work was done to move to CRTM V2.0.2 for generating simulated ABI proxy data sets. The idea was to build a generic CRTM system that manages all WRF data access and RTM model output, including data discovery and indexing, standardized variable names, management of allocated memory, and intelligent creation of output files whose fields are dimensioned as a subset of the input fields. The purpose was to greatly simplify working with WRF model data in FRTMs and NetCDF data in general, and to simplify code development/maintenance so users can focus on science outcomes rather than programming and have greater control in grid computing environments. A module to simplify access to WRF NetCDF files has already been written. A companion module to manage CRTM model execution using WRF data is currently being developed.

Validation of our simulated ABI proxy data sets was undertaken on two fronts. First, we wanted to determine the degree of realism of the clouds simulated by the WRF model. The simulation chosen for evaluation was the 16 August 2006 large-scale high-resolution model simulation over the SEVIRI domain. We used cluster analysis to objectively classify midlatitude clouds separately for simulated data and CloudSat observations matched in space and time to see how well the simulation captured the observed cloud vertical structure and other physical properties (Greenwald et al., 2010).

Figure 6.1.2 shows a comparison of water content profiles for the four cloud regimes that were identified in both the simulation and observations. These regimes were interpreted as cirrus and low-level clouds (CR1), thicker cirrus with some low-level clouds (CR2), unorganized systems with mid-level convection (CR3), and frontal precipitation (CR4). Results show that the WRF model did a remarkable job of capturing the vertical variation and magnitude of ice water content (IWC) profiles for each cloud regime, except perhaps for CR4 where the simulated ice mass peaked at a level slightly lower than observed. However, the simulation tended to underestimate liquid water content (cloud + precipitation) for all regimes except CR2. These results provide added assurance in the quality of the simulated clouds, at least in the midlatitudes and particularly for ice clouds, in the ABI proxy data sets.

The second front was to evaluate the ice single-scattering properties assumed in the FRTM, since these properties are also very important in influencing the simulated ABI IR brightness temperatures. To validate these properties, we collected spatially-matched MODIS band 31 (11 µm; corresponding roughly to ABI band 14) and CloudSat IWC observations for high single-layer, relatively thin (optical depth < 5) ice clouds over the oceans for 2007. The comparison was limited only to high optically thin clouds because it is under these conditions where multiple scattering is maximized, allowing us to more readily evaluate the scattering properties.

Early results for CRTM V2.0.2 (Figure 6.1.3) show a significant bias that can reach -20 K on average for the coldest brightness temperatures (i.e., optically thickest clouds), suggesting the CRTM tends to overestimate ice particle extinction for somewhat optically thick clouds. Even when uncertainties in the CloudSat IWC profiles are accounted for, significant differences remain. However, a more complete error analysis will be done to more precisely determine the extent of these differences.

In July, deliverables were provided to Fuzhong Weng, including source code for our latest CIMSS Fast Solar/IR Radiative Transfer Model, a journal publication (Greenwald et al., 2010), documentation and code for the UW Global IR Land Surface Emissivity Database, documentation for the gap-filled surface albedo database, and the consolidated solar/IR ice scattering property database (UV to far-IR) and documentation.

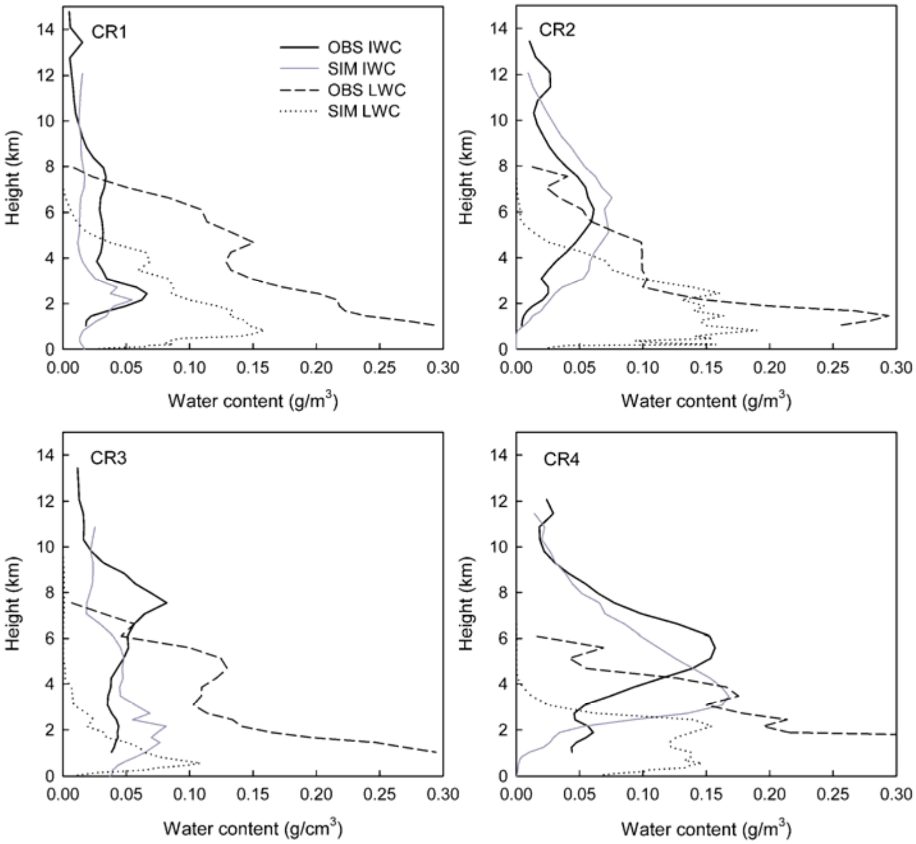

Figure 6.1.2. Mean simulated (SIM) and observed (OBS) total ice water content (IWC) and liquid water content (LWC) profiles for each cloud regime (CR).

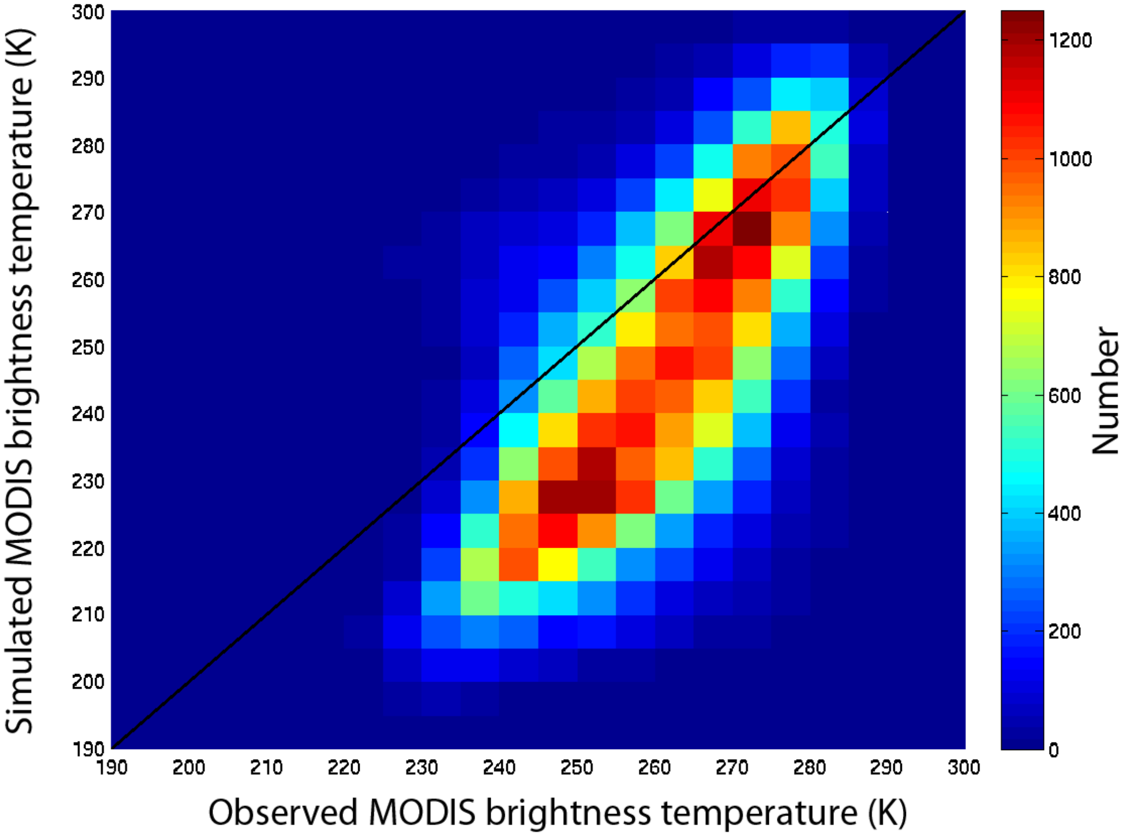

Figure 6.1.3. MODIS band 31 brightness temperatures simulated using the CRTM and CloudSat observations as compared to collocated MODIS observations for high optically thin ice clouds over the oceans.

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Davies, J., T. Greenwald, Y.-K. Lee, J. Sieglaff, and A. Huang, 2010: A comparison between the UW/SSEC Fast Solar/IR Radiative Transfer Model and the JSCDA Community Radiative Transfer Model v2.0 for AWG Proxy Data Generation. *NOAA STAR AWG/GOES-RRR Review*, 7-11 June, Madison, Wisconsin.

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Lee, Y.-K., T. Greenwald, and A. Huang, 2010: Validation of Community Radiative Transfer Model through hyperspectral infrared brightness temperature comparison over thin cirrus cloud region. *6th Annual Symposium on Future National Operational Environmental Satellite Systems-NPOESS and GOES-R*, AMS Annual Meeting, 18-21 January, Atlanta, Georgia.

Lee, Y.-K., and T. Greenwald, 2010: Evaluation of Community Radiative Transfer Model (CRTM) for thin cirrus clouds. *NOAA STAR AWG/GOES-RRR Review*, 7-11 June, Madison, Wisconsin.

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Otkin, J., J. Sieglaff, T. Greenwald, A. Huang, 2010: Model derived proxy ABI radiance datasets used for GOES-R research and demonstration activities. *6th Annual Symposium on Future National Operational Environmental Satellite Systems-NPOESS and GOES-R*, AMS Annual Meeting, 18-21 January, Atlanta, Georgia.

References

Greenwald, T., A. Huang, Y.-K. Lee, J. Sieglaff, E. Olson, 2009: Users manual to the updated fast solar/infrared radiative transfer model. *CIMSS GOES-R AWG technical document*, 25 pp.

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

Task Leaders: Mat Gunshor, Allen Huang
CIMSS Support Scientists: Ray Garcia, Graeme Martin, Erik Olson, Jason Otkin, Eva Schiffer, Justin Sieglaff, Steve Wanzong, Hong Zhang
NOAA Collaborators: Tim Schmit, Jaime Daniels.
NOAA Strategic Goals:

- Provide critical support for the NOAA mission

CIMSS Research Themes

- Clouds, Aerosols, and Radiation

Proposed Work

The GOES-R Analysis Facility for Instrument Impacts on Requirements (GRAFIIR), started in 2007, is a facility established to leverage existing capabilities and those under development for both current GOES and its successor, the Advanced Baseline Imager (ABI), in data processing and product evaluation to support GOES-R analysis of instrument impacts on meeting user and product requirements.

The GRAFIIR project is being developed by the scientists and researchers that are also GOES-R Algorithm Working Group (AWG) product team members and system developers. The approach CIMSS will undertake to accomplish the proposed GRAFIIR project includes:

Proposed Activities for 2010

- Continue to expand GRAFIIR to model ABI calibration, navigation, sensor component, and total system throughputs;
- Continue to improve upon GRAFIIR analysis functions to include more ABI products;
- Continue to provide support and datasets to assist application team members in evaluating and testing of their product algorithms;
- Continue to respond to proposed changes in ABI instrument specifications to assess their potential effects on products;
- Continue to interface with visualization team and science teams; and
- Participate in dedicated GRAFIIR meetings with AWG.

Milestones and Deliverables

- Deliver version 1 diagnostic tools for available algorithms to AIT.

Summary of Accomplishments and Findings

The GRAFIIR system continues to undergo improvements. Refinements to the ability to properly run some algorithms have been made as well. The end-to-end functionality of GRAFIIR was presented at the GOES-R AWG Annual Meeting, held 7-10 June 2010. ABI proxy data obtained from the AWG Proxy team was used as the “pure” data, or control. These data were altered with four simulated instrument effects (random noise, navigation error, calibration offset, and striping) for comparison to the control. Then level-2 baseline products (the cloud team algorithms and the sounding retrieval algorithms) were processed with both sets of data to demonstrate how sensitive the algorithms are to these changes in the data.

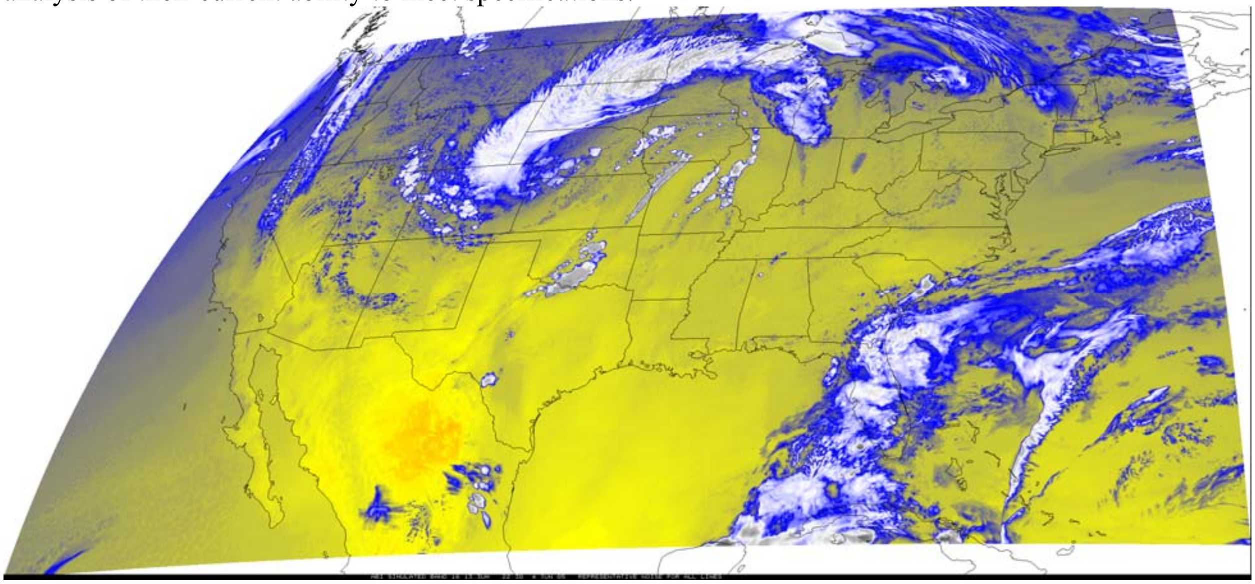
The AWG annual meeting presentation also highlighted the diagnostic statistics tool developed for GRAFIIR called Glance. Glance provides a statistical analysis comparing variables from two files. Glance can be used to compare two output files from the AIT Framework in order to help the AIT diagnose bugs in the processing Framework. It also has been used at CIMSS to diagnose issues installing the local processing system, GEOCAT, on various machines and trying to determine if the installation and algorithms work the same on different machines.

Glance, so dubbed since it gives scientists a “quick glance” at a comparison between two files, can provide a report in HTML format that includes statistics and several types of plots. Plots include a difference image, scatter plot, and histogram of the differences. It is configurable in several aspects, most notably that a value can be set for any variable being compared such that the report will alert the user to when the difference between the two files in that variable exceeds that value, called epsilon. Epsilon can be set as a crucial threshold, or at the spec value, for a variable so that the report will quickly point out how often the difference between the files exceeds that value.

Glance has undergone many upgrades in response to the needs of various AWG algorithm developers and system testers. These upgrades included more granular control over plots, improved speed and memory usage, the ability to plot original data in the same range (i.e., the same color bar), the ability to load lon/lat from a separate file, improved HDF5 support, provisions for collocating winds, and the ability to filter on additional variable data. Glance was delivered to the AWG AIT team, meeting the primary milestone for this year.

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

GRAFIIR responded to an instrument waiver in August of 2010 for the ABI (PC-1134) which was put forth by the ABI instrument vendor. The GRAFIIR team was given approximately 2 weeks to respond to this waiver, which involved increased noise in one detector on one of the ABI spectral bands, which was an effect similar, but not identical, to striping on today's GOES. This effect had to first be simulated in ABI proxy data that were generated at CIMSS by the proxy data team. Once the effect was simulated satisfactorily the data were run through imagery, cloud, winds, and sounding algorithms to compare the results before and after the "striping" to determine the effects on Level 2 product generation. The product algorithm outputs (generated for data with and without the simulated instrument waiver effect) were compared in Glance (Figure 6.2.1). It was determined that the effects were minimal and would not cause a significantly negative effect on product generation. A report detailing how the instrument effect was simulated and the subsequent effects on products was generated and presented to the Integrated Modeling Working Group and the instrument wavier "Tiger Team" that was assembled to respond to the instrument waiver. This report included an analysis of how small an impact this waiver would have on the program's ability to meet specifications for the various algorithms, which was based on the individual AWG team's analysis of their current ability to meet specifications.



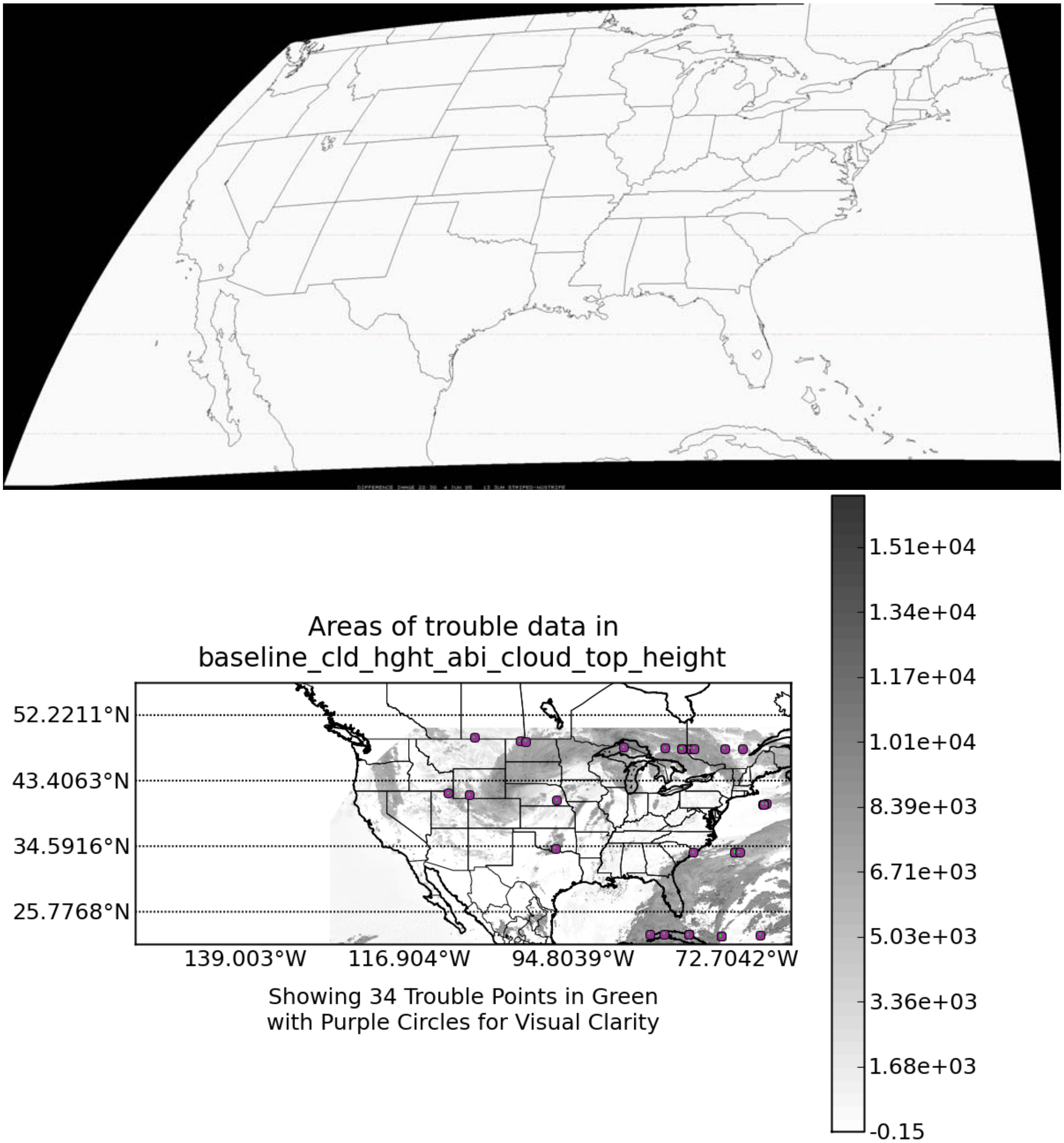


Figure 6.2.1. An instrument effect simulating increased noise for one detector of one ABI band was modeled using simulated ABI proxy data from the ABI proxy data team in a CONUS viewing scene. The top panel shows the control case and the middle panel is the difference image between the control and the scene which contains the simulated instrument effect. The bottom panel shows the results in the Cloud Height algorithm highlighting the pixels for which the cloud height changed beyond the cloud height accuracy specification. While this effect could potentially cause a small number of retrieved cloud heights to be inaccurate, overall the effect is very small since the vast majority of pixels are not significantly affected (only 34 out of nearly 1.5 million pixels were affected significantly).

Publications and Conference Reports

GRAFIIR – An efficient End-to-End Semi-Automated GOES-R ABI Algorithm Performance, Analysis, and Implementation Verification System; an oral presentation at the AMS Annual Meeting, Atlanta, Georgia, 19 January 2010.

End to End Testing Using GRAFIIR; an oral presentation at the GOES-R Algorithm Working Group (AWG) Annual Meeting, Madison, Wisconsin, 8 June 2010.

6.3. AIT Technical Support

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 Algorithm Integration Team (AIT) technical support group proposed activities principally related to "computer science" aspects of algorithm development. The activities include:

- Software integration to testing and pre-operational data processing frameworks;
- Framework-level algorithm coding, including radiative transfer model improvements and collocation software libraries;
- Enhancement of testing framework;
- Construction, maintenance and distribution of software development, deployment and verification tools;
- Retention and generation of test datasets;
- Documentation and delivery reporting;
- Regression testing of algorithms;
- Support of ancillary data collection and distribution;
- Coordination with the NOAA GOES-R AIT team and Harris/AER GOES-R implementation team;
- Coordination of treatment of sensitive (e.g., ITAR) data within CIMSS;
- Implementation of portability and testing software layers for algorithms; and
- Maintenance and enhancement of computing and storage facilities supporting algorithm development and testing.

Summary of Accomplishments and Findings

Visualization and Verification Tool Development

In cooperation with the GRAFIIR group and other teams within CIMSS/SSEC, considerable improvements were made to the 'Glance' analysis and reporting tool. Glance allows for a rapid assessment of similar datasets identifying the areas and nature of differences through statistical analysis and HTML reporting. The reports from Glance include useful plots of statistics (e.g., scatter and histogram plots) as well as geospatial, radiance or profile data that are focused on rapidly determining whether a given product meets requirements, and if not to provide rapid insight into trends of the differences that may indicate software or input data anomalies to be investigated. Development work on Glance that was funded by the CIMSS GOES-R AIT included support of software delivery verification such as r-squared statistics and GOES-R pass/fail criteria, as well as internal design improvements to allow Glance to be scripted into a wider variety of automation uses. The ability to collocate sparse vector-type data was added to Glance to support statistical analysis and plotting of GOES-R Atmospheric Motion Vector (AMV) Algorithm Working Group (AWG) output. Figure 6.3.1 shows a Glance plot of AMV team output, with wind direction represented as color.

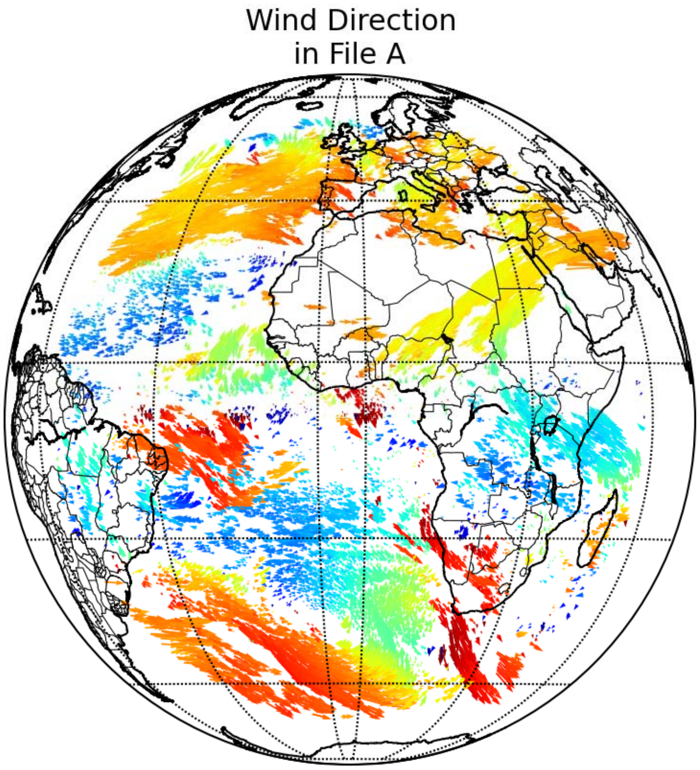


Figure 6.3.1. Glance plot of wind direction, produced from AMV team vector output for a Meteosat-8 test case from April 1, 2007 at 1200Z.

Test Framework Development

Work also continued on GEOCAT, a testing framework for GOES-R algorithms. Numerous enhancements were released as part of GEOCAT 0.8, including navigation and calibration updates, extended proxy instrument support (such as the ability to run MODIS data), the capability to build GEOCAT with the open-source gfortran compiler, the ability to have user-defined output variables, diagnostic output, as well as enhancements to the ancillary data used in GEOCAT, including spatial interpolation of NWP data, bug-fixes, updates to the standard ancillary data package and updates to the Geocat manual. Post-0.8 work has included the integration and validation of the JCSDA Community Radiative Transfer Model (CRTM) as well as ongoing user support. Figure 6.3.2 shows the clear sky bias (the brightness temperature from the Radiative Transfer Model, RTM, minus the measured brightness temperature from the satellite) from the CIMSS PFAAST/PLOD RTM (Hannon et al., 1996), left and the CRTM (Weng et al., 2005), right, for SEVIRI channel 6 (7.75 µm) for a single Meteosat-9 image (Oct 27, 2007 at 0000z), run in GEOCAT with the GDAS NWP model data as input.

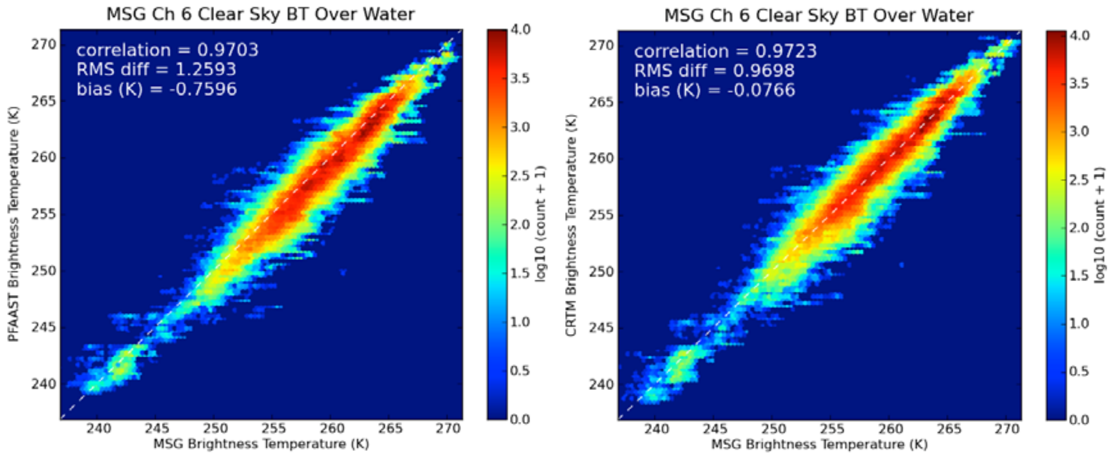


Figure 6.3.2. Clear sky bias of PFAAST (left) and CRTM (right) for MSG channel 6.

Algorithm Implementation / Modernization Work

The main focus of this AWG task is to develop a collocation library based on over 30 years of collocation development at CIMSS. The goal is to develop a maintainable library of collocation and navigation tools, capable of rapidly merging both imager and sounder observations on both polar and geo stationary platforms. 2009 activities will focus on starting to port legacy collocation software to a maintainable, documented C++ library and development of software to collocate the geo-stationary observations with polar imager and sounder observations. Table 6.3. 1 shows the various platforms that the collocation tool supports.

Table 6.3.1. Instrument combinations supported by the collocation toolkit. In each pair the master instrument has the larger footprint, so that multiple slave instrument observations may be collocated to each master observation.

Slave Master	AVHRR	CALIOP	CLOUDSAT	GOES	MODIS	POLDER	SEVIRI
AIRS		☒	☒	☒	☒		☒
AMSR-E					☒		
CLOUDSAT		☒					
GOES		☒			☒		
HIRS	☒						
MODIS		☒				☒	

These tools are flexible and designed to easily be adapted to GOES-R observations post launch,
In addition to the collocation software development we have begun developing merged products that leverage the collocation software. These products will provide the GOES-R development teams the capability to easily compare GEO observations and retrievals to the POLAR instrument suits. We have currently processed a month of SEVIRI and CALIOP collocation files and have begun implementing the product ("match") software. Figure 6.3.3 is the mean difference between the MODIS and CALIPO Cloud Top Heights (MODIS - CALIOP) aggregated using 5 degree grid cells for August 2006, which was made possible by the collocation algorithm.

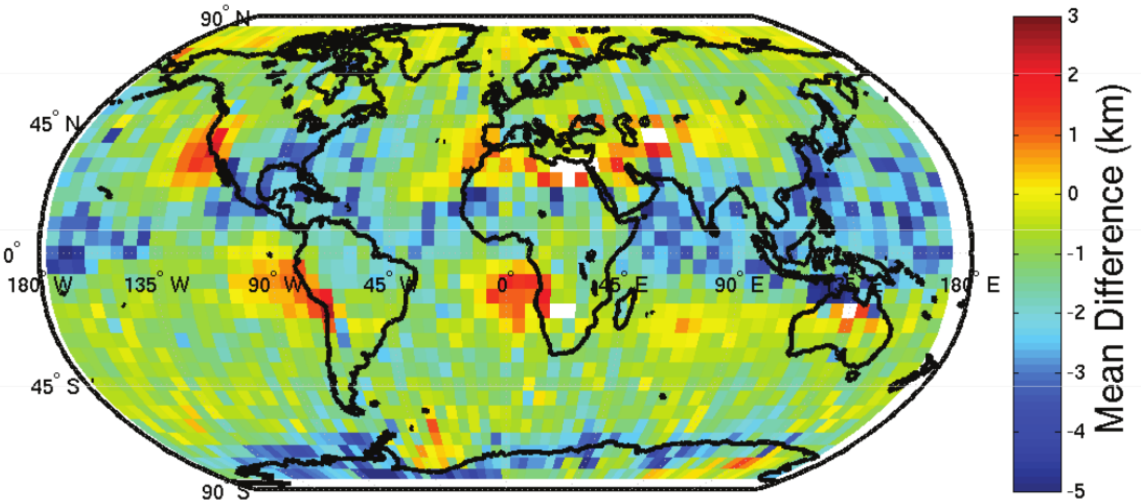


Figure 6.3.3. Comparison of MODIS and CALIOP cloud top height measurements, made possible by collocation. This plot shows the mean difference (MODIS - CALIOP) aggregated using 5 degree grid cells for August 2006.

Software Delivery and Development Support
The CIMSS AIT helped algorithm teams with delivery of ATBDs and software to the NOAA GOES-R AIT in advance of the 100% delivery of the Baseline products and 80% deliveries of the Option 2 products. Activities included cross-checking test results, ATBD consistency reviews and ATBD contributions, as well as programming, porting, testing, benchmarking, packaging, and documentation support. Software interface design discussions with the NOAA GOES-R AIT were necessary and productive in support of software delivery to the ground segment system prime contractor (Harris Corp. and AER). The CIMSS AIT participated in code reviews in connection with the CUTR milestone and in Technical Interchange Meetings involving the ground segment system prime contractor. Procedural concerns such as rules-of-engagement with the GOES-R ground segment system prime contractor, ITAR and proprietary data security were handled by the AIT in cooperation with CIMSS administration to ensure the proper treatment of sensitive data. This effort included information technology concerns such as encrypted storage and secure transfer, as well as responsible handling of data. Logistical and meeting support was provided to the GOES-R AWG teams.

Software Integration Activities
The CIMSS AIT technical support team spent a significant proportion of time on GOES-R level 2 algorithm porting efforts in cooperation with the NOAA GOES-R AIT group. Specifically, the CIMSS AIT team delivered the Baseline products ported to a more uniform, framework-agnostic set of application programmer interfaces (APIs) in order to progress toward drop-in portability (i.e., decouple interface from implementation) as well as to improving science code readability and consistency, coding

conventions and best design practices, in order to permit independent framework enhancements which would otherwise be difficult, computationally intractable, or impossible. This work included building a software idiom translation utility, authoring an API adapter layer to the internals of the testing framework, and rigorously iterating a variety of algorithms to ensure bit-for-bit matchups of the output data for delivery test cases. The ported algorithms were delivered along with patch information, such that science code development can be phased over to portable APIs over the coming months. The changes were reviewed with science staff and are expected to allow new possibilities for future algorithms to be feasible in the research environment, such as rapid development of future multi-sensor algorithms.

Data Processing and Storage Systems Maintenance and Management

Work continued on providing reliable large-scale storage of proxy, ancillary and delivery datasets with new cluster and storage systems to replace end-of-life facilities. GOES-R proxy, ancillary and test data currently masses over 50 terabytes of online storage. Where appropriate, open-source and commodity solutions are preferred for cost-effectiveness and to avoid vendor lock-in, while making use of existing internal expertise and cross-department efficiencies. Tools also continue to be developed to improve the ease of running large tests on compute clusters and large-scale storage.

References

Hannon, S., L.L.Strow, and W.W.McMillan, 1996: Atmospheric infrared fast transmittance models: A comparison of two approaches. Proceedings of SPIE Conference 2830, Optical Spectroscopic Techniques and Instrumentation for Atmospheric and Space
Research II, 12pp.

Weng, F., Y. Han, P. van Delst, Q. Liu, and B. Yan, 2005: JCSDA Community radiative transfer model (CRTM). Proc. 14th Int. ATOVS Study Conf., Beijing, China, ATOVS

6.4. Total Ozone Retrieval from ABI

Task Leader: Chris Schmidt

CIMSS Support Scientists: Jay Hoffman, Jinlong Li

NOAA Collaborators: Shobha Kondragunta (NOAA/NESDIS/STAR), Brad Pierce

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:

- Weather Nowcasting and Forecasting
- Clouds, Aerosols and Radiation
- Environmental Trends
- Climate

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.

In FY2010 CIMSS proposed to work with the Algorithm Integration Team (AIT) to perform the Code Unit Test Review (CUTR), the Algorithm Readiness Review (ARR), to provide the 100% delivery of the algorithm (software and ATBD), and to proceed with the Validation Plan.

Summary of Accomplishments and Findings

CIMSS reached all of its major milestones for the Ozone algorithm during the reporting period. The CUTR occurred in March 2010 and the Ozone algorithm was well received. The 100% algorithm package, including the Algorithm Theoretical Basis Document (ATBD) and code, was delivered during Summer 2010. The Algorithm Readiness Review occurred in September 2010 and the Ozone algorithm was shown to meet its requirements.

The ATBD and ARR included validation work done by comparing the SEVIRI ABI proxy data to data from the Ozone Mapping Instrument (OMI) on the Aura platform. Proxy data for ozone comes from SEVIRI due to the spectral similarities between it and ABI, the two instruments are very similar with respect to the ozone regression. Data were co-located with OMI footprints and within 15 minutes. The comparisons showed that the Ozone algorithm achieved accuracy of 3.3 Dobson Units (DU) and precision of 14.8 DU, relative to requirements of 15 DU and 25 DU, respectively. Figure 6.4.1 shows a scatterplot of the co-locations. The matches are generally good with some features that are due to difficult surface types (such as desert) and cloud contamination.

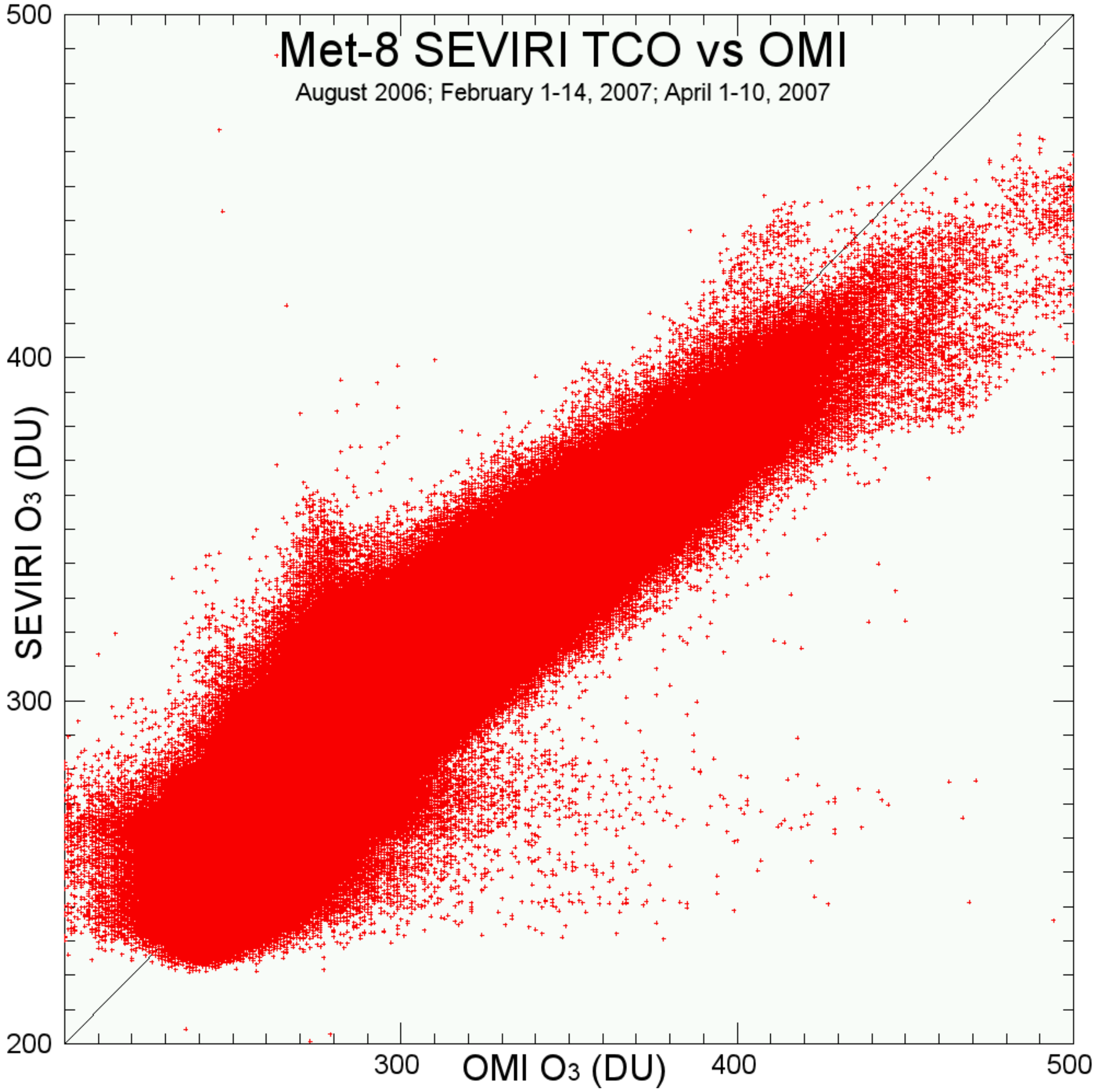


Figure 6.4.1. Met-8 SEVIRI vs. OMI total column ozone for all cloud-free pixels during the test data period August 2006, February 1-14 and April 1-10 2007. Accuracy is 3.3 Dobson Units (DU) and precision is 14.8 DU.

The long-term Validation Plan is focused on ozone values from the Ozone Monitoring Instrument (OMI) or its successors. OMI is a UV-based ozone instrument on a polar orbiting platform that provides high-confidence total column ozone values for comparison. The validation would be automated and co-locate ozone from ABI with that from the other satellite, taking into account to the extent feasible the differences in satellite footprints. The OMI footprint is approximately 13 km by 48 km at subsatellite point, compared to 2 km by 2 km for ABI (or 5 km by 5 km, remapped to a 3 km grid, for SEVIRI). This difference requires attention in the validation process as ozone can vary substantially over those scales.

Monthly progress reports that tracked effort and money spent on the Ozone algorithm were provided to the Aerosol, Air Chemistry, and Air Quality Team chair, Shobha Kondragunta (NOAA/NESDIS/STAR). The Ozone algorithm presented at the annual AWG meeting in Madison, WI.

6.5. ABI Cloud Products

Task Leaders: William Straka III,
CIMSS Support Scientists: Andi Walther, Pat Heck
NOAA Collaborators: Andrew Heidinger, Michael Pavoloinis
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:

- Clouds, Aerosols and Radiation
- Climate

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 development and validation of the various cloud algorithms. The Cloud AWG and the AIT participated in a Code Unit Test Review (CUTR) in March. Reviewing the code for NOAA/NESDIS coding standards as well as how the code performs was a requirement for the 100% code delivery.

In April, the Cloud AWG, along with the AIT, participated in a Technical Interchange Meeting (TIM) 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 2010 GOES-R AWG Annual Meeting, where a presentation was made regarding the 100% code delivery and a summary of the various products developed by the Cloud AWG.

In July, the Cloud AWG provided the final (100%) software delivery to the NOAA GOES-R Algorithm Integration Team (AIT) for integration into the GOES-R AIT Framework..

We responded to the Independent Verification and Validation (IV&V) comments of the ATBDs reviews at the GOES-R Algorithm Development Executive Board (ADEB) in September and also directly to the reviewers. This work will ensure that the GOES-R Ground Segment System Prime will be able to implement the Cloud AWG algorithms as specified.

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.

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. Figure 6.5.1 shows an example of the comparisons done between the daytime cloud optical properties verses CloudSat, MODIS and AMSR-E.

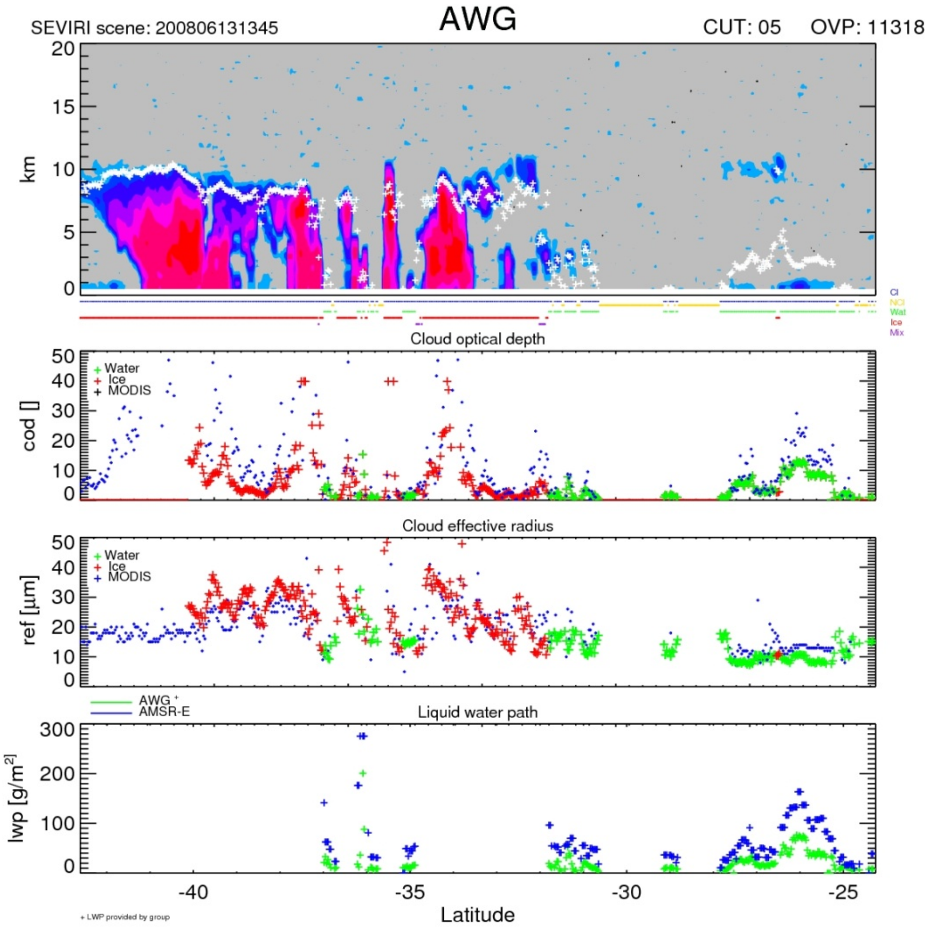


Figure 6.5.1. Validation of AWG retrievals with ATRAIN sensors. The upper panel shows CloudSat reflectivity profile with AWG cloud height product. The color bars below show cloud mask (blue – cloudy; yellow – cloudfree) and cloud phase (green – water; red- ice; purple – mixed phase). Second and third panel show comparison of Cloud Optical thickness and Cloud Effective Radius to MODIS results. Lower image illustrates comparison of Liquid water path to AMSR-E passive microwave measurements.

Finally, the Cloud AWG team continues to work with the other Algorithm Working Groups as well as other groups to continue to validate and improve the algorithms. In the next year, the Cloud AWG will 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)

6.6. Active Fire/Hot Spot Characterization (FIRE)

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 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:

- Clouds, Aerosols and Radiation
- Environmental Trends
- Climate

Proposed Work

The primary focus of this effort is to adapt the current GOES Wildfire Automated Biomass Burning Algorithm (WF_ABBA) to GOES-R ABI. CIMSS proposed to continue 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 also utilizes the improved fire monitoring capabilities on GOES-R and contains updates to the modules that identify and characterize sub-pixel fire activity. In FY10 the task included preparing and delivering the Code Unit Test Review (CUTR), the 100% Algorithm Theoretical Basis Document (ATBD) and associated 100% code delivery, and the Algorithm Readiness Review (ARR). Additionally, in coordination with NOAA scientists, CIMSS proposed to continue development of the validation plan, methods, and tools to be used in the GOES-R era. CIMSS also proposed to continue generating proxy data from MODIS and continuing to work with CIRA on using model-derived proxy data. 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

CIMSS reached all of its major milestones during the reporting period. The 100% delivery of the Active Fire/Hot Spot Characterization Algorithm Package occurred on time and the algorithm meets and exceeds its requirements. The Code Unit Test Review, which evaluates software readiness, occurred on March 15, 2010 and no major problems with the algorithm were identified. The Algorithm Readiness Review occurred on September 14, 2010 and the algorithm was shown to meet its requirements and be ready for delivery. The largest delivery, the 100% Algorithm Theoretical Basis Document, occurred on time and was sent along for further review. The Fire algorithm was also presented during the Algorithm Development Executive Board (ADEB) meeting in August 2010.

Figure 6.6.1 shows CIMSS MODIS simulated ABI 3.9 µm (band 7) data for Central America at 18:45 UTC on April 24, 2004 and the CIMSS ABI WF_ABBA fire mask product generated from it. Proxy data such as this is generated by applying a convolution to the MODIS data to simulate the ABI Point Spread Function. The fires can be seen in the 3.9 µm data as dark spots, regions where fire detection isn't possible (water, unusable surface types, or a lack of background temperature estimates) are the non-fire areas colored as colors other than black.

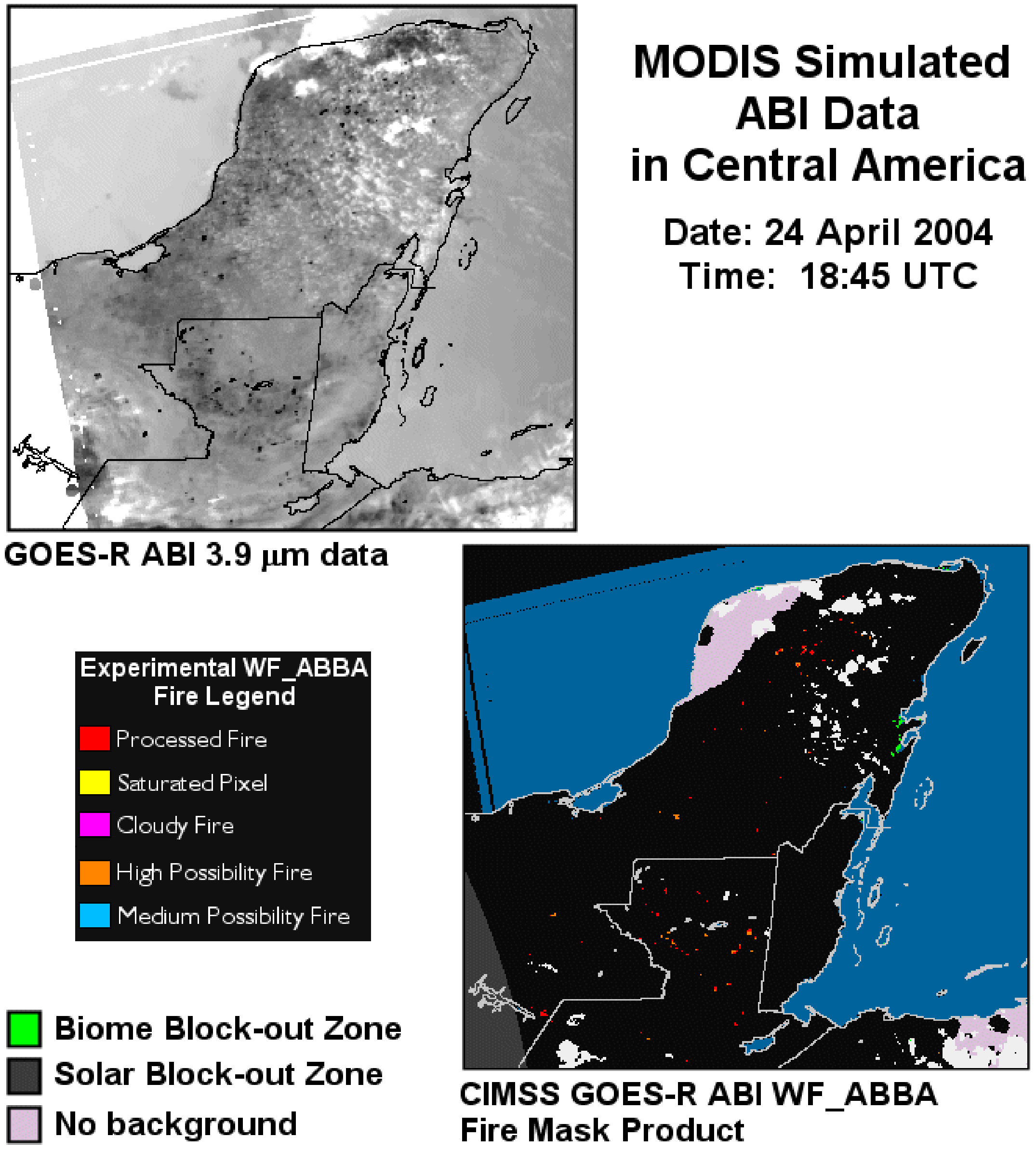


Figure 6.6.1. CIMSS MODIS simulated ABI 3.9 µm data for Central America at 18:45 UTC on April 24, 2004 and the CIMSS ABI WF_ABBA fire mask product.

