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 2008 to 30 September 2009
Cooperative Agreement Number: NA06NES4400002

Submitted to:
National Oceanic and Atmospheric Administration (NOAA)

Cooperative Agreement Annual Report

1 October 2008 to 30 September 2009

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Director, CIMSS

Thomas Achtor
Executive Director, Editor

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The work conducted as part of the CIMSS Cooperative Agreement for 1 October 2008 to 30 September 2009 is detailed in this report. While primary authors are noted, the research discussed in this report has been a result of numerous collaborations with other CIMSS and NOAA colleagues.

Table of Contents

Cooperative Agreement Annual Report
1 October 2008 to 30 September 2009

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

I. Director's Executive Summary

The National Oceanic and Atmospheric Administration (NOAA) and the University of Wisconsin-Madison have collaborated for nearly three decades in satellite meteorology and remote sensing research. This collaborative relationship between NOAA and the UW-Madison (UW), 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/SSEC have a formal basis for ongoing collaborative research efforts. UW scientists work closely with NOAA/NESDIS' Advanced Satellite Product Branch (ASPB) stationed here at Madison. This year, the National Climate Data Center stationed another NOAA employee at CIMSS, further expanding UW-Madison's collaborations with NESDIS

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.

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. More than 40% of CIMSS published papers have one or more co-authors from NOAA. Approximately 24% of the publications are co-authored with NASA collaborators. During the period 1995-2007, there were 347 federal scientists as co-authors on 414 peer-reviewed papers. 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. For example, fully automated cloud-drift wind production from GOES became operational in 1996, and wind vectors are routinely used in operational numerical models of the National Centers for Environmental Prediction (NCEP) and elsewhere. The satellite-derived winds program is a fine example of how a long-term research program can evolve into the operational environment. CIMSS also provides the Air Force Weather Agency (AFWA, DoD) with the fully automated algorithm, and this source is serving as a national backup processing system for NOAA/NESDIS. These analysis algorithms have been transferred to NOAA, but we continue to make improvements and transfer them to NOAA. For example, CIMSS scientists continue advance quality control measures for the Atmospheric Motion Vector's (AMVs).

CIMSS scientists work with ASPB scientists to develop methods for quantitatively detecting volcanic ash and estimating its height using the operational Advanced Very High Resolution Radiometer (AVHRR) processing system, CLAVR-X (The Extended Clouds from AVHRR processing system). The focus of this project is on implementing a volcanic ash algorithm in CLAVR-X to produce reliable global results on a real-time basis prior to a full operational implementation later in the project. CLAVR-X was modified in order to accommodate a cloud object based volcanic ash detection algorithm and an optimal estimation technique for retrieving the ash cloud height and mass loading. In addition, a separate program, which ingests the CLAVR-X results and issues an automated warning, if warranted, was created. This algorithm, along with the updated version of CLAVR-X, will be delivered to the Office of Satellite Data Processing and Distribution (OSDPD) in the fall of 2009 for pre-operational implementation. The updated version of CLAVR-X was successfully tested on a non-operational test computer in OSDPD.

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. The CIMSS Automated Dvorak Technique (ADT) was given “operational status” at NESDIS/SAB after the Critical Design Review (CDR) held in May 2008. The value of the ADT product as a tool that supports decision making has been demonstrated through various comments on its use by tropical storm forecasters. We provide the following as a recent example of the value of this CIMSS derived product (with bold face added for emphasis):

> TROPICAL STORM RICK DISCUSSION NUMBER 19
> NWS TPC/NATIONAL HURRICANE CENTER MIAMI FL EP202009
> 800 PM PDT MON OCT 19 2009
>
> RICK HAS BEEN WEAKENING AT A RAPID PACE...ALMOST AS FAST