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 is 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. This result implies a problem elsewhere in the software chain that remains under investigation. Figure 6.6.2 (provided courtesy of Wilfrid Schroeder and Ivan Csiszar (NOAA/NESDIS/STAR)) shows a sample false-color ASTER image with proxy ABI fire pixels overlaid on top. The offset is visible by comparing the ASTER and proxy ABI detected fires at the center of the image.

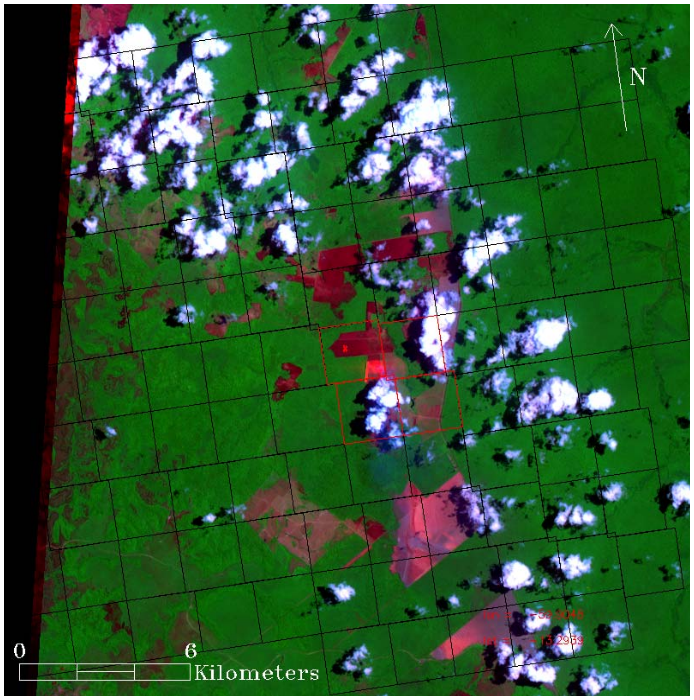


Figure 6.6.2. GOES-R ABI nominal pixels (grid) overlaid on coincident 30m resolution ASTER image (RGB 8-3-1) acquired at 14:21:59 UTC on October 19, 2002. ABI Fire pixels are outlined in red, burning regions are dark red in the ASTER image. Image courtesy of Wilfrid Schroeder and Ivan Csiszar (NOAA/NESDIS/STAR).

The Fire algorithm was part of a presentation about the AWG Land Team's efforts at the annual AWG meeting held in Madison, WI. Additionally, monthly progress reports were provided to the Land Team chair, Yunyue Yu, that tracked effort and money spent.

6.7. GOES-R Legacy Profile and Surface Infrared Emissivity Algorithm Development

Task Leader: Jun Li
CIMSS Support Scientists: Xin Jin, Zhenglong Li, Elisabeth Weisz, Jinlong Li, Chian-Yi Liu
NOAA Collaborator: Tim Schmit
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

- Weather Nowcasting and Forecasting

Proposed Work

- Develop GOES-R legacy atmospheric profile (LAP) algorithm version 5.0 and deliver to the GOES-R algorithm integration team (AIT);
- Implement and test validation tools by using the current GOES Sounder, SEVIRI, RAOB, ECMWF analysis, and ARM Site in-situ measurements;
- Create validation report document;
- Prepare unit test review and algorithm readiness review;
- Develop 100% algorithm theoretic baseline document (ATBD) for GOES-R LAP;
- Prepare GOES-R LSE algorithm critical design review (CDR);
- Perform GOES-R LSE test readiness review (TRR);
- Develop GOES-R LSE version 3 and version 4 algorithm;
- Develop GOES-R 80% ATBD LSE; and
- Perform GOES-R LSE algorithm evaluation with SEVIRI data.

Summary of Accomplishments and Findings

GOES-R LAP Product and Algorithm Development

1) GOES-R LAP algorithm performance initial evaluation conducted with 18-month ECMWF analysis.
The GOES-R ABI LAP algorithm performance has been evaluated using an 18-month collocated SEVIRI radiances and ECMWF analysis products, the dataset is provided by EUMETSAT nowcasting Satellite Application Facility (SAF) through collaboration efforts. The work was done with the stand-alone version of GOES-R LAP sounding algorithm. The SEVIRI data is processed within each 3-by-3 field-of-view (FOV) box area, only the warmest pixel in terms of 11 μm brightness temperature from all clear sky pixels within each box area is selected in the LAP retrieval process. The cloud mask is from the EUMETSAT operational product. The ECMWF 12-hour analysis is used as truth. To make the evaluation more reasonable, only the SEVIRI observations from 00 and 12 UTC are selected for evaluation. The ECMWF 12-hour forecast is also employed as background information. The SEVIRI database was collected between April 1st, 2007 and September 30th, 2008. The CIMSS baseline fit LSE database is used over land while the emissivity over ocean is from a look-up table, and the retrieval is separated over land and ocean. Figure 6.7.1 shows the evolution of retrieved relative humidity profile RMSE (against ECMWF analysis) between April 2007 and September 2008 over land. The reduction of moisture profile RMSE is remarkable, especially above 700 hPa.

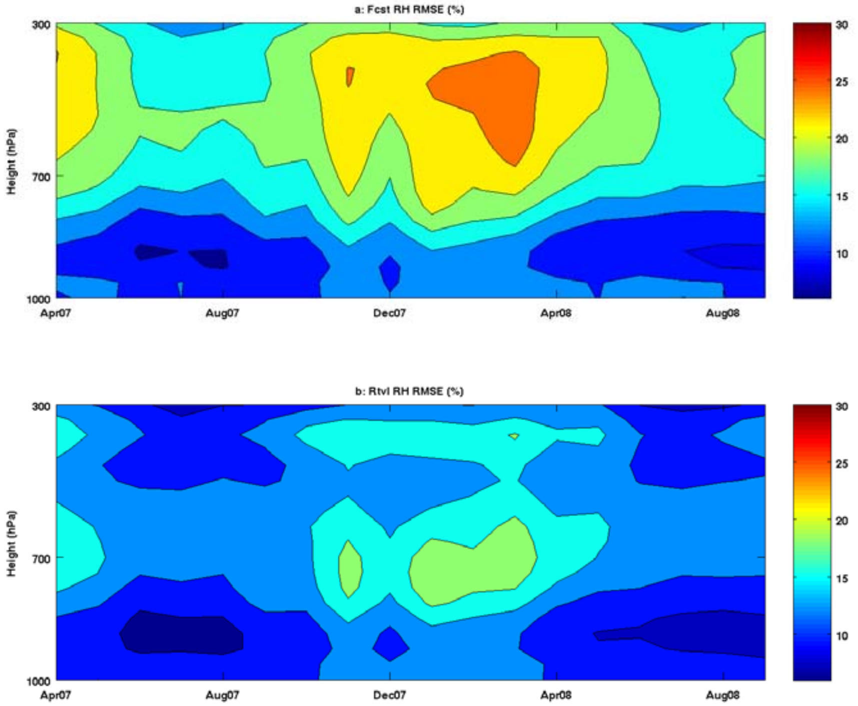


Figure 6.7.1. The retrieved relative humidity profile RMSE against ECMWF analysis between April 2007 and September 2008 over land. The upper panel is forecast and the lower panel is retrieval from SEVIRI.

2) GOES-R LAP versions 4 and 5 algorithm/software implemented in GEOCAT.

3) GOES-R LAP level 2 product validation schedules for 2010 – 1012 are developed.
The schedules are for the algorithm product validation to 100% maturity for legacy atmospheric moisture profile, legacy atmospheric temperature profile, total precipitable water, and derived atmospheric stability indices. The validation data will include SEVIRI radiance measurements, radiosondes, ARM site in situ measurements, ground based GPS TPW measurements, ECMWF/GFS analysis, and advanced level 2 products from the polar orbiting satellites.

4) GOES-R LAP versions 4 and 5 delivered to AIT mainframe through GEOCAT, it has been tested and the results are consistent with that from the GEOCAT.

5) GOES-R LAP Code Unit Test Review (CUTR) was held on 15 March 2010.
CIMSS sounding team worked closely with AIT on the CUTR. The main purpose of the CUTR is to identify software risks associated with the algorithms so that they can be addressed before the 100% delivery. The comments from the ATBD reviewers were also reviewed.

6) CIMSS sounding team prepared the 100% ATBD for LAP based on reviewers' comments and CUTR. The 100% ATBD will be consistent with the latest version of code delivery.

7) GOES-R LAP Technical Interchange Meeting (TIM) was held on May 27, 2010.

8) CIMSS sounding team has investigated the Jacobian approach in GOES-R LAP algorithm.

The current GOES-R LAP algorithm uses cRTM and its accompanying Jacobian. However, the Jacobian (K-matrix) from cRTM is much computationally expensive. To meet the GOES-R LAP latency requirement, we have implemented the analytical Jacobian approach (Li 1994) in the LAP algorithm, which requires additional output from cRTM official version. We have worked with cRTM team on this implementation.

9) CIMSS sounding team has prepare for GOES-R LAP 100% ATBD, the LAP 100%ATBD was delivered on 30 September 2010.

10) GOES-R LAP Algorithm Readiness Review (ARR) prepared.
CIMSS sounding team has prepared the GOES-R LAP algorithm readiness review (ARR), the ARR was held on 21 September 2010. Validation results with SEVIRI radiance measurements have been presented. Comparisons between PFAAST and cRTM are conducted with both simulation and SEVIRI brightness temperature measurements. The results indicate that brightness temperature calculations are similar between cRTM and PFAAST when the local zenith angle is less than 70 degree, however, the BT differences are significantly increased when the local zenith angle is greater than 70 degree.

GOES-R Land Surface Emissivity (LSE) Product and Algorithm Development
1) GOES-R LSE algorithm has been developed and implemented into CIMSS GEOCAT.
The LSE algorithm uses the time continuity information and SEVIRI/ABI radiances from multiple time steps are used to retrieve LSE product.

2) GOES-R LSE algorithm versions 1 and 2 implemented in GEOCAT.
CIMSS sounding team also worked closely with GEOCAT team on testing GOES-R land surface emissivity algorithm/software versions 1 and 2 in GEOCAT environment. The LSE versions 1 and 2 have been successful implemented in the GEOCAT for AIT to test. Figure 6.7.2 shows the land surface emissivity retrievals at 8.7 µm (upper left), 10.8 µm (upper right) and 12.0 µm (lower left) along with the surface skin temperature (lower right) for 01 August 2006 using SEVIRI observations at three time steps (00 UTC, 03 UTC and 06 UTC). Surface skin temperatures are for 06 UTC. The product resolution is 3 by 3 FOVs. Results are from GEOCAT system.

3) GOES-R LSE critical design review (CDR) was held successfully on 14 January 2010.
CIMSS sounding team worked closely with AIT on GOES-R CDR. The purpose of LSE CDR is to provide a scientific and mathematical description of the GOES-R ABI infrared band surface emissivity retrieval algorithm for product developers, reviewers and users. The CDR algorithm has been documented in the GOES-R LSE ATBD. The main features of the GOES-R LSE algorithm are: (a) using variational approach with Quasi-Newtonian iteration; (b) using regression as the first guess; (c) using time continuity for LSE (the LSE is assumed to be invariable during a short period of time while LST is variable); (d) temperature and moisture profiles from forecast are used for atmospheric correction in radiative transfer calculation; and (e) using fast and accurate radiative transfer model and K-matrix.

4) GOES-R LSE version 3.0 delivered.
The LSE algorithm has been installed on the STAR filesystem, along with Geocat 0.8, cloud mask v4 and supporting data files. LSE is composed of a main algorithm module and a set of supporting modules that are built into a library.

5) GOES-R LSE 80% ATBD prepared and delivered.
CIMSS sounding team has prepared the GOES-R LSE 80%ATBD; it has been delivered to the GOES-R program office on 30 September 2010. The LSE ATBD describes the methodology for land surface

emissivity retrieval from GOES-R; the unique feature of the algorithm is to use the high temporal information in the LSE product development.

6) GOES-R LSE algorithm Test Readiness Review (TRR) prepared.
CIMSS sounding team has prepared the GOES-R LSE algorithm TRR, the TRR was held on 15 September 2010. The TRR material, compiled jointly with the AIT, was presented to the GOES-R Program Office. The focus of the presentation was on test results, validation, and product generation. This product is in the 'option 2' set.

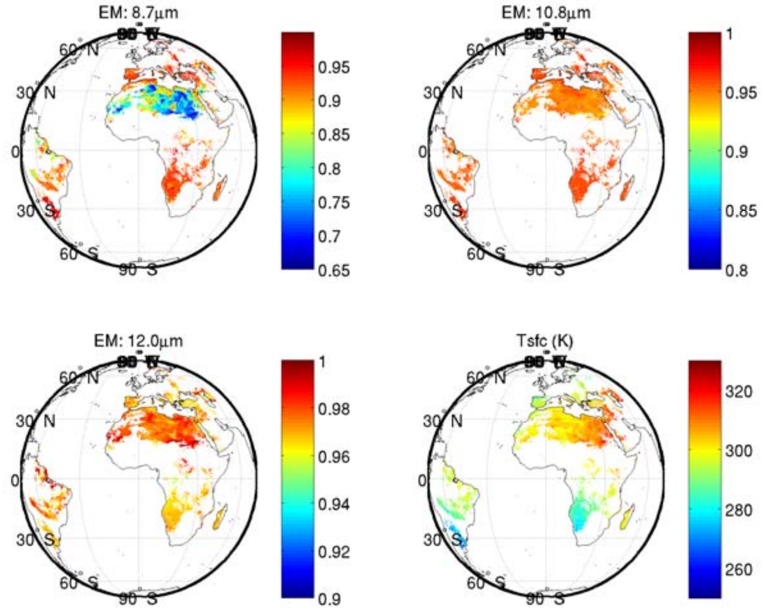


Figure 6.7.2. The land surface emissivity retrievals at 8.7 µm (upper left), 10.8 µm (upper right) and 12.0 µm (lower left) along with the surface skin temperature (lower right) for 01 August 2006 using the SEVIRI observations at 00 UTC, 03 UTC and 06 UTC. Surface skin temperature retrievals are for 06 UTC.

Publications

Jin, X., J. Li, T. J. Schmit, and M. Goldberg, 2010: Evaluation of radiative transfer models in atmospheric profiling with broadband infrared radiance measurements. *Int. J. Remote Sens.*, Jan 27, 2011.

Li, J., Z. Li , X. Jin , T. J. Schmit , L. Zhou , and M. Goldberg, 2010: Land surface emissivity from high temporal resolution geostationary infrared imager radiances - I: Methodology and simulation studies. *Journal of Geophysical Research - Atmosphere* (in press).

Li, Z., J. Li, X. Jin , T. J. Schmit , E. Borbas , and M. Goldberg, 2010: An objective methodology for infrared land surface emissivity evaluation. *Journal of Geophysical Research - Atmosphere* (in press).

6.8. AWG Winds

Task Leaders: Chris Velden, Steve Wanzong
CIMSS Support Scientist: Howard Berger
NOAA Collaborators: Jaime Daniels (STAR) and Wayne Bresky (IMSG)
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

GOES-R atmospheric motion vector (AMV) software development and testing is being done within a common processing framework that supports a tiered algorithm processing approach that allows the output of lower-level algorithms to be available to subsequent higher-order algorithms while supplying needed data inputs to all algorithms through established data structures. NOAA employees based at CIMSS have developed the current framework, GEOCAT. GEOCAT allows user algorithms to be plugged into its framework. The framework performs input data handling of calibrated/navigated radiances and ancillary data. These data are then loaded into established data structures that can be accessed by all algorithms. Other established data structures enable the output of the lower-level algorithms to be accessible by higher-level algorithms. While we are leveraging and building upon existing target selection/quality control/feature tracking that is used operationally on GOES data at NESDIS today, there are some important differences. For example, the target selection and height assignment we are employing relies on utilization of pixel level cloud mask and cloud height products generated upstream via algorithms delivered by the GOES-R Algorithm Working Group (AWG) cloud application team. Simulated Advance Baseline Imager (ABI) data, and archived Meteosat-8 data are being used to test the software adaptability.

The proxy ABI imagery begins as a high resolution Weather Research and Forecasting (WRF) model simulation. WRF model output, including the surface skin temperature, atmospheric temperature, water vapor mixing ratio, and the mixing ratio and effective particle diameters for each hydrometeor species, are ingested into the Successive Order of Interaction (SOI) forward radiative transfer model in order to generate simulated top of atmosphere (TOA) radiances. From these TOA data, imagery is derived and used to track features. The targeting and tracking software was developed outside of CIMSS, but within the GOES-R AWG Winds team. It has been successfully installed, tested, and modified on local CIMSS hardware.

Meteosat-8 data from August 2006 and February 2007 are also being heavily used for AMV testing purposes. The spectral channels and horizontal resolution are very similar to the future GOES-R ABI instrument. The Meteosat-8 data is remapped to ensure excellent registration between images, which will also be comparable to the ABI.

During this reporting period we helped to finish modifications to the Delivery 5 AMV software, developed software to compare Meteosat AMVs to GFS analysis grids, and contributed to the 100% AMV ATBD.

Summary of Accomplishments and Findings

During this reporting year, the development of the winds retrieval algorithm for GOES-R ABI targeted the following goals:

1. Supply Delivery 5 of the AMV software to the GOES-R algorithm integration team (AIT).
2. Test the algorithm performance using simulated and proxy data sets. We mainly concentrated on Meteosat-8 AMVs from August 2006 and February 2007.

Much of the year's efforts were spent working towards the 100% GOES-R AMV software and ATBD deliveries. The efforts included making modifications to the AMV software, and keeping four SSEC software packages up to date with the AMV software deliveries. The SSEC software is outside of the AMV framework, but still important to the 100% ATBD delivery.

Our main contribution to the AWG winds software package was adding the ability to filter out AMVs according to rules defined by the Expected Error (EE). Filtering is defined as setting the output flag of the AMV from a "good" wind to a "bad" wind. Current filtering occurs as such: 1) IR AMV with EE > 4.5 m/s, 2) Visible AMV with EE > 5.5 m/s, 3) Clear sky water vapor with EE > 5.0 m/s, and 4) Short wave AMV with EE > 5.0 m/s. Late in the reporting cycle, cloudy sky band 8 AMVs were introduced into the software. A detailed study will be necessary to calculate the filtering limit for this product. As part of the EE filtering addition, we also were able to add AMVs back using a combination of EE and QI filtering. A flag set in the configuration file controls the use of this addition.

Table 6.8.1. Criteria for re-introducing AMVs that have been flagged bad by EE filtering.

Band	EE	QI	AMV Speed
2	EE < 5.5 m/s	QI > 95	Spd > 30 m/s
7	EE < 5.0 m/s	QI > 95	Spd > 30 m/s
8	EE < 5.0 m/s	QI > 95	Spd > 30 m/s
10	EE < 5.0 m/s	QI > 95	Spd > 30 m/s
14	EE < 4.5 m/s	QI > 90	Spd > 25 m/s

We extended the AMV ASCII output file within the AWG winds code with several potential useful diagnostic variables: land/water mask, date/time information of the tracking images, McIDAS satellite number, low level inversion flag, dominant cloud phase of the target, and the dominant cloud type of the target.

Most of our resources this year were spent developing 4 downstream algorithm packages using the ASCII AMV output file as the starting point. The first program reads the AMV ASCII output file and converts it into a NetCDF file. It is flexible enough to allow for the many changes to the AMV output. As NetCDF data structures, the AMVs can be plotted natively in McIDAS-V.

A McIDAS program was then developed to take the AMV NetCDF file, and compare the winds to the GFS analysis winds. The output produced a "match" NetCDF file that extends the existing AMV NetCDF file. The GFS analysis allows nearly every AMV to be matched to a grid point. Only AMVs over oceans are considered.

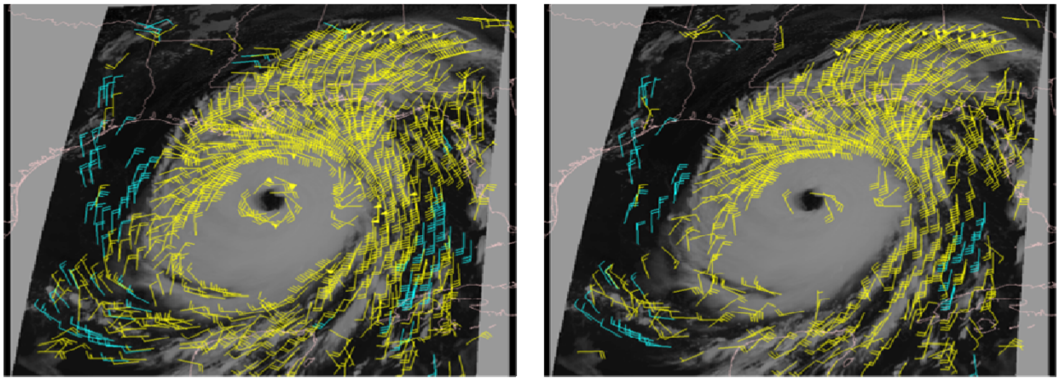
A Fortran 90 routine then takes these individual "match" NetCDF files and concatenates them into a single NetCDF file. This approach allows for many day and time periods to be represented by 1 file.

Lastly, another Fortran 90 software package was written to supply AMV GFS analysis statistics for the 100% ATBD. We concentrated on the two months of Meteosat-8 data consisting of August 2006 and February 2007. The table below was part of a larger group of statistics submitted in the ATBD. The sample includes all AMVs taken as one set. It can be seen that the computed metrics are within the required F&PS specifications.

Table 6.8.2. Accuracy and Precision estimates of AMVs (QI > 60) derived from full disk (ocean only) Meteosat imagery for the months of August 2006 and February 2007. These estimates were determined from comparisons to collocated GFS analysis winds at 00 and 12 UTC. F&PS accuracy and precision requirements are shown for comparison.

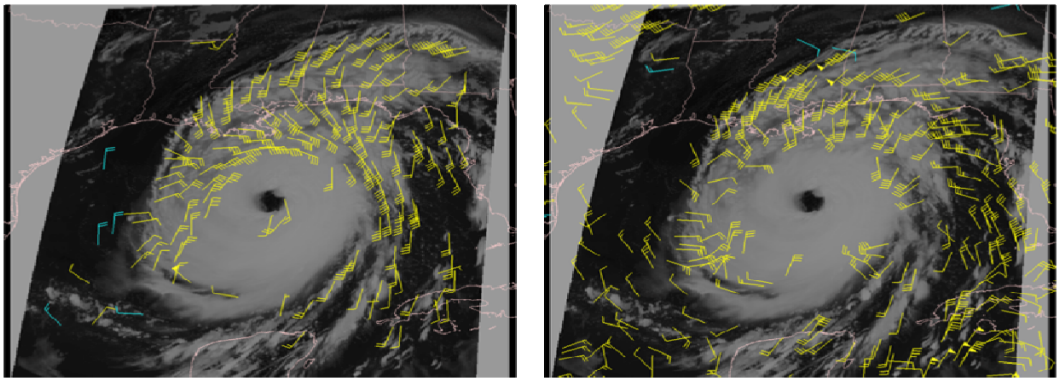
F&PS Performance Metric	F&PS Requirement (m/s)	Computed Metric (m/s)	Sample Size
Accuracy	7.5	4.31	3145211
Precision	4.2	3.70	3145211

A hurricane Katrina ABI simulation was made available to the AWG community. The AWG winds team worked with the SSEC AWG Proxy data team to correctly align the navigation for conversion of NetCDF images to McIDAS AREA files. This step is necessary as the GEOCAT framework requires AREA files as input. As a result of this collaboration, all SSEC ABI simulations may now be easily converted to McIDAS AREA files. The GOES-R program office requested the figure below. Figure 6.8.1a is the result of using the 2km resolution, 5-minute step to produce the AMVs. Figure 6.8.1b used the 2km resolution, but a 15-minute time step. Even at this stage you can see the diminished AMVs in the hurricane eyewall as well as a thinning in the outflow regions. Figure 6.8.1c is the result when reducing the ABI imagery from 2km to 4km resolution. It also used the 15-minute time step. This would be similar to what we see today with an operational scanning schedule. Figure 6.8.1d is the result of using 4km, 15-minute data from the GOES-12 imager. This exercise shows the expected improvement with the future ABI.



(a) 2 km resolution; 05 minute time step

(b) 2 km resolution; 15 minute time step



(c) 4 km resolution; 15 minute time step

(d) 4 km resolution; 15 minute time step – GOES-12 AMVs

Figure 6.8.1. Various AMV sets derived from simulated ABI data (a) - (c), and real GOES-12 data (d)

We also participated in several meetings and telecons. These included the AWG Winds Code Unit Test Review (CUTR), the annual GOES-R AWG conference, the Technical Interchange Meeting (TIM) with Harris, the Algorithm Readiness Review (ARR) and the Algorithm Development Executive Board (ADEB) meeting.

Publications and Conference Reports

Wanzong, Steve and Velden, Chris, 2010: Exploring the behavior of atmospheric motion vector (AMV) errors through simulation studies. 10th International Winds Workshop, Tokyo, Japan. Manuscript in preparation.

Wanzong, Steve; Velden, Chris; Daniels, Jaime and Bresky, Wayne. Exploring the behavior of atmospheric motion vector (AMV) errors through simulation studies. GOES Users' Conference, 6th, Madison, WI, 3-5 November 2009. Manuscript not available for publication; abstract only.

Otkin, Jason; Greenwald, Tom; Sieglaff, Justin; Gunshor, Mat; Bah, Kaba; Schmit, Tim; Huang, Allen and Wanzong, Steve. High-resolution simulated ABI datasets used for GOES-R research and demonstration activities. GOES Users' Conference, 6th, Madison, WI, 3-5 November 2009. Manuscript not available for publication; abstract only.

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

Task Leaders: Tim Olander, Chris Velden
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. During this reporting period, CIMSS scientists proposed to help deliver new versions of the HIE and supporting documentation (Algorithm Theoretical Baseline Documents, ATBDs) to the GOES Project Office. It was also proposed to utilize GOES-R proxy data sets to further evaluate the accuracy and impact of the improved ABI data on the HIE, including the use of MSG SEVERI data and model-derived synthetic data.

Summary of Accomplishments and Findings

Several important benchmarks have been met during the reporting period in order to satisfy the AWG 100% delivery requirements (completed in September 2010), including the delivery of the HIE algorithm (Version 5), all related documentation (100% ATBD), and several formal meetings and reviews (Code Unit Test Review (CUTR), Technical Interchange Meeting (TIM), Algorithm Development Executive Board (ADEB) Meeting, and Algorithm Readiness Review (ARR)). In addition, it was determined that the initial precision requirements for the HIE was unrealistic, so a formal review was conducted and the precision requirement for the HIE was changed from 5.0 m/s to 8.5 m/s (accuracy was left unchanged at 5.0 m/s). Using several datasets for evaluation of the HIE performance (including current GOES, synthetic GOES-R, MODIS, and current MSG/SEVERI imagery) it was determined that the HIE will successfully meet both accuracy and precision specifications.

Publications and Conference Reports

Olander, T., and C. Velden, 2010: The GOES-R AWG Hurricane Intensity Estimation (HIE) Algorithm, GOES-R Algorithm Working Group Meeting, Madison, Wisconsin, June 7-10.

References

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

6.10. Aviation Weather

6.10.1. Tropopause Fold Turbulence Product (TFTP)

Task Leader: Anthony Wimmers
CIMSS Support Scientist: Wayne Feltz
NOAA Collaborator: Ken Pryor (NOAA/NESDIS/STAR)
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:

- Weather Nowcasting and Forecasting

Proposed Work

The tropopause folding turbulence product (TFTP) is designed to resolve regions of dynamical turbulence caused by tropopause folds at air mass boundaries. Identifying these regions of turbulence is critically important to the aviation community (commercial and non-commercial) for purposes of hazard awareness and safety. The product is in its third year of development and will reach 100% maturity in July 2011.

The TFTP product is a natural fit for the GOES-R Advanced Baseline Imager (ABI) because turbulence-generating tropopause folds are evident through synoptic-scale gradients in moisture, which appear 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 creates a distribution of regions of expected turbulence (Figure 6.10.1.1). Previous studies have presented the underpinning of this algorithm (Wimmers and Moody 2004a,b) and verified the assumptions with in situ data (Wimmers and Feltz 2005).

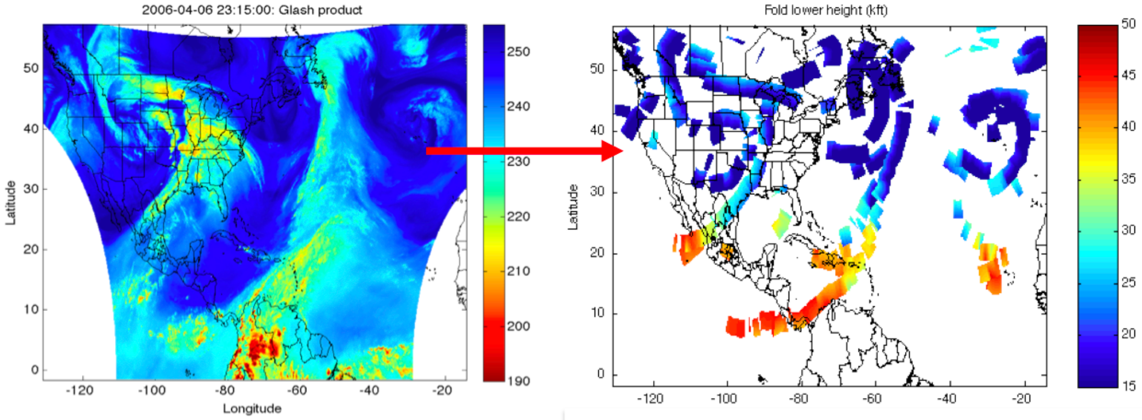


Figure 6.10.1.1. Left: Input water vapor distribution, derived from the GOES-10 water vapor channel and normalized for ambient temperature and zenith angle. Right: corresponding distribution of tropopause fold objects from the TFTP algorithm.

The objectives of the work for FY2010 were to further adapt the algorithm to the standards and requirements of the GOES-R Algorithm Working Group (AWG) for the Version 3 delivery, to report on the algorithm performance in the Test Readiness Review (TRR), to complete an extensive calibration/validation to demonstrate that the algorithm meets the product requirements, and to deliver the 80% Algorithm Theoretical Basis Document (ATBD).

Summary of Accomplishments and Findings

Version 3 of the TFTP was delivered to the Algorithm Integration Team (AIT) in January 2010. This version achieved complete standardization of algorithm code; full product precedence; usage of designated proxy data sets; and initial performance tests with common ancillary data and latency tests. The product development was approved with a successful TRR in March 2010.

Product calibration/validation was completed in September 2010. We compared the TFTP product to corresponding automated aircraft in-situ observations of turbulence from November 2005 to December 2007 (Figure 6.10.1.2). The dataset was composed of 996 product images and over 1000 cases of Moderate or Greater turbulence. The validation achieved 53% accuracy, which satisfies the 50% accuracy requirement from the AWG. In this calibration/validation process we demonstrated how to increase product accuracy with higher limits on tropopause fold intensity, direction and vertical location within the tropopause fold object.

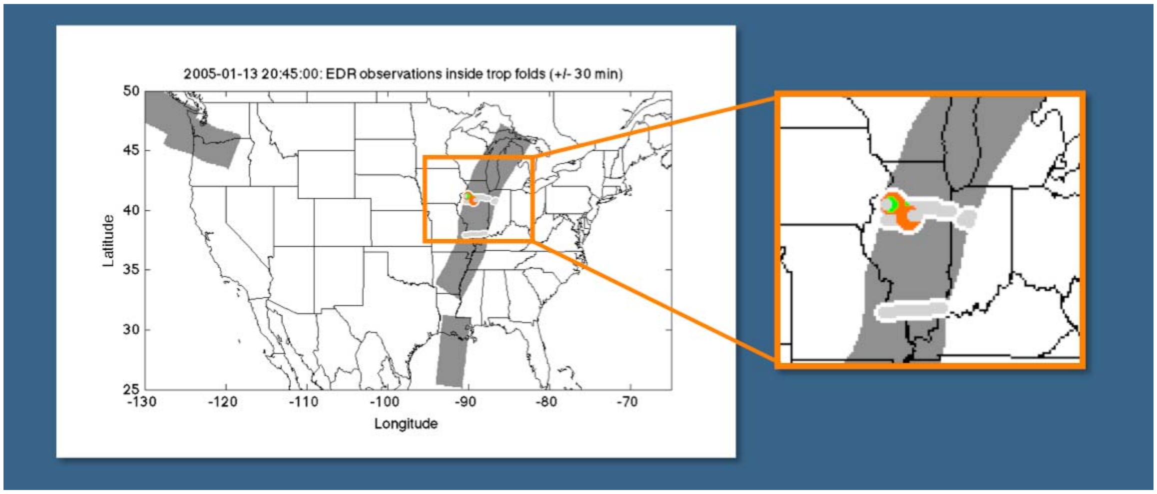


Figure 6.10.1.2. Left: Horizontal distribution of product-resolved tropopause folds for January 13 2005, 2045 UTC. Right: Detail of the left image, showing corresponding in-flight turbulence reports inside the tropopause fold volume (gray is null, green is light turbulence and orange is moderate turbulence).

The ATBD was delivered on schedule to the AIT in May 2010. This 80% version includes a thoroughly updated Theoretical Description; Mathematical Description; a report of Test Data Sets and Algorithm Output; and a report of the Algorithm Validation. The document was evaluated by an independent reviewer and the Algorithm Development Executive Board (ADEB), and was approved in August 2010 after minor revisions.

An additional accomplishment that was not included in our scheduled work was the production of the GOES-R Turbulence Fact Sheet, which we produced together with the GOES-R outreach team.

Publications and Conference Reports

Wimmers, A. J. and W. F. Feltz, 2010: Predicting turbulence by satellite and validating with in situ data: A full-scale analysis with the GOES-R Tropopause Folding Turbulence Product. 17th Conference on Satellite Meteorology and Oceanography. Annapolis, MD. September 2010, Amer. Meteor. Soc., P1.5.

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.

6.10.2 AWG Aviation Weather –Volcanic Ash

Task Leader: Justin Sieglaff
NOAA Collaborator: Michael Pavolonis
NOAA Strategic Goals:

- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes

- Weather Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Proposed Work

During the 2010 fiscal year we proposed to perform a more statistically significant validation of the Advanced Baseline Imager (ABI) volcanic ash height and ash mass loading algorithm retrievals developed during previous fiscal years. Additionally, the version 5 code delivery and the 100% Algorithm Theoretical Basis Document (ATBD) deliveries were also to be completed. This project will ensure the readiness of the volcanic ash algorithm for operational implementation upon the deployment of GOES-R.

Summary of Accomplishments and Findings

In previous years, a tri-spectral (8.5, 11, and 12 μm) cloud optical depth based volcanic ash detection algorithm and a tri-spectral (11, 12, and 13 μm) optimal estimation based volcanic ash height/mass loading algorithm were developed. The ash height and mass loading algorithms are only applied to pixels determined to contain volcanic ash. To validate these algorithms, it is necessary to utilize existing observations of volcanic ash using satellites with similar spectral channels to ABI. The Moderate Resolution Imaging Spectroradiometer (MODIS) imager is one such instrument. Additionally Aqua-MODIS orbits the Earth in the A-train satellite constellation. An additional instrument within the A-train is the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP). CALIOP gives very accurate cloud heights and the co-location with Aqua-MODIS allows for global validation of the ABI volcanic ash height/mass loading algorithm. Volcanic eruptions are relatively rare. To make a statistically significant validation of the ABI volcanic ash height/mass loading algorithm, large-scale airborne dust storms are commonly observed and serve as a proxy for volcanic ash. The use of airborne dust as a proxy for volcanic ash is reasonable because volcanic ash and dust have very similar emissivity spectra through the infrared window (8 to 13 μm).

Previous reports have indicated eight SEVIRI full disk scenes absent of volcanic ash and dust (null case events) were well within GOES-R F&PS Specifications for mass loading (mean mass loading bias < 0.03 tons/km^2 and standard deviation < 0.8 tons/km^2.). This continues to be the case and non-trivial case validation is highlighted within this report. For non-trivial validation results, the CALIOP is used to provide accurate information on cloud height. Using the same assumptions as the ash mass loading retrieval, the CALIOP cloud boundaries can be used to compute a "truth" mass loading. During FY 2010, 434 ash pixels and 3432 dust pixels from Aqua-MODIS were co-located with CALIOP truth data for use in validation analysis. The ash (dust) retrieved heights were compared to CALIOP height and CALIOP computed "truth" mass loading. Figure 6.10.2.1 shows a qualitative example of an Aqua/CALIOP overpass over a 4-panel plot of a false color image, retrieved ash height, mass loading, and effective particle size (top) and a cross-section of retrieved GOES-R ash heights versus CALIOP total attenuated backscatter (bottom) for an ash cloud from the Chaiten Volcano in Chile during May 2008. In this example, the retrieved ash heights agree well with CALIOP heights. Table 6.10.2.1 summarizes validation results for ash and dust pixel validation matchups. The ash and dust height retrievals have a small negative bias compared to CALIOP (-0.74 km and -1.43 km, respectively) that is well within the GOES-R F&PS Specification for ash height (3.0 km). Additionally, ash and dust pixel mass loading retrievals are shown to be very accurate (0.58 ton/km^2 and 0.40 ton/km^2, respectively) well within the GOES-R F&PS Specification for mass loading (2.0 ton/km^2). Table 6.10.2.1 also shows the ash mass loading precision for ash and dust pixels are well within the F&PS Specification (2.5 ton/km^2).

In addition to scientific validation of the volcanic ash height and mass loading algorithms, the following milestones were also achieved:

- Delivery of 100% Algorithm Theoretical Basis Document (ATBD) and Version 5 of the volcanic ash code to GOES-R Algorithm Implementation Team (AIT)

Publications and Conference Reports

Pavolonis, M. J. and J. Sieglaff: GOES-R Volcanic Ash: Detection and Height Algorithm Theoretical Basis Document (ATBD), 100% revisions submitted June 2010.

Pavolonis, M. and J. Sieglaff, 2010: Using the GOES-R AWG Volcanic Ash Algorithm to Track Eyjafjallajokull Volcanic Ash: Impacts on Operations and Research. 2010 GOES-R AWG Meeting, Madison, Wisconsin, June 2010 – Oral presentation.

Sieglaff, J. and M. Pavolonis, 2010: Advances in Volcanic Cloud Remote Sensing. 17th Conference on Satellite Meteorology and Oceanography, Annapolis, Maryland, September 2010 – Oral presentation.

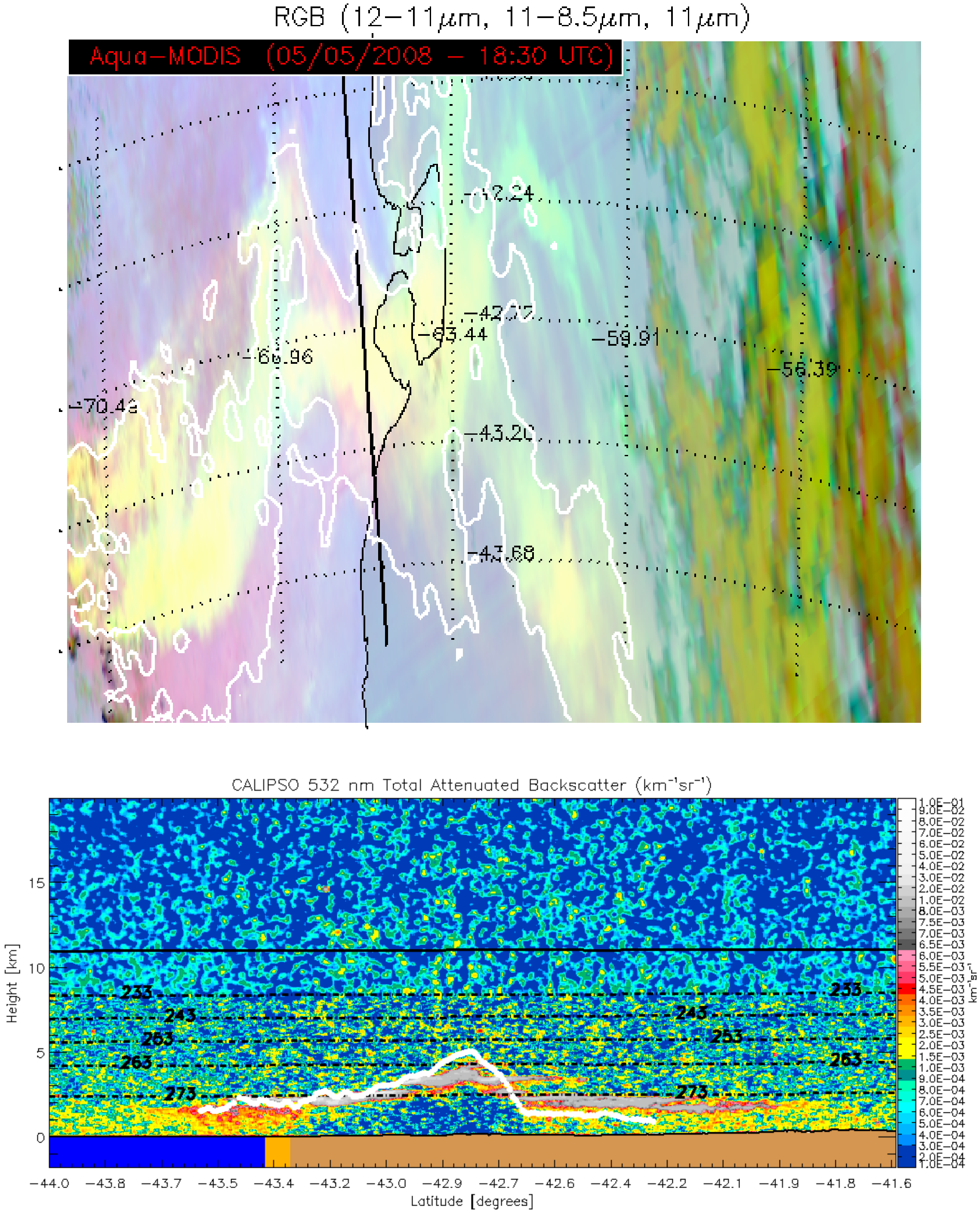


Figure 6.10.2.1. Qualitative example of Aqua-MODIS and CALIOP matchups for Chaiten Ash Cloud (Chile, May 5, 2008) used in validation. False color image (top) with CALIOP overpass indicated by black stripe. Bottom panel shows CALIPSO 532nm Total Attenuated Backscatter (shaded colors) and GOES-R retrieved ash heights (white dots).

Table 6.10.2.1. Summary of ash and dust Aqua-MODIS/CALIOP validation matchups. Height accuracy, mass loading accuracy and precision are well within GOES-R F&PS Specifications.

Dataset	Number	Height Accuracy (spec=3km)	Height Precision (spec=none)	Mass Loading Accuracy (spec=2.0 ton/km^2)	Mass Loading Precision (spec=2.5 ton/km^2)
Ash	434	-0.74 km	2.24 km	0.58 ton/km^2	1.95 ton/km^2
Dust	3432	-1.43 km	1.49 km	0.40 ton/km^2	1.03 ton/km^2
Total	3866	-1.35 km	1.61 km	0.42 ton/km^2	1.17 ton/km^2

6.10.3 Fog/Low Cloud

Task Leader: Corey Calvert
CIMSS Support Scientist: William Straka
NOAA Collaborator: Michael Pavolonis
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:

- Weather Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Proposed Work

The second 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, combined with pre-determined look-up tables (LUTs) to produce a probabilistic approach to detection. We proposed to expand on this approach to further improve the quality of the fog/low cloud detection algorithm by grouping adjoining pixels with relatively high fog/low cloud probabilities into cloud objects. Spatial and spectral statistics from these cloud objects are then used to further analyze the objects to better determine whether fog/low cloud is present. We also introduced a new definition for fog/low cloud that will more accurately relate to aviation weather. Fog/low cloud is now defined as a cloud with a ceiling low enough to produce Instrument Flight Rules (IFR) conditions, defined as having a ceiling below 1000 ft. There are visibility requirements included in the IFR definitions; however, surface visibility is not available for the GOES-R fog/low cloud detection algorithm and is therefore not used. New LUTs were created to take into account the new definition of fog/low cloud. The fog depth 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 11/12 processing stream (http://cimss.wisc.edu/geocat) for continuous evaluation, and additional validation using LIDAR and surface observations will be used for further tuning. 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 Instrument Flight Rules (IFR) conditions, defined as having a cloud ceiling below 1000 ft above ground level, in the absence of overlapping water or ice clouds. The fog detection algorithm utilizes textural and spectral information, as well as the difference between the cloud radiative temperature and 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 also tends 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. At night, the algorithm utilizes the 3.9 and 11 μm channels to detect IFR conditions. Fog/low cloud detection during the day is determined using the 0.65, 3.9, and 11 μm channels. LUTs were created using a 3.9 μm pseudo-emissivity (night), a 3x3 pixel 11 μm brightness temperature spatial uniformity metric (day) and the difference between the cloud radiative temperature and surface temperature (both day and night) from both fog and non-fog water clouds determined by surface observations and the GOES-R cloud type algorithm. Each table returns a probability that fog/low cloud is present at any given pixel. Once the fog/low cloud probability is estimated the algorithm utilizes advanced spatial analysis (cloud object analysis) to minimize false positive results. Adjoining pixels with relatively high probabilities are grouped together to form cloud objects. When forming the objects, several statistical parameters calculated using the observed spectral data are saved for each object. These object statistics are then applied to threshold tests to help differentiate cloud objects that are not fog/low cloud (false positives) from ones that are. The fog/low cloud depth is calculated for each pixel flagged by the detection algorithm 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 6.10.3.1.

The following additional project milestones were achieved:

- Completed the fog/low cloud Test Readiness Review (TRR), May 2010;
- Delivered the fog/low cloud 80% code to the Algorithm Implementation Team (AIT). June 2010; and
- Completed the second draft (80%) of the fog/low cloud Algorithm Theoretical Basis Document (ATBD). September 2010.

Publications and Conference Reports

Pavolonis, M.J. and C. Calvert: GOES-R Fog and Low Cloud Detection Algorithm Theoretical Basis Document (ATBD), Second Draft (80%).

Pavolonis, M. and C. Calvert, 2010: The GOES-R Fog/Low Cloud Products. AWG Annual Meeting, Madison, WI, June 2010 – Oral presentation.

Pavolonis, M. and C. Calvert, 2010: An overview of the GOES-R Fog/Low Cloud Products. OCONUS GOES-R Proving Ground Meeting, Honolulu, HI, July 2010 – Oral presentation.

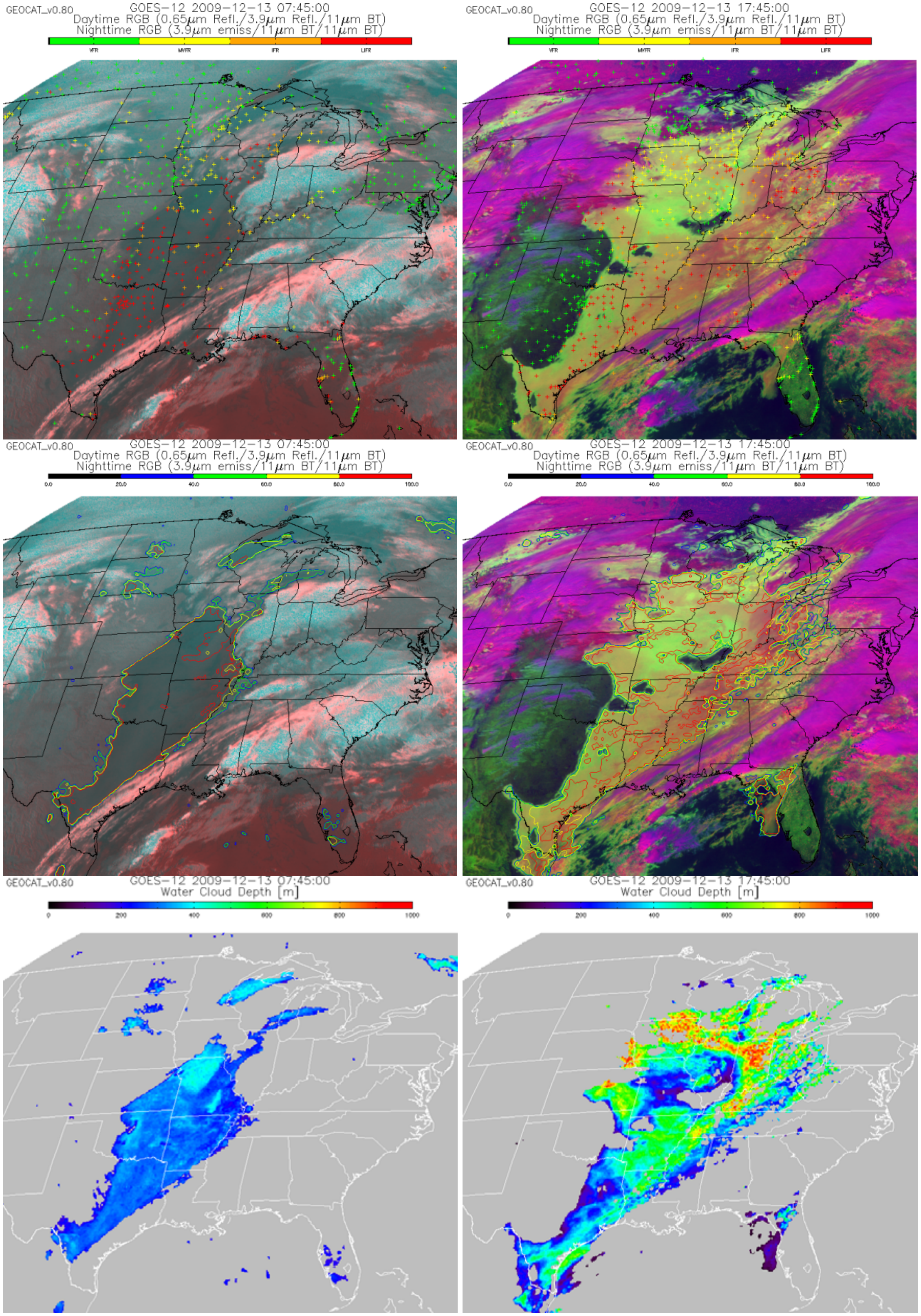


Figure 6.10.3.1. Example output from the GOES-R fog/low cloud algorithm from December 13, 2009 at 07:45 UTC (left side images) and 17:45 UTC (right side images) centered over the Midwest United

States. The top two panels are false color RGB images with surface observations showing instrument flight rules (IFR) conditions where no overlapping water or ice clouds are detected by the GOES-R cloud type algorithm. The middle two panels are false color RGB images with the fog/low cloud probability from the algorithm contoured over top. The bottom two panels show the estimated fog depth output from the fog/low cloud algorithm.

6.10.4. GOES-R Algorithm Working Group: Aviation Weather, Overshooting Top and Enhanced-V Detection

Task Leader: Jason Brunner
CIMSS Support Scientists: Wayne Feltz, Rich Dworak, Lee Cronce
NOAA Collaborator: Ken Pryor (NOAA/NESDIS/STAR)
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:

- Weather Nowcasting and Forecasting

Proposed Work

This work represents the third 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 (see Figure 6.10.4.1), 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.

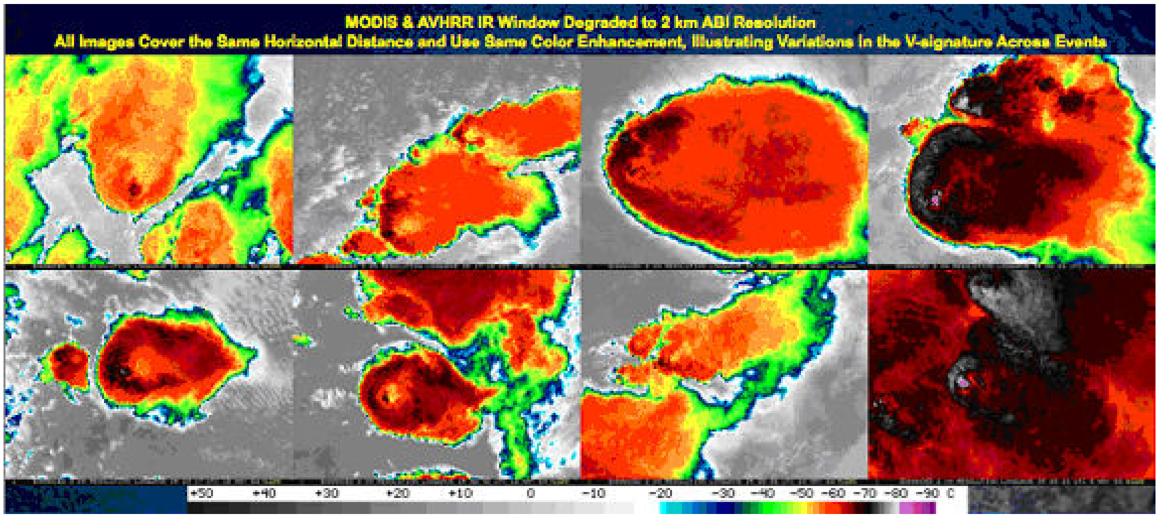


Figure 6.10.4.1. An example of 8 cold (or enhanced)-U/V producing storms in MODIS and AVHRR ~11 µm brightness temperature imagery across the continental U.S. The color enhancement and horizontal distance shown in each panel is identical, illustrating the variability of the enhanced-V signature.

Summary of Accomplishments and Findings

The Test Readiness Review for the enhanced-V and OT product was successfully completed on March 12, 2010. Also, the Version 2 and Version 3 enhanced-V and OT products were delivered to the Algorithm Implementation Team in November 2009 and January 2010, respectively. In addition, the 80% ATBD, the proxy test data sets, and the documentation of the proxy test data sets and validation for the enhanced-V and OT product were all delivered to the Algorithm Implementation Team in June 2010.

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. Figure 6.10.4.2 provides a rare view of an OT producing storm over the Ivory Coast on 5 February 2008, which was photographed by the International Space Station. MSG SEVIRI imagery shows the characteristic region of cold 10.8 µm IRW BTs and lumpy appearance in 1 km high-resolution visible imagery of the OT photographed by the Space Station. The IRW-texture technique identified the OT region perfectly in this case. Another unique way of looking at deep convective storms is through NASA CloudSat and CALIPSO profiles. Figure 6.10.4.3 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.

A five-year OT detection climatology using the IRW-texture method shows that OTs occur frequently across the continental U.S. and there are clear diurnal differences in OT activity. (Bedka et al., 2010) Comparisons with objective aircraft observations show that turbulence is more often observed during aircraft flight near an OT compared to ordinary non-OT cold cloud pixels in the ~11 µm infrared window

(IRW) channel. In addition, results show that lightning is more often observed near OTs and the minimum IRW brightness temperature (BT) within an OT can be used as an indicator of cloud-to-ground lightning. These results indicate that the IRW-texture technique offers a more consistent day/night OT detection capability than other existing methods, allowing for unambiguous interpretation and application of product output for aviation and severe weather forecasting.

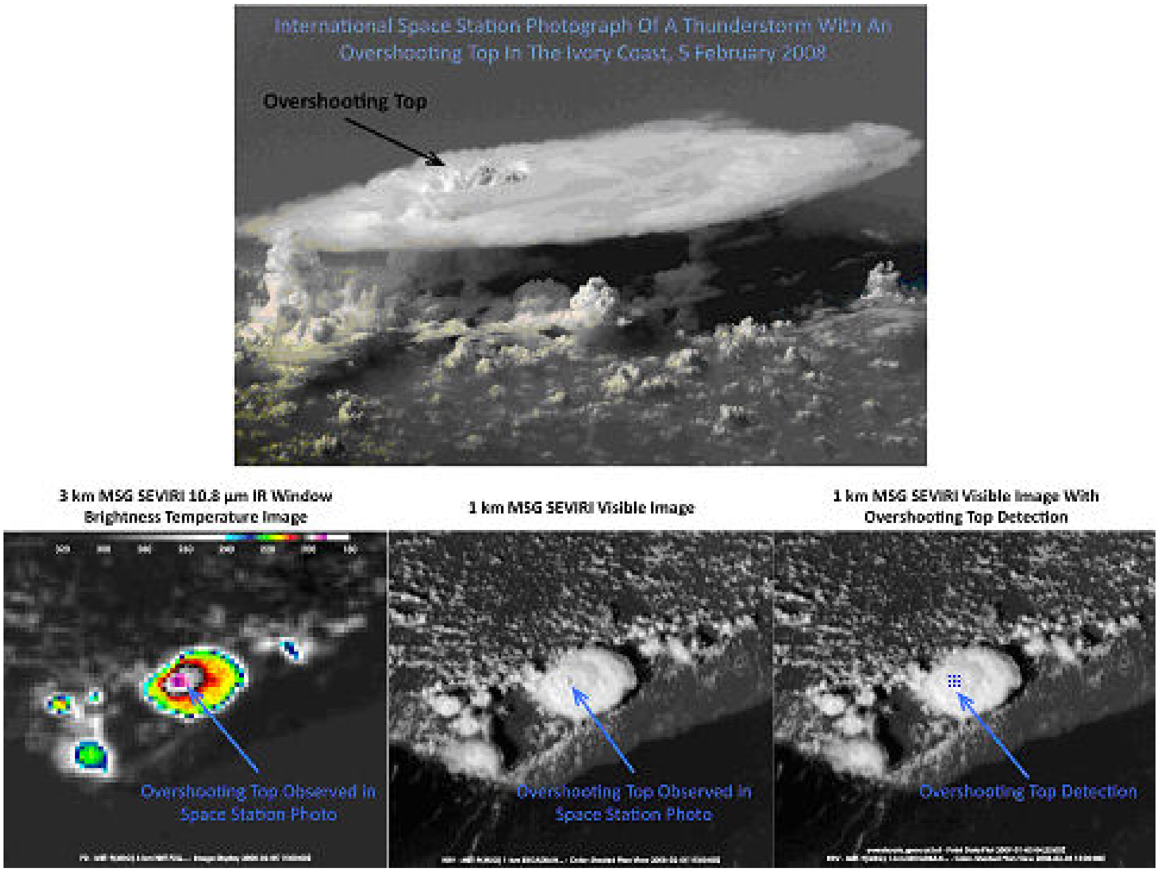


Figure 6.10.4.2. (top) A photograph of an overshooting top producing storm over the Ivory Coast in western Africa on 5 February 2008. (bottom panels) (left) 3 km MSG SEVIRI 10.8 µm brightness temperature imagery, 1 km SEVIRI high-resolution visible with (right) and without (center) IRW-texture overshooting top detections.

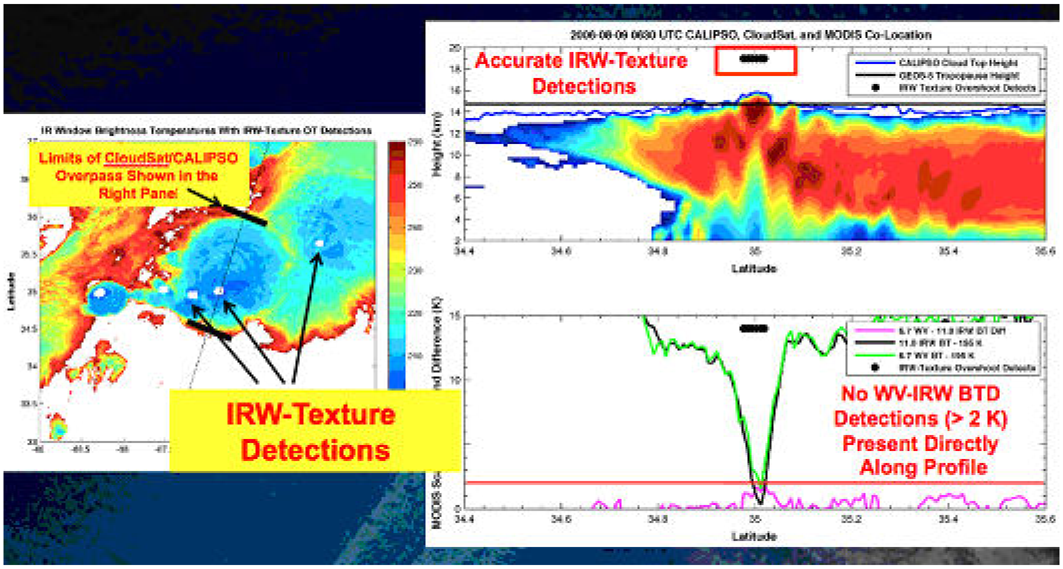
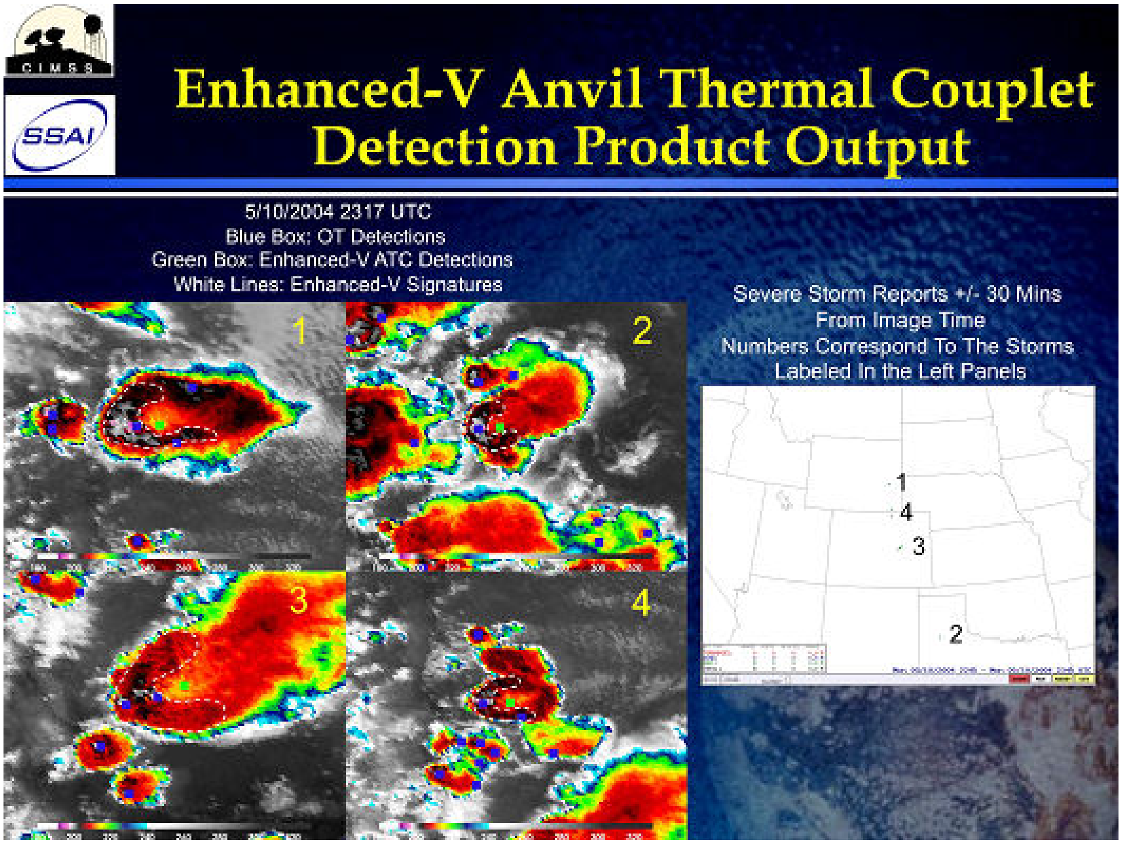


Figure 6.10.4.3. (left) Aqua MODIS 1 km 10.7 µm brightness temperature imagery with IRW-texture OT detections (white dots). (right) IRW-texture OT detections co-located with MODIS brightness temperatures, CloudSat radar reflectivity, CALIPSO cloud top height, and the NASA GEOS-5 model tropopause height analysis.

An example of objective enhanced-V/anvil thermal couplet detection is provided in Figure 6.10.4.4. 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 203 enhanced-V producing storms that occurred across 55 MODIS or AVHRR images. The validation indicates that the probability of enhanced-V detection was 60% and the false alarm rate was 17%. 72% of these 203 storms produced severe weather within +/- 30 mins of the time of the image and within 60 km of the OT location. 76% of the storms detected by the algorithm were severe and 67% of the undetected storms were severe, indicating that this algorithm is detecting a larger fraction of the severe storms in our database. Efforts are currently underway to expand the enhanced-V couplet database to include more cases for validation of the product.



Enhanced-V Anvil Thermal Couplet Detection Product Output

5/10/2004 2317 UTC
Blue Box: OT Detections
Green Box: Enhanced-V ATC Detections
White Lines: Enhanced-V Signatures

Severe Storm Reports +/- 30 Mins From Image Time
Numbers Correspond To The Storms Labeled In the Left Panels

Figure 6.10.4.4. 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

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

Brunner, J. C., K. Bedka, W. F. Feltz, R. Dworak, and L. M. Cronce, 2010: An update on the GOES-R ABI overshooting top and enhanced-V anvil thermal couplet detection algorithms. 17th Conference on Satellite Meteorology and Oceanography. Annapolis, MD. September 2010, Amer. Meteor. Soc., P1.5.

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.

6.10.5 Aviation Weather – Visibility

Task Leader: Wayne Feltz
CIMSS Support Scientist: Allen Lenzen
NOAA Collaborator: Brad Pierce
NOAA Strategic Goals:

- Support the nation's commerce with information for safe, efficient, and environmentally sound transportation

CIMSS Research Themes:

- Weather Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Proposed Work

Cloud optical thickness (COT) is used to retrieve visibility in the presence of low-cloud/fog and Aerosol Optical Depth (AOD) is used to retrieve visibility in the presence of haze, dust, and smoke. Measurement requirements dictate the need to distinguish between Clear (Vis ≥ 30 km), Moderate (10 km ≤ Vis < 30 km), Low (2 km ≤ Vis < 10 km) and Poor (Vis < 2 km) with a categorical accuracy of 80% and a precision, defined as the standard deviation of the errors, of 1.5 categories. Conversion from AOD (which is the integrated aerosol extinction over the depth of the atmosphere) to extinction requires knowledge of the depth of the aerosol layer, which is assumed to be determined by the depth of the planetary boundary layer (PBL). MODIS based boundary layer aerosol extinction (AOD/PBL depth) and GOES based boundary layer fog/low cloud extinction (COT/Fog depth) will be regressed against coincident extinction measurements from the Automated Surface Observing System (ASOS) to develop bias correction and scale factor look-up table (LUT) of boundary layer visibility.

FY10 activities focus on development of the fog/low-cloud component of the ABI visibility algorithm. This work will involve collection of GOES 12 radiances for 2007-2008, generation of GOES-R fog/low-cloud mask, depth, and COT product within GEOCAT, and co-location of ASOS visibility, GOES-12 fog/low-cloud COT, and fog depth data for statistical analysis. Regression analyses will be conducted to establish statistical relationship (monthly and categorical) between ASOS measurements and GOES-12 based fog visibility estimates. A statistical retrieval of horizontal visibility from GOES-12 fog/low-cloud COT and fog/low-cloud depth will be developed based on regression analysis. Software and algorithms will be documented using AIT standards.

Summary of Accomplishments and Findings

A multi-year (2007-2008) GOES-12 based fog/low-cloud mask, thickness and cloud optical thickness data base was generated within the GEOCAT framework at CIMSS. The GEOCAT retrievals were then co-located with ASOS visibility measurements for statistical analysis. Statistical analysis was conducted to determine monthly categorical bias corrections for fog/low-cloud visibility based on ASOS regression statistics and the resulting LUT were implemented into the GEOCAT V1.0 visibility algorithm. Merged GOES-R ABI visibility retrievals using MODIS (aerosol) and GOES (fog/low cloud) proxy data have been validated against ASOS visibility measurements during May-June 2010. Figure 6.10.5.1 shows categorical histograms of the coincident ASOS and merged MODIS aerosol and GOES fog/low cloud blended visibilities. The merged aerosol plus low-cloud/fog visibility retrieval results in a 72.8% categorical success rate for 3804 coincident ASOS/MODIS plus 202 coincident ASOS/GOES measurement pairs during May-June 2010.The merged aerosol plus low-cloud/fog visibility retrieval captures the frequency of clear, moderate and poor visibility relatively well but underestimates the frequency of low and poor visibility. The Critical Design Review (CDR) for ABI Visibility was conducted in August 2010 and V1.0 of the visibility algorithm and draft ATBD were delivered to AIT in September 2010.

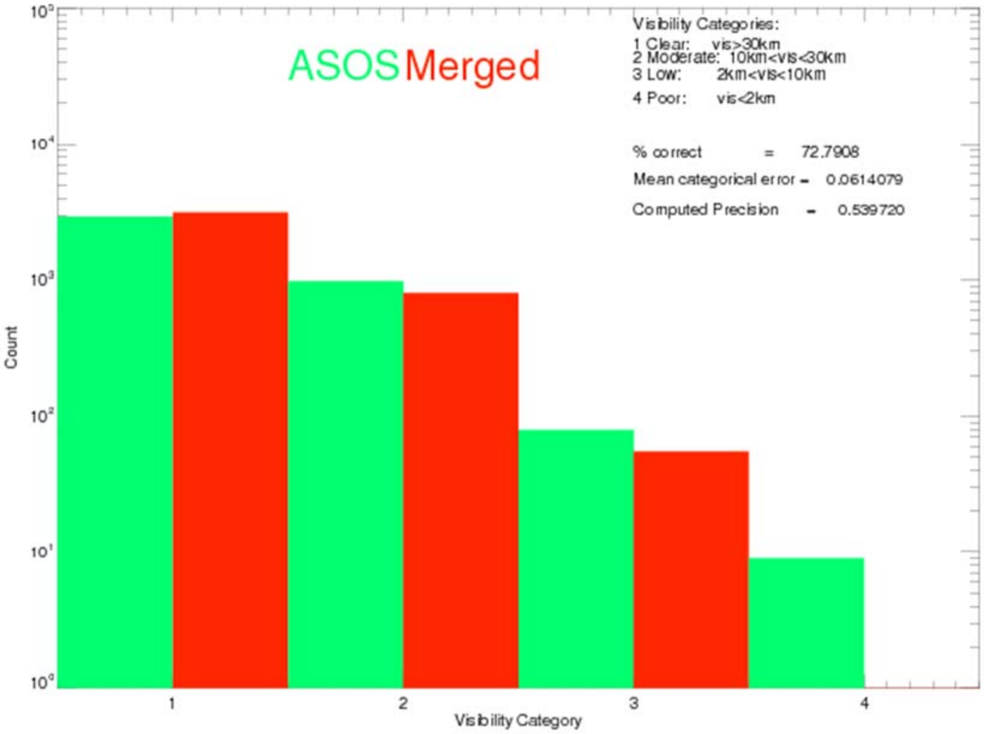


Figure 6.10.5.1. Categorical Histogram of Merged MODIS/GOES (red) and ASOS (green) aerosol plus fog/low cloud visibility for May-June 2010 coincident pairs.

6.10.6 AWG Aviation Weather –SO_2

Task Leader: Justin Sieglaff
CIMSS Support Staff: Andrew Parker
NOAA Collaborator: Michael Pavolonis
NOAA Strategic Goals:

- Support the nation's commerce with information for safe, efficient and environmentally sound transportation

CIMSS Research Themes

- Weather Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Proposed Work

During FY2010 we proposed to continue SO_2 detection algorithm development and validation to ensure the GOES-R F&PS Specifications for SO_2 detection are met. Previous reports showed that the spectral information from the four-channel approach (7.3, 8.5, 11 and 12 µm channels) alone was not sufficient for meeting F&PS Specifications. To meet the F&PS specifications, advanced use of spatial information, specifically cloud objects will be incorporated into the SO_2 detection algorithm. Again, algorithm validation is performed using a skill score metric via comparisons to SO_2 detected by the Ozone Monitoring Instrument (OMI), which is highly sensitive to SO_2.

Summary of Accomplishments and Findings

Previously, the 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) 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. Skill score metrics compared to OMI data indicated this information, on a pixel-by-pixel basis was not sufficient for meeting F&PS specifications and advanced spatial information must be included in the algorithm.

Generically, cloud objects are defined as a group of adjacent satellite pixels that meet some criteria. Specifically, within the SO_2 detection algorithm cloud objects are constructed from pixels whose β ratios have a low frequency of occurrence in a training data set that does not contain SO_2 clouds. For each cloud object, sets of spectral and spatial cloud object statistics are generated (β ratios CDFs, cloud emissivity CDFs, spatial uniformity, etc.) and that information is used to determine if the object is SO_2; an example is shown in Figure 6.10.6.1.

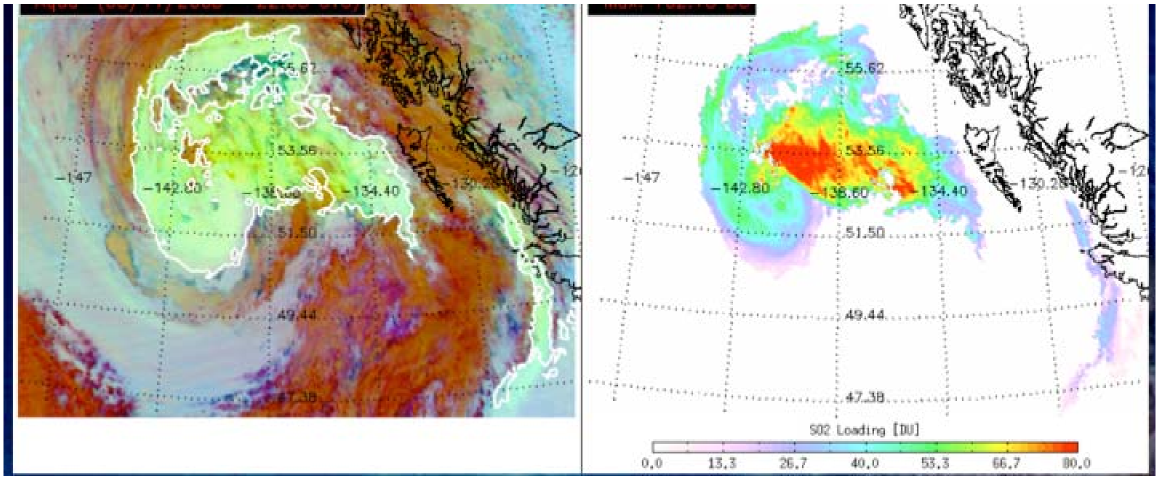


Figure 6.10.6.1. An example of SO_2 objects detected for Kasatochi Volcano eruption on August 11, 2008 viewed by Aqua-MODIS. The left panel is a false color image with objects outlined in white and right panel is SO_2 loading (DU) for the SO_2 objects.

This approach has been validated for 35 Aqua-MODIS/OMI SO_2 scenes. The 35 scenes result in 270,000 validation matchup points between Aqua-MODIS and OMI retrieved SO_2 column amount (in Dobson Units (DU)). A probability of detection is generated, which measures the amount of OMI-derived SO_2 that the ABI SO_2 algorithm is able to detect. Conversely, SO_2 detected by SEVIRI/MODIS alone is considered false alarm. Combining the probability of detection and the false alarm rate generates a skill score. At the 80% delivery point, the skill score is 0.64 (Figure 6.10.6.2) when OMI indicates 10 DU or more of SO_2. The F&PS 100% delivery requirement is a skill score of 0.70 for 10 DU or more of SO_2 and thus the 80% delivery requirement would be a 0.56 skill score. It should also be noted the 100% skill score requirement of 0.70 is currently met at approximately 11.5 DU of SO_2. The improved spatial and temporal resolution of the ABI, along with a 7.3 μm channel is that is better suited for SO_2 detection will likely lead to a improved SO_2 detection capabilities (relative to SEVIRI and MODIS).

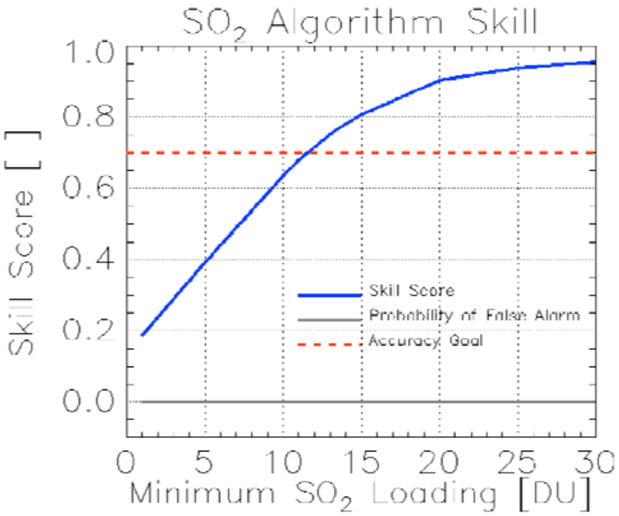


Figure 6.10.6.2. GOES-R algorithm skill score (blue) for 35 Aqua-MODIS/OMI SO_2 cloud matchups (over 270,000 pixels). The GOES-R algorithm skill score is shown as a function of the total column SO_2 retrieved by OMI.

In addition to algorithm development and scientific validation of the SO_2 detection algorithm, the following milestones were also achieved:

- Delivery of 80% Algorithm Theoretical Basis Document (ATBD) and Version 3 of the SO_2 detection code to GOES-R Algorithm Implementation Team (AIT).

Publications and Conference Reports

Pavolonis, M. J. and A. Parker: GOES-R SO_2 Detection Algorithm Theoretical Basis Document (ATBD), 80% Delivery, September 2010.

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

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

- Weather Nowcasting and Forecasting
- Environmental Trends
- Climate

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 selected, improved, and developed superior 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

The project started in May 2007. This report covers 12 months of effort from 1 October 2009 to 30 September 2010. The major accomplishment this year was the development, validation, and uncertainty assessment of the version 4 algorithms that generate the ice products. We have conducted the Cryosphere Test Readiness Review (TRR) with the GOES-R AWG AIT in May 2010, and completed ATBD independent peer reviews. The 80% ATBDs were delivered to the Algorithm Integration Team (AIT). AVHRR, MODIS, and SEVIRI data were used as proxy data for the purpose of the algorithm testing. Submarine, mooring, and meteorological station measurements were used for the comparison and validation. Maturity studies were performed to quantify algorithm uncertainty, and algorithm 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 4 of this algorithm has been in progress, 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 is ongoing. Figure 6.11.1 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, the parameterization of OTIM residual heat flux to make the model more robust to deal with 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 6.11.2 is the comparison result between OTIM derived ice age with MODIS proxy data and the ice age derived from passive microwave ice concentration data using tracking method.

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 show that current products meet the required accuracy and precision of ice motion speed and direction.

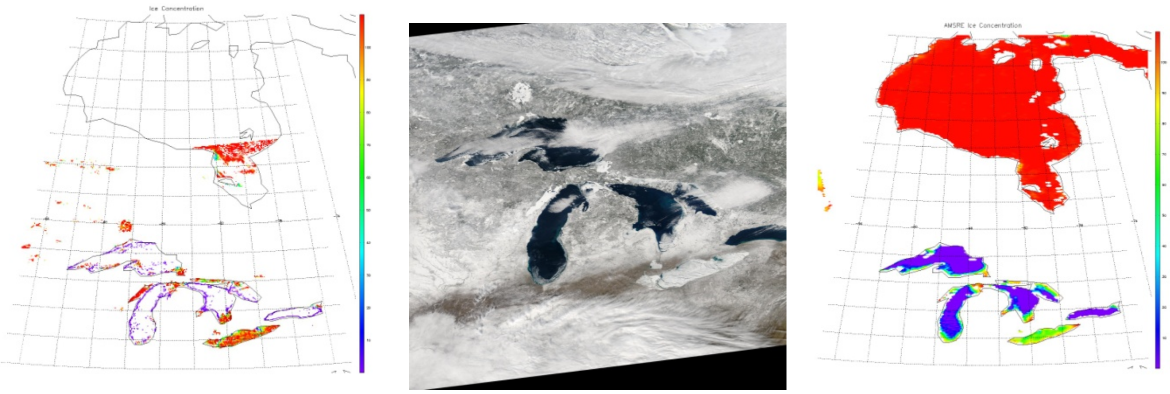


Figure 6.11.1. Lake ice concentration (%) with MODIS Aqua data (left), MODIS true color image (middle), and from AMSR-E (right) over Great Lakes on February 24 2008.

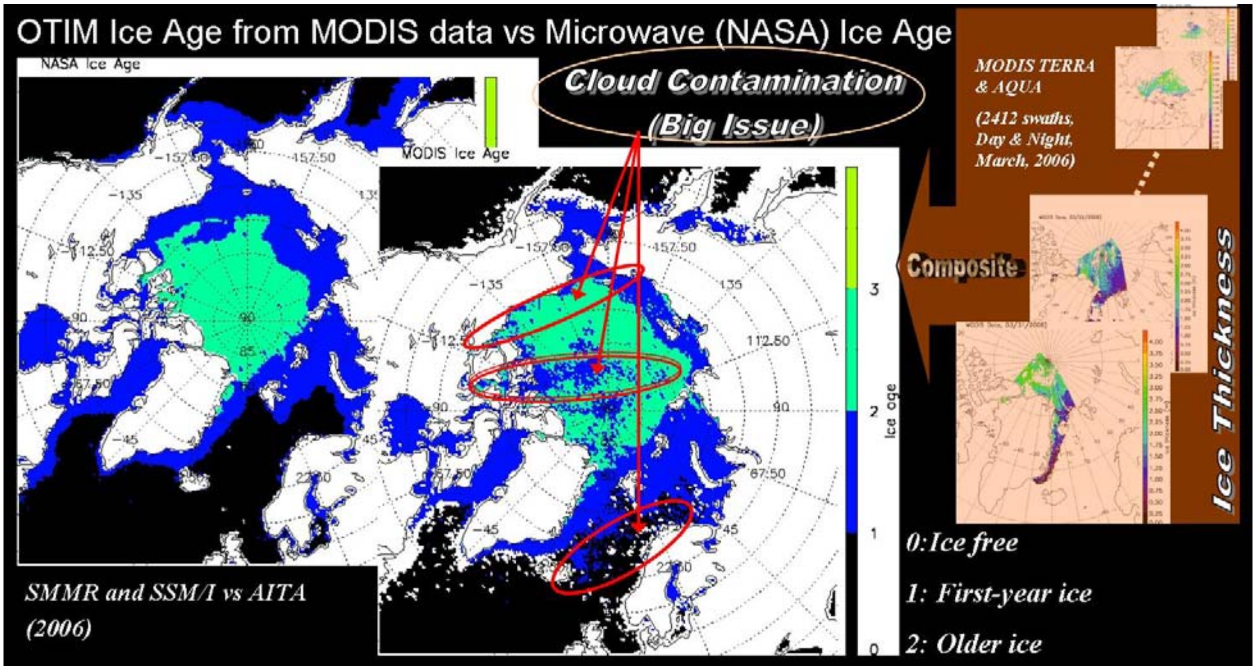


Figure 6.11.2. MODIS derived ice age (middle) using OTIM from a composite of Terra & Aqua MODIS data in March 2006, and the ice age (left) derived from passive microwave ice concentration data (NASA team algorithm) using a tracking method over the year 2006.

Publications and Conference Reports

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.*, doi:10.1029/2009JC005857, in press, 2010.

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.*, doi:10.1029/2009GL040708, 2009.

Wang, X., J. R. Key, and Y. Liu, 2010: Derivation of Ice Thickness and Age for Use with GOES-R ABI Data, 2010 NOAA STAR AWG/GOES-RRR Review, at Concourse Hotel, Madison, WI, 7-11 June 2010.

Wang, X., J. R. Key, and Y. Liu, 2010: Changing Arctic Sea Ice and Its Trends over 1982-2004, STATE OF THE ARCTIC, 16-19 March 2010, at Hyatt Regency, Miami, Florida

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Wang, X., J. R. Key, and Y. Liu, 2009: Arctic Sea Ice and Its Changes during the Satellite Period, 2009 AGU Fall Meeting, 14-18 December 2009, San Francisco California, USA.

Liu, Y., J. R. Key, and X. Wang, 2009: On the Interactions of Arctic Sea Ice, Cloud Cover, and Surface Temperature from Satellite Observations, 2009 AGU Fall Meeting, 14-18 December 2009, San Francisco California, USA.

References

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Key, J. and M. Haefliger, 1992: Arctic ice surface temperature retrieval from AVHRR thermal channels. *J. Geophys. Res.*, 97(D5), 5885-5893.

6.12. Imagery and Visualization

Task Leaders: Tom Rink, Tom Achtor
NOAA Collaborator: Tim Schmit
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:

- Weather, Nowcasting and Forecasting

Proposed Work

1. Define version 1.0 file format in NetCDF for ABI calibrated/navigated radiances, adopting community standards for data structure and meta-data.
2. Continue development of interactive multi/hyper-spectral analysis and visualization capability for GOES-R.

Summary of Accomplishments

The use of NetCDF as a storage format for GOES-R was mandated by the Program Office. To support this requirement, version 1.0 of the ABI radiance product NetCDF files, which follow community conventions for internal structure and metadata (CF-compliant), has been developed. This effort required determination and implementation of the ABI Fixed Grid Format (FGF) pixel navigation.

The FGF comprises a set of fixed view angles at regular intervals, and their respective intersections with the GRS80 Earth geoid, from an ideal or nominal point in space in the equatorial plane. The geometric transformations from FGF coordinate to Earth location, and vice-versa, have been implemented in the

McIDAS-V geo-location framework, and necessary CF-compliant description metadata have been added to NetCDF files. FGF longitude/latitude full disk master files have also been generated for reference.

Radiances are stored as scaled 2-byte integers, and un-scaled to floating point physical values via (CF-compliant) scale and offset metadata. Proxy radiances from various sources including simulation, SEVIRI and MODIS, have been remapped to the longitude/latitudes of the FGF and stored in the official radiance product file. These files are then pulled through the GOES-R AWG Product Generation Framework to generate the various ABI products. Many of these framework products can be imported directly into McIDAS-V, as they themselves are following CF conventions as closely as possible, and the structure and semantics of CF conventions are understood programmatically. This will allow McIDAS-V to serve as an interactive visualization and data integration platform to support instrument and product validation as well as new research, and visualization for GOES-R (Figure 6.12.1).

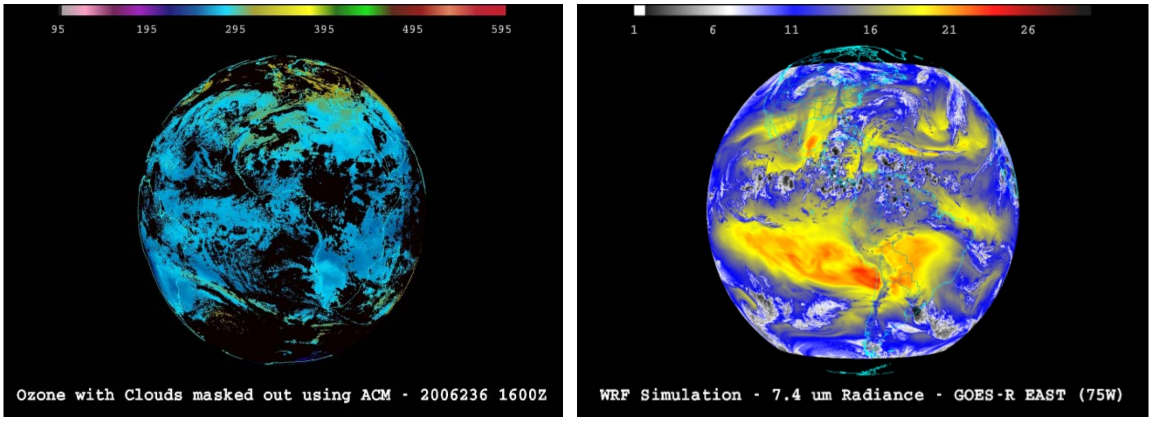


Figure 6.12.1. Simulated GOES-R ABI radiance (left), and Ozone product derived from proxy data (right). Both displayed on the FGF, and displayed in McIDAS-V.

McIDAS-V supports scripting, including background processing, via a Python interface, wherein users can define their own computations to create new data, and/or configure the display components like color tables, map projection settings, display labels, etc. The scripts can be processed interactively, plugged into the GUI, or run in the background to generate display captures in various file formats including KMZ, which can be fed into Google Earth (Figure 6.12.2).

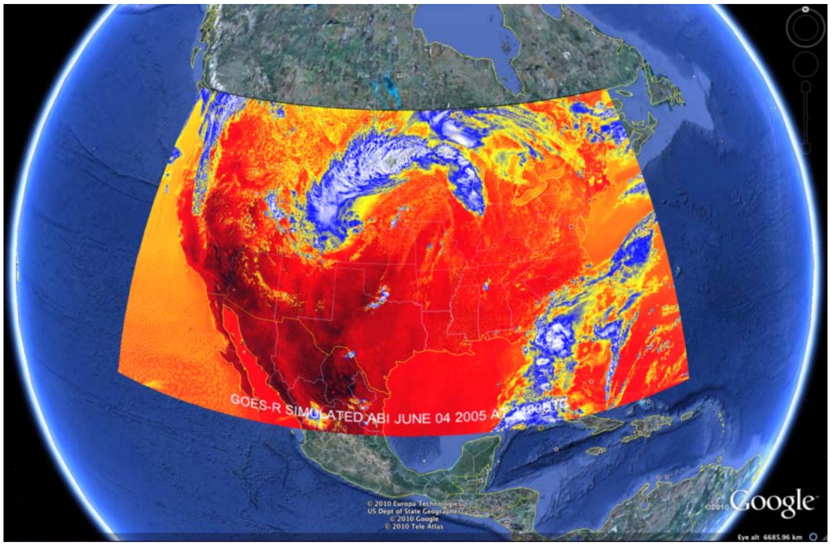


Figure 6.12.2. Simulated GOES-R data in KMZ format generated by McIDAS-V.

As part of the HYDRA functionality incorporation effort, additional multi-spectral analysis capability was added, including a RGB composite tool, which allows the user to instantaneously modify the data to color coordinate transformation as a linear or simple power law relationship. Improvements to the rendering process for geo-stationary perspective displays to increase rendering speed and reduce memory consumption have been accomplished, as well as, the ability to view space pixels around the Earth's limb (Figure 6.12.3).

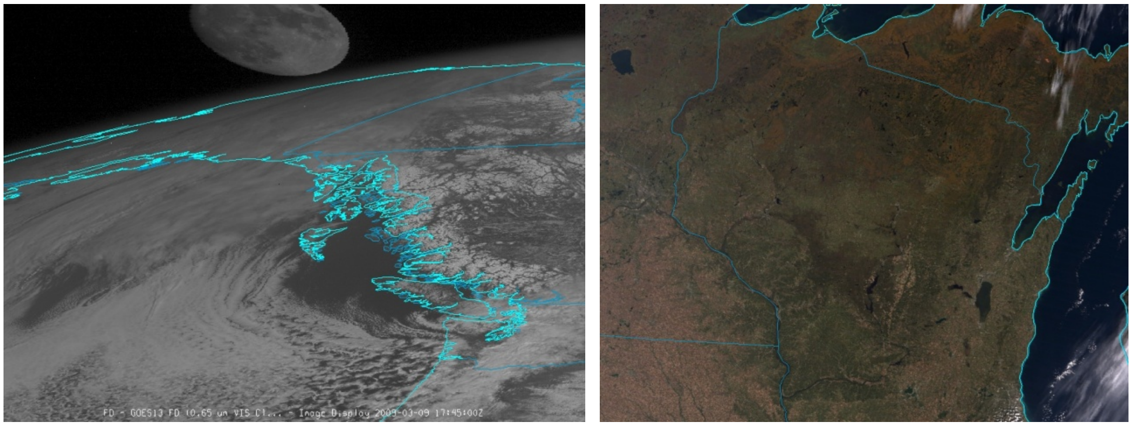


Figure 6.12.3. RGB Composite (left) Aqua MODIS 500m, Bands 1,4,3. GOES-WEST (right) with moon in space scene. Both McIDAS-V.

Conference Reports

EUMETSAT Satellite Conference, McIDAS-V: Advances in Data Analysis and Visualization for Environmental Satellite Data, September 2010, Cordoba, Spain

GOES-R Annual Meeting, An Overview of McIDAS-V Capabilities for GOES-R, July 2010, Madison, WI

SPIE, McIDAS-V: A Data Analyis and Visualization Application for GEOSS, August 2010, San Diego, CA

AMS, McIDAS-V: A Powerful Data Analysis and Visualization Tool for Multi and Hyper-spectral Environmental Satellite Data, January 2010, Atlanta, GA

AGU, McIDAS-V: A Data Analysis and Visualization Tool for Environmental Satellite and Geophysical Data, December 2009, San Francisco, CA

6.13. GOES-R Aerosol and Ozone Proxy Data Simulation

Task Leader: Todd Schaack
NOAA Collaborator: Brad Pierce
NOAA Strategic Goals:
- Serve society's needs for weather and water information

CIMSS Research Themes:
- Clouds, Aerosols and Radiation

Proposed Work

The main focus of this AWG task is to augment the current GOES-R AWG WRF ABI proxy data capabilities with proxy data sets for aerosols and ozone over the continental US (CONUS) and Africa. The aerosol and ozone proxy data sets are generated with Weather Research and Forecasting Chemistry (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). Output from the coupled WRF-CHEM+RAQMS ozone and aerosol simulations are used to construct simulated radiances using the NOAA Community Radiative Transfer Model (CRTM) (Han et al., 2006). Both RAQMS and WRF-CHEM include on-line aerosol modules from the Goddard Global Ozone Chemistry Aerosol Radiation and Transport (GOCART) model (Chin et al., 2002). The GOCART aerosol module predicts concentrations of seven aerosol species (SO4, hydrophobic OC, hydrophilic OC, hydrophobic BC, hydrophilic BC, dust, sea-salt) which are the basis for the CRTM look-up tables for aerosol optical properties.

Summary of Accomplishments and Findings

Activities during this reporting period focused on delivery of simulated high resolution (4km) ABI radiances over the African continent for August 16, 2006. August 16, 2006 was chosen since it is the time period of an existing full disk WRF ABI proxy data set and for the availability of SEVIRI radiances for generation of "ABI-like" single channel AOD retrievals. SEVIRI AOD retrievals were assimilated within 36km WRF-CHEM simulations to provide improved initial conditions for the high resolution African simulations. The final 4km WRF-CHEM simulation over the SEVIRI domain was conducted with the National Center for Supercomputing Applications (NCSA) Cobalt computer at Champaign, IL. This simulation required special system administration approval due to its large use of NCSA resources. The final 30hr (00Z August 16-06Z August 17, 2006) simulation utilized 50% (256 processors) of the Cobalt computer and used a total of 330 hours of wall clock time. Synthetic radiances were computed at ½ hour intervals based on the newly released CRTM version 2 over the SEVIRI domain. CRTM V2 synthetic radiance calculations were compared to the beta version of the CRTM used in the previous CONUS proxy data set and found to be reasonable. Maximum radiance differences in ABI channel 0.47 microns are < 3% and are associated with cloudy scenes. GRB scaled integer files with ABI synthetic radiances over the SEVIRI domain were delivered to AIT. Validation of the simulated infrared radiance and visible reflectance datasets has been conducted using co-located SEVIRI observations. Figure 6.13.1 shows a comparison of simulated and observed SERVIRI 3.9 micron radiances and 0.6 micron reflectances for 12 UTC on 16 August 2006. The lowest (i.e., coldest) 3.9 micron radiances are associated with high convective clouds while higher radiances correspond to warm desert surfaces (gray regions in 0.6 micron visible image). Overall, the simulated 3.9 micron radiances agree very well with the observations though the simulated 0.6 micron visible reflectances tend to be overestimated for clouds and underestimated for bright surfaces such as the Sahara Desert.

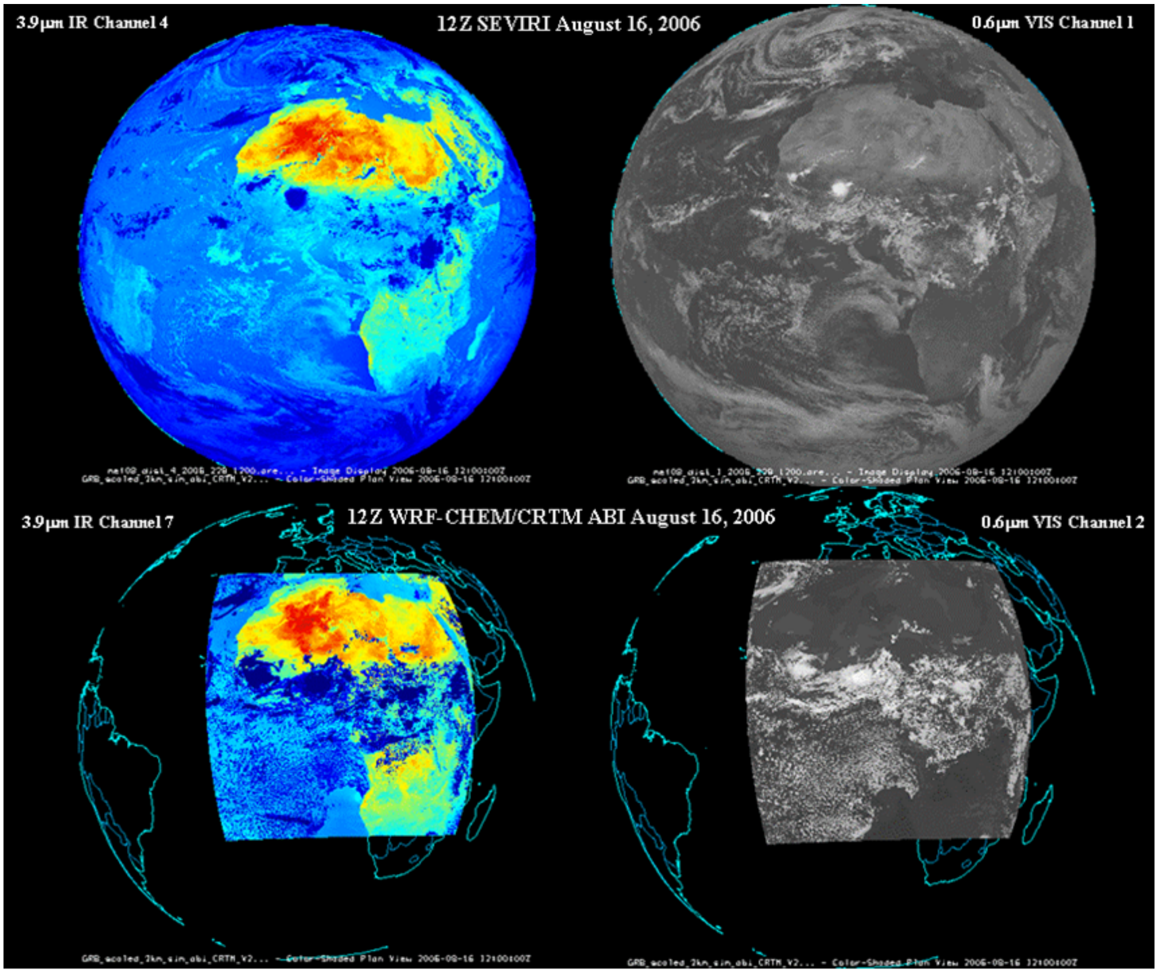


Figure 6.13.1. Comparisons between simulated (lower panels) and SEVIRI (upper panels) IR (3.9 micron) radiances (left) and Visible (0.6 micron) reflectance (right) for 12Z August 16, 2006.

References

Chin, M., et al., 2002: Tropospheric aerosol optical thickness from the GOCART model and comparisons with satellite and sunphotometer measurements. *J. Atmos. Sci.,* ***59***, 461-483.

Grell, G. A., et al., 2005: Fully coupled online chemistry within the WRF model. *Atmos. Environ.*, **39**, 6957-6975.

Han, Y., et al., 2006: Community Radiative Transfer Model (CRTM) - Version 1. NOAA Technical Report 122.

Pierce, R. B., et al., 2007: Chemical data assimilation estimates of continental U.S. ozone and nitrogen budgets during the Intercontinental Chemical Transport Experiment–North America. *J. Geophys. Res.*, **112**, D12S21, doi:10.1029/2006JD007722.

7. High Impact Weather Studies with Advanced IR Soundings

Task Leader: Jun Li
CIMSS Support Scientists: Jinlong Li, Chian-Yi Liu, Kevin Baggett, Jason Otkin
NOAA Collaborator: Tim. Schmit
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

- Weather Nowcasting and Forecasting

Proposed Work

This work is to conduct studies on high impact weather studies with advanced IR sounding products. Severe weather warning, monitoring and forecasting require nearly continuous monitoring of the vertical temperature and moisture structure of the atmosphere on various spatial scales. An advanced high temporal and vertical resolution infrared (IR) sounder in geostationary orbit provides the needed observations to improve severe weather warning and forecasts. This improvement includes a more accurate (and hours sooner) depiction of atmospheric conditions related to developing severe weather, and improved track and intensity forecast for tropical storms. The unique value of these geostationary high spatial and high-spectral resolution observations in high impact weather (convective and tornadic storms, tropical cyclones, etc.) will be studied and demonstrated using both simulated geostationary advanced IR radiances and full spatial resolution hyperspectral IR sounding data from polar-orbiting satellites. Using combined GOES-R ABI and polar-orbiting advanced IR soundings in high impact weather applications will also be investigated.

Summary of Accomplishments and Findings

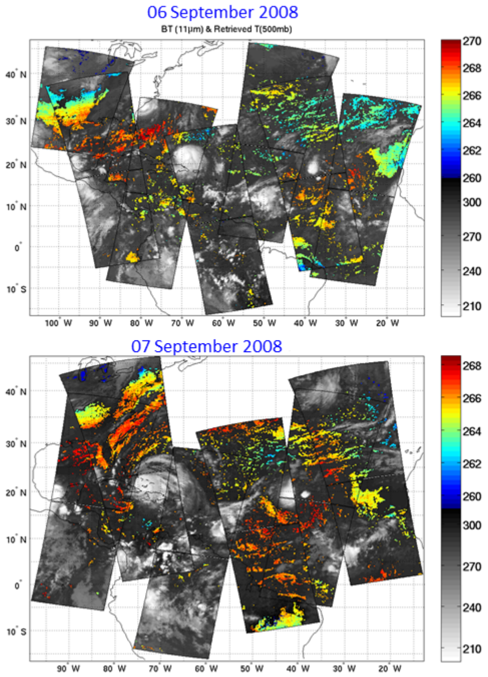
Hurricane Forecast Improvement using High Spatial Resolution Water Vapor Soundings Derived from High Spectral Resolution IR Radiance Measurements.

Three components of water vapor measurements are important for hurricane forecast: the high spatial resolution, high temporal resolution and good accuracy. Currently the AIRS and IASI radiance measurements have been directly assimilated into global numerical weather prediction (NWP) model and greatly improved the middle-range forecast although only limited channels over ocean in clear skies are used. Better use of advanced IR water vapor measurements through radiance assimilation in global NWP remains a challenge, and the applications of advanced IR sounding measurements in mesoscale NWP model have not been well investigated. In this project, we have investigated the application of advanced IR sounding measurements in hurricane/typhoon forecast, full spatial resolution (single field-of-view) resolution AIRS temperature and moisture profiles, derived with CIMSS hyperspectral IR sounding retrieval (CHISR) algorithm, are used in hurricane forecast study with NCAR (National Center for Atmospheric Research) WRF/DART (Weather Research and Forecasting / Data Assimilation Research Testbed) ensemble assimilation system (36 km resolution). Typical hurricane and typhoon cases such as Ike (2008), Dean (2008), and Sinlaku (2008) are studied with WRF/DART. Two-day assimilation followed by 4-day forecast are conducted, the control run uses NCEP (National Centers for Environmental Prediction) analysis with the following data assimilated: radiosonde, satellite cloud winds, aircraft data, and surface data. Besides the control run, the following assimilation experiments are conducted:

1. AIRS run (Control run + AIRS full spatial resolution temperature and moisture profiles in clear skies);
2. AIRS + COSMIC/GPS run (Control run + AIRS temperature and moisture profiles + COSMIC/GPS soundings);

3. AIRS + AMSU run (Control run + AIRS temperature and moisture profiles + operational Aqua AMSU-A temperature profiles);
4. AIRS T run (Control run + AIRS temperature profiles only);
5. AIRS Q run (Control run + AIRS moisture profiles only).

Figure 7.1 shows the AIRS clear sky SFOV sounding coverage (color) overlaying on the AIRS 11 µm channel brightness temperature image (B/W), the color represents 500 hPa temperatures from all AIRS granules from 06 to 07 September 2008, these two days' AIRS soundings are used in the assimilation experiments.


06 September 2008

BT (11µm) & Retrieved T(500mb)

07 September 2008

Figure 7.1. The AIRS clear sky SFOV sounding coverage (color) overlaying on the AIRS 11 µm channel brightness temperature image (B/W) for 06 and 07 September 2008.

We find that:

1. AIRS full spatial resolution temperature and moisture profiles significantly improve the hurricane and typhoon track in both assimilation and forecast systems.
2. AIRS + AMSU slightly improve AIRS alone in the assimilation.
3. AIRS + COMIC/GPS slightly improve AIRS alone in the assimilation.
4. AIRS moisture profiles are more important than AIRS temperature profiles in hurricane track and intensity forecast.

Figure 7.2 shows the Hurricane Ike track error (km) in the analysis period starting from 06 UTC on 06 September 2008, from the control run (black dashed line), the assimilation of AIRS SFOV clear sky temperature and moisture profiles with the CHISR algorithm (blue dashed line), the Aqua AMSU-A temperature profiles (green dashed line), both AIRS and AMSU profiles together (magenta dashed lines), both AIRS and COSMIC/GPS together (black solid line). It can be seen that AIRS full spatial resolution temperature and moisture profiles in clear skies play a more important role when compared with AMSU and COSMIC soundings in this particular case. This result might be due to the coarser spatial resolution of AMSU, and limited spatial and temporal coverage of COSMIC.

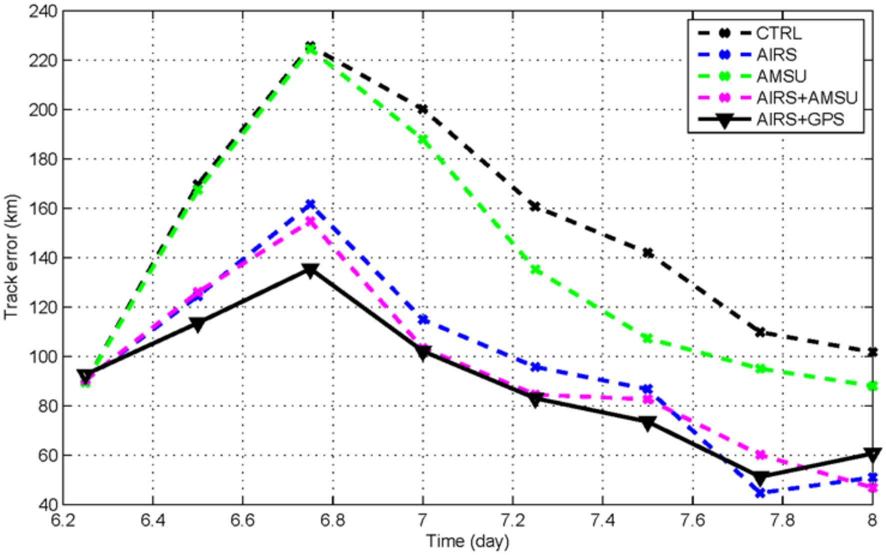


Figure 7.2. The Hurricane Ike (2008) track error (km) in the two-day analysis period starting from 06 UTC on 06 September 2008, from the control run (black dashed line), the assimilation of AIRS SFOV clear sky temperature and moisture profiles with the CHISR algorithm (blue dashed line), the assimilation of Aqua AMSU-A temperature profiles (green dashed line), both AIRS and AMSU profiles together (magenta dashed lines), both AIRS and COSMIC/GPS together (black solid line).

Pre-convection Storm Environment Warning with Advanced IR Soundings

Advanced IR sounders (e.g., AIRS and IASI) provide atmospheric temperature and moisture profiles with high vertical resolution and high accuracy in pre-convection environment. The derived atmospheric stability indices such as lifted index (LI), convective available potential energy (CAPE), K-index (KI), etc. provide critical warning information 3 -~ 6 hours before the severe storm genesis. A recent local severe storm happened 7 -8 August 2010 in Zhou Qu, China killed 1435 people and with another 435 people missing. AIRS full spatial resolution soundings provide local extremely instable atmospheric structure 3.5 hours before the storm genesis. Figure 7.3 shows the AIRS full spatial resolution sounding derived LI (color) in pre-convection environment in Zhou Qu area (center of the circle) overlaying on the AIRS 11 µm brightness temperature (B/W) at 6:35 UTC on 07 August 2010. The left panel indicates the relative humidity profile from AIRS for Zhou Qu, moisture vertical structure is depicted. From 10 UTC 07 August to 00 UTC 08 August 2010, severe storm brought heavy local precipitation to Zhou Qu county, the maximum rain rate is 77.3 mm, which cases a massive mudslide took place in urban area of Zhou Qu. The AIRS observed the atmospheric instability ~ 3.5 hours before the storm genesis, during the pre-convection storm environment, the current regional NWP model has limited capability on forecasting the local storm genesis and development, while radar can only provide important information only after the storm is initiated.

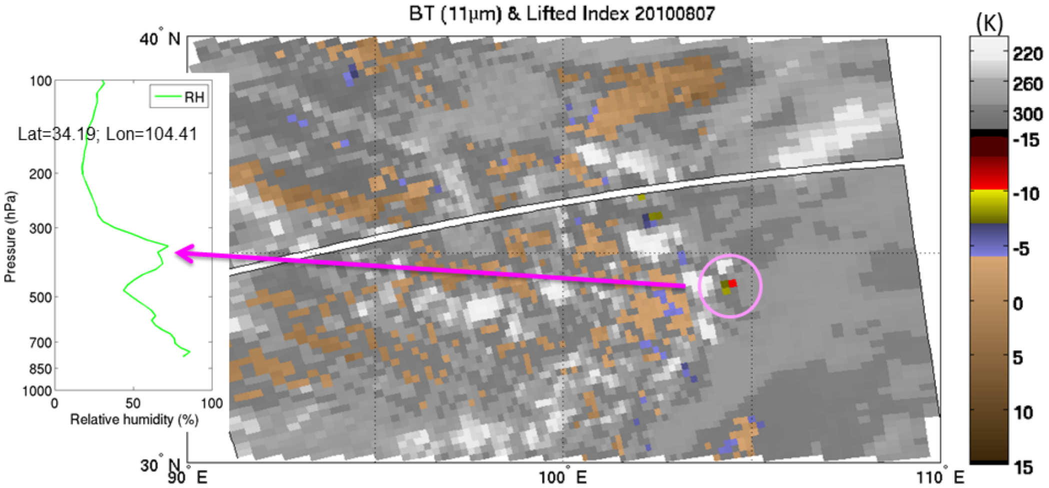


Figure 7.3. The AIRS full spatial resolution sounding derived LI (color) in pre-convection environment in Zhou Qu area (center of the circle) overlaying on the AIRS 11 µm brightness temperature (B/W) at 6:35 UTC on 07 August 2010.

Combining Advanced IR Sounding and High Spatial Resolution Imaging Data for Convective Detection and Precipitation Estimation

We have studied to use the combined advanced IR sounding and high spatial resolution imaging data for convective cloud detection and rainrate estimation. There are two steps, in the first step, the tropopause penetrating convection (TPC) is detected using the advanced IR sounder brightness temperatures, while in the second step, and the high spatial resolution imager IR data are used for the rainfall estimation. The chosen channel to distinguish the TPC from thunderstorm anvils is the strong water vapor line at 1419 cm^{-1}. When presenting a brightness temperature reversal between this water vapor line and the atmospheric window at 1231 cm^{-1}, the AIRS footprint is considered within the existence of TPC because the air parcel at the cold cloud top is brought to the lower stratosphere by an updraft overshooting, therefore the sensitivity of the BT is from the relatively warmer stratosphere. Meanwhile, the averaged BT in the longwave window channels, which are eleven channels centered at 910 cm^{-1}, lower than 220 K threshold in the non-polar latitudes is applied as well. This test is similar to Aumann et al. [2009, IGARSS presentation], while the TPC cloud tops are within 20 hPa of the cold point tropopause. The Typhoon Morakot case shows that cluster of TPCs are highly associated with heavy rainfall. Although the cold cloud top AIRS spectra have a lower longwave window BTs, the TPC AIRS spectra do represent high potential of strong conviction.

Publications and Conference Reports

Li, J., Jinlong Li, T. J. Schmit, and J. Otkin, 2010: Application of geostationary advanced infrared sounding system on severe storm nowcasting – a simulation using IHOP case, Journal of Applied Meteorology and Climate (submitted).

Li, J., H. Liu, and T. Schmit, 2010: Advanced Infrared Water Vapor Measurements Improve Hurricane Forecasts, SPIE Newsroom Article, 012337/FAE9473B/000053.

Li, J., T. J. Schmit, S. J. Goodman, and J Gurka, 2010: High impact weather nowcasting and short range forecasting using future geostationary advanced IR sounding data, EUMETSAT Nowcasting and Short Range Forecast Workshop, 26 – 28 April 2010, Madrid, Spain.

Li, J., H. Liu, J. Li, and T. J. Schmit, 2010: Using water vapor measurements from hyperspectral advanced IR sounder for tropical cyclone forecast, SPIE Asia-Pacific Remote Sensing Symposium, 11 – 14 October 2010, Incheon, Republic of Korea.

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

Task Leader: Wayne Feltz
CIMSS Support Scientists: Scott Bachmeier, Scott Lindstrom, Lee Cronce, Justin Sieglaff
NOAA Collaborators: Tim Schmit; Gary Wade
NOAA Strategic Goals:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Weather Nowcasting and Forecasting

Proposed Work

This proposal is to support the NOAA GOES-R Proving Ground that will test and validate ideas, technologies and products before they are integrated into operational use. The Proving Ground mission is designed to ensure User Readiness on Day 1 for GOES-R. To this end, we are seeking assistance via the GOES-R Proving Ground in evaluating the GOES-R Algorithm Working Group demonstration algorithms and baseline 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 will develop GOES-R era products from existing measurement systems and simulations. They will expand partnerships with NWS Forecast Offices to provide these products, train forecasters in their applications, and evaluate their utility. This work will help to ensure that GOES-R products will be available and useful to forecasters soon after launch. The primary focus is to test, apply, and improve select GOES-R AWG satellite baseline and option 2 imagery/products in support of National Centers and Local NWS offices. Develop GOES-R ABI Weather Event Simulations (WES) for NWS office AWIPS training and provide simulated ABI radiance bands using WRF NWP modeling output.

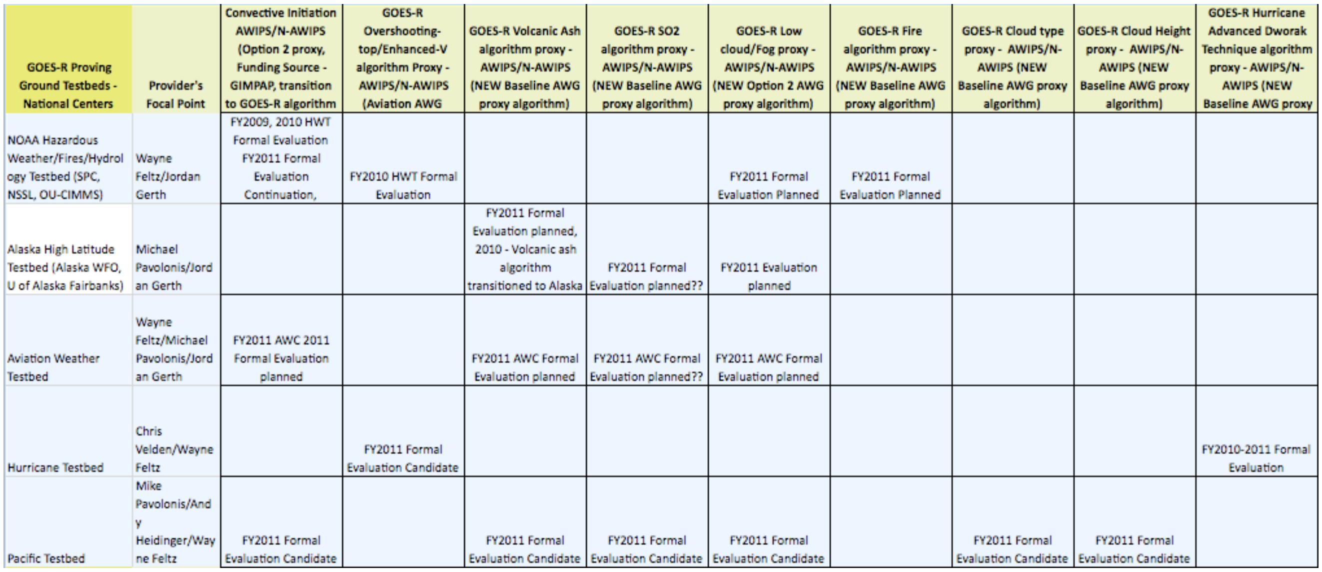
Summary of Accomplishments and Findings

UW-CIMSS has been engaged in multiple GOES-R proving ground decision support product demonstrations within newly formed testbed opportunities. Main focus has been most mature testbed, the NOAA Hazardous Weather Testbed (HWT) where University of Wisconsin Convective Initiation (UWCI), GOES overshooting-top/enhanced-V (OTTC), and WRF ARW simulated decision support products where made available and NWS end user evaluation accomplished as GOES-R proxy information. A summary of current and new testbeds and UW-CIMSS datasets provided in support of GOES-R proxy decision support demonstration is shown in Figure 8.1.

UW-CIMSS is providing 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 2010 experiment as a proxy for future GOES-R option 2 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 2010 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 (Sieglaff et al., 2010) is generated at the University of Wisconsin for each GOES-13 scan, including rapid-scans, and distributed via LDM in GRIB2 format.

The OTTC product is a new addition within the 2010 Spring Experiment. The product utilizes GOES-13 IR window brightness temperature spatial testing to identify overshooting-top and thermal couplet (also known as enhanced-V) features within mature convective storm cloud-tops as described by Bedka et al. (2010). The OTTC product provides detections and relative magnitudes of overshooting-top and thermal couplet features in real-time. Similar to the UWCI product, the OTTC product is generated at the University of Wisconsin for each GOES-13 scan, including rapid-scans, and distributed via LDM in GRIB2 format to AWIPS and N-AWIPS systems. Figure 8.2 shows both UWCI and OTTC simultaneously displayed on AWIPS four-panel image.



GOES-R Proving Ground Testbeds - National Centers	Provider's Focal Point	Convective Initiation AWIPS/N-AWIPS (Option 2 proxy, Funding Source - GIMPAP, transition to GOES-R algorithm	GOES-R Overshooting-top/Enhanced-V algorithm Proxy - AWIPS/N-AWIPS (Aviation AWG	GOES-R Volcanic Ash algorithm proxy - AWIPS/N-AWIPS (NEW Baseline AWG proxy algorithm)	GOES-R SO2 algorithm proxy - AWIPS/N-AWIPS (NEW Baseline AWG proxy algorithm)	GOES-R Low cloud/Fog proxy - AWIPS/N-AWIPS (NEW Option 2 AWG proxy algorithm)	GOES-R Fire algorithm proxy - AWIPS/N-AWIPS (NEW Baseline AWG proxy algorithm)	GOES-R Cloud type proxy - AWIPS/N-AWIPS (NEW Baseline AWG proxy algorithm)	GOES-R Cloud Height proxy - AWIPS/N-AWIPS (NEW Baseline AWG proxy algorithm)	GOES-R Hurricane Advanced Dworak Technique algorithm proxy - AWIPS/N-AWIPS (NEW Baseline AWG proxy
NOAA Hazardous Weather/Fires/Hydrology Testbed (SPC, NSSL, OU-CIMMS)	Wayne Feltz/Jordan Gerth	FY2009, 2010 HWT Formal Evaluation FY2011 Formal Evaluation Continuation,	FY2010 HWT Formal Evaluation			FY2011 Formal Evaluation Planned	FY2011 Formal Evaluation Planned			
Alaska High Latitude Testbed (Alaska WFO, U of Alaska Fairbanks)	Michael Pavolonis/Jordan Gerth			FY2011 Formal Evaluation planned, 2010 - Volcanic ash algorithm transitioned to Alaska	FY2011 Formal Evaluation planned??	FY2011 Evaluation planned				
Aviation Weather Testbed	Wayne Feltz/Michael Pavolonis/Jordan Gerth	FY2011 AWC 2011 Formal Evaluation planned		FY2011 AWC Formal Evaluation planned	FY2011 AWC Formal Evaluation planned??	FY2011 AWC Formal Evaluation planned				
Hurricane Testbed	Chris Velden/Wayne Feltz		FY2011 Formal Evaluation Candidate							FY2010-2011 Formal Evaluation
Pacific Testbed	Mike Pavolonis/Andy Heidinger/Wayne Feltz	FY2011 Formal Evaluation Candidate		FY2011 Formal Evaluation Candidate	FY2011 Formal Evaluation Candidate	FY2011 Formal Evaluation Candidate		FY2011 Formal Evaluation Candidate	FY2011 Formal Evaluation Candidate	

Figure 8.1. A summary of GOES-R decision support test beds (left column) and UW-CIMSS provided GOES-R Proving Ground proxy datasets (top row).

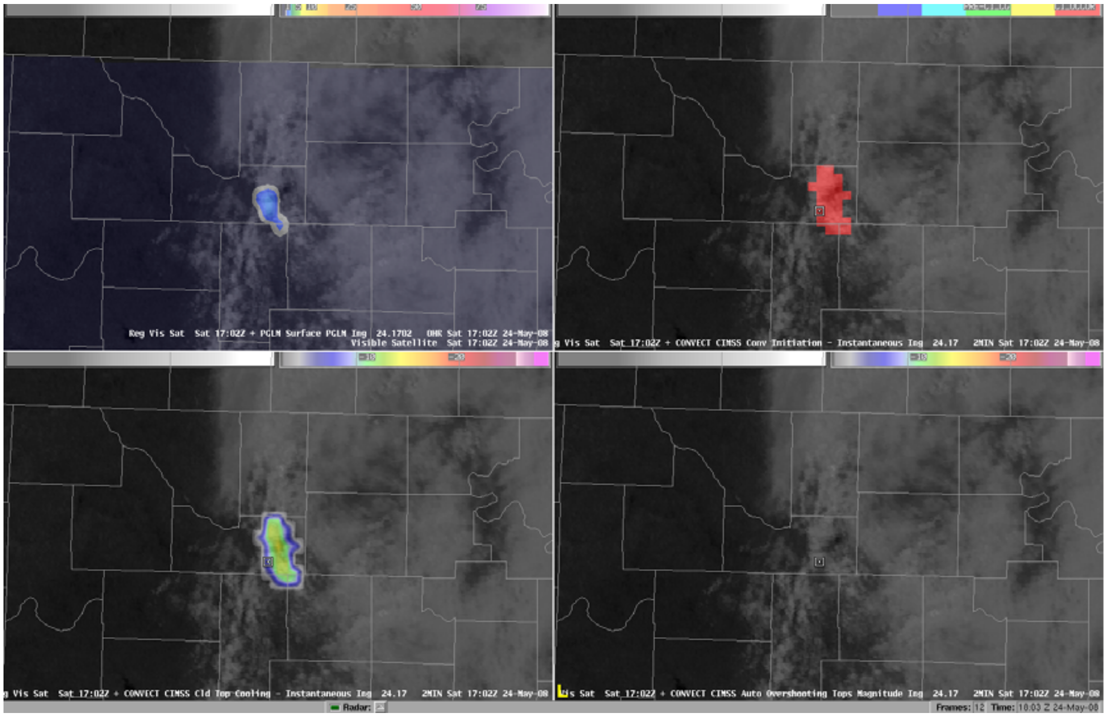


Figure 8.2. 4-panel display within AWIPS of the GOES-R products provided within the EWP including 8-km Pseudo-GLM (top left), UWCI convective initiation (top right), UWCI cloud-top cooling rate (bottom left), and overshooting-top magnitude (bottom right) for the 24 May 2008 archive case event.

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://www.zoomerang.com/Shared/SharedResultsPasswordPage.aspx?ID=L24E52GPZQ4T

In general, forecasters found that the UWCI products were a useful aid 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:

"Areal descriptions of convective initiation described by UWCI could be added to short term forecasts, or even significant weather advisories/warnings if quick development is expected."

Forecasters also noticed lead-times on their subjective interpretation of convective initiation based on signals from radar generally of about 5 to 30 minutes. There were occasions where the UWCI had negative lead-times, but this result was usually due to cirrus contamination, satellite scan time limitations or varied definitions of "convective initiation" by the forecasters. When comparing UWCI to the first occurrence of CG lightning detected by the NLDN, forecasters found that UWCI lead times extended, often to 60 minutes. However, there were occasions where convection would develop and radar reflectivities would reach in excess of 55 dBZ, but no CG lightning would be detected, so determining a lead time was difficult and forecasters became confused on how they were supposed to evaluate the product.

In general, while forecasters found the idea of the OTTC product exciting, the limitations of the current observational system severely limited the OTTC product as demonstrated in severe weather warning operations. There were instances of “many overshooting tops were observed on visible satellite that were not detected by the OTTC product” mentioned within the online surveys and during EWP daily briefings. Since the OTTC product relies on spatial tests to detect IR features associated with overshooting-tops and thermal couplets, the coarse IR resolution of GOES-13 was often unable to detect these features since they are generally smaller than the GOES-13 IR footprint. The product has been shown to work well on current low-earth orbiting satellite instruments, such as MODIS on NASA’s Terra and Aqua satellites (see Bedka et al., 2010), whose spatial resolution is better suited to detect these features. The forecasters would like to see the product demonstrated using these high spatial resolution datasets in an operational sense, but unfortunately that is not currently possible as MODIS data is only available twice a day.

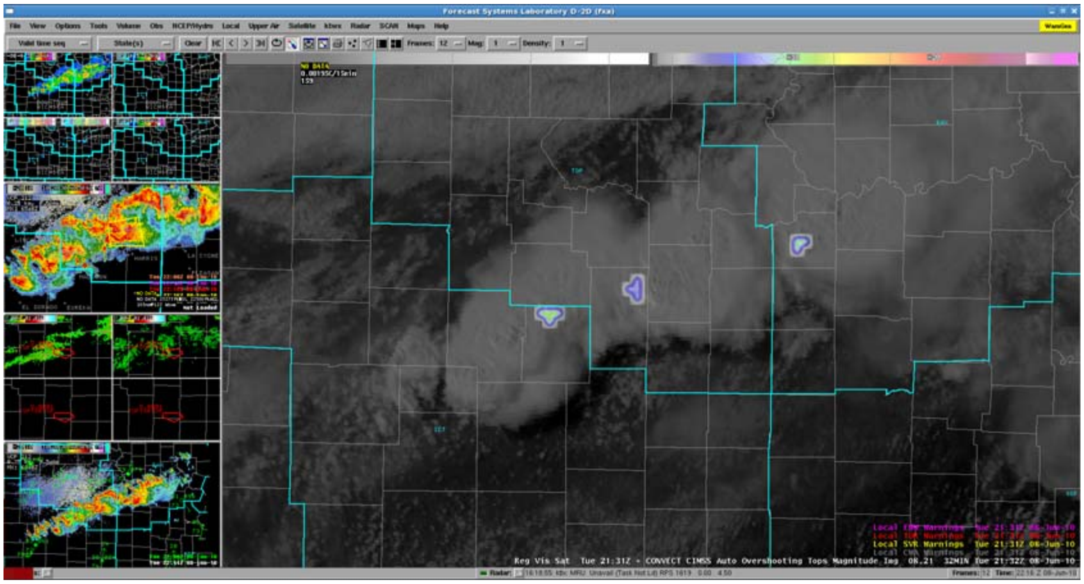


Figure 8.3. Overshooting-top magnitudes overlaid on visible satellite imagery within AWIPS at 2131 UTC on 8 June 2010.

In addition, the Milwaukee-Sullivan National Weather Service Forecast Office is also receiving the real-time data feed via AWIPS and has provided additional operational feedback through UW-CIMSS researcher collaborations during forecaster shifts during the summer of 2010.

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 8.4). 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. While participants were excited by the availability of the three levels of water vapor information, they were unsure as to how this information would be utilized operationally. This is something that we need to communicate further to the operational community during future experiments and demonstrations.

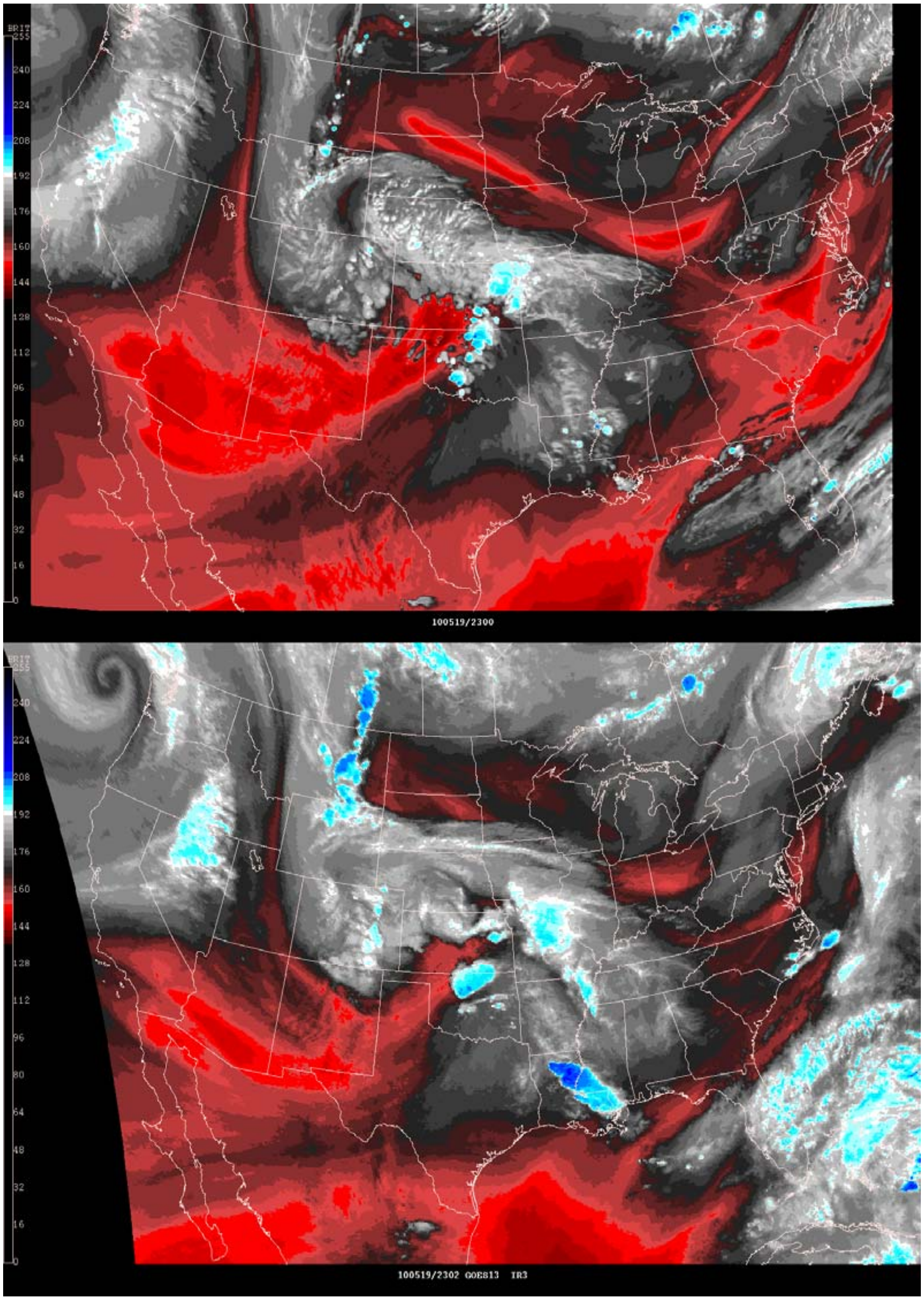


Figure 8.4. UW-CIMSS NSSL-WRF simulated GOES-R ABI band 9 imagery (top) for 2300 UTC on 19 May 2010 and observed GOES-13 water vapor imagery valid for same time.

In 2010, a new GOES-R Weather Event Simulation (WES) was developed to simulate planned location over Pacific Ocean at 137 degrees in longitude. Figure 8.5 shows WRF ARW simulated images of ABI bands as they would be seen if in current orbit.

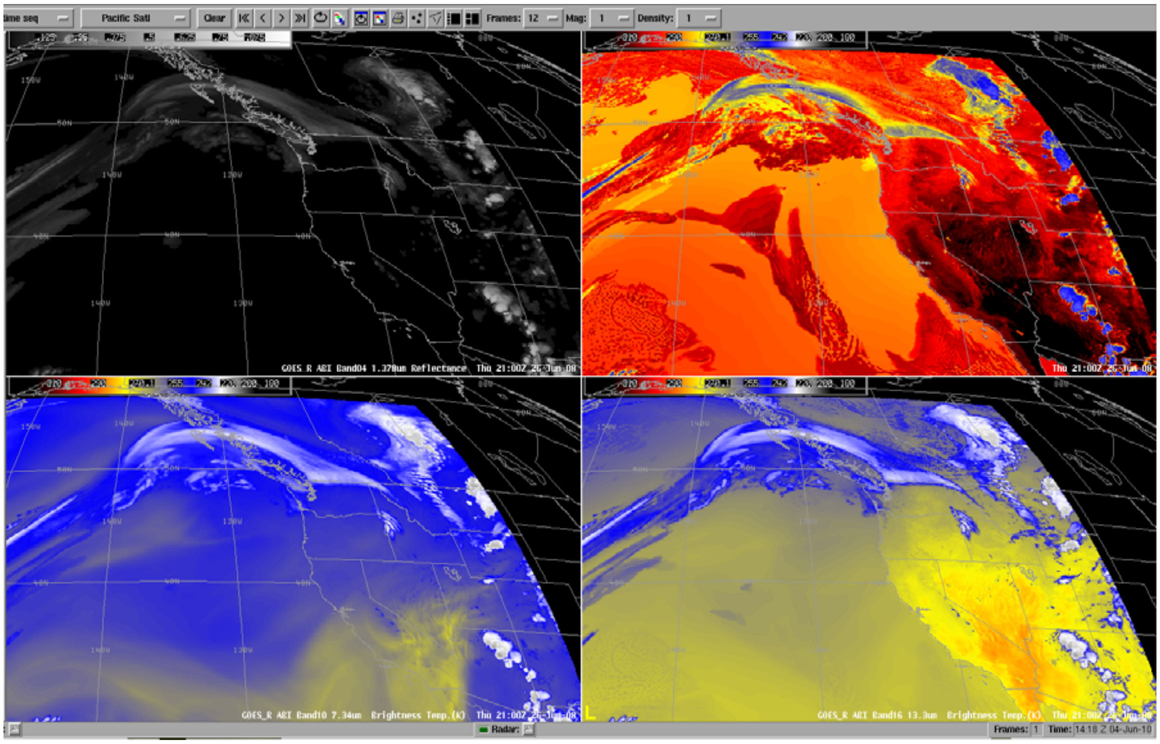


Figure 8.5. West Projection simulation of the ABI showing the Pacific Projection at 137° West.

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 telcons.

Presentations and Conference Reports

Ackerman, S. and T. Schmit, 2010: UW-CIMSS Interactions with WFO's, 2010 NWS Science Services Division (SSD) Chief Meeting, NSSTC, Huntsville, AL, 2 March 2010.

Feltz, W. F., 2009: GOES-R Proving Ground Activities – CIMSS, 6th GOES Users Conference, Madison, Wisconsin, 3-5 November 2009

Feltz, W. F., J. Gerth, and T. Schmit, 2010: CIMSS Status and Plans, 3rd Annual Proving Ground All-hands, Boulder, Colorado, May 18-19, 2010

Feltz, W. F., 2010: UW-CIMSS GOES-R Proving Ground Participation in NOAA HWT, 17th Conference on Satellite Meteorology and Oceanography, Annapolis, Maryland, September 27-30, 2010. (Poster)

Gerth, Jordan J. and Aune, Robert M., 2009: A New Numerical Weather Prediction Approach to the NDFD's Sky Cover Grid. National Weather Association 34th Annual Meeting, Norfolk, Virginia, October 17-22, 2009. (Oral presentation)

Gerth, Jordan J., 2010: Enhancing Local Model Studies with Initial Conditions from Satellites for Great Lakes Research. 18th Annual Canada/US Great Lakes Operational Meteorology Workshop, Toronto, Ontario, Canada, March 22-24, 2010. (Oral presentation)

Gerth, Jordan J., 2010: Confronting data delivery challenges of the future via the GOES-R Proving Ground. 17th Conference on Satellite Meteorology and Oceanography, Annapolis, Maryland, September 27-30, 2010. (Poster)

Timothy J. Schmit, Kaba Bah, Jordan Gerth, Marcia Cronce, Jason Otkin, Justin Sieglaff, Gary Wade., 2010: A Weather Event Simulator (WES) for the GOES-R Advanced Baseline Imager (ABI), Sixth Annual Symposium on Future National Operational Environmental Satellite Systems – NPOESS and GOES-R at the American Meteorological Society (AMS) Annual Meeting, 17-21 January 2010, Atlanta, GA.

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

Task Leader: Paul Menzel

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

Summary of Accomplishments and Findings

Contribution to GOES Sounder Module

In October 2009, P. Menzel was interviewed for sound bites that could be used on the COMET module titled "Toward an Advanced Sounder on GOES?" being produced by Patrick Dils. It was released in early 2010.

EUMETSAT MTG User Consultation

In late 2009, P. Menzel responded to various queries regarding waiver request form European industry working on the MTG IRS and FCI. One concerned the high saturation temperature of 350 K for an 8.7

micron channel on FCI for possible fire applications. It was noted that there is no heritage application of the 8.7 um for fire detection (or fire size and temperature determination) and that a specification of Tmax = 330 K would be consistent with MODIS where there are heritage atmospheric applications. MODIS like specifications were eventually applied.

GOES-R Users Conference VI

On Tuesday 3 November 2009, P. Menzel chaired the session at GUC VI wherein the international community presented their geo satellite plans. Noteworthy was the preponderance of international plans for geostationary high spectral resolution infrared sounders (Europe, China, Japan), China's exemplary satellite development program that starts with demonstrations of new instrument capabilities followed by operational implementation on subsequent satellites, and growing interest and plans for highly elliptical orbiting (HEO) complementary to geostationary (GEO) orbiting platforms by Canada and Brazil. I also drafted a session summary for the GUC VI report.

AMS

The week of 18 January P. Menzel attended the AMS, gave a talk on the first meteorological satellite experiment, and chaired (with Steven Goodman) the session on Meteorological and Environmental Satellite Observing Systems in which Richard Anthes (Decadal Survey), Michael Freilich (NASA plans), Mary Kicza (NESDIS plans), Henry Revercomb (geo sounder), and Dave Emmitt (Doppler Wind Lidar) gave presentations. It became obvious that NOAA plans for a geo sounder seem to be dormant, unless buying one from Europe is a plan.

STAR Review

From 9 – 11 March, P. Menzel participated in the STAR Review in College Park, MD. Eleven scientists outside of STAR (chaired by Ghassem Asrar) made recommendations for NESDIS consideration. A major part of the review dealt with the JPSS reconfiguration and the role of STAR in JPSS and GOES-R algorithm development and validation.

Training Indian Visitors in Use of INSAT 3D Data

From May through October 2010 SSEC is hosting 5 visitors from IMD (the Indian Meteorological Department) and ISRO (the Indian Space Research Organization) and helping them to learn how to (1) improve INSAT navigation, (2) stage satellite and ancillary data and products for visualization with McIDAS-X and –V, (3) produce atmospheric motion vectors, and (4) produce soundings from multispectral measurements. ISRO is supporting SSEC to perform this training, which will also include one week courses in Delhi next year.

GOES-R AWG and Risk Reduction Review

From 7 - 11 June, P. Menzel attended the GOES-R Algorithm Working Group and the subsequent GOES-R Risk Reduction (R3) meetings as a reviewer. Comments and recommendations for the AWG and R3 were submitted. For AWG they included (1) extending the length of the post-launch check-out to one year, (2) putting GOES-R into operational service as soon as possible, (3) planning and coordinating field campaigns for validation, (4) pursuing an advanced geostationary sounder, (5) alleviating ITAR restrictions on the characterization of GOES-R data (spectral bands, signal to noise, bit depth, ,..), (6) testing the process for updating/adjusting the operational algorithms before launch, (7) emphasizing study of the impact of missing data as well as rectification / saturation / truncation / striping error on products, (8) making use of temporal continuity for validation, (9) streamlining the process for introducing new operational products, (10) strengthening NWP engagement, particularly through the JCSDA, in early testing of improved ABI/GLM products, and (11) transitioning new GOES-NOP operational products onto the day-1 list for GOES-R. For R3 general comments / questions included (a) after how long must an R3 effort produce new product (b) where does R3 end and AWG begin, (c) team (within R3 and between

R3 and AWG) collaborations should be encouraged, and (d) preparation for day one NWP impact needs to address assimilation of hourly (or more frequent) measurements.

IASI Pre-convective Case Studies

A study of pre-convective situations where IASI depicts the impending weather situation has been started by Paolo Antonelli. About 1500 IASI observations have been collected in a 1 by 1 degree box centered in Pratica di Mare, Italy (see Figure 9.1) for July through September 2007. The clear sky observations where inverted and instability indices were derived from the retrievals and were compared to those derived collocated rawinsondes. Good agreement was found (see Figure 9.2) between instability derived from satellite and from rawinsondes as well as nearby electrical activity (lightning). Future investigation will collect more years and include results from NEFODINA, a convection detection scheme developed in Italy at Centro Nazionale di Meteorologia e Climatologia Aeronautica (CNMCA) using SEVIRI data.

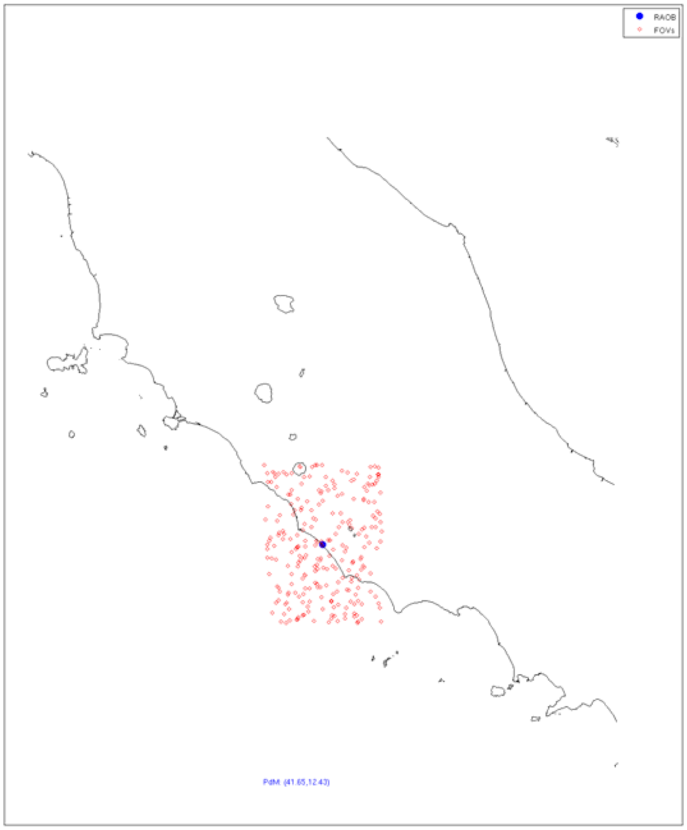
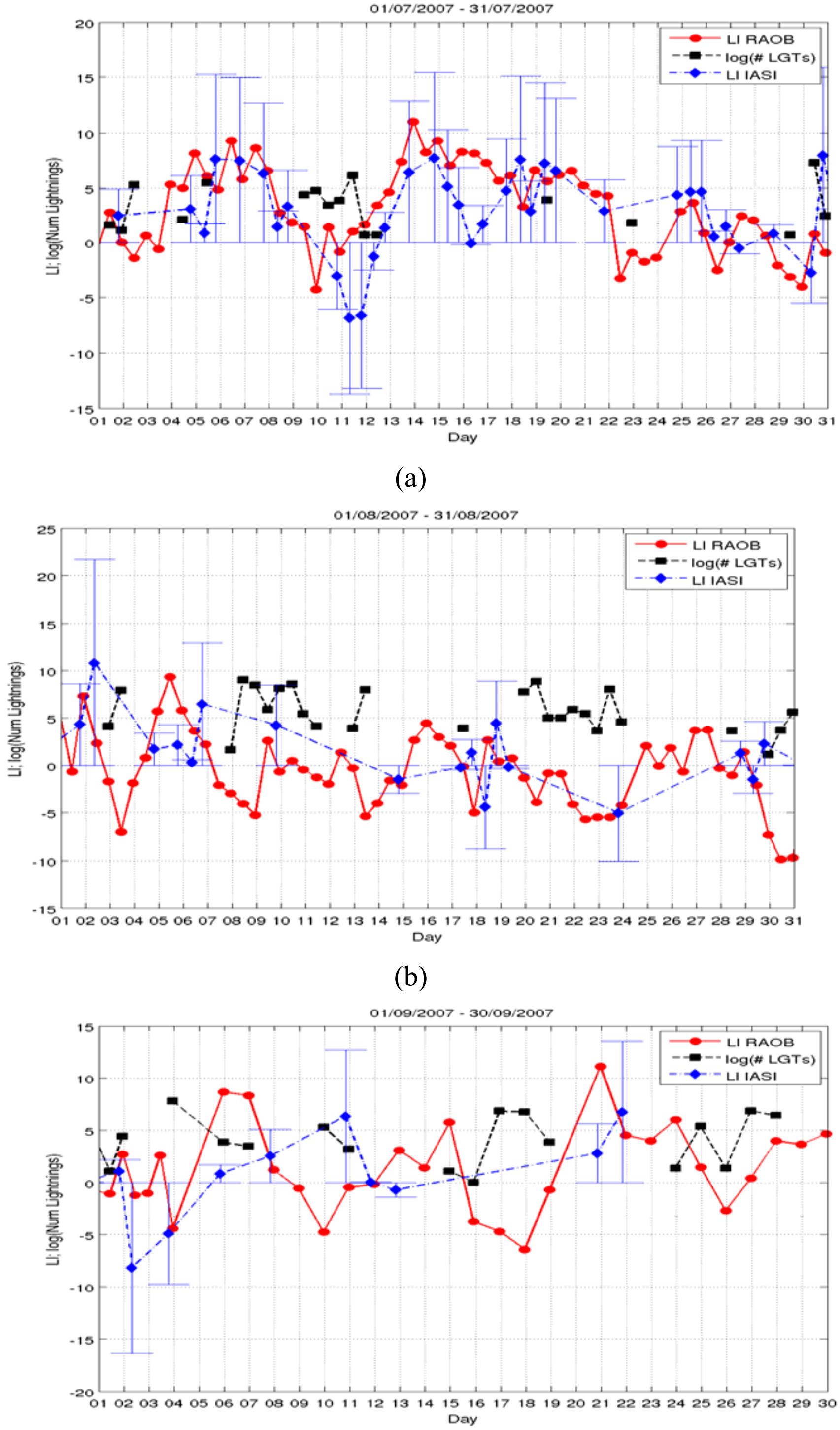


Figure 9.1. Map of successful IASI retrievals (red) and rawinsonde site (blue).



(c)

Figure 9.2. A, b, and c show the monthly time series of LI. Red circles indicate the values of LI derived from 00:00 and 12:00 UTC rawinsondes; blue diamonds show the mean values of LI for all the retrievals co-located with the rawinsondes; blue error bars are associated with the variability of the IASI derived LI retrievals; black squares show the number of lightning strikes observed within 10 hours of the rawinsonde launch in a 1x1 degree box centered over Pratica di Mare.

10. CIMSS Support of STAR Cal/Val Activities for 2009-10

Task Leader: Mat Gunshor
CIMSS Support Scientists: Bob Knuteson, Scott Lindstrom, Paul Menzel, Dave Tobin
NOAA Collaborators: Andy Heidinger, Tim Schmit
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:

- Clouds Aerosols and Radiation
- Environmental Trends
- Climate

Proposed Work

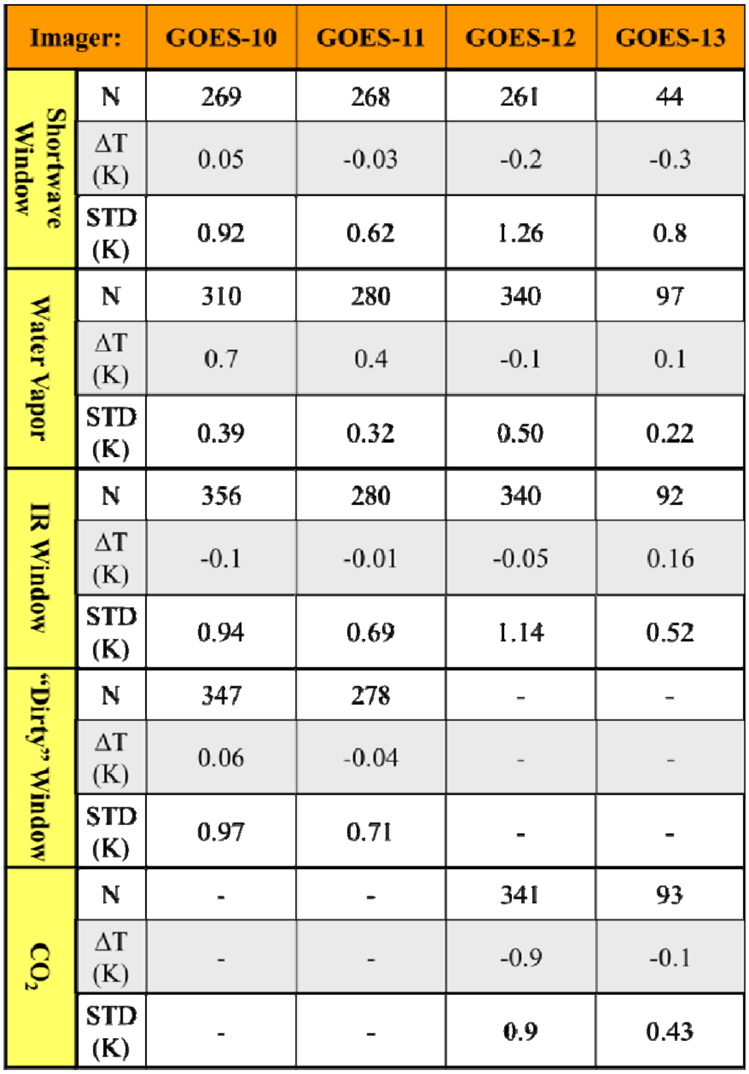
The primary task of the intercalibration project is to compare select infrared channels on geostationary instruments (GOES, Meteosat, etc) with those obtained from the polar-orbiting instruments such as the Atmospheric InfraRed Sounder (AIRS), or Infrared Atmospheric Sounding Interferometer (IASI). Multiple comparisons are made at the geostationary sub-satellite points yielding an average brightness temperature difference between the geostationary imager and the polar orbiter. What was proposed was to look back at approximately two years of IASI and GOES observations. IASI is a high-spectral resolution interferometer on EUMETSAT's polar-orbiting METOP-A satellite.

In 2008 using a single version of AIRS data, the same set of channels for the entire data record and applying a consistent method provided a valuable comparison and analysis. Repeating this exercise with IASI could provide further insights into the calibration accuracy of the GOES Imagers during the overlapping time-period. It will provide insight into how well the comparisons between GOES/AIRS and GOES/IASI match and it will provide insight into how well the gap-filling method used for AIRS works.

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 World Weather Watch (WWW) Global Observing System (GOS) and Global Earth Observing System of Systems (GEOSS). While the bulk of the effort currently with GSICS is in getting a system working for currently operational sensors, there is also a task to look back in time and make assessments. This project supports GSICS and also the NOAA Mission Goals of Climate and Weather and Water.

Summary of Accomplishments and Findings

The methodology employed previously for intercalibration using AIRS (Gunshor et al., 2009) was applied using IASI. A distinct advantage to using IASI for intercalibration is that it has complete spectral coverage from 3.62 to 15.50 micrometers. This range covers most of the infrared bands on the current suite of operational imagers; the shortwave band on some of the imagers extends beyond this range, but in the case of GOES it is just the wing on the shortwave side of the spectral response function. Comparisons to IASI were done for GOES-10, -11, -12, and -13 Imagers from June 2007 through October 2009 (Figure 10.1).



Imager:		GOES-10	GOES-11	GOES-12	GOES-13
Shortwave Window	N	269	268	261	44
	ΔT (K)	0.05	-0.03	-0.2	-0.3
	STD (K)	0.92	0.62	1.26	0.8
Water Vapor	N	310	280	340	97
	ΔT (K)	0.7	0.4	-0.1	0.1
	STD (K)	0.39	0.32	0.50	0.22
IR Window	N	356	280	340	92
	ΔT (K)	-0.1	-0.01	-0.05	0.16
	STD (K)	0.94	0.69	1.14	0.52
“Dirty” Window	N	347	278	-	-
	ΔT (K)	0.06	-0.04	-	-
	STD (K)	0.97	0.71	-	-
CO_2	N	-	-	341	93
	ΔT (K)	-	-	-0.9	-0.1
	STD (K)	-	-	0.9	0.43

Figure 10.1. Intercalibration results comparing GOES to IASI covering the period of June 2007 through October 2009 (depending on the availability of the GOES data during that period). N is the number of comparisons, ΔT is the mean temperature difference (GOES-IASI), and STD is the standard deviation.

These results were presented at the 6th GOES User’s Conference (3-5 November, 2009) in Madison WI and also at the 6th Annual Symposium on Future National Operational Environmental Satellite Systems-NPOESS and GOES-R, 2010 AMS Annual Meeting, 19-21 January 2010 in Atlanta, GA. These results were also presented to the GSICS Research Working Group (GRWG) by Andy Heidinger (NOAA/STAR/ASPB) at the GRWG Meeting in Toulouse, France 9-11 February, 2010.

Publications and Conference Reports

Gunshor, Mathew M., Timothy J. Schmit, W. Paul Menzel, and David C. Tobin, 2009: Intercalibration of Broadband Geostationary Imagers Using AIRS. *J. Atmos. Ocean. Technol.*, **26**, 4, 746-758.

Knuteson, Bob, 2009: Intercalibration of Broadband Geostationary Imagers using AIRS. NASA Sounder Science Team Meeting, October 13-16, 2009, Greenbelt, Maryland. (oral presentation)

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11. Joint Center for Satellite Data Assimilation (JCSDA) Projects

11.1. The Development of Hyperspectral Infrared Water Vapor Radiance Assimilation Techniques in the NCEP Global Forecast System

Task Leader: Jim Jung
CIMSS Support Scientist: Todd Schaack
NOAA Collaborators: John Derber, Paul van Delst, Chris Barnet, Lars Peter Riishojgaard and John LeMarshall
NOAA Strategic Goals:

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

CIMSS Research Themes:

- Weather Nowcasting and Forecasting
- Global Hydrological Cycle

Proposed Work

We are working with the Atmospheric Infrared Sounder (AIRS) Science Team, the National Center for Environmental Prediction (NCEP), the National Environmental Satellite, Data and Information Service (NESDIS) personnel and others in developing techniques to assimilate AIRS and the Infrared Atmospheric Sounding Interferometer (IASI) water vapor channels. There are several problems which must be resolved in using these data. In general, the non-linearity of the water vapor channels makes them difficult to assimilate and channels which have significant dependencies to water vapor in the stratosphere are not modeled well by the Gridpoint Statistical Interpolation (GSI) software. The specific issues of supersaturation and small negative moisture values in the GSI must also be addressed before the water vapor channels can be used in operations.

We propose to continue investigating the assimilation of infrared (IR) water vapor channels into NCEP’s Global Data Assimilation System / Global Forecast System (GDAS/GFS). We will continue to investigate ways to improve the moisture field while reducing the number of supersaturated and negative moisture points within the analysis. Specifically, we will be investigating two upgrades to the Community Radiative Transfer Model (CRTM) along with experiments designed to reduce the number of negative moisture values. We will take into account the performance (convergence and penalty) of the GSI when selecting the water vapor channels to assimilate. Threat scores and anomaly correlations, from NCEP verification software will be used to quantify GDAS/GFS forecast changes. Forecast impact of relative humidity and precipitable water will also be used to quantify changes made to the water vapor fields.

Within the Numerical Weather Prediction (NWP) community the observation errors for Atmospheric Motion Vectors (AMV) are assigned by the image type (infrared, visible, water vapor) and/or tracking feature (cloud top, clear air). We propose to investigate a new approach which involves basing the observation error on AMV height assignment type. We will be generating AMV statistics for the various height assignment types with respect to the NCEP GDAS/GFS.

We will quantify the errors associated with each of the AMV height assignment techniques used operationally at NOAA/NESDIS. Once quantified, this information can be used to improve the assimilation techniques and potentially improve the impact and forecast skill AMVs have in NWP.

Summary of Accomplishments and Findings

Infrared Hyperspectral Water Vapor Channel Assimilation

Issues continue to be investigated in relation to the infrared hyperspectral water vapor radiance assimilation which need to be resolved before these IR water vapor channels can be used in operations. The background error variances and the error structure function for the pseudo-relative humidity in the stratosphere will need to be updated, given the new information from IASI and AIRS. Recent changes to the GSI and GFS seem to make the model dryer than the actual atmosphere, which has caused temperature biases to appear in the upper troposphere and stratosphere. When the radiances are allowed to adjust the moisture in the stratosphere, the temperature bias is significantly reduced. Due to the feedback from the GFS radiation scheme and the dynamic bias correction used by radiances in the GSI, the transition to this reduced bias state is very slow and takes several months to stabilize.

Various techniques to correct the supersaturation GFS are also being tested. The technique which seems to work best involves returning the supersaturated values to saturation at the beginning of each outer loop in the GSI. This technique increases the sensitivity of the water vapor channels (both infrared and microwave). To compensate the background error must also be adjusted. The result of using this supersaturation technique is to create an analysis which has more moisture in the tropics and less moisture near the poles. Van Thien et al. (2010) compared the water vapor fields of the GFS and NAM to the Aura Microwave Limb Sounder and found the GFS to be too dry in the tropics while too moist at higher latitudes. The changes made to the analysis by assimilating the IR water vapor channels are consistent with their results.

Work (and testing) continues with the help of NCEP's global modeling group to try to help the forecast model accommodate the changes in the moisture field. We also hope to start comparing the stratospheric moisture field in the GFS (from assimilating the IR radiances) to products generated from NASA's Aura Microwave Limb Sounder. This comparison will be similar to Van Thien et al. (2010) but hopefully more favorable.

AMV Height Assignment Technique Error Statistics

Within the NWP community the observation errors for AMVs are assigned using the image type (infrared, visible, water vapor) and/or tracking feature (cloud top, clear air). The purpose of this study is to quantify the errors associated with each of the AMV height assignment techniques used operationally at NOAA/NESDIS. Once quantified, this information can be used to improve the assimilation techniques and potentially improve the impact and forecast skill AMVs have in numerical weather prediction models.

We have stratified the height assignment error statistics by satellite and tracking image type. The water vapor channels are different on the two current Geostationary Operational Environmental Satellites (GOES). Thus, GOES-11 and GOES-12 AMVs have different error characteristics. GOES-12 also has a CO_2 channel allowing for the use of the CO_2 technique. Although the tracking methods are the same for the water vapor image and the infrared window image, the error characteristics of the height assignments are very different.

The height assignment error statistics of normalized Mean Vector Difference (MVD) Root Mean Square Error (RMSE) and bias by pressure level for the GOES-11 and GOES-12 water vapor images are shown in Figure 11.1.1. The height assignment techniques (CO_2, H_2O, WIN and HIST) are explained briefly in Jung et al. (2010). In general, the CO_2, H_2O, and HIST technique RMSEs are consistent with each other. They show normalized errors of around 0.5 except near the tropopause. The bias shows more inconsistency with the best being the H_2O technique. Most NWP centers use only those winds between the tropopause and 500 hPa. For the water vapor images, the WIN technique is not used for height assignment.

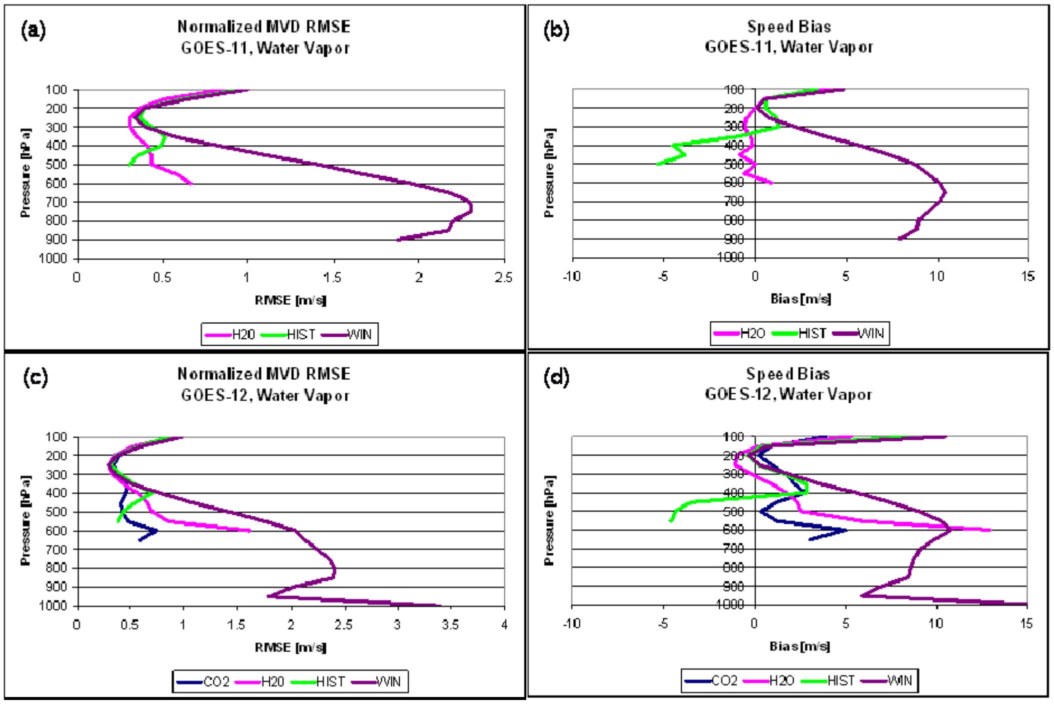

Figure 11.1.1. Normalized MVD RMSE and speed bias vs. pressure for the various height assignment types of cloud drift winds derived from the water vapor image. The top panels (a and b) are from GOES-11, the bottom panels (c and d) are from GOES-12.

The height assignment error statistics of normalized MVD RMSE and bias by pressure level for the infrared window image cloud top tracking technique applied to GOES-11 and GOES-12 imager data are shown in Figure 11.1.2. In contrast to the water vapor image, the infrared window image height assignment techniques show little consistency with each other. In general, the WIN technique has the least error and bias from the tropopause to around 400 hPa. Typically, the CO_2 and H_2O techniques are considered superior in this region. The CO_2 technique shows the least error in the lower levels but the sample size is small due to only using the CO_2 technique only for cloud top temperatures colder than 273K. The winds generated from the infrared window images do not use the HIST technique.

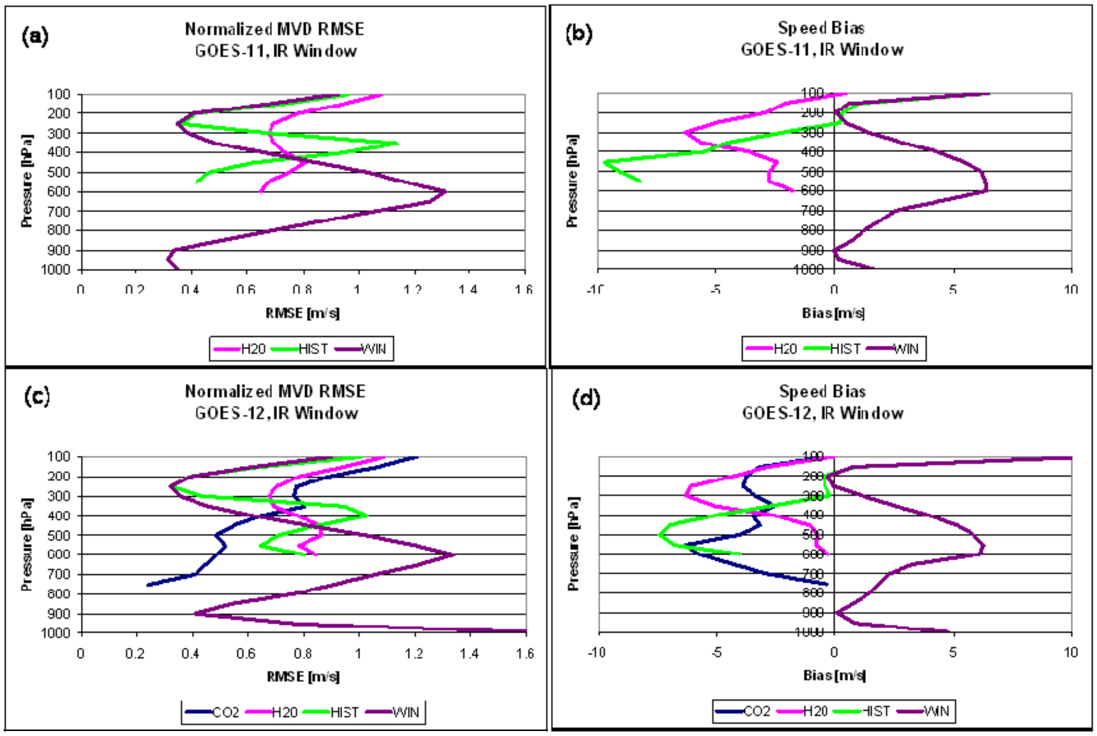

Figure 11.1.2. Normalized MVD RMSE and speed bias vs. pressure for the various height assignment types of cloud drift winds derived from the infrared window image. The top panels (a and b) are from GOES-11, the bottom panels (c and d) are from GOES-12.

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Jung, J. A., J. F. Le Marshall, J. Daniels, and L. P. Riishojgaard, 2010: Investigating Height Assignment Type Errors in the NCEP Global Forecast System. *10th International Winds Workshop*, Tokyo, Japan. 22-26 February 2010.

11.2. Implementation of GOES and OMI Total Column Ozone Assimilation within NAM-CMAQ to Improve Operational Air Quality Forecasting Capabilities

Task Leader: Todd Schaack

NOAA Collaborator: Brad Pierce

NOAA Strategic Goals:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Weather Nowcasting and Forecasting

Proposed Work

This project utilizes the NCEP Gridpoint Statistical Interpolation (GSI) system implemented into a developmental version of the North American Meso-scale (NAM) Community Multi-scale Air Quality (CMAQ) Modeling System (NAM-CMAQ) model to test capabilities to assimilate GOES sounder and OMI Total Column Ozone (TCO) data. NAM-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 will be conducted to determine the impact of GOES, OMI and GOES+OMI TCO on regional ozone analyses via comparison with ozonesonde and aircraft measurements. Upon completion of the first year tasks, the NAM-CMAQ/GSI GOES and OMI regional TCO assimilation capability will be delivered to developers at the Air Resources Laboratory (ARL) for forecast impact assessments. Results of the ARL assessments will provide guidance for operational implementation at EMC.

Summary of Accomplishments and Findings

The CIMSS proposal could not be submitted to NOAA until the CIMSS re-compete was awarded (June 09, 2010), consequently the start date of CIMSS JSDI task is July 1, 2010. Only the first two months of this proposal are covered under this CIMSS Annual Report. The following tasks have been completed:

1. Submitted NOAA Computing and Subversion account Request for JSDI ozone assimilation project. New Subversion GSI branch has been defined for GOES TCO development. We are currently awaiting NASA GMAO implementation of chem_bundle within GSI prior to further GSI development.
2. Conducted NAM-CMAQ forecasts on vapor for two parallel runs (one with static and one with RAQMS lateral boundary conditions (LBC)) during the 2010 CalNex field mission which is the focus time period of our assimilation studies due to availability of Carbon Bond V (CB-V) chemistry and emissions.
3. Acquired both OMI and GOES TCO for the May-June 2010 time period for GOES TCO bias correction and development of buffer format for assimilation within GSI.

11.3. Observation Error Characterization for Radiance Assimilation of Clouds and Precipitation

Task Leaders: Ralf Bennartz, Tom Greenwald
CIMSS Support Scientist: Mark Kulie
NOAA Collaborators: Paul van Delst, Yong Chen, Fuzhong Weng, 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
- Provide critical support for the NOAA mission

CIMSS Research Themes

- Weather Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Proposed Work

1. Integrate the Successive Order of Interaction (SOI) forward, tangent linear and adjoint microwave radiative transfer models into the Community Radiative Transfer Model (CRTM) framework.
2. Provide quantitative estimates of observation error covariances attributed to uncertainties in microwave ice single-scattering properties.

Summary of Accomplishments and Findings

Work was completed on integration of the SOI forward, tangent linear, and adjoint models into the CRTM. This work was done directly with the JCSDA developer team within the NCEP software repository. Testing of the forward and tangent linear code has also been completed. However, the adjoint code has not yet been tested. Once this testing is done, the SOI model suite will became available as part of CRTM V2.1.

In collaboration with Yong Chen and Fuzhong Weng at the JCSDA, we completed a study on quantifying uncertainties in microwave ice single-scattering properties, which will not only be useful for providing estimates of observation error covariances for radiance data assimilation but also for retrieving ice properties from microwave observations.

This study used a combined active/passive modeling system that converts CloudSat observations into simulated microwave brightness temperatures, ranging from 18 to 157 GHz, to assess published ice particle models under precipitating conditions. Most of these ice models are based on discrete dipole approximation (DDA) calculations that attempt to more realistically characterize single-scattering properties by taking into account particle shape, while others simply assume low-density ice spheres.

Figure 11.3.1 shows results for a cross-section through a frontal system for simulated and observed MHS 89 GHz and 157 GHz channels for the various ice models. Results clearly show that DDA-based ice models compare best to observations, while low-density ice sphere models give unrealistically low simulated brightness temperatures, mainly caused from greatly overestimating ice water path.

Our comparison analysis was done for 31 CloudSat overpasses coincident with MHS on NOAA-18 and AMSR-E on Aqua as described by Chen et al. (2008). From this database we obtained 5153 data points for which precipitation was occurring. This subset of data was then classified into five categories of precipitation: mid-latitude stratiform, low freezing level (FL) stratiform (< 1 km), high FL stratiform (> 1 km), stratiform with brightband, and low-topped convection. Because uncertainties also depend on ice water path, the data set was yet further divided into various bins of a quantity called the integrated reflectivity (Z_{int}), which is the attenuation-corrected CloudSat Cloud Profiling Radar (CPR) reflectivities computed from the freezing level to the top of atmosphere. This quantity is used as a proxy for the IWP and has the advantage of being independent of the ice model.

The analysis showed that uncertainties (as measured in brightness temperature error covariances) varied considerably with precipitation type, Z_{int}, and channel frequency. Results for the lower FL stratiform and higher FL stratiform precipitation cases are indicated in Tables 11.3.1 and 11.3.2, respectively, for one of the Z_{int} bins. Errors tend to be larger for higher FL stratiform cases relative to lower FL cases since they are more sensitive to emission from precipitation below the freezing level. Since the observation error covariance matrix largely determines how observations are used in the data assimilation scheme, it is expected that the assimilation will probably be sensitive to these results. Furthermore, current data assimilation schemes ignore off-diagonal terms in this matrix and the results obtained here show that the magnitude of some of these terms can be significant.

Table 11.3.1. Lower freezing level stratiform precipitation model error covariances (K^2) from the 40 dBZ_{int} data bin for the following frequencies: 18V, 23V, 36V, 89V, and 157 GHz, where V is vertical polarization.

	18V	**23V**	**36V**	**89V**	**157**
18V	1.99	1.70	1.42	0.18	0.80
23V	1.70	1.99	1.44	0.43	0.75
36V	1.42	1.44	1.84	0.40	0.33
89V	0.18	0.43	0.40	5.21	2.13
157	0.80	0.75	0.33	2.13	5.13

Table 11.3.2. Same as Table 11.3.1 but for higher freezing level stratiform precipitation.

	18V	**23V**	**36V**	**89V**	**157**
18V	4.51	3.52	5.86	0.57	0.60
23V	3.52	3.17	4.87	0.35	0.35
36V	5.86	4.87	11.39	4.17	1.00
89V	0.57	0.35	4.17	15.79	4.99
157	0.60	0.35	1.00	4.99	5.15

Publications and Conference Reports

Kulie, M. S., R. Bennartz, T. J. Greenwald, Y. Chen, F. Weng, 2010: Uncertainties in microwave properties of frozen precipitation: Implications for remote sensing and data assimilation. *J. Atmos. Sci.*, in press.

References

Chen, Y., F. Weng, Y. Han, and Q. Liu, 2008: Validation of the community radiative transfer model by using CloudSat data. *J. Geophys. Res.,* **113**, D00A03, doi:10.1029/2007JD009561.

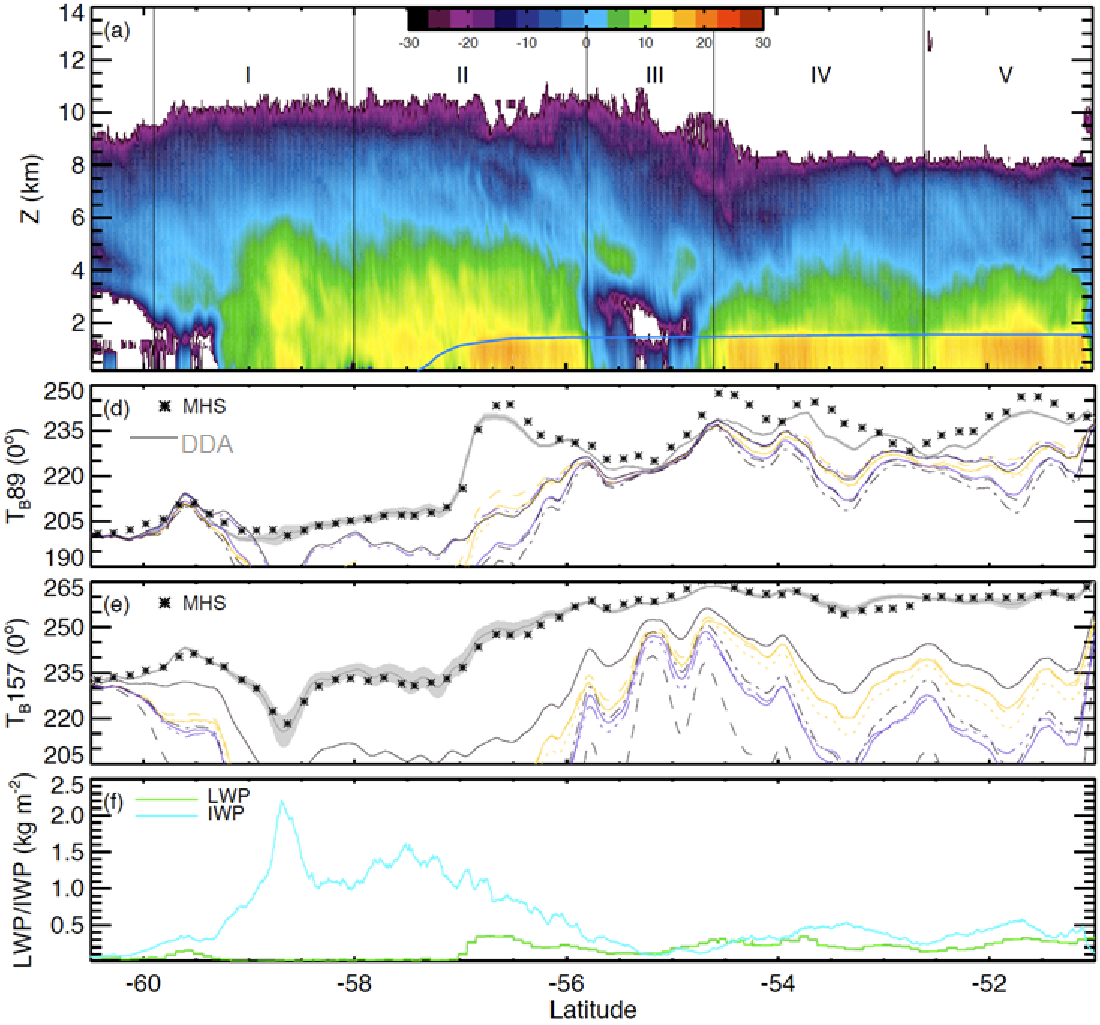


Figure 11.3.1. Comparison of simulated and observed MHS brightness temperatures. Top panel (a) includes the attenuation-corrected observed CloudSat radar reflectivity (dBZ) and the freezing height as determined from ECMWF analyses (blue line). Next two panels (d and e) are comparisons of the observations (asterisks) and simulations for DDA-based ice models (gray shading) and low-density ice sphere models (purple and yellow lines) at 89 GHz and 157 GHz, respectively. Bottom panel (f) shows the CloudSat ice water path (IWP) and AMSR-E liquid water path (LWP) products.

12. Virtual Institute for Satellite Integration Training (VISIT) Participation

Task Leaders: Scott Bachmeier, Steve Ackerman
CIMSS Support Scientists: Scott Lindstrom, Tom Whittaker, Jordan Gerth
NOAA Collaborators: Tim Schmit, Robert Aune, CIRA, WDTB
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
- Education, training 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 that the National Weather Service (NWS) forecaster can more easily relate to.

We also proposed to begin 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 WES case using simulated Advanced Baseline Imager (ABI) data has been developed at CIMSS as part of the GOES-R Proving Ground effort headed by Tim Schmit.

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 in 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 in AWIPS" project that has been ongoing since 2006).

Summary of Accomplishments and Findings

32 live tele-training sessions (using VISITView) were given to a total of 49 NWS offices during this period, on the following seven topics: Interpreting Satellite Signatures, Basic Satellite Principles, Mesoscale Convective Vortices, TROWAL Identification, CRAS Forecast Imagery in AWIPS, POES and AVHRR Data in AWIPS, and the UW Convective Initiation Product. Recorded versions of these seven training topics are also present with the National Weather Service's LMS, and are available to forecasters via that route.

Three new lessons that were developed and added to the VISIT training calendar were: 1) POES and AVHRR Data in AWIPS, 2) The UW Convective Initiation Product, and 3) The UW Nearcasting Product. These lessons introduce new types of satellite imagery and products that a NWS forecast office can choose to add to their local AWIPS workstations. In addition, work began on 3 new lessons: 1) One-Stop Inventory of Satellite Products in AWIPS; 2) PREs (Predecessor Rain Events) Associated with Tropical Cyclones and 3) Objective Satellite-based Detection of Overshooting Tops.

Figure 12.1 illustrates an example of the POES AVHRR Sea Surface Temperature (SST) product displayed in AWIPS. The SST product revealed that the oil slick from the Deepwater Horizon oil slick exhibited SST values that were several degrees F cooler than the surrounding waters in the northern Gulf of Mexico. Figure 12.2 shows an example of the UW Convective Initiation (UWCI) product displayed in AWIPS. In this particular case, the UWCI product flagged an area of developing convection over the northern Texas Panhandle at 18:40 UTC -- about 1 hour before it produced its first report of 1.0 inch diameter hail, and almost 2 hours before it produced 6.0 inch diameter hail.

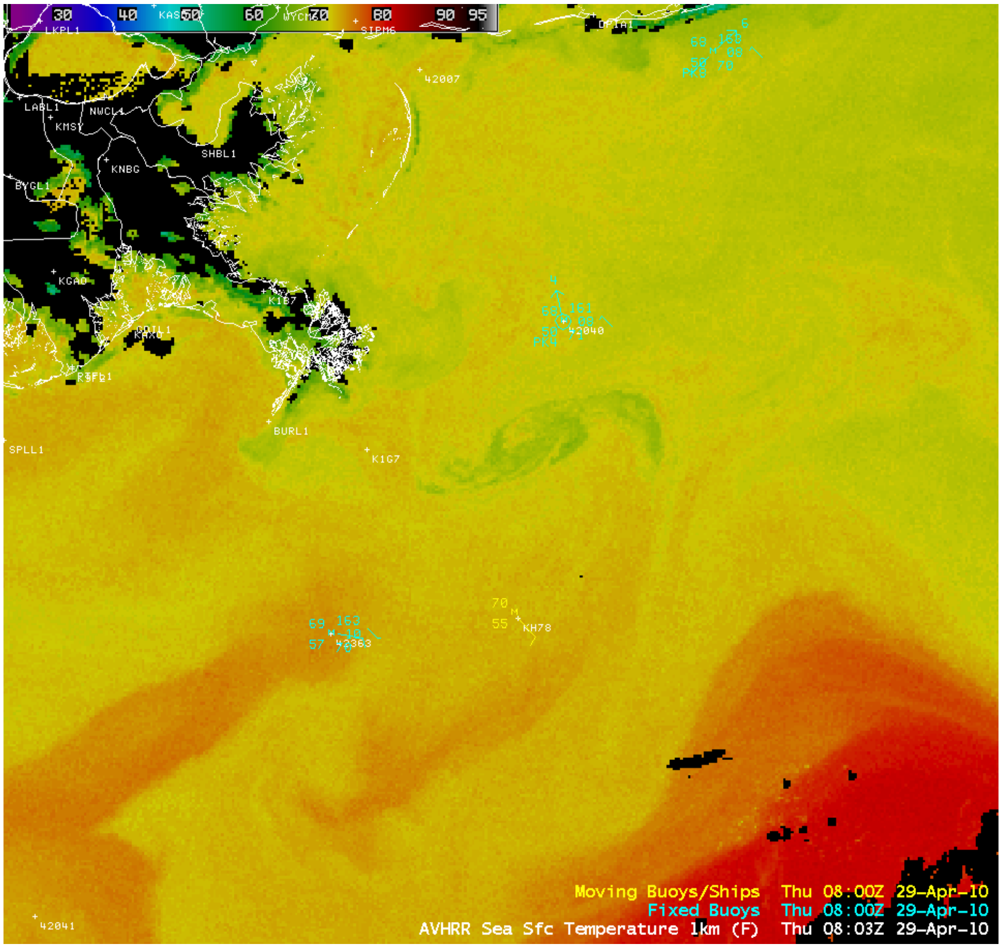


Figure 12.1. POES AVHRR Sea Surface Temperature (SST) product displayed in AWIPS, showing cooler SST values associated with the Deepwater Horizon oil slick in the northern Gulf of Mexico on 29 April 2010.

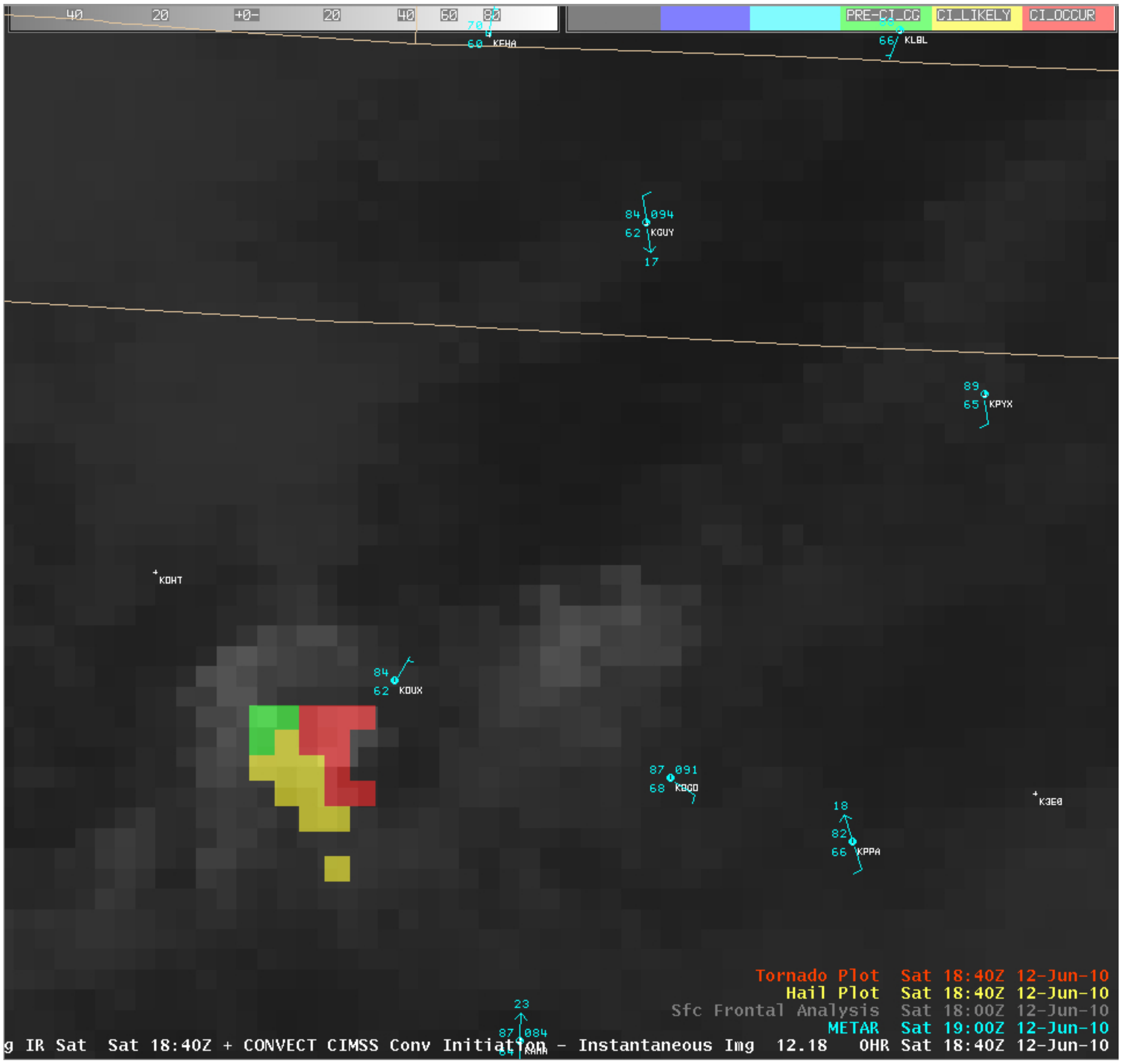


Figure 12.2. UW Convective Initiation product displayed in AWIPS, flagging a developing area of convection over the Texas panhandle region at 18:40 UTC on 12 June 2010; about 2 hours later, this particular thunderstorm produced hail up to 6.0 inches in diameter.

As an adjunct to the VISIT teletraining lessons, CIMSS also actively maintains the CIMSS Satellite Blog (http://cimss.ssec.wisc.edu/goes/blog), which serves as a very effective "just-in-time" satellite training resource to supplement the existing teletraining modules. As one example, on the day that GOES-13 replaced GOES-12 as the operational GOES-East satellite, a blog post was added to the "Training" category which discussed how the new GOES-13 visible channel was different from that on GOES-12 (which required the use of a different default enhancement for optimal viewing of GOES-13 visible imagery), as well as highlighted a few examples to show the significant improvements in the GOES-13 Sounder images compared to GOES-12. Presently, the CIMSS Satellite Blog contains nearly 700 posts, covering 38 different categories (ranging from Air Quality to Winter Weather). Over 150 blog posts were added during the October 2009 – September 2010 period.

In order to help ensure that the VISIT training material and some of the newly-developed satellite products in AWIPS were properly meeting the needs of the forecasters, about 30 site visits were made to the local NWS office at Milwaukee/Sullivan.

Looking to the future, CIMSS has also been participating in the evaluation of AWIPS II Task Order releases in collaboration with the NWS Office of Science and Technology. Specifically, we are interested in the features of the migrated AWIPS software package which are easily configurable and allow for the proper transition of locally produced products and enhancements created under the original AWIPS operational build deployments.

13. SHyMet Activities

Task Leaders: Steve Ackerman, Scott Bachmeier
CIMSS Support Scientists: Bill Bellon, Scott Lindstrom
NOAA Collaborators: Gary Wade, Tim Schmit
NOAA Strategic Goals:

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

Proposed Work

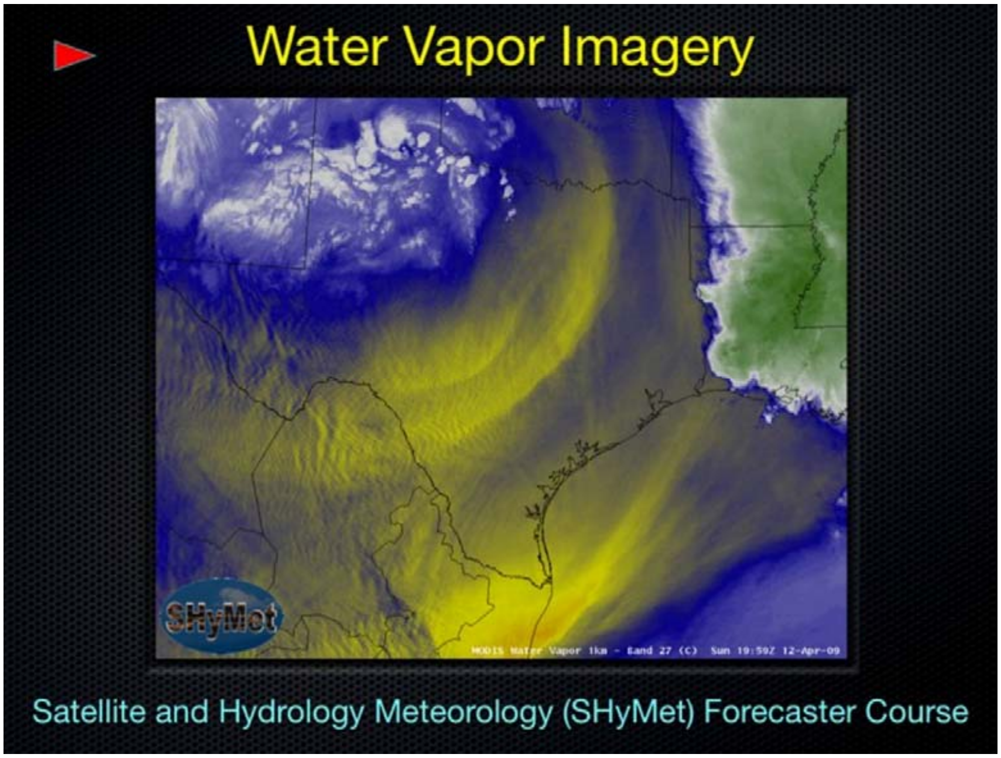
CIMSS continues to participate in the Satellite Hydrology and Meteorology (SHyMet) training course through close collaboration with experts at the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University, Colorado. The role of CIMSS in SHyMet is to 1) provide advice on the educational design of the program, 2) assist in the development of the curriculum, 3) support distance learning activities, 4) develop and test appropriate satellite education materials, and 5) assist in the teaching of the courses as appropriate.

Summary of Accomplishments and Findings

The teletraining portion of the course is being met by utilizing the already established Virtual Institute for Satellite Integration Training (VISIT) program. Previously, CIMSS developed and delivered the lessons "GOES Sounder Data and Products" and "GOES High Density Winds" for the initial "SHyMet for Interns" course. The "GOES Sounder Data and Products" lesson provided an introduction to the data and products available from the latest generation of GOES Sounder instruments, along with examples of sounder Derived Product Imagery (DPI) and their applications to weather analysis and forecasting. The "GOES High Density Winds" lesson reviewed techniques for measuring satellite winds (atmospheric motion vectors), and provided details on the display of GOES high density winds on AWIPS.

For the follow-on and more advanced "SHyMet for Forecasters" course, two new lessons "Water Vapor Channels" and "Interpreting Satellite Signatures" were completed and added to the NOAA Learning Management System (LMS). The "Water Vapor Channels" lesson reviews the characteristics of the water vapor channel, and discusses the identification of common signatures seen in water vapor imagery and how to use water vapor imagery to assess the performance of numerical weather prediction models. The "Interpreting Satellite Signatures" lesson provides examples of common satellite features that are frequently observed, and explains the atmospheric conditions that support the observed features.

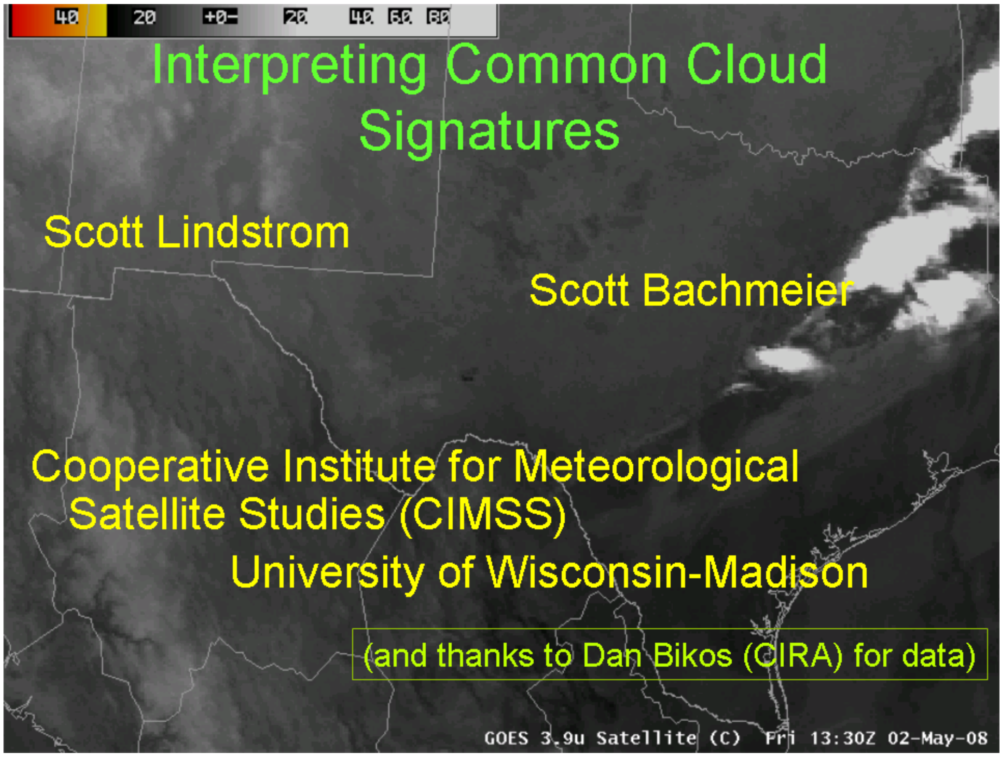
CIMSS staff are tasked with maintaining the lessons, evaluating feedback from the SHyMet for Interns and the SHyMet for Forecasters courses, and making appropriate modifications based upon input from the students.



Water Vapor Imagery

Satellite and Hydrology Meteorology (SHyMet) Forecaster Course

Figure 13.1. Title slide from the “Water Vapor Imagery” lesson of the SHyMet for Forecasters course.



Interpreting Common Cloud Signatures

Scott Lindstrom

Scott Bachmeier

Cooperative Institute for Meteorological Satellite Studies (CIMSS)

University of Wisconsin-Madison

(and thanks to Dan Bikos (CIRA) for data)

Figure 13.2. Title slide from the “Interpreting Satellite Signatures” lesson of the SHyMet for Forecasters course.

14. Estimation of Cloud Microphysics from MODIS Infrared Observations

Task Leader: Michael 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:

- Weather, Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

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.

Our objective is to develop a research-oriented algorithm to address this need.

We use MODIS data to develop an IR retrieval algorithm for cloud optical thickness and particle size (and hence water content). This approach will be apply to global data, and then compared to independent measurements sources, such as CALIOP or CloudSat data.

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).

An additional aspect of this work will focus on VIIRS, the imager succeeding MODIS on JPSS. The VIIRS imager has neither CO2 bands nor water vapor bands. Estimation of cloud properties at night from VIIRS will require use of multiple infrared window channels. While a baseline VIIRS algorithm exists that uses 3.7, 8.5, 11 and 12 μm channels, it has not been thoroughly tested or compared to MODIS results. At this time we are unable to assess the viability of the VIIRS cloud retrieval approach. As part of this study, we propose to conduct studies to quantify the impact on nighttime cloud properties due to the loss of CO_2 absorption channels on VIIRS

Summary of Accomplishments and Findings

Project Status

- Develop an algorithm to derive cirrus optical and microphysical properties from the MODIS IR observations coupled with existing MYD06 cloud heights [DONE]
- Conduct studies to characterize and understand the IR results in relation to existing daytime products. [IN PROGRESS]
- Implement in future MODIS/JPSS Atmospheres data products. [TBD]

Methodology

Using MYD06 cloud height, cloud emissivity is computed for 8.5, 11 and 12 μm observations from which β values (akin to Angstrom exponents) are derived from the 8.5/11 and 11/12 channel pairs. Only single layer cirrus pixels are used. For a given habit and a given channel combination, a value of effective radius can be derived from each β value (see Figure 14.1). Ice scattering properties provided by Ping Yang et al., 2005.

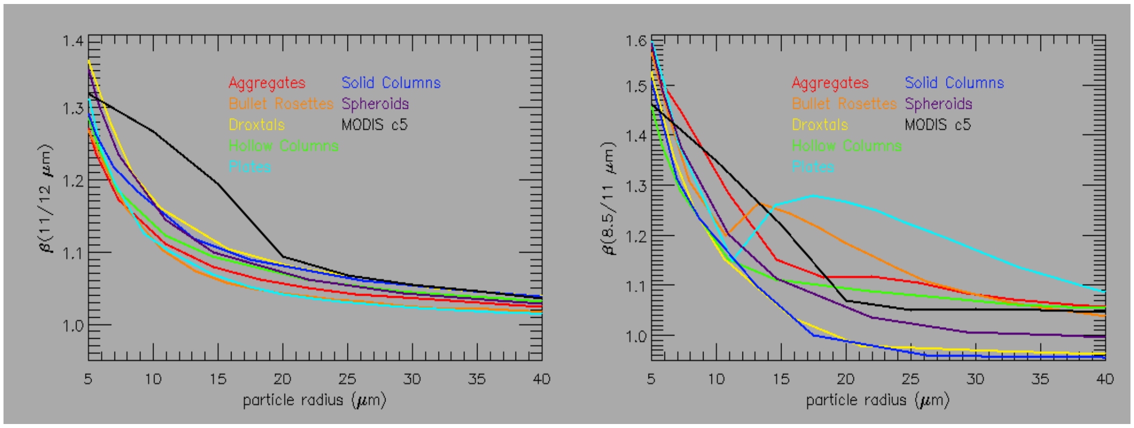


Figure 14.1. β values as a function effective radius for each habit type. The left panel shows β for the 11/12 μm channels while the right panel shows β for the 8.5/11 μm channels.

An optimal habit is selected based on the habit that produces the minimum difference in the effective radius from each β value. As shown in Figure 14.2 the resulting effective radius difference is << 10 μm indicating this method has skill (optimal differences are smaller than those when habit is ignored).

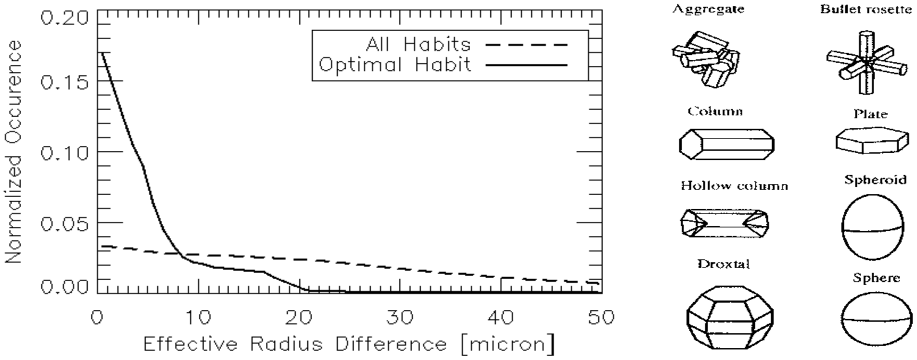


Figure 14.2. Occurrence of differences between β(11/12 μm) and β(8.5/11 μm) when using all habits (dotted line) versus optical habits (solid line) as a function of effective radius. The right panel illustrates some idealized shapes of the different habits.

Analysis of results for all habits shows that certain habits behave similarly. We therefore defined the following bulk habits:

- Bulk Spheroids = aggregates + spheroids
- Bulk Plates = plates + droxtals
- Bulk Columns = solid columns + hollow columns + bullet rosette + MODIS Collection 5 (C5 – *Bryan Baum et al.*)

Comparison to MYD06

For greatest impact, we have to understand and reconcile the IR and MYD06 estimates. Figure 14.3 shows MYD06 optical depths are roughly a factor of two larger than IR optical depths (adjusted to 0.65 μm), which is similar to comparisons of CALIPSO/CALIOP optical depths to MYD06. MYD06 particle radii are much smaller than the IR estimates using the optimal habit implying that MYD06 models are too absorbing at 2.1 μm and scatter too much in the forward direction at 0.65 μm (relative to the IR models).

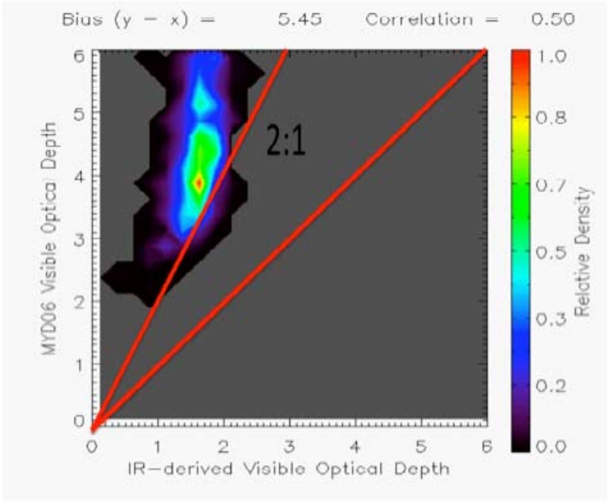


Figure 14.3. Relative density of occurrence of MYD06 visible optical depth versus IR-derived optical depth.

Conclusions

The MODIS IR observations provide useful information on cirrus microphysics that complements those currently available in MYD06. This includes some information on ice crystal habit, which to our knowledge represents one of the first satellite inferences of habit. This methodology fits in well with the current MYD06 framework and could be added to future versions of MYD06. We are currently proposing this. However, the IR results are not consistent with the MYD06 results generated from solar reflectance, which, according to our analysis, indicates that the C5 mixture may be too heavily influenced by columns. These inferences are likely to change when new more realistic scattering models become available.

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, in press.

References

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.

15. Support for the WVSS-II Field Program

Task Leaders: Ralph Petersen, Wayne Feltz
CIMSS Support Scientists: Erik Olson, Lee Cronce
NOAA Collaborator: David Helms (NWS/OST)
NOAA Strategic Goals:

- Serve society’s needs for weather and water

CIMSS Research:

- Weather Nowcasting and Forecasting

Proposed Work

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) University of Wisconsin-Madison (UW) proposed performing intercomparison validation analyses of the co-located rawinsonde and WVSS-II observations taken on evenings during fall 2009 and spring and summer 2010 at Rockford IL (RFD). Rawinsonde observations were taken using Vaisala model RS-92 instruments with new humidity sensors. The observations were made at approximately 3-hourly intervals, immediately before, after and between periods when UPS-757 aircraft equipped with the WVSS-II instruments landed and departed. Unlike previous intercomparisons, the following analysis was conducted using all available data from all aircraft, excluding those with known engineering failures.

Summary of Accomplishments and Findings

Direct Data Intercomparison

Subjective comparisons between the aircraft and rawinsonde observations provide a direct means of comparing the data from WVSS-II equipped aircraft to individual rawinsonde reports. The majority of both ascent and descent data showed very similar vertical structures to the rawinsonde data. This similarity was especially true in the lowest 300hPa of the atmosphere where all aircraft were flying essentially along the same paths and close to the rawinsonde launch site. The agreement between successive (and independent) WVSS-II soundings provides confidence in the accuracy of and consistency between the individual WVSS-II observations.

The WVSS-II moisture data comparisons to individual rawinsonde Specific Humidity (SH) reports were generally within ±0.5 g/kg, including across the moisture inversion. In many aircraft ascents, however, the temperature profiles showed notable warm Biases. Although ascending reports dominated the co-located data sets, the fit and consistency between descending reports was also very good, including across inversions in a very moist environment. Unlike the ascending observations, the descent moisture data in general show a slight moist Bias and a smaller warm Bias. In general, the WVSS-II observations fell well within the bounding rawinsonde data.

Overall, the ascent data exhibit a positive SH Bias of 0.19 g/kg (systematic difference), with a Standard Deviation (StDev – random difference) of 0.91 g/kg. In middle/lower moisture ranges, the Bias increases slightly to .21 g/kg, while the StDev decreases to .56 g/kg. The SH data from descending aircraft show a slightly smaller Bias (+0.09 g/kg) and random difference (StDev of 0.85 g/kg), compared with +0.25 g/kg Bias and 0.91 g/kg StDev for ascending reports. The fact that multiple aircraft showed these same behaviors points both to good consistency between the aircraft reports and to the possibility that the rawinsonde data taken at 3 hourly intervals may not have been fully representative of the small-scale moisture structures observed by the WVSS-II aircraft. The WVSS-II and rawinsonde SH reports also displayed consistent variations across the full range of rawinsonde RH observations.

Statistical Assessment

Summary statistics were calculated over the entire test period comparing all aircraft observations (ascent and descent) to the nearest rawinsonde observation. For these calculations, an additional set of criteria were used to limit the temporal difference in Relative Humidity (RH) between successive reports. The RH temporal difference was to be <7% and vertical differences between adjacent vertical levels to be <10%. The effect of this was to eliminate both the effects of scattered clouds that could have been along the rawinsonde trajectory and to eliminate cases where shallow banks of moisture and fronts were moving vertical during the test period.

The best agreement appears in the lowest 250 hPa, where RH Biases are very small and random differences are on the order of 5-7%. Above 875 hPa, the random error increases to nearly 10% and a slight positive Bias forms. These differences decrease again to near-surface values above 700 hPa, but with a second spike in both Bias and StDev differences above 600 hPa. When the effects of the temperature Biases are removed from the RH data by using rawinsonde temperature in both the WVSS-II and rawinsonde calculations, the Random Error (StDev) remains essentially unchanged but the Biases increase from negligible near the surface to exceed ±5% at several higher levels. This should not present a major problem in applications since the effect of these systematic errors can be removed if the VWSS-II aircraft data (both SH and temperature) are monitored regularly.

Profiles of differences in SH (the variable reported by the WVSS-II instrument) are shown in Figure 15.1. These results also show positive Biases at all levels, ranging from 0.1 to 0.3 g/kg. Again, this systematic behavior of the instrument can readily be removed and modified over time if the instrument performance is monitored against a calibrated standard on a regular basis. More importantly, however, the random difference between the WVSS-II and rawinsonde moisture observations ranges between 0.2 and 0.7 g/kg at the majority of levels. Increases aloft occur where the number of intercomparisons and average time/space separation between the 2 observing systems increases. This performance is well with WMO standards for both global and mesoscale applications.

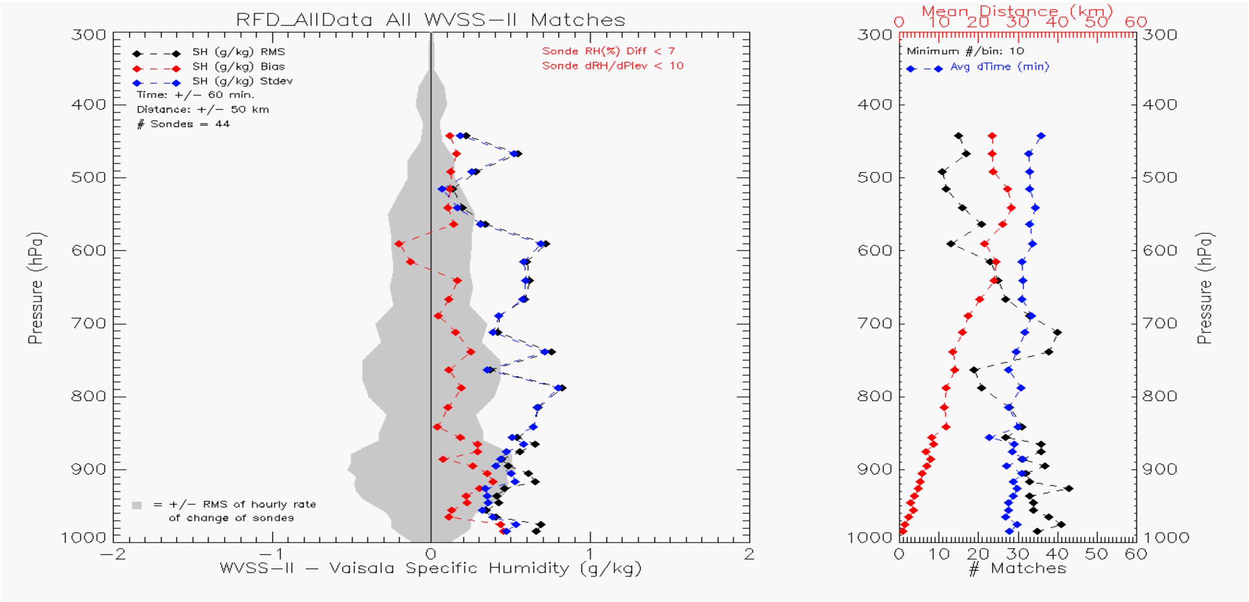


Figure 15.1. Left - Plots of SH comparison statistics between co-located observations from WVSS-II and rawinsonde data taken for all 2009-2010 intercomparison periods at Rockford, IL (Bias, °C - red; RMS, °C - black; StDev, °C - blue). Right - Number of observations intercomparisons used (black, mean distance between reports (km, red) and mean time difference between reports (Min., blue). Shading area indicates ± 1 RMS of variations (scaled to 1 hour time interval) observed between all approximately 3-hourly rawinsonde pairs used.

As another measure of the robustness of the WVSS-II observation, intercomparisons were computed between WVSS-II observation pairs made within specific time, height and spatial limits. The results presented in Figure 15.2 indicate both that the variability increases systematically with both time and space separation, and more importantly, that WVSS-II observations taken within 15 minutes, 20 km and 55 m altitude of each other agreed to within better than 0.2 g/kg. Even using the longer 1 hour and 60 km limits (periods comparable to those used in the rawinsonde-to-WVSS-II comparisons), the variability is <0.4 g/kg. The fact that this figure is much lower than that obtained in the rawinsonde-to-WVSS-II comparisons indicates that a substantial portion of the difference detected in the multiple instrument intercomparisons may have been due to errors in the rawinsonde reports.

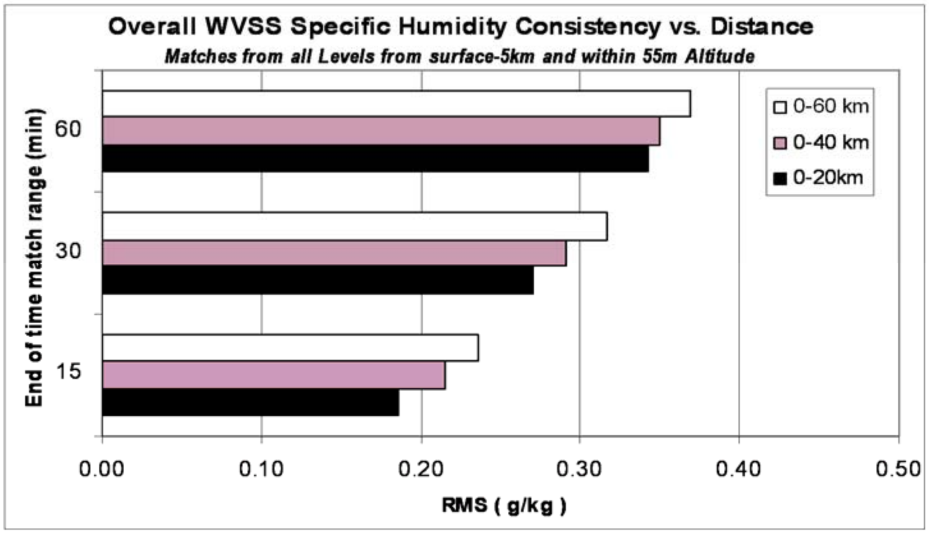


Figure 15.2. Variability (RMS) of Specific Humidity observations between nearby WVSS-II observations by time difference and range interval for all levels from the surface to 5km throughout the full intercomparison period.

Summary

When the large match-up differences that are probably due to small-scale natural variability are excluded, the re-engineered WVSS-II systems appear to meet WMO observing requirements across all SH ranges and in both ascent and descent. The engineering changes made to the WVSS-II since 2008 seem to have alleviated the problems with descent data seen in earlier tests.

Overall, the WVSS-II SH observations match the rawinsonde data very closely, with random differences ranging from 0.2 to 0.7 g/kg, well within WMO recommendations. Although the data show a slight moist Bias (ranging from 0.1 to 0.3 g/kg), the Bias should be correctable in post-processing if the WVSS-II data are monitored regularly. Intercomparison within the WVSS-II data set observations made within 15 minutes, 60 km distance and 55 m altitude showed variability of less than 0.2 g/kg, exceeding the performance of most, if not all, other operational data sets.

Supplementary analyses are underway to further enhance and clarify the results presented here. Among others, these analyses are planned to include: 1) Interpolating the two rawinsonde reports bounding the WVSS-II observations to the WVSS-II observations should remove large scale, systematic advection processes that could bias the comparisons., 2) Adjusting distance criteria used in filtering the WVSS-II data to be more consistent with the parcel displacement distance expected from the mean winds observed during the test period., and 3) Adding wind observation variability limits to the statistical analysis process to provide an independent standard for identifying periods of low and high natural atmospheric variability.

Publications and Conference Reports

Petersen, R.A., L. Cronce, W. Feltz, E. Olson and D. Helms, 2010: WVSS-II MOISTURE OBSERVATIONS: A tool for validating and monitoring satellite moisture data. Keynote Paper, EUMETSAT Satellite Conference, Cordoba, Spain.

Petersen, R.A., L. Cronce, W. Feltz, E. Olson and D. Helms, 2010: Assessment of WVSS-II moisture Observation. Invited Paper, WMO AMDAR Panel, 2010, Geneva, Switzerland.

16. A Product Development Team for Snow and Ice Climate Data Records

Task Leader: Xuanji Wang
CIMSS Support Scientist: Yinghui Liu
NOAA collaborator: Jeff Key
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:

- Environmental Trend
- Climate

Proposed Work

The availability, consistency and accuracy of cryospheric products, namely snow and ice, are critical for applications such as climate change detection, weather and climate modeling, shipping, and hazard mitigation. The development of cryospheric 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 will create a Cryosphere Product Development Team that will provide 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 will coordinate existing and new products, establish “best practices,” and update heritage products to allow NOAA to continue with their production and dissemination. The CIMSS focus is on the cryospheric products that can be derived from optical (visible, near-IR, and thermal IR) imagers. FCDRs will be 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 Oct 2009 to 30 September 2010. During this period, the primary accomplishment was to inventory existing algorithms and models, begin data collection, revise and add new algorithms to our retrieval tool, i.e., CASPR, especially for consistent cloud detection, inter-satellite data calibration, and ice characteristics. The eXtended AVHRR Polar Pathfinder (APP-x) products have been updated over 1982~2004, and validation efforts have provided quantitative error assessments. This effort involves the production of both FCDRs and TCDRs. The APP-x products currently include climate information about clouds, surface temperature and albedo, solar and thermal radiation, and Cryosphere. A number of papers have been published on the use of the APP-x snow and ice CDR products for climate studies with major findings summarized below.

- It was found that 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.
- 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.

There have been numerous updates to our core APP-x algorithm code, including the addition of ice concentration and thickness/age algorithms, sunglint to improve cloud detection, and surface type change tracking. Based on our experience in producing long-term geophysical fields from satellite data, as demonstrated in Figure 16.1 for surface, cloud, radiation, and snow and ice from APP-x products, we will extend current APP-x products to JPSS VIIRS era.

Publications and Conference Papers

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.*, in press, 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.

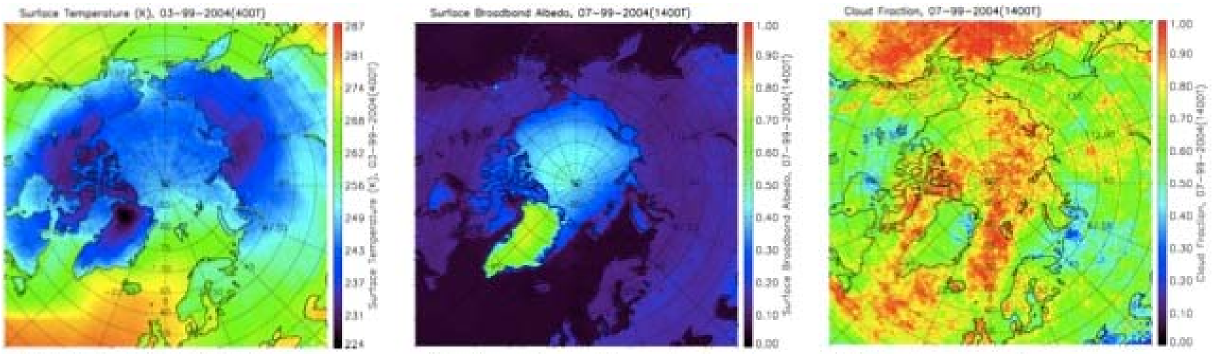
Fernandes, R., H. Zhao, X. Wang, J. R. Key, X. Qu, and A. Hall, 2009: Controls on Northern Hemisphere snow albedo feedback quantified using satellite Earth observations. *Geophys. Res. Lett.*, **36**, L21702, doi:10.1029/2009GL040057.

Wang, X., J. R. Key, Y. Liu, 2010: Changing Arctic Sea Ice, Its Trends and Impacts on Arctic Climate Change over 1982-2004, 17TH CONFERENCE ON SATELLITE METEOROLOGY AND OCEANOGRAPHY, AMS Fall Meeting, 27 September -1 October 2010, Annapolis, MD, USA.

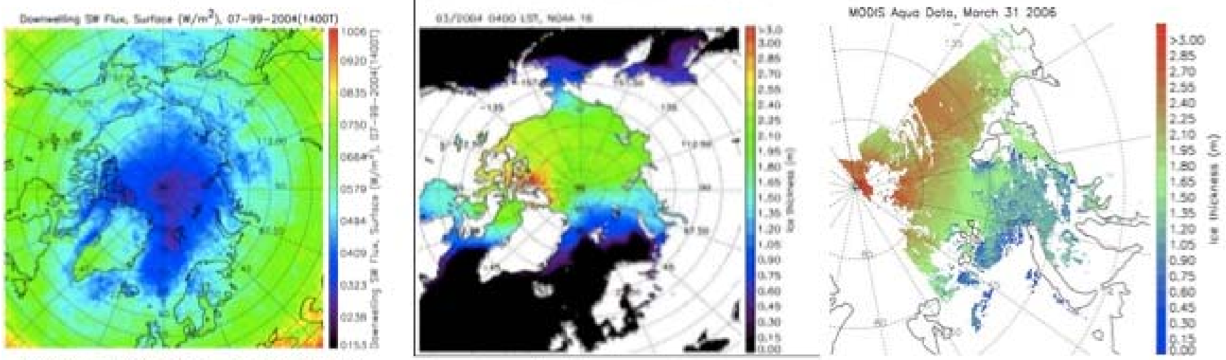
Wang, X., J. R. Key, Y. Liu, 2010: Changing Arctic Sea Ice and Its Trends over 1982-2004. STATE OF THE ARCTIC, 16-19 March 2010, at Hyatt Regency, Miami, Florida, USA.

Liu, Y., J. R. Key, X. Wang, 2009: On the Interactions of Arctic Sea Ice, Cloud Cover, and Surface Temperature from Satellite Observations. 2009 AGU Fall Meeting, 14-18 December 2009, San Francisco California, USA.

Liu Yinghui, Key R. Jeffrey, Wang Xuanji, 2010: Linkages of Arctic Sea Ice, Cloud Cover, and Surface Temperature from Satellite Observations (Talk), 2010 State of the Arctic Conference, 16-19 March 2010, Miami, Florida, USA.



Surface temperature Surface broadband albedo Cloud amount



Surface SW flux, downward Sea ice thickness, AVHRR Sea ice thickness, MODIS

Figure 16.1. Examples of APP-x products. Clockwise from upper left: surface temperature (March 2004), surface albedo (July 2004), cloud fraction (July 2004), sea ice thickness from MODIS (March 31, 2006), sea ice thickness from AVHRR (March 2004), and surface downward shortwave flux (July 2004).

17. NPOESS (JPSS) Projects

17.1. VIIRS Cloud Studies for NPOESS

Task Leader: Richard Frey
CIMSS Support Scientists: Mike Foster, Chang-Hwan Park
NOAA Collaborator: Andrew Heidinger
NOAA Strategic Goals:

- Understand climate variability and change to enhance society's ability to plan and respond

CIMSS Research Themes:

- Clouds, Aerosols and Radiation

Proposed Work

The goal of this project is to support the Calibration and Validation Teams created by the Integrated Program Office. Half of this funding will support our efforts to improve and validate the VIIRS cloud mask. The second effort is the validation of the VIIRS cloud properties beyond cloud mask. By processing MODIS data through VIIRS algorithms globally, we can use our traditional validation approaches to expose weaknesses in VIIRS algorithms that might go unnoticed until after launch. In addition, we plan to run modified algorithms in parallel with the VIIRS baseline algorithms and demonstrate improvements for future algorithm updates.

Summary of Accomplishments and Findings

The VIIRS cloud mask (VCM) algorithm has been evaluated by comparing results to collocated CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) cloud boundary data, using MODIS proxy radiance and geo-location data as input. The VCM has been produced using several months of Aqua data, including twelve contiguous months from July 2007 through June 2008. This work has been accomplished using the Atmospheric Product Evaluation And Test Element (PEATE) processing system at CIMSS. A comparison created in April 2010 is shown in Figure 17.1.1. Plotted is the percentage of collocated CALIOP (version 2) and VCM (version 1.5.0.48) results that were in agreement ("hit rate") during the twelve months above, given that the locations were over non-polar, daytime surfaces. Note that this version of the VCM is the latest that has been made available to CIMSS. Also shown is the agreement between CALIOP and the proposed Collection 6 MODIS cloud mask (MOD35) generated from the same inputs. Though input radiances were from MODIS and the ancillary data used are, in general, not the same as will be used to process future VIIRS data, the inputs are exactly the same for both the VCM and MOD35. Thus, the differences seen are algorithmic only, except for the caveat that no VCM I-band tests are performed. This could depress the hit rate for water scene VCM/CALIOP comparisons. Global agreement over the twelve months shown is 79.0 percent. The agreement between Collection 6 MOD35 and CALIOP is 86.9 percent. These and other results from the year-long collocation data set were presented at the VIIRS Operational Algorithm Team Meeting in Madison, WI, May 5, 2010.

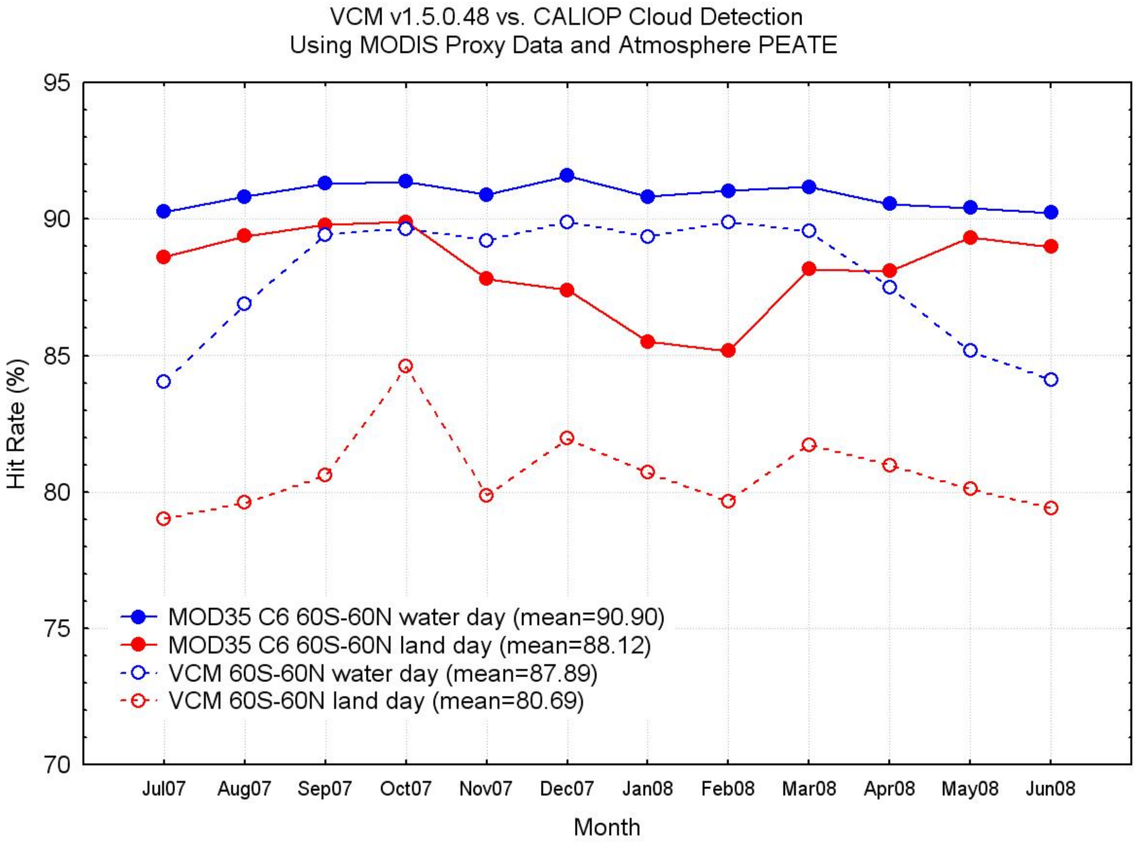


Figure 17.1.1. Agreement between VCM and CALIOP cloud detection algorithms (dotted lines). MOD35 agreement is also shown for comparison (solid lines). Blue lines indicate non-polar daytime water scenes, while red is for daytime land.

VCM developers requested that CIMSS analyze both land and water nighttime cloud tests and make suggestions for improvements in thresholds or formulation of spectral tests. Modifications were proposed for three nighttime water cloud tests (11 µm surface temperature, 3.7-11 µm BTD, tri-spectral BTD) and one for nighttime land (3.7-11 µm BTD). Figure 17.1.2 shows clear and cloudy-sky 11-3.9 µm BTDs vs. total precipitable water (TPW) values from GDAS (Global Data Assimilation System) NWP model output and a sample cloud test threshold calculation using MODIS proxy data. In this case, thresholds have been made a direct function of TPW and are seen on the solid black line. A similar test is being implemented for the MODIS Collection 6 algorithm for both nighttime land and water surfaces and has resulted in monthly skill score improvements of up to 8% in comparisons to CALIOP version 3 cloud detection data. Other recommendations included replacing the ocean tri-spectral test (8.6-11 µm BTD as a function of 11-12 µm BTD) with a simple 8.6-11 µm threshold test to reduce over-clouding in the tropics, and changing the form of the ocean surface temperature (SST) test. All of these recommended changes will appear in the MODIS Collection 6 algorithm. These recommendations and validation statistics for other cloud tests were presented in a poster at the 2009 AGU Fall Meeting in San Francisco, 14-18 December.

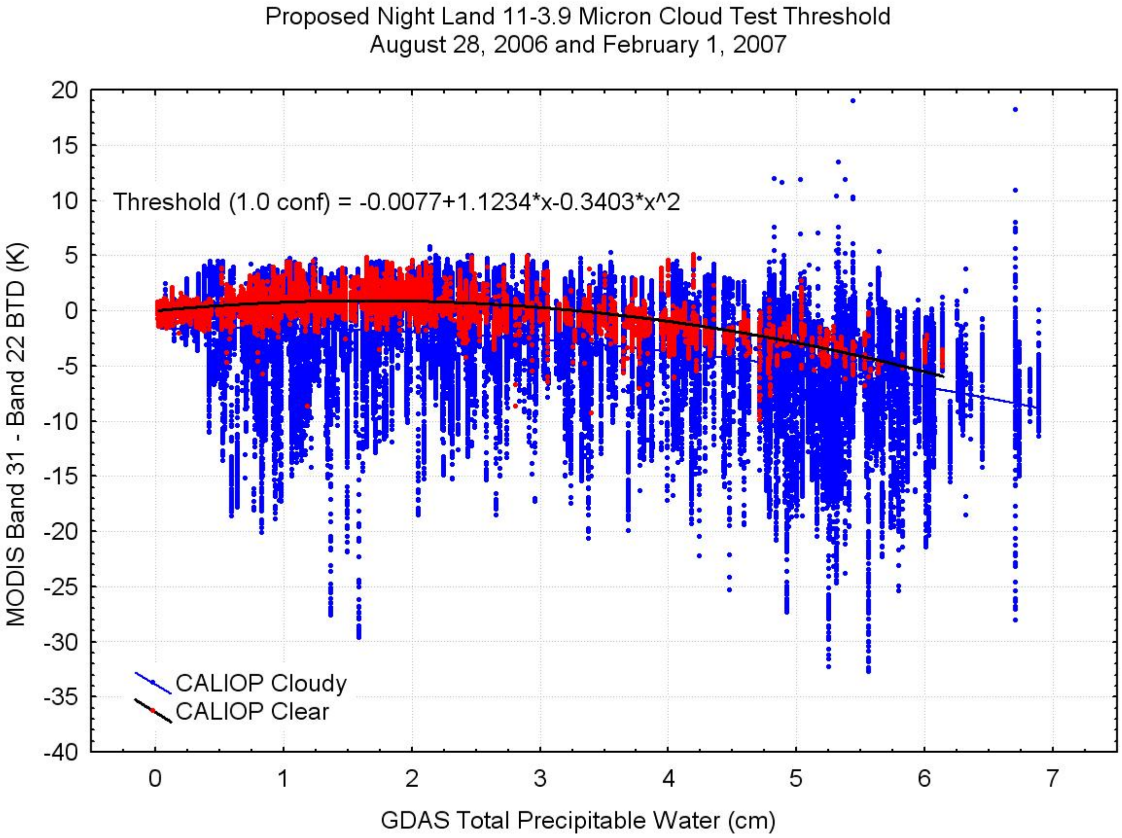


Figure 17.1.2. Proxy MODIS observed 1-km 3.9-11 µm BTDs for clear-sky (red) and cloudy-sky (blue) scenes over nighttime land where clear vs. cloudy has been determined from collocated CALIOP data. BTDs are shown as a function of GDAS TPW values. Clear-sky threshold values are found on the solid black line.

Another request from the VCM developers was to generate cloud amounts and hit rates (agreement) between CALIOP cloud detection data and VCM results using MODIS proxy radiance data but only where CALIOP indicated cloud optical depths > 1.0. Figure 17.1.3 shows zonal mean cloud amount differences over all surface types for the month of July 2007. Blue, red, and green curves represent CALIOP (all clouds minus clouds with optical depths > 1.0), CALIOP minus VCM for all clouds, and CALIOP minus VCM for cloud optical depths > 1.0, respectively. Latitudes where a peak in the blue curve coincides with large differences between the red and green curves indicate where increased sensitivity to thin clouds (presumably mostly cirrus) would have a large positive impact on cloud detection skill. It is anticipated that the VIIRS 1.38 μm reflectance band will have enhanced capabilities compared to that of MODIS, thus leading to improved cloud detection in these regions. Note that there is increasing cloud fraction difference between CALIOP and the VCM for even thick clouds (optical depth > 1.0, green curve) as one moves from the tropics toward the poles. This difference occurs primarily over water surfaces in the southern hemisphere and primarily over land in the northern hemisphere. The reason for the upward blip in differences seen from about 20-40 degrees latitude is unknown but may be related to confusion between aerosols and clouds in the CALIOP version 2 data. To a lesser extent, this phenomenon is also seen in CALIOP vs. MOD35 comparisons.

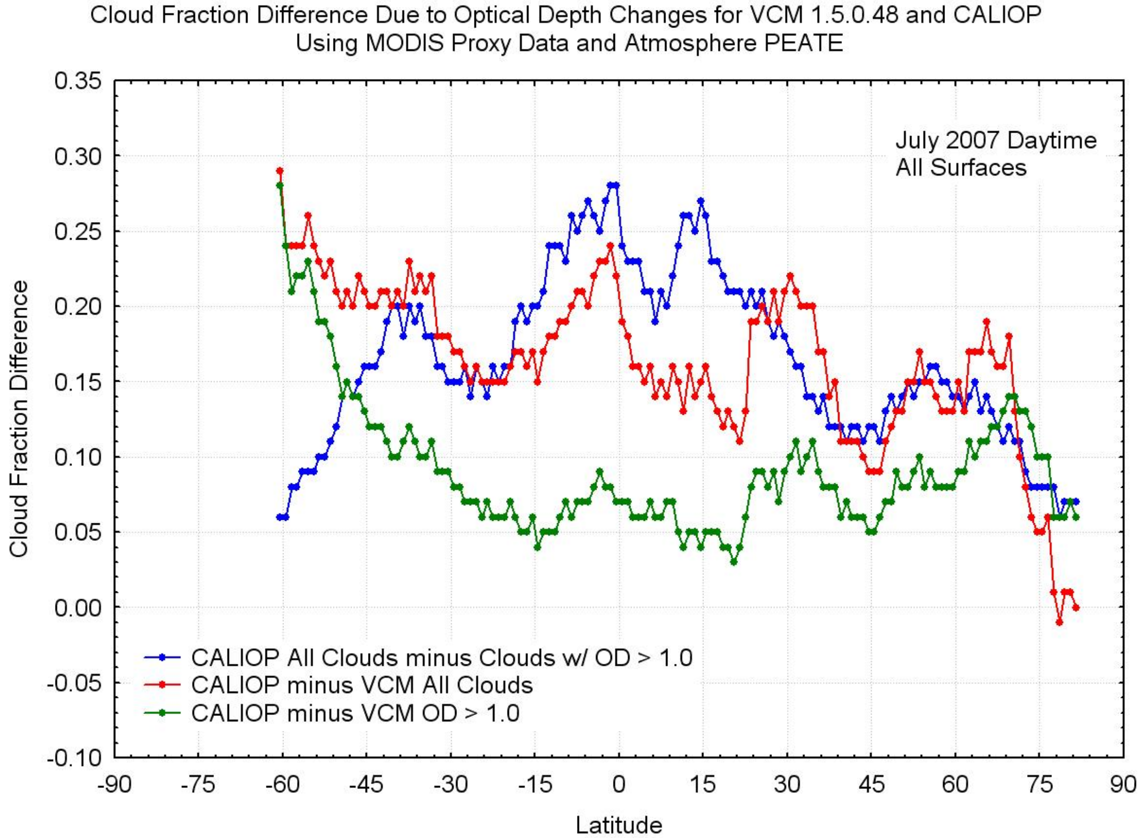


Figure 17.1.3. Cloud fraction difference between all clouds and clouds with optical depths > 1.0 from CALIOP (blue), CALIOP minus VCM cloud fraction for all clouds (red), and for cloud optical depths > 1.0 (green).

In addition to the validation of the cloud mask, this project also includes the validation of other VIIRS cloud properties. This project is included within the larger UW PEATE effort. One of the goals is to demonstrate the performance of VIIRS cloud properties algorithms in relation to that of its predecessors (e.g., AVHRR). To facilitate this analysis, we have modified our AVHRR processing system to ingest MODIS data. This modification will allow us to implement VIIRS algorithms because MODIS provides all relevant channels and direct comparisons with AVHRR and VIIRS approaches become possible. However, the current state of the VIIRS cloud algorithms is not mature enough to allow for any meaningful comparisons. While these algorithms reach maturity, we continue to test the expected performance based on the spectral information. A study reported in Heidinger et al., 2010 accomplished this in the context of cloud height retrievals.

Publications and Conference Reports

Heidinger, A. K., M. J. Pavolonis, R. E. Holz, Bryan 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. *Journal of Geophysical Research*, **115**, Doi:10.1029/2009JD012152.

17.2 NPP/NPOESS Cryospheric Products Calibration & Validation Activities

Task Leader: Yinghui Liu
CIMSS Support Scientist: Xuanji Wang
NOAA collaborator: Jeff Key
NOAA Strategic Goals:

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

CIMSS Research Themes:

- Weather Nowcasting and Forecasting
- Global Hydrological Cycle

Proposed Work

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) (launch expected in 2011) and afternoon overpass NPOESS platforms (launches expected in 2014 and 2021) will each carry the 22-band Visible/Infrared Imager/Radiometer Suite (VIIRS). Data from VIIRS will be used to operationally generate a suite of land and cryosphere products, including Environmental Data Records (EDRs), Application Required Products (ARPs) and Intermediate Products (IPs). This project is the cryosphere portion of the Land and Cryosphere Validation Plan. Our objective is to evaluate the accuracy of VIIRS algorithms for snow and ice products, increase our understanding of their limitations, and suggest improvements where appropriate. This project is reducing risk and assuring a successful transition from current polar orbiting operational environmental satellites to the future system. Each of the multiple data products, including ice surface temperature, surface albedo over snow/ice, ice age/thickness, and an ice concentration intermediate product, requires a validation strategy, effort and investment. The proposed work is being done in collaboration with Dr. James Maslanik, University of Colorado-Boulder, who is funded separately.

Summary of Accomplishments and Findings

This project started in June 2009. This report covers the period from Oct 1st 2009 to September 30th 2010. During this period, validation data sets were acquired. These datasets include AVHRR-derived APP-x data (surface temperature); NCEP reanalysis (surface temperature); buoy observations from the International Arctic Buoy Programme (surface temperature); AMSR-E passive microwave imagery for ice concentration and extent; National Ice Center charts; high spatial resolution data from Landsat; upward-looking submarine sonar from Scientific Ice Expeditions (SCICEX); in situ ice thickness and on-ice snow depth measurements the Canadian Ice Service; ice draft data from the Beaufort Gyre Exploration Project.

Validation data sets also include products generated with our own algorithms, University of Wisconsin-Madison ice age, thickness (One-dimensional Thermodynamic Ice Model (OTIM), Wang et al., 2010), surface temperature data (Key and Haefliger 1992), and ice concentration. These products have been validated with collocated in situ observations and other satellite observations. Results show high accuracy and high precision of these products (Table 17.2.1 and 17.2.2). These products are ready to be compared to NPP/NPOESS products using the VIIRS proxy data from NPP-Land PEATE.

MODIS swath data has been acquired corresponding to dates used by Northrop Grumman Space Technology (NGST), which developed the algorithm for NPP/NPOESS. Using the same MODIS swath data, products from NGST and from our own algorithm have been compared (Figure 17.2.1).

Products based on VIIRS proxy data (from MODIS) were generated by the NPP-Land PEATE, and have been downloaded. There are some problems with the current PEATE code, which produced all "missing data" for ice characterization EDRs and the ice concentration intermediate product. Validation of these products with in situ observations and other satellite products will be carried out once this problem is solved.

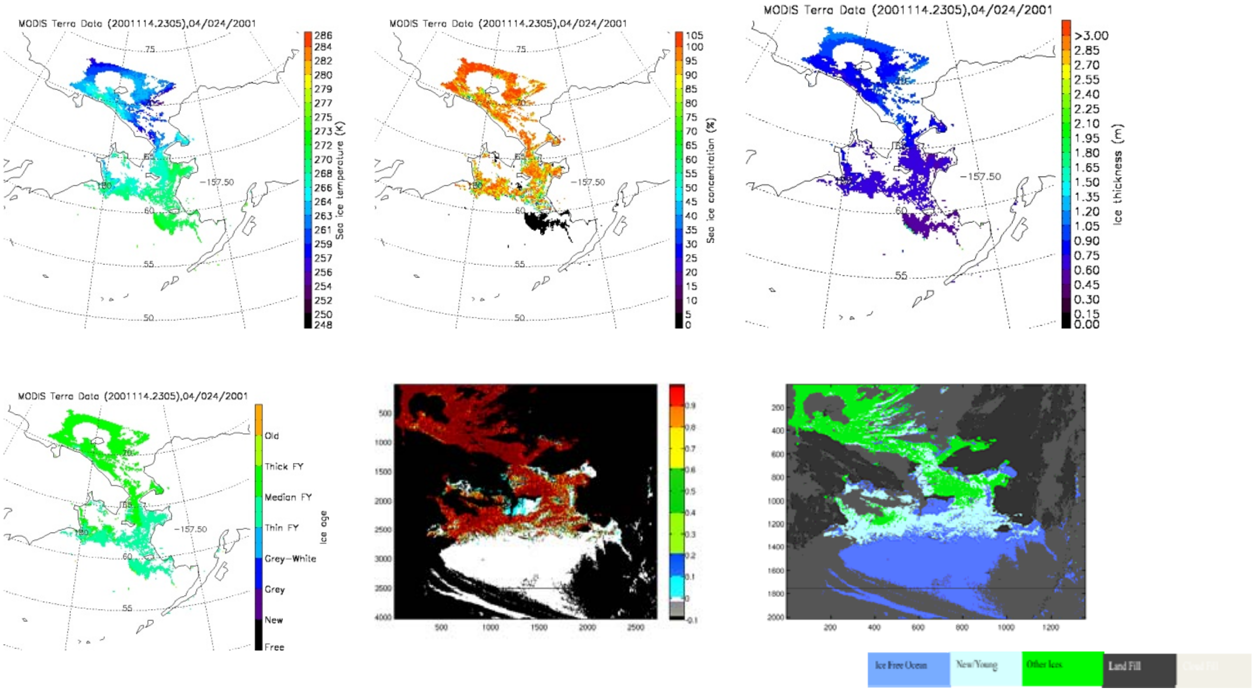


Figure 17.2.1. Sea ice surface temperature, concentration, thickness (top panel, left to right), and age (left bottom panel) from our own algorithm, and sea ice concentration and age (middle and right bottom panel) from NGST.

Table 17.2.1. Performance of retrieved ice concentration using our own algorithm with those from AMSR-E.

Ice concentration difference of AMSR-E product and MODIS product as proxy	Mean bias (%)	Standard Deviation (%)
Over Arctic Ocean	4.0	15.7
Over Great Lakes	-4.0	25.6

Table 17.2.2. Comparison of OTIM derived Ice Thickness with Submarine and Moored ULS measurements, and station measurements

In situ Measurements and OTIM	Thickness mean (m)	Bias (m)	Accuracy (%)
Submarine	1.80	-0.07	96
OTIM	1.73		
Mooring Sites	1.29	-0.09	93
OTIM	1.20		
Stations	1.31	-0.11	91
OTIM	1.20		
All	1.47	-0.09	94
OTIM	1.38		

Publications and Conference Reports

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.*, doi:10.1029/2009GL040708.

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.*, in press, doi:10.1029/2009JC005857.

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Key, J. and M. Haefliger, 1992: Arctic ice surface temperature retrieval from AVHRR thermal channels. *J. Geophys. Res.*, **97**(D5), 5885-5893.

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.*, in press, doi:10.1029/2009JC005857.

17.3. A Broad Scope of Cal/Val and Independent Verification and Validation Activities in Support of IPO, with an Emphasis on CrIS

Task Leader: Hank Revercomb

CIMSS Support Scientists: Fred Best, Bob Knuteson, Joe Taylor, Lori Borg, Dave Tobin

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

- Weather nowcasting and forecasting
- Clouds, aerosols and radiation
- Global hydrological cycle
- Environmental trends
- Climate

Proposed Work

The University of Wisconsin-Madison (UW-Madison) 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 NPOESS mission. The general purpose of these efforts is to provide expertise to the IPO 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 NPOESS goals, by making use of the broad experience in instrument design, testing, algorithms, and science gained from previous and ongoing UW-Madison SSEC research activities. Special focus is in the areas of (1) pre-launch CrIS instrument performance assessments, (2) pre- and post-launch CrIS and IASI calibration and validation, and (3) independent verification and validation of SDR and EDR products through development of test cases and detailed evaluation of industry provided code performance.

Summary of Accomplishments and Findings

Accomplishments in the past year have included further investigations and findings regarding the CrIS Flight Model 1 thermal vacuum testing and the development of calibration/validation approaches.

CrIS Pre-launch Test Support and Thermal Vacuum Analyses

As with last year, the majority of our efforts fall under this task, including refinements of our analyses based on thermal vacuum cycle 4. There are many issues and results involved in the CrIS Flight Model 1 thermal vacuum test analyses. The primary result from our perspective is that the CrIS FM1 performance is very good in terms of noise and calibration accuracy – exceeding the calibration requirements – and providing for the potential of climate quality observations from FM1 on the NPP platform. Details of our analyses, as well as simple statements of the conclusions, can be found in our presentation at the June 2010 SOAT meeting. The primary conclusion is shown in Figure 17.3.1, below. This figure shows our engineering estimates of the FM1 In-flight Radiometric Uncertainty (RU), presented as 3-sigma brightness temperature uncertainties (bottom panels) for selected spectral channels in the longwave, midwave, and shortwave spectral bands. Primary contributors to these uncertainties include uncertainties in the Internal Calibration Target (ICT) temperature, the ICT emissivity, the environmental temperature of the ICT, and the detector nonlinearity. For each contributor, we have assigned conservative estimates of the uncertainties to derive the RU estimates. For the midwave band, changes in the nonlinearity characteristics of several detectors were observed between thermal vacuum cycle 4 and previous cycles. The on-orbit characterization approach will be to use detectors with negligible nonlinearity as references for detectors (FOVs) with larger nonlinearity, and to perform an on-orbit adjustment to these reference detectors yielding excellent radiometric performance for all FOVs, as depicted by the arrows in the figure. Also, for brightness temperatures greater than ~240K where the TVAC testing uncertainties are suitably low, these RU estimates are verified by actual comparisons of observed and calibrated radiance spectra. The results show conservative 3-sigma brightness temperature uncertainties for CrIS FM-1 of 0.2K or less for all spectral channels and FOVs, with the exception of the midwave FOVs with the largest detector non-linearity. This performance is very good, and if realized in orbit, CrIS will contribute and extend the climate observations begun by AIRS and IASI. Going forward, our analyses in this area will include refinements of the nonlinearity coefficients and comparisons of the UW-based calibrations with those from the operational software. The radiometric noise performance of CrIS is also expected to be very good, and our analyses of the noise performance is presented in Figure 17.3.2, along with comparisons to the CrIS and IASI radiometric noise.

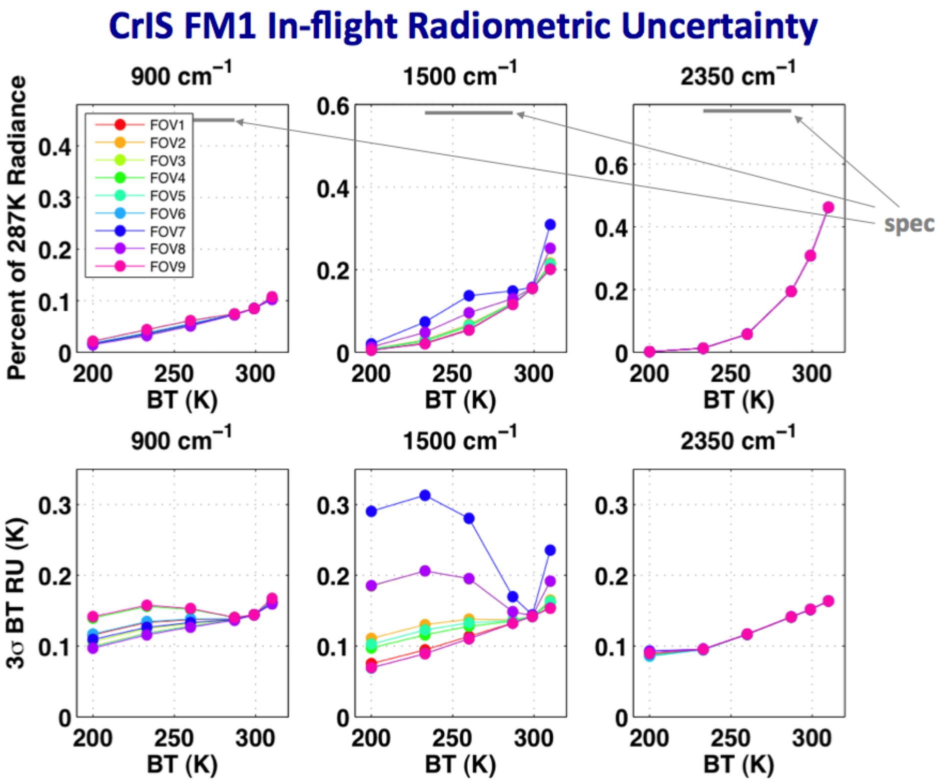


Figure 17.3.1. CrIS Flight Model 1 In-flight Radiometric Uncertainty Estimates. See the text for the description.

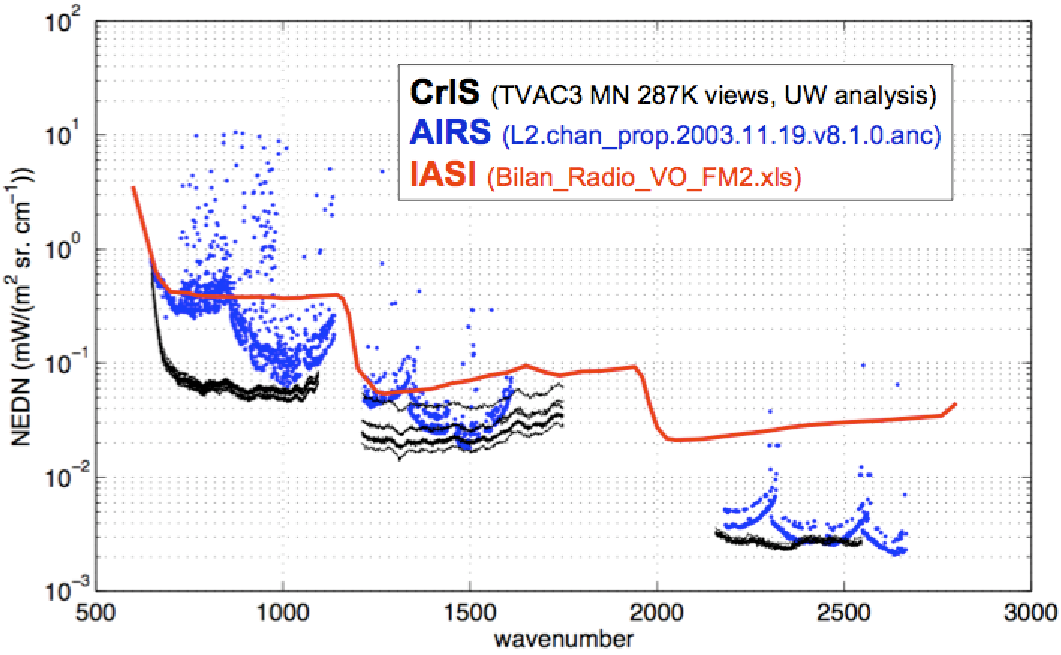


Figure 17.3.2. CrIS Flight Model 1 Radiometric Noise Performance, compared to that of AIRS and IASI. Noise for each sensor is shown for its “native” properties (i.e., spectral resolution, FOV size, apodization, etc.).

In-Orbit Intercomparisons of AIRS, IASI, and CrIS

An important component of post-launch cal/val for CrIS will be the intercomparison of CrIS with AIRS and IASI observations using Simultaneous Nadir Observations, which we have reported on in the past. Accomplishments this period include the extension of this approach to include off-nadir comparisons using Simultaneous Off-Nadir Observations for AIRS and IASI to help detect and diagnose any scan angle dependent biases present in either the AIRS or IASI observations. AIRS has a Denton coasted silver 45 degree scene mirror (scan angle independent of mirror incident angle) while IASI has an uncoated gold paddle wheel design (scan angle dependent on of incidence angle) scene mirror, and so the two are expected to have different scan angle dependent bias characteristics. CrIS, with an uncoated gold 45 degree scene mirror, is expected to have negligible scan angle dependent biases. The results of our current analyses of AIRS versus IASI as a function of scan angle are shown in Figure 17.3.3. The analysis shows a bias pattern which is fairly symmetrical with respect to scan angle for all but the largest scan angles, and suggests contributions to the bias from both AIRS and to a lesser extent IASI. The cause of these biases is under investigation.

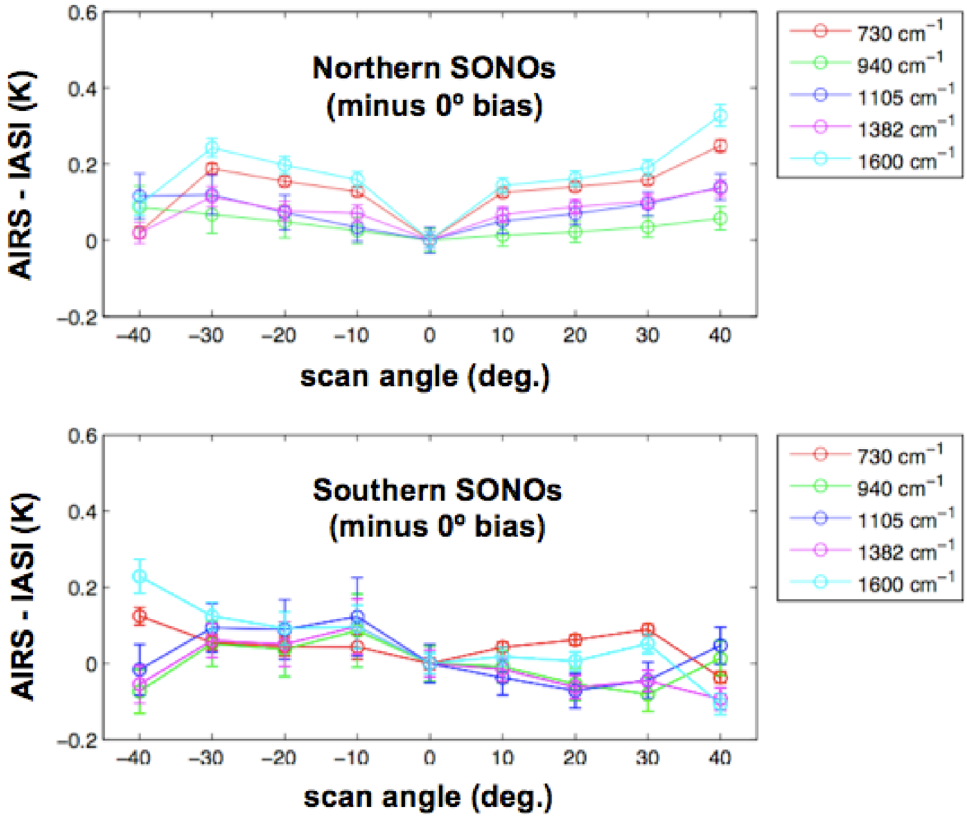
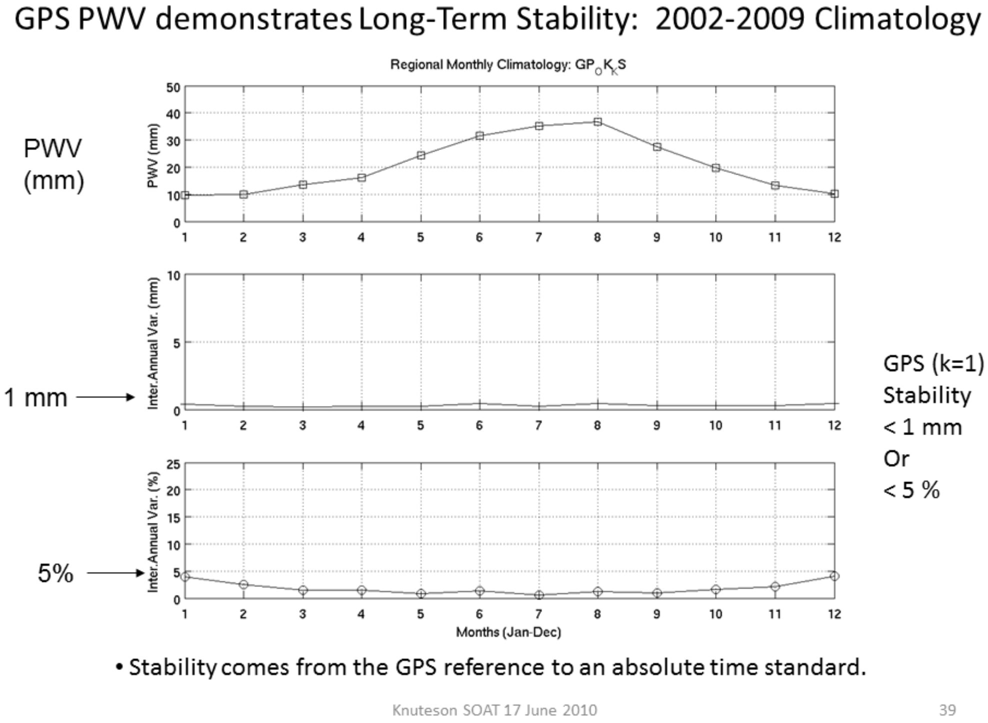


Figure 17.3.3. Differences between AIRS and IASI observed brightness temperatures as a function of scan angle using Simultaneous Off-Nadir Observations.

Sounder Precipitable Water Vapor Validation

UW CIMSS researchers have recently published a detailed analysis of the accuracy of AIRS total column water vapor retrievals using ground based microwave radiometer (MWR) validation data from the DOE ARM sites (Bedka et al., 2010). As a risk reduction activity in the definition of CrIS/ATMS water vapor profile validation, we have extended the previous analysis beyond the northern Oklahoma ARM site to include the NOAA GPS-Met and Suomi-net ground-based GPS sensors. These networks provide much greater geographic coverage of North America and include dozens of sites around the world with similar accuracy. The long-term PWV climatology of the Oklahoma/Kansas region derived from ground-based GPS observations (see Figure 17.3.4) suggests these measurements can be used to validate both the instantaneous PWV overpasses and the long-term stability requirement of the CrIS/ATMS products.



GPS PWV demonstrates Long-Term Stability: 2002-2009 Climatology

- Stability comes from the GPS reference to an absolute time standard.

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Figure 17.3.4. Climatology of precipitable water vapor (PWV) for the Oklahoma/Kansas region centered at the DOE ARM Southern Great Plains (SGP) site using a network of GPS receivers. The eight year mean PWV (upper panel) is shown for each month of the year along with the inter-annual variability (middle and lower panels) of monthly averages.

Publications and Conference Reports

Bedka, S., R. Knuteson, H. Revercomb, D. Tobin, and D. Turner, 2010: An assessment of the absolute accuracy of the Atmospheric Infrared Sounder v5 precipitable water vapor product at tropical, midlatitude, and arctic ground-truth sites: September 2002 through August 2008. *J. Geophys. Res.*, **115**, D17310, doi:10.1029/2009JD013139.

17.4. Radiance Cal/Val, Cloud Property Determination and Combined Geometric plus Radiometric Soundings with Emphasis on VIIRS

Task Leaders: Eva Borbas, Chris Moeller, Tom Achtor
CIMSS Support Scientists: Youri Plokhenko, Tom Rink
NOAA Collaborator: Bruce Guenther (JPSS)
NOAA Strategic Goals:

- Serve society's need for weather and water

CIMSS Research Themes:

- Weather, Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Proposed Work

Data and products from the Moderate resolution Imaging Spectro-radiometer (MODIS) and the Atmospheric Infrared Sounder (AIRS) will continue to be used to explore Visible Infrared Imager Radiometer Suite (VIIRS) and Cross Track Infrared Sounder (CrIS) capabilities for producing the required Environmental Data Records (EDR). Visualization tools to interrogate the NPOESS multi-spectral data will continue using the HYDRA (HYperspectral viewer for Development of Research Applications). This work reduces risk and assures successful transition from the current polar orbiting operational environmental satellites to the future NPOESS. The proposed efforts are in six categories:

- Assessing VIIRS prelaunch performance; participating in Government Team (non-VOAT) Flight Unit 1 (FU-1) performance test planning, test readiness assessment, TVAC test data collection, and data evaluation; and participating in Government Team discussion/actions for FU-2 performance issues:
    - Continue participation in VIIRS Operational Algorithm Team (VOAT) instrument specification and ATBD algorithm testing and the associated trade offs: review scientific basis for algorithms and their performance against heritage algorithms;
    - Support Govt. Team (non-VOAT) FU-1 activities: Support on-site FU-1 TVAC testing as member of GOST and serve as POC for FP-15/16 test data collection and analysis, and review performance of all aspects of FU-1;
    - Participate in Govt Team discussion/actions/reviews for FU-2 issues.
- Developing visualization tools:
    - Develop HYDRA visualization tools and integrate with McIDAS-V: Demonstrate with MODIS and AIRS/IASI and AMSU data, and incorporate HYDRA into McIDAS-V for NPP Cal/Val application
- Estimating cloud top pressure with VIIRS:
    - Test VIIRS plus CrIS cloud property definition: Explore alleviation of VIIRS cloud problems using CrIS (use MODIS and AIRS for test data), study cloud profile estimation with AIRS / CrIS in semi-transparent cloud situations (for cloud thickness and cloud bottom EDRs), and continue demonstration of improvement in EDRs with addition of a VIIRS water vapor channel.
- Estimating atmospheric profiles from AIRS measurements:
    - Study CO_2 sounding retrieval optimization with CrIS: Test/refine CrIS equivalent clear radiances and cloud property products from combined CrIS cloudy radiances and VIIRS data at CrIS single field-of-view (SFOV) basis, quantify sensitivity of CO_2 profiles to CrIS radiances, and test three dimensional strategy for combined surface and atmospheric profile estimation with AIRS data.

Summary of Accomplishments and Findings

Assessing VIIRS prelaunch performance; participating in Government Team (non-VOAT) Flight Unit 1 (FU-1) performance test planning, test readiness assessment, TVAC test data collection, and data evaluation; and participating in Government Team discussion/actions for FU-2 performance issues

Work continued in assessing and designing tests using alternative GSE for F2 spectral (i.e., FP-15, FP-16) measurements. A project budget and work statement was developed and delivered for the FTIR based RSR measurement system. These included all elements needed to design, fabricate and demonstrate the FTIR based RSR measurement system in the Fall 2010 timeframe. In the latest progress, the optical design for the system is nearing completion. A set of recommendations for test/hardware upgrades in F2 and beyond was provided by Wisconsin to the project. These recommendations are one of several inputs representing the interests of the government team. The recommendations will be socialized in the government team to reach consensus. The recommendations for F2 included:

- Reduce scattering/cross talk in VisNIR IFA (expected to occur)
- Spectral testing that includes FTIR and laser techniques with flood illumination
- Plan deep space maneuvers to validate TEB RVS at BOL and EOL.
- Repeat measurements of RSR in pre-launch to help better define uncertainties

And for J1 and Beyond:

- Everything shown for F2
- Add atmospheric band(s) to spectral complement (including considering J. Puschell pathway to AIRS-like high spectral resolution grating system for TEB)
- Reduce truncation error (ADC) on cold end of MWIR bands, using bi linear strategy that improves quantization at cold scenes.
- Separate OLS (DNB) from climate sensor
- Eliminate FOV aggregation on-orbit
- Eliminate bowtie deletion on-orbit

Visualization Tools

Development of visualization and analysis tools for NPP instrument data products within McIDAS-V has continued with the creation of custom Java components, which extend the McIDAS-V framework. A specialized Data Source class analyzes a directory containing NPP proxy data, collects the appropriate meta-data including scaling coefficients and pixel navigation, and generates an instance of the abstract Data model. These internalized Data can be rendered to the main display by the core system's data-to-display transformation algorithms, and/or used in computation with other Data. Granule aggregation allows the user to interactively select spatial subsets across several consecutive granules with the swaths time-ordered and automatically stitched together on-the-fly for display or computation (Figure 17.4.1). Previous IPO funded development to introduce the multi/hyper-spectral capabilities of HYDRA into McIDAS-V has been instrumental in this process, leveraging experience and software development with MODIS/AIRS. A live demonstration of McIDAS-V using NPP proxy data was given at the IGARSS 2010 NPP Data User's Workshop and we have been invited to give a demonstration at the upcoming AMS NPP User's Seminar.

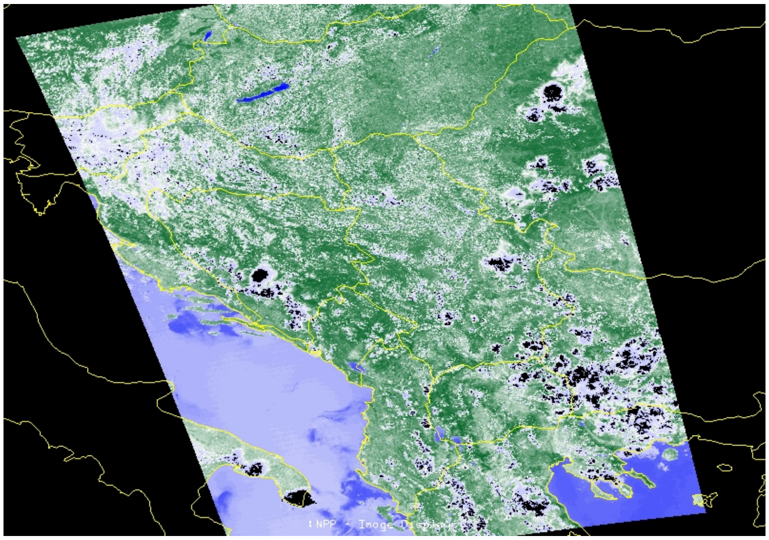


Figure 17.4.1. VIIRS I-band 1,2 combined to create NDVI displayed in McIDAS-V. This image is actually from 3 consecutive aggregated granules contained in separate files. An interactive image enhancement tool was used for the color mapping.

The initial focus has been on VIIRS SDR/EDR, but work has begun with proxy ATMS and CrIS. Previous code to handle the conversion from time ordered to spatially contiguous FOV displays for IASI L1C will be adapted for use with CrIS which has a similar storage format. An initial version of a re-projection process for VIIRS to handle image artifacts is being developed (Figure 17.4.2).

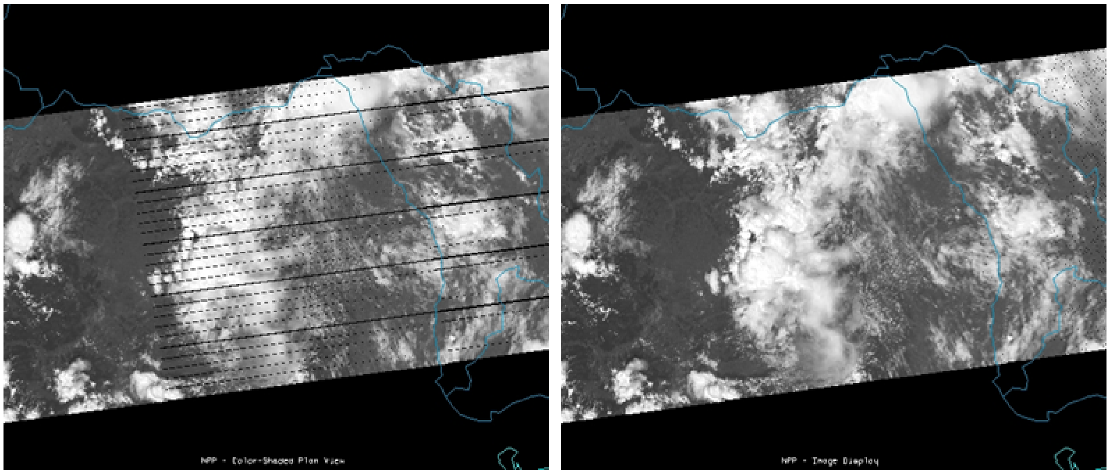


Figure 17.4.2. Original (left) and re-projected (right) VIIRS I-Band 1.

Estimating Cloud Top Pressures with VIIRS

UW continued experimenting with the multi-layer approach for estimation of the altitude of high thin clouds at night at full VIIRS resolution. In the absence of any infrared spectral band sensitive to atmospheric absorption, VIIRS will have to rely upon coarser resolution CrIS measurements. The MODIS window channel (11 μm, Band31) brightness temperatures and AIRS calculated lapse rates are used to make adjustments to AIRS cloud top pressures (CTPs). The algorithm is

$$CTP_{MODIS} = CTP_{AIRS,i} + \frac{BT_{MODIS} - \overline{BT_{MODIS}}}{\gamma}$$

where $\overline{BT}_{MODIS}$ is the mean MODIS BT for the cloudy pixels within the AIRS pixel, *i* indicates the *ith* AIRS FOV, and γ accounts for the temperature lapse rate within clouds. γ has been calculated from AIRS temperature profiles over cloudy scenes for four layers (low, middle and high below and above the tropopause level). The technique is called as four-layer AIRS+MODIS lapse rate (4LR) method. In addition, changes in AIRS CTPs from pixel to pixel are related to changes in infrared window Band measurements in a 3-band regression (referred as EWregr, described in Weisz et al., 2010); these results are also used for comparison in this study.

The EWregr regression and the 4LR method CTP results have been compared to the MODIS 1km CTP products (MYD06) for three selected granules (granule 47, 187 and 213) on Aug 28, 2006. Table 17.4.1. shows the mean and standard deviation between the two AIRS+MODIS combined CTP and the MODIS 1km MYD06 CTP products for the three granules. The mean and standard deviation of the AIRS only (obtained by the UW IMAPP AIRS Utility v1.1) CTP retrievals are also shown for reference. Comparing the granule CTPs using the MODIS 1km products as truth, we have found that the four-layer lapse rate method produces the smallest bias and standard deviation for these three selected granules.

Validation with products from CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) on CALIPSO and from CPR (Cloud Profiling Radar) on CloudSat were also included into our study. CTPs from 4LR (for VIIRS +CrIS) and AIRS-only (for CrIS only) are converted into Cloud Top Heights and then compared to CALIOP, CPR, and the MODIS-only CO2 slicing Cloud Top Heights (CTHs) (Collection 6, processed at 1km resolution).

		AIRS+MODIS vs MODIS1km		**AIRSonly vs MODIS1km**	
		Mean	**stdev**	**mean**	**stdev**
Gr047	**4**LR	0.18	184.73	10.94	201.66
	EWregr	12.84	207.71	10.94	201.66
Gr187	4LR	13.27	141.09	17.27	148.66
	EWregr	19.27	153.38	17.27	148.66
Gr213	4LR	-56.94	169.65	-49.71	182.76
	EWregr	-49.02	185.19	-49.71	182.76

Table 17.4.1. Comparison of the AIRS+MODIS combined CTP by the 4LR method and the EWregr regression to the MODIS 1km CTP products for three selected granules (granule 47, 187 and 213) on August 28, 2006. Means and standard deviations between the combined CTP and MODIS 1km CTP and between the AIRS only and MODIS 1km CTP are shown.

With our focus on the high, thin clouds at nighttime (where VIIRS will need help from CrIS), our results are expected to be between the CTH from CALIOP, which is very sensitive to optically thin clouds, and CPR, where the radar measures the extent of thick clouds but is not capable to detect thin clouds at higher levels. Figure 17.4.3 shows the comparison. VIIRS+CrIS is performing well in the thin cirrus between 3 and 5 N.

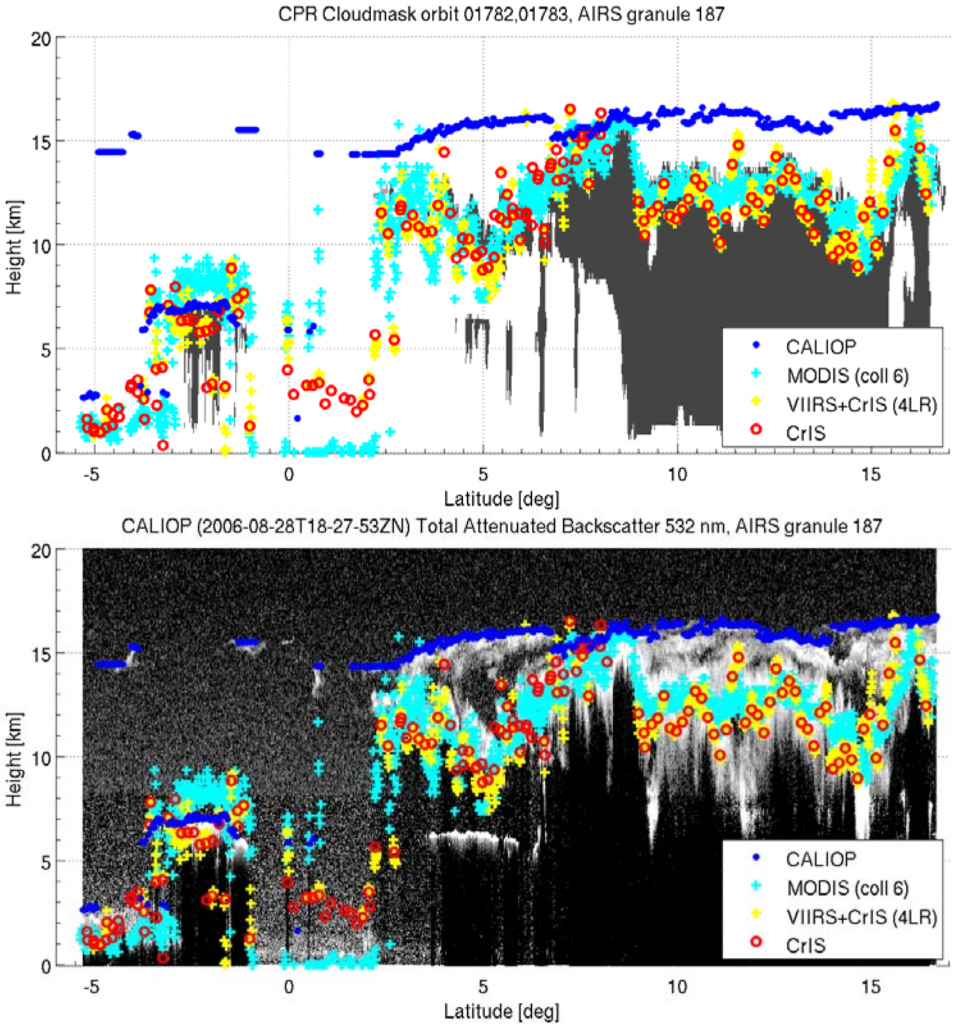


Figure 17.4.3. Cross-section along the CloudSat/CALIPSO track for AIRS granule 187 (28 Aug 2006). Top: CPR cloudmask (gray background). Bottom: CALIOP 532 total attenuated backscatter/km/steradian (background). Cloud Top Heights from CALIOP (blue), MODIS collection 6 (cyan), VIIRS+CrIS (yellow, with MODIS+AIRS representing VIIRS+CrIS), and CrIS (red, with AIRS representing CrIS) are plotted.

Estimating Cloud and CO2 profiles from AIRS measurements

Combining CrIS and VIIRS for single FOV cloud-cleared radiances and cloud property products

A fast and accurate hyperspectral infrared cloudy radiative transfer model has been used to convert the forecast field to simulated cloudy radiances. The purpose of this work is (1) to validate the cloudy radiative transfer model by comparing the simulated cloudy radiances and the observed radiance measurements, and (2) to evaluate the cloudy property retrieval algorithm (the forecast field serves as truth in the simulation). Forecast hydrometers were converted into cloud optical thickness (COT) at 0.55 µm and cloud particle size (CPS) in diameters (µm). The input parameters came from the Weather Research and Forecasting (WRF) mesoscale model providing mixing ratios for five microphysical species: graupel, ice, liquid water, snow and rain. The cloud top pressure (CTP) for each pixel is calculated and used to evaluate the cloud phase and the CPS. Effective particle diameters are calculated for each microphysical species using a method adapted from Mitchell (2002), which uses the mixing ratio and the number concentration of a given species. From the mixing ratio of each species, the cloud water content is calculated and related to the liquid and ice water paths. The latter are converted into cloud optical thickness. COT, CTP and CPS are given as input to a fast cloudy radiative transfer model to simulate cloudy radiances. Atmospheric Infrared Sounder (AIRS) radiances were simulated onto a grid-domain of 279×279 points using the data of June 13th, 2002 at 00:00 UTC where very thick clouds with a high vertical extension like cumulonimbus were present over the states of Texas, Oklahoma, Kansas and Iowa. The results reveal low clouds in New Mexico, Colorado and some in South Texas. A few regions of the domain were completely clear. The CIMSS baseline fit emissivity database was used in the simulation.

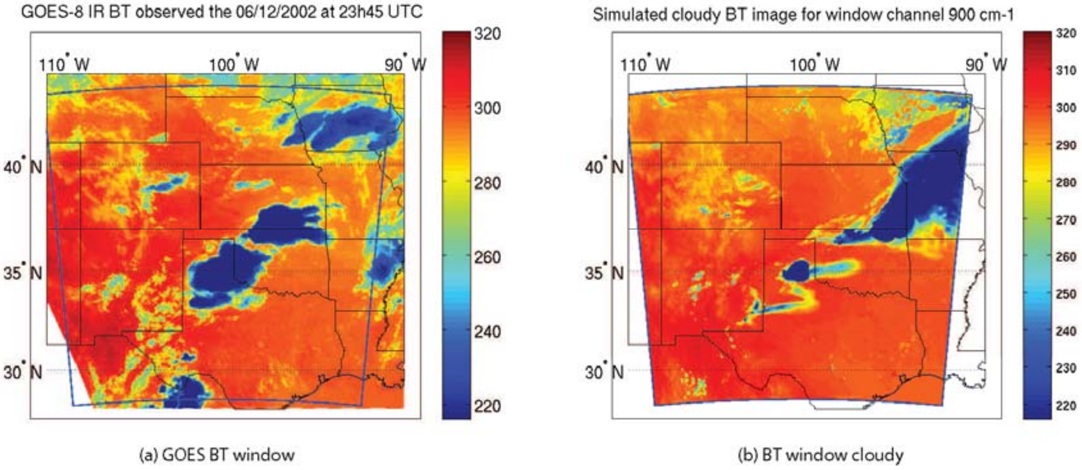


Figure 17.4.4. Simulated window channel (900 cm^{-1}) BT (K) in cloudy-sky (right) and real BT observed by the satellite GOES-8 (left).

Figure 17.4.4 shows the simulated brightness temperature (BT) image at an AIRS window channel (900 cm^{-1}) (right panel) and the observed BT from the GOES-8 Imager (left panel), real data from AIRS at that time is available for comparison. The differences between the two images are essentially from the WRF forecast. The WRF model detects the convective clouds well and locates them in the correct states; however, it does not generate enough clouds in Northern Texas and Iowa and develops too many clouds in Missouri. The WRF detects the low clouds over the Rocky Mountains, Southern Texas and Nebraska very well. The next step is to test and evaluate 1D-Var retrieval scheme with simulated AIRS radiances.

Estimating cloud profiles

Cloud vertical profile estimates from AIRS data on 28 August 2008 have been compared with CALIOP over dry polar conditions and over moist tropical conditions. The comparisons are presented in Figures 17.4.5. and 17.4.6. In moist atmospheres the agreement is better than in very dry atmospheres. Low clouds remain elusive for AIRS since the thermal contrast between clear and cloudy is reduced. Overall, we believe that these case studies of AIRS measurements used in a radiative transfer formulation show promise for determining cloud profiles in semi-transparent cloud conditions and for using CrIS to validate cloud base determinations attempted with VIIRS. Good agreement was demonstrated with respect to satellite borne lidar measurements. Comparisons from pole to pole reveal that tuning for low clouds and moisture in the troposphere has made cloud profile retrievals possible in diverse atmospheric conditions.

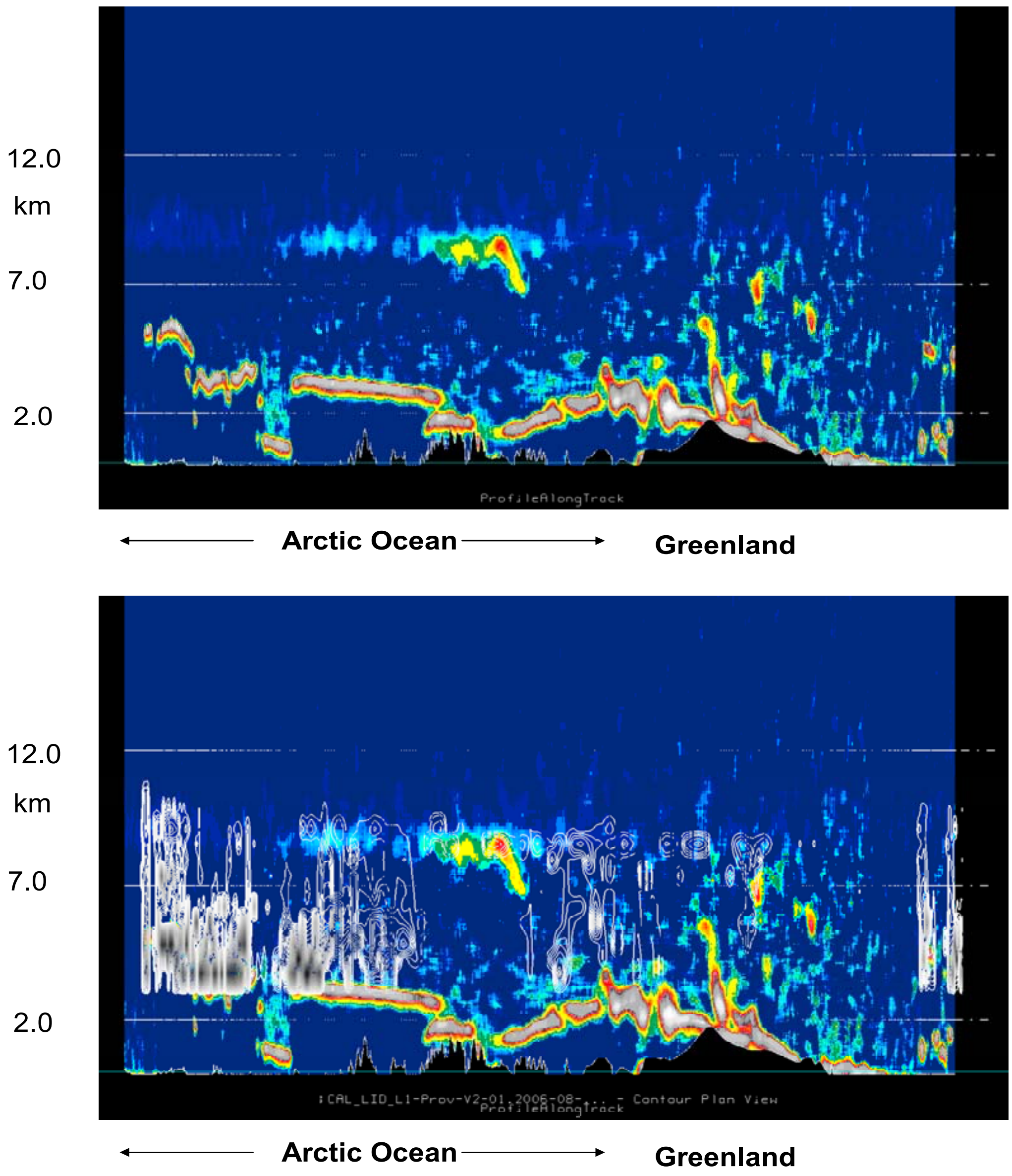


Figure 17.4.5. Vertical cross-section of CALIPSO cloud detection on 26 August 2008 from the Arctic Ocean to Greenland with AIRS cloud profiles overlaid (bottom).

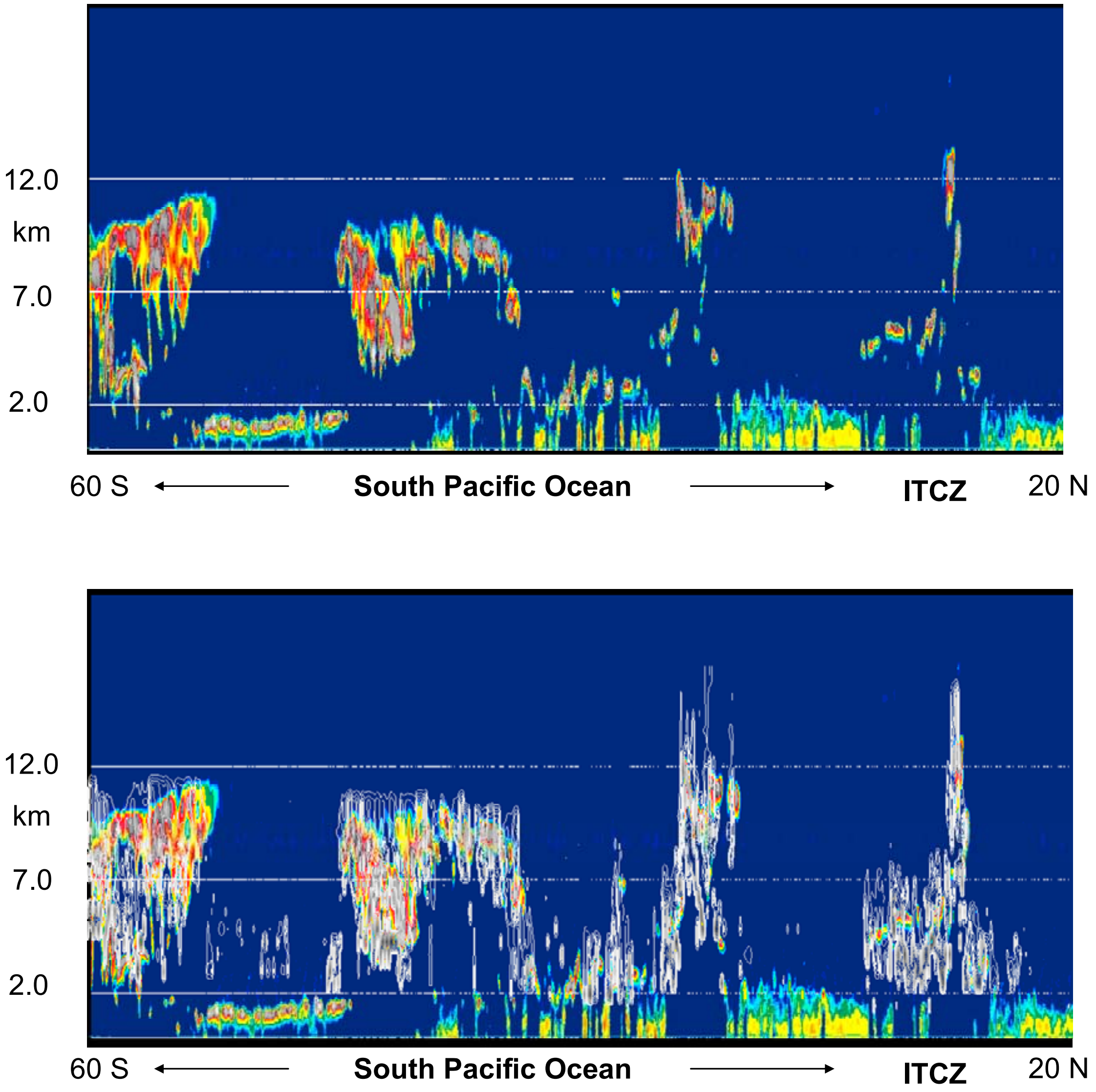


Figure 17.4.6. Vertical cross-section of CALIPSO cloud detection on 26 August 2008 from 60 S to 20 N latitude (top) with AIRS cloud profiles overlaid (bottom).

Publications and Conference Reports

Ding, S., P. Yang, F. Weng, Q. Liu, Y. Han, P. van Delst, J. Li, and B. Baum, 2010: Validation of the Community Radiative Transfer Model. *Journal of Quantitative Spectroscopy & Radiative Transfer* (submitted).

Plokhenko, Y., W. P. Menzel, R.O. Knuteson and C. M. Moeller: Estimating cloud profiles with AIRS. Submitted to *JGR*.

Moeller, C: M. MODIS band 35 and 36 radiometric biases and VIIRS F1 spectral performance (talk) on the MODIS and VIIRS calibration workshops held at Greenbelt, MD on Jan. 25, 2010.

Moeller, C.M.: NPP VIIRS Prelaunch Spectral Calibration (poster, co-author) on the MODIS/VIIRS Science Team meeting, held in Washington DC, January 26-28, 2010.

Moeller, C.M.: Special spectral tests that were conducted during the spacecraft level test program in spring 2010 (talk) on the NIST-hosted workshop held on April 6, 2010 in Gaithersburg, MD.

Dan LaPorte and Chris Moeller attended the CalCon 2010 conference held in Logan, UT August 23-26, contributing to papers on VIIRS F1 Spacecraft level laser based spectral testing (Moeller), and on interferometer-based RSR measurements (Laborite).

Tom Rink and Tommy Jasmin gave a software demonstration of NPP Data Visualization with McIDAS-V on IGARSS 30th, held in Honolulu, Hawaii 25-30 July 2010.

17.5. International Polar Orbiting Processing Package (IPOPP) for Direct Broadcast Users

Task Leaders: Allen Huang, Liam Gumley
CIMSS Support Scientists: Geoff Cureton, Ray Garcia, Graeme Martin, Nadia Smith
NOAA Collaborator: Richard Ullman
NOAA Strategic Goals:

- Serve society's needs for weather and water

CIMSS Research Themes:

- Weather Nowcasting and Forecasting

Proposed Work

CIMSS/SSEC proposes to develop and release IPOPP software in conjunction with IPO and DRL for NPP and subsequently for NPOESS. The baseline package will adopt IPO provided software and adapt it to execute successfully in a user-friendly fashion with modest computing hardware requirements under common UNIX operating systems, such as Linux and Solaris.

CIMSS/SSEC will follow the IPOPP Master Schedule to deliver the following IDPS PRO algorithms ported to a Linux environment:

1. VIIRS cloud mask and phase
2. VIIRS cloud effective particle size
3. VIIRS cloud optical thickness
4. VIIRS cloud top temperature and height
5. VIIRS cloud cover layers
6. VIIRS cloud base height
7. VIIRS aerosol optical thickness
8. ATMS SDR calibration and navigation
9. CrIS SDR calibration and navigation
10. CrIMSS temperature and moisture profile

The primary objective for the reporting period was to deliver working Linux versions of these algorithms to the NASA Direct Readout Laboratory (DRL) by 30 June 2010, at the direction of the NPOESS Integrated Program Office (IPO). These were to be based on IDPS PRO v1.5.0.18 or 1.5.0.48 algorithms, built from source on Linux, and capable of reading standard HDF5 product files as defined by the NPOESS CDFCB.

Summary of Accomplishments and Findings

CIMSS/SSEC successfully delivered Linux-ready versions of VIIRS Atmosphere EDR, CrIS and ATMS SDRs, and CrIMSS EDR algorithms to IPO/DRL on 30 June 2010, on time according to the schedule agreed to by IPO. All algorithms were delivered in compiled binary executable format, ready to run with test cases containing input and output data, and documentation. All packages also contained all the source code required to build the algorithms on 64-bit Linux systems. The algorithms were all tested using input data from the Mini IDPS operated by the NPP Science Data Segment at GSFC. All of the algorithms are able to read and write data in the standard HDF5 product formats defined in the Common Data Format Control Books (CDFCBs) released by Northrop Grumman. Details of the algorithm deliveries are as follows:

1. Delivery of VIIRS Atmosphere EDRs to IPO/DRL
    - Delivered VIIRS Atmosphere EDR package for Linux to draca on June 30, 2010. Delivery contains LEOCAT version of VIIRS Cloud Mask, Cloud Phase, Cloud Top Properties, Cloud Optical Properties, and Aerosol Optical Thickness.
    - LEOCAT package is able to use VIIRS SDR HDF5 or MODIS L1B HDF4 as input; writes IDPS HDF5 as output.
    - Aggregated AOT has some problems, probably related to combination of climatology and retrievals.
    - Users should note the AOT product must be interpreted carefully, as both climatological and retrieved values are mixed in the output file (must use quality flags to interpret these correctly).

2. Delivery of CrIS and ATMS SDR to IPO/DRL
    - Delivered CrIS SDR and ATMS SDR packages for Linux to draca on June 30, 2010.
    - CrIS SDR is a port done independently at UW.
    - ATMS SDR is a hybrid of the ADL v1.0 version and an independent port at UW (byte flipping logic was developed at UW). This is a model for the future ADL Intel versions of the CrIS and ATMS SDR algorithms (including HDF5 input and output).
    - Data format read on input is CrIS and ATMS HDF5 RDR.
    - Data format written on output is CrIS and ATMS HDF5 SDR.

3. Delivery of CrIMSS EDR to IPO/DRL
    - Delivered CrIMSS EDR package for Linux to draca on June 30, 2010.
    - CrIMSS EDR is a port done independently at UW.
    - Data format read on input is CrIS and ATMS HDF5 SDR.
    - Data format written on output is CrIMSS HDF5 EDR.

Additional accomplishments during the reporting period included:

- IPOPP Face to Face Meeting Support
  CIMSS/SSEC hosted the IPOPP Team Face to Face Meeting at SSEC on October 7-8, 2010. CIMSS/SSEC presented detailed status of the UW IPOPP effort at this meeting. The only other Face to Face meeting scheduled during the reporting period was canceled by IPO at the request of DRL.
- Status Reports to IPO
  CIMSS/SSEC submitted bi-weekly status reports via email to IPO detailing recent activities, upcoming work, and impediments to progress.

17.6. NPP-VIIRS-CrIS Calibration and Validation Activities

17.6.1 NPP-VIIRS-CrIS Calibration and Validation Activities

Task Leader: David Tobin
CIMSS Support Scientist: Greg Quinn
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

- Weather Nowcasting and Forecasting
- Clouds, Aerosols and Radiation
- Global Hydrological Cycle
- Environmental Trends
- Climate

Proposed Work

Validation of the VIIRS radiance calibration must be performed and the impact of any changes on products must be assessed. It is the intent of this proposal to perform studies with the CrIS high spectral resolution measurements to create highly accurate comparisons with VIIRS broadband sensor observations. Initially AIRS and MODIS measurements will be used as surrogates; IASI and HIRS intercomparison will also be performed. Previous work done with AIRS and MODIS has established the appropriate approach.

Comparisons of the AIRS and MODIS radiance observations have illustrated the utility of using high spectral resolution measurements to create highly accurate comparisons with broadband sensor observations. In the analysis, the high spectral resolution AIRS spectra were reduced to MODIS spectral resolution and the high spatial resolution MODIS data were reduced to AIRS spatial resolution for global data collected on selected days. Gaps present in the AIRS spectral coverage were accounted for (referred to as convolution corrections) by simulating the effects of the AIRS spectral gaps in computed spectra for each MODIS band. Spatially uniform scenes were selected and the observed differences were characterized as a function of several parameters including scene temperature, sensor scan (view) angle, and solar zenith angle. The comparisons were within the expected radiometric accuracies of the sensors, with mean brightness temperature differences of 0.1 K or less for many of the MODIS bands. However, for some MODIS bands the differences were greater and suggested that the spectral response functions should be adjusted (shifted and possibly half-width altered). The impact of these spectral shifts on several MODIS products (cloud top pressures, cloud phase, cloud micro-physics) continues to be studied.

Specific tasks:

FY10:

- Intercompare IASI and HIRS measurements from METOP and study the effects of suggested spectral shifts on HIRS cloud products.
- Determine the impact of the spectral shift in MODIS bands 34, 35, and 36 on the cloud top pressure product. Use CALIPSO determinations to confirm product improvement.
- Study MODIS IRW cold scene behavior and any impact on cloud products.

FY11:

- Intercompare VIIRS and CrIS and study the effects of suggested spectral shifts on HIRS cloud products and TPW.
- Pay special attention to VIIRS IRW cold scene behavior and any impact on cloud products.

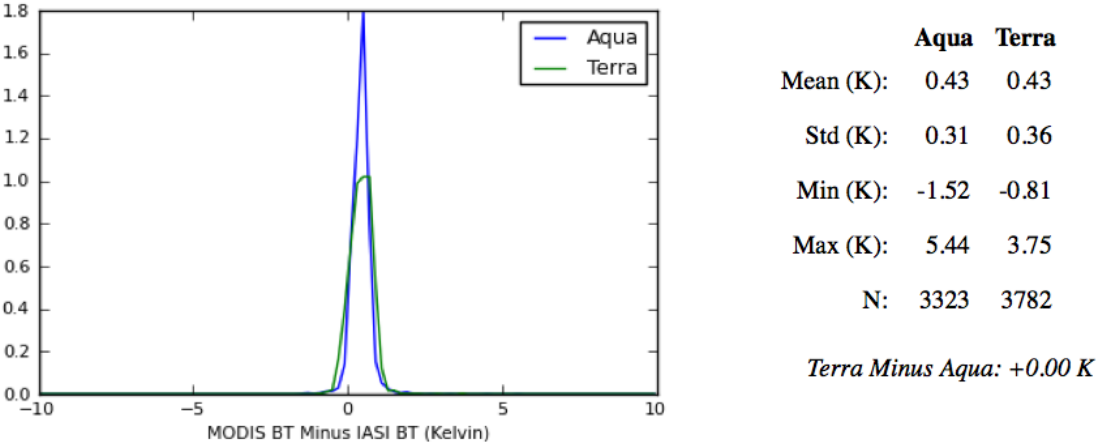
Summary of Accomplishments and Findings

For VIIRS, one of the most useful evaluation analyses that will be performed soon after launch is the intercomparison of VIIRS infrared radiance observations with METOP-A IASI observations for Simultaneous Nadir Overpass (SNO) conditions. To prepare for this analysis, and for its own merit for MODIS, we have conducted MODIS/IASI SNO analyses, which exercises the same methodology and code. Using techniques developed previously for SNOs and Aqua AIRS/MODIS evaluations, here we present some initial results of evaluating both Terra and Aqua MODIS using SNO based comparisons with METOP-A IASI. Based on evaluations of IASI using numerous techniques, IASI is an excellent reference for evaluating MODIS. Particularly regarding previous evaluations using AIRS, a so-called “convolution correction” to account for spectral gaps, is not required for IASI due to its continuous spectral coverage.

The approach used for these initial evaluations is to determine the exact nadir crossings of the Aqua and METOP-A and Terra and METOP-A platforms. Criteria for spatial and temporal “simultaneity” are then defined and mean MODIS and IASI spectra are computed for each SNO. Data within calendar year 2009 are included for approximately 3500 cases. Nominal (i.e., not spectrally shifted) detector averaged MODIS SRFs are used for this analysis. Sample results for MODIS bands 35, 30, and 27 are shown below.

For band 35, we see the same bias with respect for IASI for Terra and Aqua MODIS. The bias for Aqua MODIS is generally consistent with the bias expected based on spectral shift analyses performed previously using AIRS as a reference. As a next step, we plan to apply the previously determined spectral shift to both Terra and Aqua MODIS SRFs and see how the biases change.
For band 30, previous evaluations using AIRS have had large (unacceptable) uncertainties due to a very large spectral gap in the AIRS spectral coverage of the ozone band. So this is our first direct assessment of band 30 using the SNO technique. There are appreciable biases for both Terra and Aqua MODIS with respect to IASI, and a considerable bias between Terra and Aqua MODIS. We plan to investigate potential SRF spectral shifts on these results. Also, the impact of MODIS de-striping will be investigated.

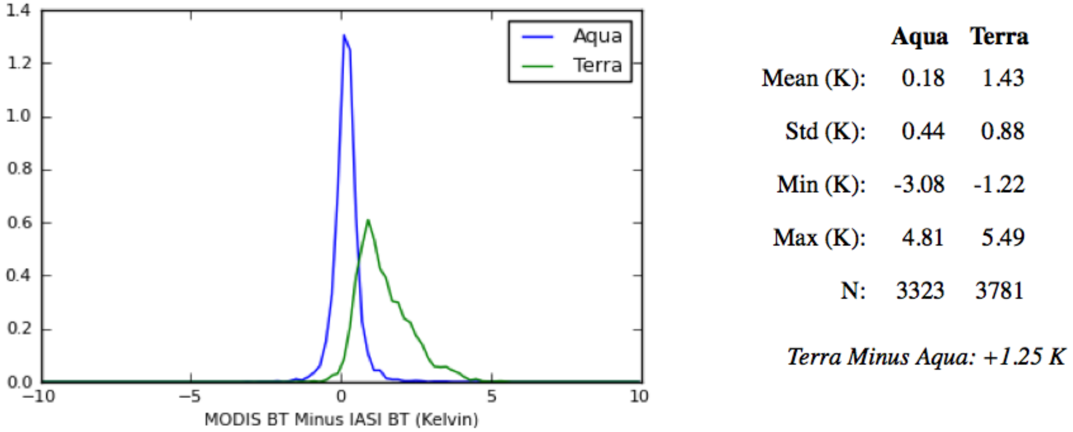
For band 27, similar to Band 35, the bias for Aqua MODIS is generally consistent with the bias expected based on spectral shift analyses performed previously using AIRS as a reference, and we plan to apply the spectral shifts to this dataset as well. Results for Terra MODIS are degraded considerably with respect to those for Aqua MODIS, in terms of mean bias and variability, and the impacts of SRF spectral shifts and de-striping will be investigated.
For these bands and others, the differences between Terra and Aqua MODIS L2 products (in particular cloud heights and water vapor products) are also being assessed based on these new findings.



	Aqua	Terra
Mean (K):	0.43	0.43
Std (K):	0.31	0.36
Min (K):	-1.52	-0.81
Max (K):	5.44	3.75
N:	3323	3782

Terra Minus Aqua: +0.00 K

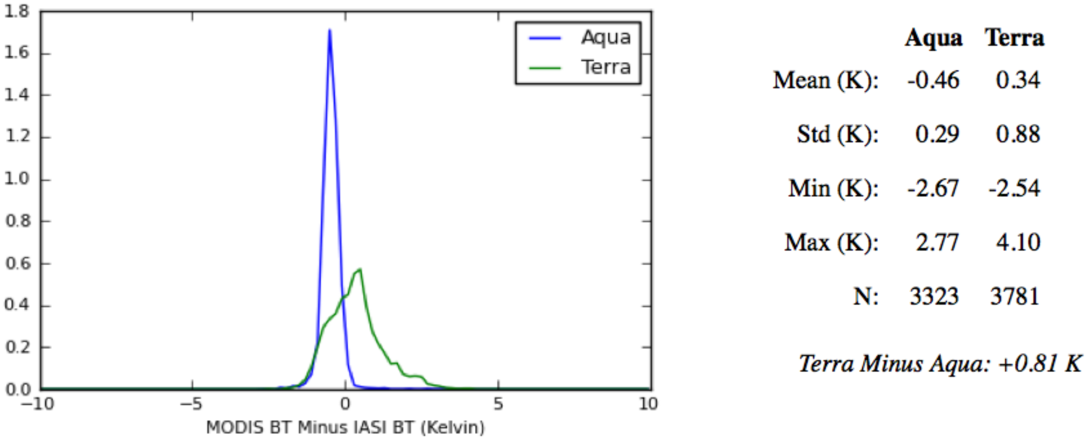
Band 35 results for SNO comparisons of Terra and Aqua MODIS with respect to IASI.



	Aqua	Terra
Mean (K):	0.18	1.43
Std (K):	0.44	0.88
Min (K):	-3.08	-1.22
Max (K):	4.81	5.49
N:	3323	3781

Terra Minus Aqua: +1.25 K

Band 30 results for SNO comparisons of Terra and Aqua MODIS with respect to IASI.



	Aqua	Terra
Mean (K):	-0.46	0.34
Std (K):	0.29	0.88
Min (K):	-2.67	-2.54
Max (K):	2.77	4.10
N:	3323	3781

Terra Minus Aqua: +0.81 K

Band 27 results for SNO comparisons of Terra and Aqua MODIS with respect to IASI.

17.6.2. NPP-VIIRS Ice Cloud Property EDR Validation Activities

Task Leader: Bryan Baum

NOAA Strategic Goals:

- Serve society's needs for weather and water

CIMSS Research Themes:

- Weather, Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Cal/Val Activities with Cloud Macrophysical Parameters such as Cloud Top Height (CTH)

We analyzed two full orbits of cloud products generated at the mini-IDPS at NASA GSFC from VIIRS proxy data for 25 January 2003. While these two orbits of data are the only products that have been provided to NASA and associated scientific personnel for evaluation/assessment, the contractor stresses that these two orbits should not be used for this sort of activity. Regardless of whether these two orbits should be used for assessment, matlab code was built to subset and grid both MODIS and VIIRS proxy cloud products to a common grid, providing an ability to easily intercompare products from different sensors. The premise for this cal/val product is that the scanner data provided by imagers and sounders (e.g., AVHRR and HIRS on NOAA polar orbiters; MODIS and AIRS on Terra/Aqua; VIIRS and CrIS on NPP) can be subsetted and subsequently snapped to a common lat/lon grid. This approach was used in a report by this investigator earlier in 2010 to compare MODIS cloud products to those from the mini-IDPS using VIIRS proxy data. A sample figure (Figure 17.6.2.1) is provided below to show the approach.

Upon launch of NPP, each full day of products will be analyzed to provide separate maps for ascending and descending orbits. The benefit of this product is that it can also be applied to existing data products from any polar orbiting platform including the Earth Observing System Terra/Aqua platforms. This is essentially a Level-2 gridded cloud product that contains some of the calibrated radiance information. This software is going through further development and is being extended for use with other products available from both imagers such as AVHRR and interferometers such as AIRS and IASI.

This approach is now being modified further in the following ways:

- The calibrated reflectances or brightness temperatures for selected channels of each sensor will be included,
- Cloud products from each imager/sounder sensor will be included, and
- Some information regarding the processing path for the cloud parameters will be included.

The primary benefit of this approach is that it provides a very convenient way to intercompare cloud products from a variety of platforms, both from the historical perspective (from 1980 to present) but also from the platforms expected to be operational at the time of the NPP launch. This product will provide sanity checks on the performance of current operational cloud retrieval algorithms between different platforms, promote the effort to find areas of disagreement between various sensors, and form a basis upon which to evaluate the products that will be generated from NPP. By including some of the calibrated radiances (in the form of reflectances or brightness temperatures), we can more easily track down how an algorithm may have arrived at its answer should a discrepancy occur without having to go back to the original Level 1B (or SDR) data.

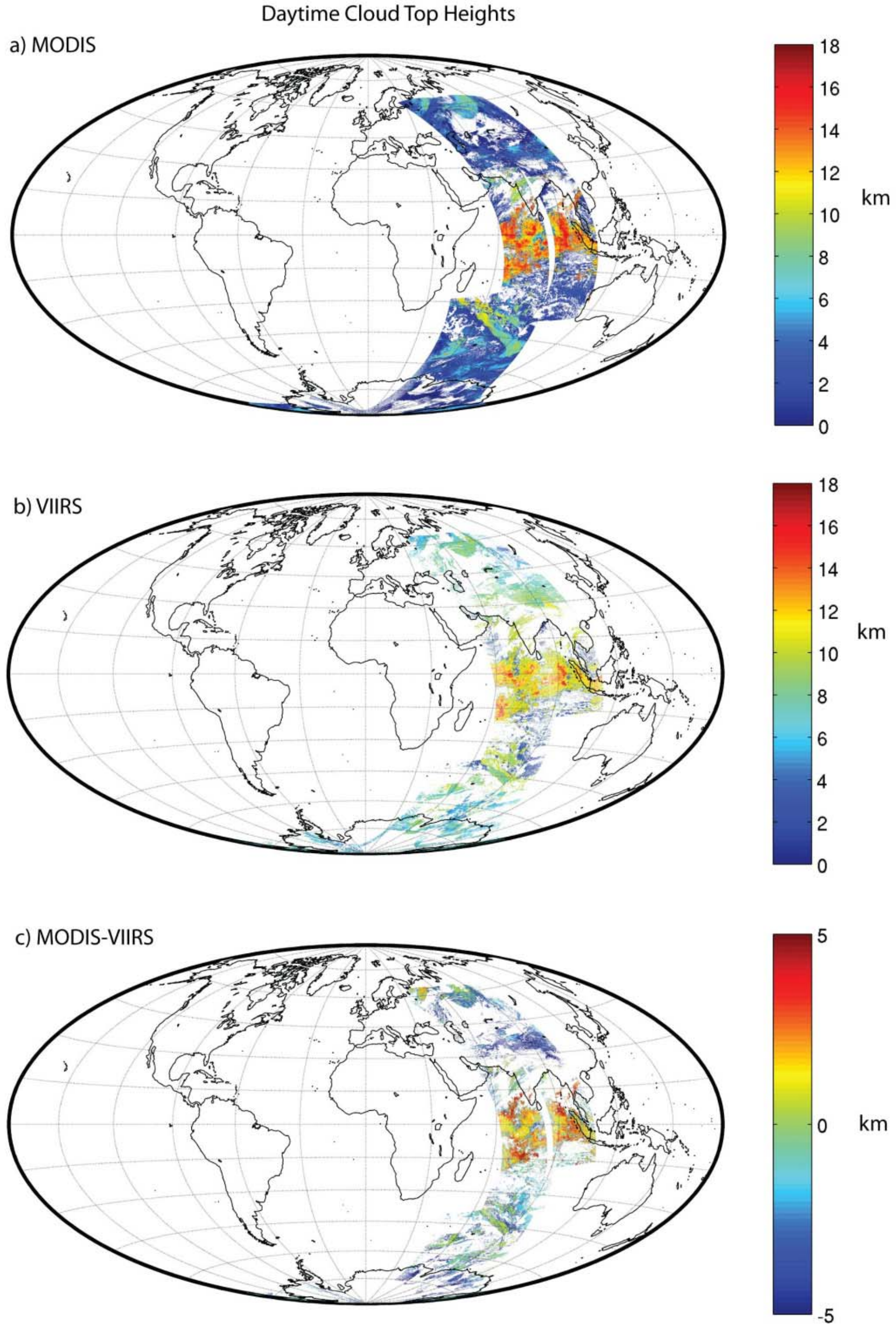


Figure 17.6.2.1. Daytime cloud top heights (in km) snapped to the 0.05˚ equal-angle grid (roughly 5 km resolution at the equator) for (a) upcoming MODIS Collection 6 at 1–km spatial resolution, (b) VIIRS proxy data developed from MODIS, and (c) the (MODIS–VIIRS) differences. Note the large differences in ice cloud CTH found in the tropics over water (MODIS CTH > VIIRS proxy CTH). There are also large differences found in low-level clouds over both water and land (MODIS CTH < VIIRS CTH).

Progress in Development of Improved Bulk Ice Cloud Optical Models

In comparing the MODIS Collection 5 ice cloud optical thickness with that inferred from CALIOP, it has been noted that there was up to a factor of two difference in magnitude for optically thin clouds, with MODIS being higher than CALIOP. Part of this difference can be mitigated by using a "roughened" ice particle model for MODIS. In fact, use of a roughened ice particle model for MODIS will have the effect of lowering the inferred optical thickness and increasing the effective particle size. The MODIS ice cloud look-up tables are going to undergo some rather large changes in Collection 6. The library of single scattering properties has been updated by Dr. Ping Yang and colleagues at Texas A&M. Improvements include the use of new habits (hollow bullet rosettes and aggregates of plates), the full phase matrix, improvements in light scattering calculations, an updated ice index of refraction following Warren and Brandt (JGR, 2008), and particle roughening. Several new ice cloud bulk scattering models have been delivered to the MODIS team at NASA GSFC for evaluation. Once a specific model has been chosen, if any, then models will be built for other sensors (including VIIRS) using the same approach. To make models for VIIRS, we will need to have spectral response functions. Two papers have been written this year on this effort; one is now published and the other has just been submitted and is currently under revision. These papers document the various changes and are available upon request.

Publications

Baum, B. A., P. Yang, Y.-X. Hu , and Q. Feng, 2010: The impact of ice particle roughness on the scattering phase matrix. *J. Quant. Spectrosc. Radiant. Transfer,* **111**, doi:10.1016/j.jqsrt.2010.07.008, 2534-2549.

Baum, B. A., P. Yang, A. J. Heymsfield, C. Schmitt, Y. Xie, A. Bansemer, Y.-X. Hu, and Z. Zhang: Improvements to shortwave bulk scattering and absorption models for the remote sensing of ice clouds. Submitted to *J. Appl. Meteor. Clim. (currently in revision)*

17.6.3 NPP-VIIRS-CrIS Calibration and Validation Activities

Task Leader: Bob Holz

NOAA Strategic Goals:

- Serve society's needs for weather and water

CIMSS Research Themes:

- Weather, Nowcasting and Forecasting
- Clouds, Aerosols and Radiation

Our IPO efforts have focused on finalizing the Linux implementation of the contractor aerosol algorithms and continuing our intercalibration characterization of Terra, Aqua, and HIS with IASI and AIRS. For the aerosol component our goal is to refine the Linux implementation so that our implementation agrees closely with the contractor results. Our accomplishments for this quarter are noted below.

Comparison Between LEOCAT (Linux) with Mini-IDPS and NGAS

To provide a context to this work, Northrop Grumman (NP) has provided limited VIIRS proxy data sets that provide our only means to confirm the UW LEOCAT AOT retrievals accurately reproduce the contractor algorithms. These are:

- Mini-IDPS aerosol product: mini-IDPS (operational code) intended for IDPS functional tests based on operational code. There are two orbits of data available for 25 Jan 2003.
- NGAS aerosol data: NPP proxy 24 granules test data results from NGAS science code. 14 granules of 6 Sep 2002 and 10 granules of 25 Jan 2003 are available.

The UW implementation of the VIIRS contractor algorithms LEOCAT (Low Earth Orbit Cloud Algorithm Testbed) VIIRS algorithm works in a Linux environment and can produce both VIIRS and MODIS resolution products. For the VIIRS resolution processing flow, SDR granules from the mini-IDPS processing chain are directly used as input to the LEOCAT VIIRS software. For the MODIS resolution processing, MODIS L1 B is used as input to the VIIRS algorithm in LEOCAT. The same algorithm (and code) is used for both processing streams. For both VIIRS and MODIS processing, LEOCAT uses GDAS and NCEP model data. The VIIRS resolution processing applies the VIIRS LUT while the MODIS resolution processing applies MODIS LUT. The MODIS resolution LEOCAT implementation runs on MODIS Level 1b granules providing the capability to produce years of retrievals leveraging the UW SSEC processing capability.

Due to limited VIIRS proxy data, we can only compare mini-IDPS and NGAS data to the LEOCAT for 25 Jan 2003. Since LEOCAT VIIRS resolution, mini-IDPS and NGAS are in the same IP resolution, we use the LEOCAT aerosol quality flag to mask and ensure data in Figures 17.6.3.1 and 17.6.3.2 exclude the fill in NAAPS data.

Based on the AOT comparison we found significant differences between the LEOCAT, mini-IDPS, and NGAS results with a granule level comparison provided in Figures 17.6.3.1 and 17.6.3.2. Figures 17.6.3.3 and 17.6.3.4 present AOT differences between the LEOCAT, mini-IDPS, and NGAS. We find that LEOCAT has better agreement with the mini-IDPS. For NGAS the largest differences are over land. Further investigation has revealed LEOCAT uses a different granulation (gridding) method to the 1-degree ancillary data (NCEP) used by mini-IDPS and NGAS proxy data. We also found significant differences in the cloud filtering between the LEOCAT and contractor implementations. Much of our efforts have focused on addressing these issues to improve the closure between LEOCAT, mini-IDPS and NGAS.

MODIS Resolution LEOCAT VIIRS Algorithm

Using the LEOCAT MODIS resolution processing, we created a six-month AOT data set leveraging the UW processing capabilities. The six months of LEOCAT processing took approximately four days. Results from one day of LEOCAT AOT are presented in Figure 17.6.3.5. In addition to comparisons with contractor retrievals, we compared the LEOCAT VIIRS results to the collection 5 MODIS MYD04. The global image and quantitative comparisons are presented in Figures 17.6.3.6 and 17.6.3.7. Because the MODIS MYD04 is at 10km resolution and LEOCAT (VIIRS) IP is 1km resolution, we select every 10th LEOCAT pixel to aggregate up to the 10km MODIS resolution. We compare only pixels when both the MODIS and LEOCAT (VIIRS) successfully retrieve an AOT. From these comparisons we find that the majority of the large AOT differences occur over land or in heavy aerosol regions. Further investigation has revealed that much of the differences can be attributed to the cloud/aerosol masking in LEOCAT.

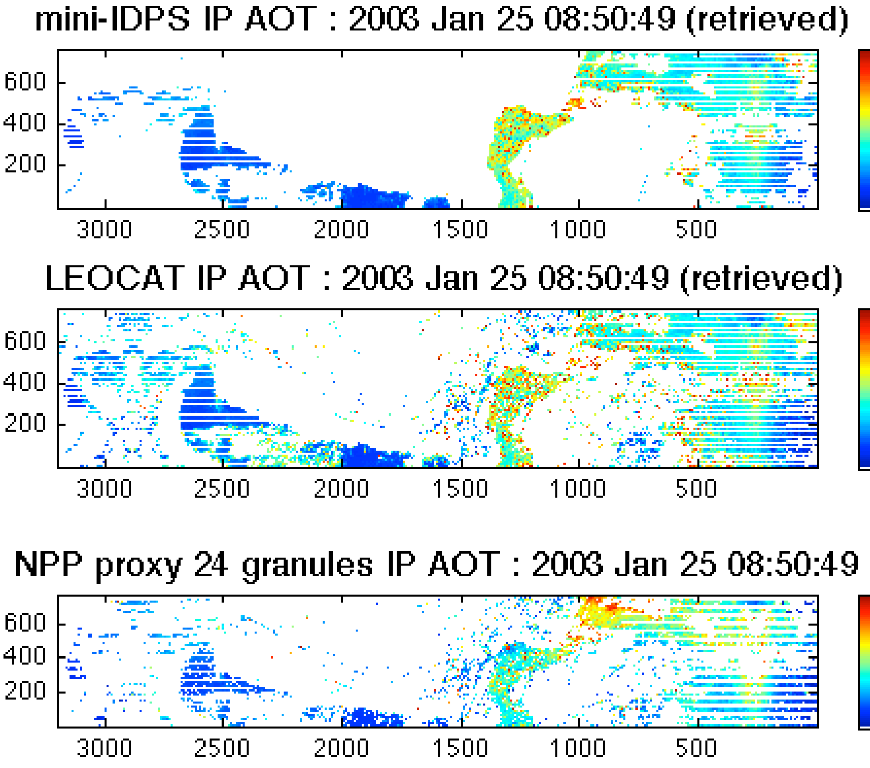


Figure 17.6.3.1. Comparisons between LECOCAT, mini-IDPS, and NPP proxy AOT retrievals.

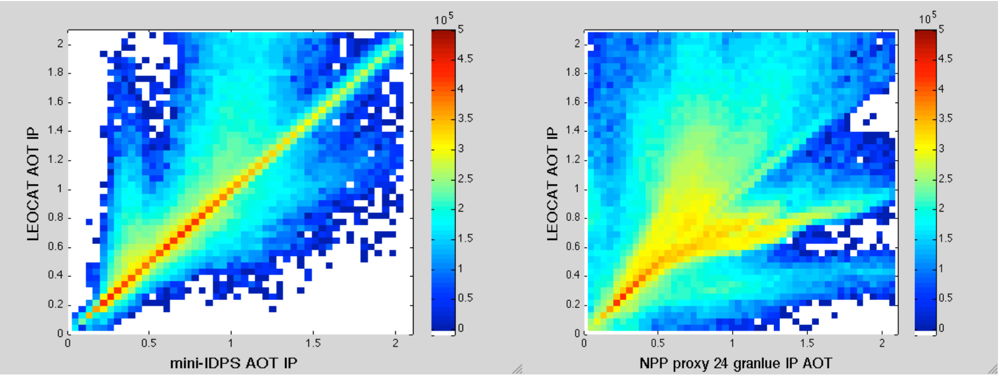


Figure 17.6.3.2. 2-D histogram of the pixel-to-pixel comparisons between LEOCAT and Contractor AOT retrievals (color bar is in log 10 scale).

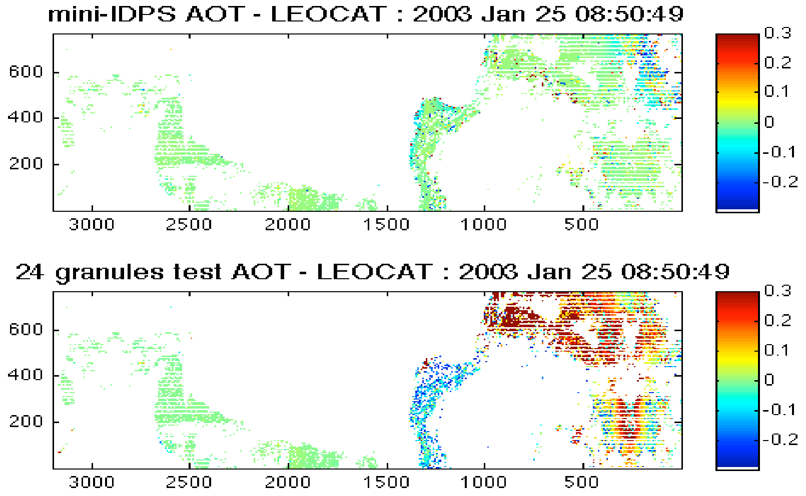


Figure 17.6.3.3. AOT differences between mini-IDPS, NGAS (24 granules) and LEOCAT.

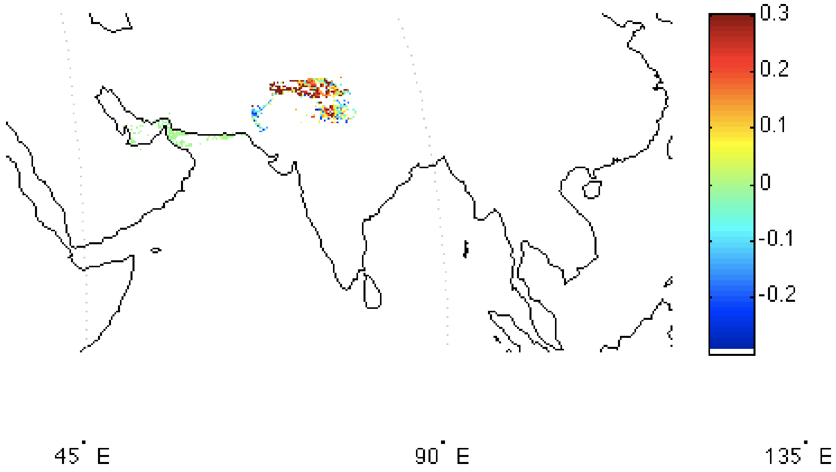


Figure 17.6.3.4. AOT differences between NGAS (24 granules) and LEOCAT geo-location.

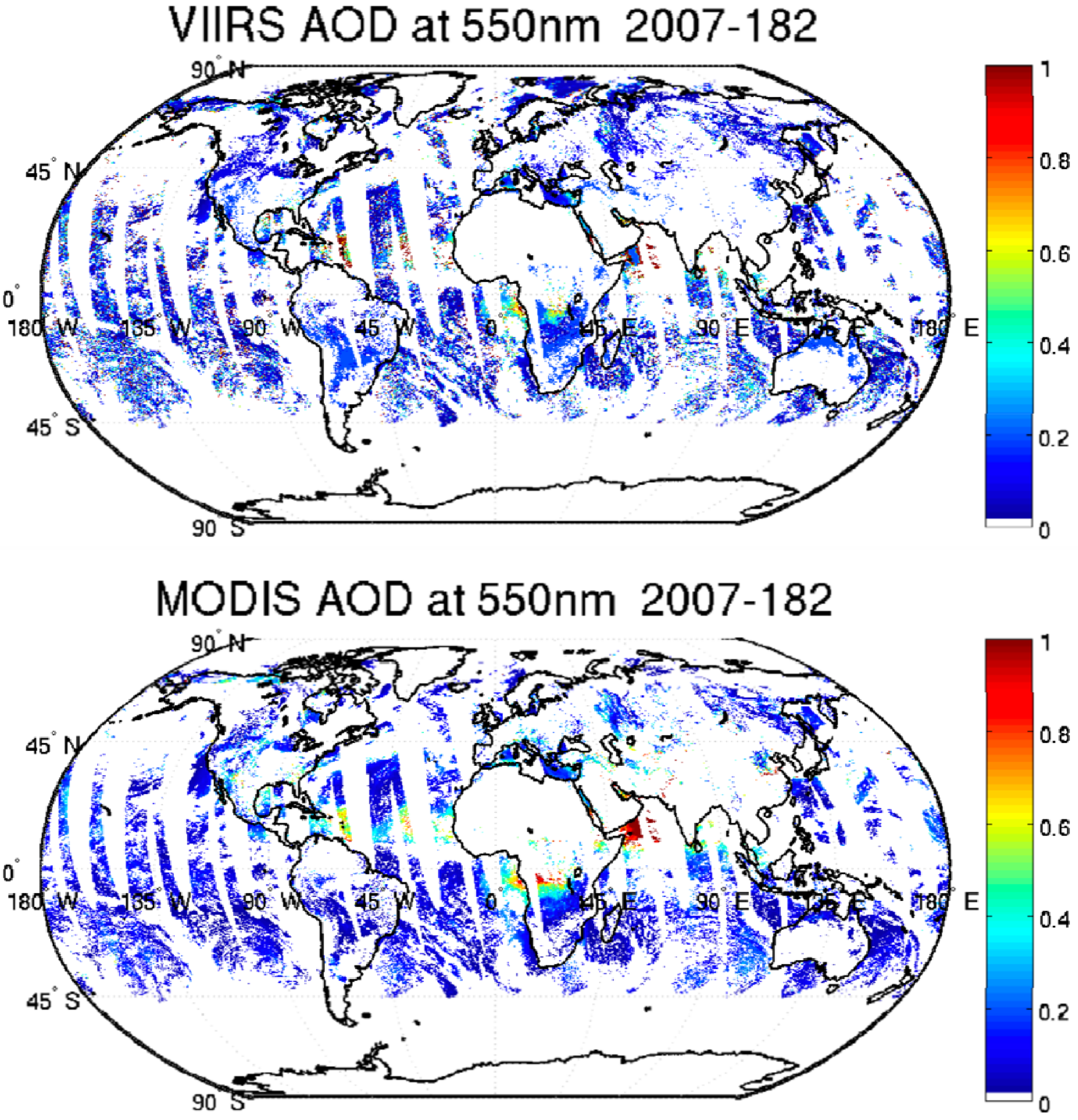


Figure 17.6.3.5. Global comparisons between the MODIS derived AOD pixels of MODIS and VIIRS (LEOCAT).

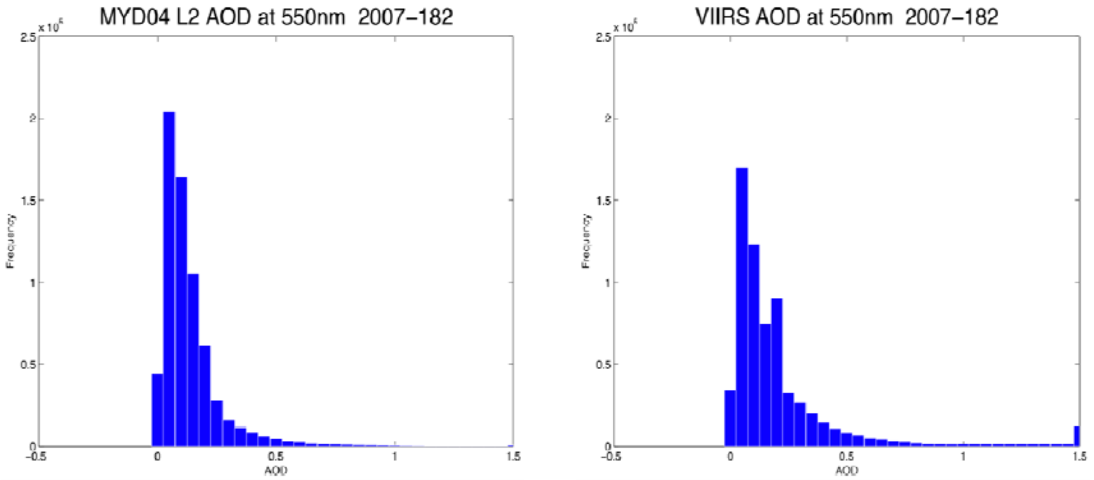


Figure 17.6.3.6. Frequency of MODIS and VIIRS (LEOCAT) AOD.

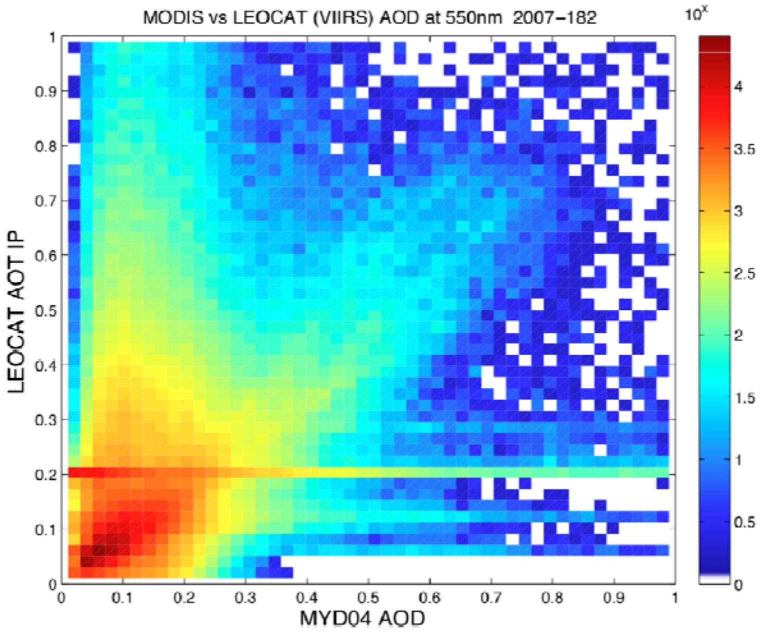


Figure 17.6.3.7. 2-D histogram of the pixel-to-pixel comparisons between LEOCAT and MODIS AOD (color bar is in log 10 scale).

18. Holding Teacher Workshops in Conjunction with ESIP Meetings

Task Leader: Margaret Mooney
CIMSS Support Scientist: Steve Ackerman
NOAA Collaborator: Nina Jackson
NOAA Strategic Goals:

- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Education, training and outreach

Proposed Work

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) recruited presenters and participants for a teacher workshop held in conjunction with the 2010 Federation of Earth System Information Partners (ESIP) summer conference at the University of Tennessee in Knoxville on July 19th, 20th and 21st. With support from NOAA, participating G6-12 teachers were invited to attend the ESIP conference plenary and two full days of workshop sessions that featured hands-on computer activities demonstrating ways that data and tools can be used in science classrooms. Sessions were led by ESIP members from NOAA, CIMSS, NASA, EPA and other ESIP organizations.

Summary of Accomplishments and Findings

A total of twenty-two attendees registered for the teacher track sessions at the conference. The first twenty science teachers who applied were awarded time and travel stipends funded by NOAA. All participating educators had their conference registration fees covered through NOAA support.

The teacher track agenda included multiple events showcasing hands-on data activities for educators. It also featured the first face-to-face meeting of NOAA Climate Stewards. The workshop evaluation distributed at the end of the meeting garnered top scores and numerous constructive comments about NOAA products and services. The agenda and complied workshop evaluations are available on-line at http://cimss.ssec.wisc.edu/teacherworkshop/esip/2010agenda.htm.

ESIP Teacher Workshop Group Photo 7/19/10

19. A Replacement Laser for the Arctic High Spectral Resolution Lidar

Task Leader: Ed Eloranta

NOAA Strategic Goals:

- Serve society's needs for weather and water

CIMSS Research Themes:

- Clouds, Aerosols and Radiation

The University of Wisconsin-Madison has operated a High Spectral Resolution Lidar at Eureka, Nunauvt since August of 2005 in order to provide information on Arctic clouds and aerosols. This deployment has been supported with a combination of NSF and NOAA funds. The laser transmitter in the lidar has failed. This grant provided 50% of the funds to buy a laser and coupling optics to replace the failed unit. NSF provided the other half of the necessary funds. The laser has been purchased and has passed acceptance testing. The lidar will be shipped back to Madison for the installation in early November.

Appendices

Appendix 1: List of Awards to Staff Members

2010

Steven Ackerman: NASA Exceptional Public Service Medal
Scott Bachmeier: NESDIS Team Member of the Month
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

2009

Steven Ackerman: AMS Teaching Excellence Award
Annie Lenz: AMS Father James B. Macelwane Award, which recognizes an original undergraduate student research paper
Jeff Key: NOAA Administrator's Award for scientific leadership and excellence in support of domestic and international polar observing activities during the International Polar Year
Chris Velden: Elected to Fellow of the American Meteorological Society
Amato Evan, Yinghui Liu, and Xuanji Wang: University of Wisconsin-Madison's NOAA-CIMSS Collaboration Award for innovative uses of operational weather satellites to understand climate change and to quantify trends in the global climate system.
Mat Gunshor: University of Wisconsin-Madison's NOAA-CIMSS Collaboration Award for developing NOAA's Strategic Satellite Plan to balance requirements, observation capabilities, and resources.
Steven Ackerman: State University of New York at Oneonta Distinguished Alumnus Award
Colleen Mouw: NASA MPOWIR (Mentoring Physical Oceanography Women to Increase Retention) selected speaker – competitive selection of a junior female physical oceanographer to give a seminar at a NASA research center
Chian-Yi Liu: Second Prize in Oral Presentation, Sixth Annual NOAA/NESDIS/CoRP Symposium
Jordan Gerth: Wisconsin Space Grant Consortium Graduate Fellowship Award
Chian-Yi Liu: Henry Vilas Travel Grant
Jun Li: University of Wisconsin-Madison's NOAA-CIMSS Collaborative Award for developing NOAA's Strategic Satellite Plan to balance requirements, observation capabilities, and resources
R. Bradley Pierce: NASA Group Achievement Award for outstanding accomplishments in the successful Arctic Research of the Composition of the Troposphere with Aircraft and Satellites (ARCTAS) mission in Alaska and Canada

Appendix 2: Publications

The tables below show the number of papers on which CIMSS and ASPB scientists were first author (Table A2.1) or contributors (Table A2.2) to reviewed journal articles and non-reviewed articles. Note that data for 2010 is incomplete.

Table A2.1:
Peer Reviewed and Non Peer Reviewed journal articles having CIMSS and/or NOAA lead authors, 2008-2010*. Publications categorized by Institute, NOAA and Other Lead Author.

	Institute Lead Author			NOAA Lead Author			Other Lead Author		
	2008	2009	2010*	2008	2009	2010*	2008	2009	2010*
Peer Reviewed	24	19	8	1	4	9	45	44	25
Non Peer Reviewed	4	1	2	0	0	1	0	1	0

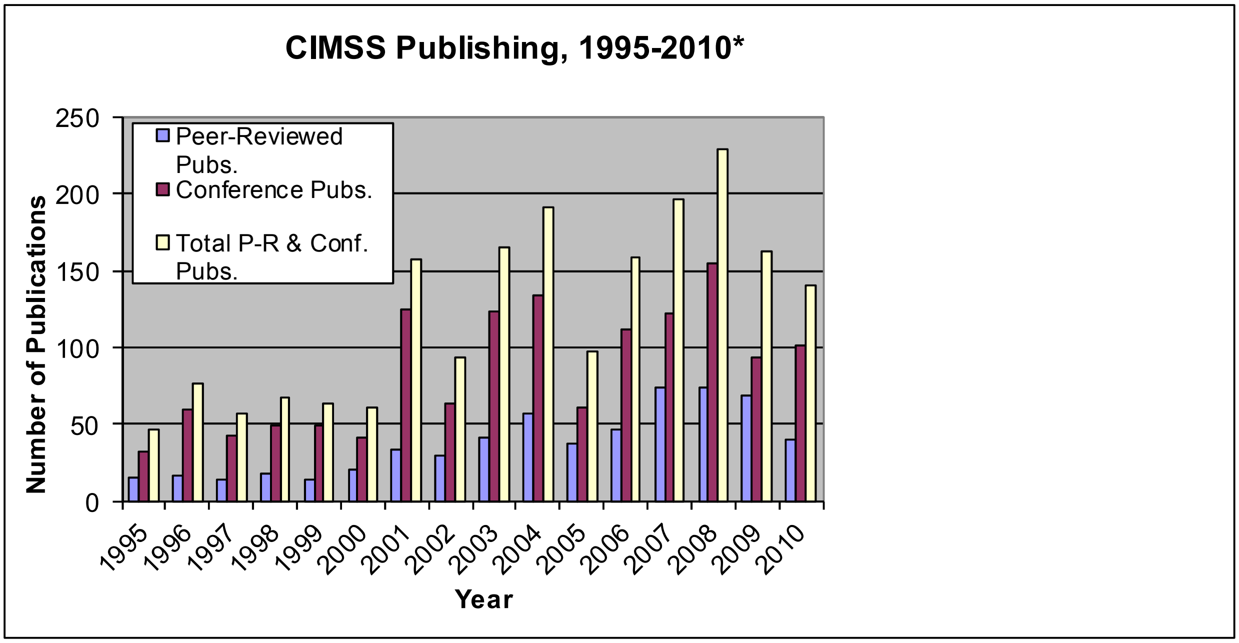
*incomplete

Table A2.2:
Peer Reviewed and Non Peer Reviewed journal articles having one or more CIMSS and/or NOAA Co-Authors, 2008-2010.

	Institute Co-Author			NOAA Co-Author		
	2008	2009	2010*	2008	2009	2010*
Peer Reviewed	61	58	28	22	21	14
Non Peer Reviewed	2	2	2	1	0	1

*incomplete

Table A2.3:
CIMSS Publishing History, showing peer reviewed and conference publications.
(*2010 incomplete)



Publications of the Advanced Satellite Products Lab (ASPB) are available at:
http://library.ssec.wisc.edu/resources/aspb/aspb.php .

Appendix 3: Employee Information

CIMSS Staff and Student Labor Hours on NOAA CA Projects
October 2009 through September 2010

Name	Title	Hours	% Time
Wang, Xuanji	Scientist, PostDoc	1750	100%
Liu, Yinghui	Researcher I	1750	100%
Lee, Yong-Keun	Researcher I	1750	100%
Calvert, Corey	Researcher I	1750	100%
Jin, Xin	Researcher I	1750	100%
Bah, Momodou	Researcher I	1750	100%
Gunshor, Mathew	Researcher II	1727	99%
Lenzen, Allen	Researcher III	1726	99%
Straka, William	Researcher I	1716	98%
Jung, James	Scientist I	1712	98%
Hoffman, Jay	Researcher I	1712	98%
Wanzong, Steven	Researcher II	1706	97%
Li, Jinlong	Researcher II	1660	95%
Nelson, James III	Researcher III	1638	94%
Li, Zhenglong	Researcher I	1620	93%
Sieglaff, Justin	Researcher I	1607	92%
Martin, Graeme	Computer Scientist I	1606	92%
Cronce, Lee	Researcher I	1556	89%
Schreiner, Anthony	Researcher III	1535	88%
Rink, Thomas	Computer Scientist I	1464	84%
Bachmeier, Anthony	Researcher II	1456	83%
Schiffer, Eva	Computer Programmer I	1452	83%
Brunner, Jason	Researcher I	1394	80%
Yao, Zhigang	Researcher I	1392	80%
Rozoff, Christopher	Researcher I	1375	79%
Foster, Mike	Researcher I	1352	77%
Liu, Chian-Yi	Student, Graduate	1344	77%
Tobin, David	Scientist I	1344	77%
Olander, Timothy	Researcher II	1302	74%
Schaack, Todd	Researcher III	1300	74%
Wimmers, Anthony	Scientist I	1272	73%
Li, Jun	Scientist II	1268	72%
Park, Chang Hwan	Researcher I	1256	72%
Garcia, Raymond	Computer Scientist III	1230	70%
Greenwald, Thomas	Scientist I	1207	69%
Otkin, Jason	Researcher II	1204	69%
Parker, Andrew	Computer Scientist I	1199	69%
Lindstrom, Scott	Researcher II	1157	66%
Gerth, Jordan	Graduate Student	1118	64%
Pasowicz, Daniel	Student, Undergrad	1101	63%
Nielsen, Johannes	Researcher I	1093	62%
Monette, Sarah	Student, Graduate	1058	60%
Oo, Min	Scientist, PostDoc	1040	59%
Moeller, SzuChia	Researcher II	997	57%
Mozer, Katherine	Student, Graduate	990	57%

Feltz, Wayne	Scientist I	988	56%
Schmidt, Christopher	Researcher III	986	56%
Borbas, Eva	Researcher II	980	56%
Knuteson, Robert	Scientist I	932	53%
Vasys, Egle	Executive Assistant	929	53%
Sorce, Ashley	Student, Undergrad	910	52%
Huang, Hung-Lung	Scientist III	896	51%
Smith, Nadia	Researcher I	896	51%
Zhang, Hong	Researcher II	856	49%
Antonelli, Paolo	Researcher II	854	49%
DeSlover, Daniel	Researcher II	854	49%
Stettner, David	Researcher I	844	48%
Quinn, Greg	Computer Programmer I	844	48%
Lim, Agnes	Graduate Student	788	45%
Weisz, Elisabeth	Researcher II	780	45%
Moeller, Christopher	Scientist I	744	43%
Davies, James	Computer Programmer II	728	42%
Avila, Leanne	Documentation Specialist II	686	39%
Dworak, Richard	Manager III	685	39%
Molling, Christine	Researcher II	648	37%
Velden, Christopher	Scientist III	616	35%
Whittaker, Thomas	Computer Scientist III	590	34%
Schiferl, Luke	Student, Undergrad	575	33%
Cureton, Geoffrey	Computer Scientist II	546	31%
Jasmin, Tommy	Computer Scientist II	468	27%
Baum, Bryan	Scientist II	451	26%
Nagle, Frederick	Post Retirement Rehire	442	25%
Berthier, Sebastien	Researcher I	440	25%
Gumley, Liam	Researcher III	432	25%
Petersen, Ralph	Scientist III	428	24%
Holz, Robert	Researcher II	412	24%
Frey, Richard	Computer Programmer III	411	23%
Menzel, Wolfgang	Scientist III	410	23%
Yang, Kaixin	Student, Graduate	404	23%
Huang, Bormin	Scientist I	396	23%
Dengel, Russell	Computer Programmer III	386	22%
Staude, Jessica	Researcher I	375	21%
Roman, Jocola	Student, Undergrad	375	21%
He, Feng	Graduate Student	375	21%
Liu, Wei	Graduate Student	375	21%
Feltz, Joleen	Researcher I	364	21%
Achtor, Thomas	Scientist III	356	20%
Strabala, Kathleen	Researcher III	354	20%
Olson, Erik	Computer Scientist I	342	20%
Mooney, Margaret	Outreach Specialist II	330	19%
Plokhenko, Youri	Researcher III	324	18%
Santek, David	Scientist I	257	15%
LaPorte, Daniel	Researcher III	225	13%
Kulie, Mark	Graduate Student	225	13%
Flynn, Bruce	Computer Scientist I	200	11%
Garms, Elise	Student, Undergrad	185	11%
Revercomb, Henry	Scientist III	160	9%

Bellon, Willard	Data Manager II	147	8%
Bearson, Nicholas	Researcher I	143	8%
Borg, Lori	Researcher I	134	8%
Gebre, Embibel	Student, Undergrad	131	7%
Schaffer, Rebecca	Researcher I	104	6%
Hart, Caitlin	Graduate Student	90	5%
Lewis, William	Researcher I	84	5%
Parker, David	Computer Scientist I	81	5%
Heinzelman, Jay	Researcher I	80	5%
Ackerman, Steven	Scientist III	69	4%
Lazzara, Mathew	Researcher III	68	4%
Kohrs, Richard	Researcher II	60	3%
Demke, Thomas	Quality/Safety Manager III	54	3%
Taylor, Joseph	Engineer II	48	3%
Wu, Wenhua	Business Service Provider	48	3%
Woolf, Harold	Computer Scientist III	42	2%
Hartung, Daniel	Researcher I	32	2%
Moy, Leslie	Researcher I	32	2%
Tucker, Camillia	Executive Assistant	26	1%
Behling, Patsy	Researcher I	22	1%
Berger, Howard	Researcher I	16	1%
Jones, David	Electronics Technician II	14	1%
Beavers, Jonathan	Computer Programmer I	10	1%
	Total labor hours	94973	
	Equivalent full time employees	54	

Research Topics of Current CIMSS Graduate Students and Post-Doctors

NOAA FUNDED GRADUATE STUDENTS

Jordan Gerth

Research studies the impact of varied initial conditions and lateral forcings on numerical weather prediction forecasts, and works heavily on research to operations exercises supporting future National Weather Service use of the Geostationary Operational Environmental Satellite R-Series (GOES-R) as part of a proving ground effort.

Agnes Lim

PhD Thesis title: "Examining Atmospheric Variability within Convective System through Hyperspectral Infrared Satellite Data and Their Assimilation." Forecast skill on summer convective precipitation remains low. The aim of this study is to identify specific channels of a hyperspectral sensor (IASI) that can pick up the thermodynamics and dynamics characteristics of convective systems and incorporate this information into the initialization of NWP models through variational data assimilation to increase the forecast skill. Both clear sky and cloudy sky conditions will be tackled.

Sarah Monette

Current research examines operational uses for an objective overshooting top detection algorithm. Presently working on 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, as well as detecting the climatological signal of the El Niño Southern Oscillation.

Kathryn Mozer
Research involves the PATMOS-x satellite dataset (1982-2009) created by Andrew Heidinger and comparing low cloud fraction (over the eastern South Pacific) from PATMOS-x, NCAR/ CCSM3.0 (20th century and SRESa1b experiments),and GFDL/CM2.0 (20th century and SRESa1b experiments)to lower tropospheric static stability as described in Klein and Hartmann 1993, calculated from the models and NCEP Reanalysis data. The goal is to determine how well the models compare to the satellite and if LTS is indeed an appropriate diagnostic for low cloud in this region.

Matthew Sitkowski
Ph.D. Thesis title: "The Physical Processes and Prediction of Secondary Eyewall Formation." This study explores some of the physical processes that occur within the inner-core of a hurricane during the formation of a secondary eyewall. An environmental and GOES based algorithm is also developed to predict the likelihood of secondary eyewall formation. Flight-level aircraft data are being utilized to examine structure and intensity changes associated with eyewall replacement cycles.

NOAA FUNDED POST DOCS

Michael Foster
Currently working on a naive Bayesian cloud-masking algorithm as well as a technique for integrating HIRS measurements into the PATMOS-x processing framework. Other projects include studying 3D radiative transfer through broken cloud fields and the effects deep convective clouds have on stratospheric energy balance.

Zhenglong Li (recently hired into permanent position)
Ph.D. Thesis title: "Improvements and Applications of Atmospheric Soundings from Geostationary Platform." Now research focuses on two projects. The first one focuses on retrieving the surface properties, including the surface emissivity and the land surface temperature, from the SEVIRI instrument. The second one focuses on combining the GOES Sounder and AIRS in order to improve the current sounding products.

STUDENTS FUNDED ON OTHER PROJECTS THAN NOAA

Utkan Kolat
Thesis title: “Re-evaluation of HIRS Detection of High Clouds.” HIRS data are re-processed with two adjustments to the CO2 slicing algorithm. (1) Stratospheric clouds are identified when more opaque CO2 channels are warmer than less opaque CO2 channels. (2) The cloud detection threshold (clear minus cloudy radiances required to indicate cloud presence in CO2 bands) is lowered to force more CO2 slicing solutions for high thin clouds. This work will study the resulting changes in high cloud detection.

Mark Kulie
Ph.D. Thesis title: "Combined active-passive microwave remote sensing of clouds and precipitation at higher latitudes." This work uses a combined active-passive microwave observation and modeling system to quantify simulated uncertainties due to the assumed ice particle model and particle size distribution (PSD) used to characterize frozen hydrometeors. A database of microwave optical properties using previously published ice particle models has been created to demonstrate both the potential uncertainties

in multi-frequency microwave simulations of clouds and precipitation and to test what ice models produce the most realistic results when compared to observations. Sensitivity tests for space-borne dual-frequency radar applications will also be undertaken to highlight the large uncertainties due to common underlying assumptions of ice model and PSD.

Aronne Merrelli
Ph.D. Thesis title: "Information Content of High Resolution Far Infrared Spectra." Currently investigating information content of Far Infrared (FIR) spectra, using modeled satellite observations of clear-sky atmospheric profiles. Future work will extend the analysis to profiles with ice and mixed-phase layer clouds.

John Sears
Currently working to maximize the accuracy of the ADT, an automated hurricane strength estimating program. Goal is currently to use readily available information from the processing to improve the overall estimations. Future (thesis) work will focus on PREDICT, a project to understand early tropical cyclone development.

Mark Smalley
Master's research title: "An analysis of uncertainties in retrieved cloud top heights associated with CO2 Slicing." There are many uncertainties that can propagate through the CO2 slicing equation and into retrieved cloud top heights. This research focuses investigating the sensitivity of retrieved cloud top heights using CO2 slicing to differences in MODIS and HIRS instrument spectral response functions. HIRS and MODIS radiances are simulated with convolved AIRS radiances.

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
Master's Thesis title: "Constraining Predicted Trends in Arctic Methane Release using Satellite Observations." 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.

Erin Wagner
Ph.D. title: "A comprehensive analysis of boundary layer structure via Raman lidar water vapor mixing ratio retrievals." Boundary layer turbulence structure is analyzed using 10-second resolution Raman lidar data based in Lamont, Oklahoma. Case studies focus on well-mixed boundary layer updraft/downdraft structure and entrainment. Once techniques are refined through case studies a 4-year climatology of the data will be compiled with the goal of identifying conditions associated with specific boundary layer structures for comparison with climate and weather models.

Tim Wagner

The impact that cumulus clouds have on the environment is a function of the rate of entrainment of environmental air into the developing cloud. Typically observations of entrainment are obtained from aircraft-borne instruments, but we are developing an algorithm to remotely retrieve entrainment rate from ground-based profiling instruments. This will make it possible to evaluate cumulus parameterizations as well as generate climatologies of entrainment.

POST DOCTORS FUNDED ON OTHER PROJECTS THAN NOAA

Giuseppe Baldassarr)

Ph.D. Thesis title: "A performance analysis of advanced MSG-SEVIRI fire detection algorithms (WF_ABBA and RST_FIRES) over Italy." Research activities consist of comparing WF_ABBA (Wildfire Automated Biomass Burning Algorithm) and RST_FIRES (Robust Satellite Techniques Fires) fire products with the fire ground truth provided by the Italian State Forestry Department and see the performances of this two satellite techniques.

Colleen Mouw (recently hired into permanent position)

Ph.D. dissertation title (2009): "Bio-optical and remote sensing investigation of phytoplankton community size structure." Current research interests in refining and developing optical algorithms to improve the retrieval of biological and biogeochemical parameters from satellite imagery of the ocean, Great Lakes and small inland lakes of Wisconsin. Utilizes in situ data sets, various sources of satellite imagery to understand the physical drivers of biological variability in aquatic systems.

Appendix 4. CIMSS Subcontracts summary

Dr. Ping Yang, Texas A&M University
"Research in Support of GOES-R Risk Reduction Project"
January 2007 to date; total funding $100,000 in 2007, $50,000 in 2008, $50,000 in 2009, $50,000 in 2010.

Dr. Xiolie Zhou, Florida State University
"FSU Participation in the CIMSS GOES-R Risk Reduction Project"
January 2007 to date; total funding $50,000 in 2007 and $50,000 in 2008 (nothing in 2009 or 2010).

Dr. Hui Liu, NCAR, Data Assimilation Research Section
"Evaluating the impact of assimilating hyperspectral IR soundings on tropical storm analyses and forecasts using the WRF/DART Ensemble data assimilation system".
Total amount is $50K for the period of 9/1/08 - 8/31/09. (nothing in 2010)

Dr. Crystal Schaaf, Boston University
“MODIS Gap-filled Albedo and Reflectance Anisotropy Products”
Total amount is $24,950 for the period of 7/1/09 – 6/30/10

Appendix 5. List of CIMSS Students and/or Staff hired by NOAA during this period

Jessica Staude, NOAA/NESDIS/ESRL (contractor)

Appendix 6. CIMSS publications for 2009-2010

CIMSS Reviewed Publications, 2009-2010

2009

Ackerman, Steven A.; Phillips, Jean M.; Achtor, Thomas A., and Bull, Daniel S. Using a publication analysis to explore mission success. Bulletin of the American Meteorological Society v.90, no.9, 2009, pp1313-1320.

Alexandrov, Mikhail D.; Schmid, Beat; Turner, David D.; Cairns, Brian; Oinas, Valdar; Lacis, Andrew A.; Gutman, Seth I.; Westwater, Ed R.; Smirnov, Alexander, and Eilers, James. Columnar water vapor retrievals from multifilter rotating shadowband radiometer data. Journal of Geophysical Research v.114, no.D2, 2009, ppdoi:10.1029/2008JD010543 .

Bedka, Kristopher M.; Velden, Christopher S.; Petersen, Ralph A.; Feltz, Wayne F., and Mecikalski, John R. Comparisons of satellite-derived atmospheric motion vectors, rawinsondes, and NOAA wind profiler observations. Journal of Applied Meteorology and Climatology v.48, no.8, 2009, pp1542–1561.

Bi, Lei; Yang, Ping; Kattawar, George W.; Baum, Bryan A.; Hu, Yong X.; Winker, David M.; Brock, R. Scott, and Lu, Jun Q. Simulation of the color ratio associated with the backscattering of radiation by ice particles at the wavelength of 0.532 and 1.064 microns. Journal of Geophysical Research v.114, no.2009, ppdoi:10.1029/2009JD011759.

Brioude, J.; Cooper, O. R.; Feingold, G.; Trainer, M.; Freitas, S. R.; Kowal, D.; Ayers, J. K.; Prins, E.; Minnis, P.; McKeen, S. A.; Frost, G. J., and Ysie, E.-Y. Effect of biomass burning on marine stratocumulus clouds off the California coast. Atmospheric Chemistry and Physics v.9, no.2009, pp8841-8856.

Cadeddu, Maria P.; Turner, David D., and Liljegren, James C. A neural network for real-time retrievals of PWV and LWP from Arctic millimeter-wave ground-based observations. IEEE Transactions on Geoscience and Remote Sensing v.47, no.7, 2009, pp1887-1900.

Champollion, C.; Flamant, C.; Bock, O.; Masson, F.; Turner, D. D., and Weckwerth, T. Mesoscale GPS tomography applied to the 12 June 2002 convective initiation event of IHOP 2002. Quarterly Journal of the Royal Meteorological Society v.135, no.640, 2009, pp645-662.

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Crewell, Suzanne; Ebell, Kerstin; Lohnert, Ulrich, and Turner, D. D. Can liquid water profiles be retrieved from passivel microwave zenith observations. Geophysical Research Letters v.36, no.2009, ppdoi:10.1029/2008GL036934.

Ding, Shouguo; Xie, Yu; Yang, Ping; Weng, Fuzhong; Liu, Quanhua; Baum, Bryan, and Hu, Yongxiang. Estimates of radiation over clouds and dust aerosols: Optimized number of terms in phase function expansion. Journal of Quantitative Spectroscopy and Radiative Transfer v.110, no.13, 2009, pp1190-1198.

Dworak, Richard and Key, Jeffrey R. Twenty years of polar winds from AVHRR: Validation and comparison with ERA-40. Journal of Applied Meteorology and Climatology v.48, no.1, 2009, pp24-40.

Evan, Amato T.; Vimont, Daniel J.; Heidinger, Andrew K.; Kossin, James P., and Bennartz, Ralf. The role of aerosols in the evolution of tropical North Atlantic Ocean temperature anomalies. Science v.324, no.5928, 2009, pp778-781, supplement.

Fairlie, T. Duncan; Szykman, James; Gilliland, Alice; Pierce, R. Bradley; Kittaka, Chieko; Weber, Stephanie; Engle-Cox, Jill; Rogers, Raymond R.; Tikvart, Joe; Scheffe, Rich, and Dimmick, Fred. Lagrangian sampling of 3-D air quality model results for regional transport contributions to sulfate aerosol concentrations at Baltimore, MD, in summer 2004. Atmospheric Environment v.43, no.20, 2009, pp3275-3288.

Feltz, W. F.; Bedka, K. M.; Otkin, J. A.; Greenwald, T., and Ackerman, S. A. Understanding satellite-observed mountain-wave signatures using high-resolution numerical model data. Weather and Forecasting v.24, no.1, 2009, pp76-86.

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Greenwald, Thomas J. A 2 year comparison of AMSR-E and MODIS cloud liquid water path observations. Geophysical Research Letters v.36, no.2009, ppdoi:10.1029/2009GL040394.

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 v.26, no.4, 2009, pp746-758.

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Hendricks, Eric A.; Schubert, Wayne H.; Taft, Richard K.; Wang, Huiqun, and Kossin, James P. Life cycles of hurricane-like vorticity rings. Journal of the Atmospheric Sciences v.66, no.3, 2009, pp705-722.

Hillger, Donald W. and Schmit, Timothy J. The GOES-13 science test: A synopsis. Bulletin of the American Meteorological Society v.90, no.5, 2009, pp592-597.

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Hu, Yongxiang; Winker, David; Vaughan, Mark; Lin, Bing; Omar, Ali; Trepte, Charles; Flittner, David; Yang, Ping; Nasiri, Shaima L.; Baum, Bryan; Sun, Wenbo; Liu, Zhagyan; Wang, Zhien; Young, Stuart; Stamnes, Knut; Huang, Jianping; Kuehn, Ralph, and Holz, Robert. CALIPSO/CALIOP cloud phase discrimination algorithm. Journal of Atmospheric and Oceanic Technology v.26, no.11, 2009, pp2293-2309.

Klein, Stephen A.; McCoy, Renata B.; Morrison, Hugh; Ackerman, Andrew S.; Avramov, Alexander; de Boer, Gijs;

Chen, Mingxuan; Cole, Jason N. S.; Del Genio, Anthony D.; Falk, Anthony; Foster, Michael J.; Fridlin, Ann; Golaz, Jean-Christopher; Hashino, Tempei; Harrington, Jerry Y.; Hoose, Corinna; Khairoutdinov, Marat F.; Larson, Vincent E.; Liu, Xiaohong; Luo, Yali; McFarquhar, Greg M.; Menon, Surabi; Neggers, Roel A. J.; Park, Sungsu; Poellot, Michael R.; Schmidt, Jerome M.; Sednev, Igor; Shipway, Ben J.; Shupe, Matthew D.; Spangenberg, Douglas A.; Sud, Yogesh C.; Turner, David D.; Veron, Dana E.; von Salzen, Knut; Walker, Gregory K.; Wolf, Audrey B.; Xie, Shaocheng; Xu, Kuan-Man; Yang, Fanglin, and Zhang, Gong. Intercomparison of model simulations of mixed-phase clouds observed during the ARM Mixed-Phase Arctic Cloud Experiment, I: Single-layer cloud. Quarterly Journal of the Royal Meteorological Society v.135, no.641, 2009, pp979-1002.

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Liu, X.; Zhou, D. K.; Larar, A. M.; Smith, W. L.; Schlussel, P.; Newman, S. M.; Taylor, J. P., and Wu, W. Retrieval of atmospheric profiles and cloud properties from IASI spectra using super-channels. Atmospheric Chemistry and Physics v.9, no.23, 2009, pp9121-9142.

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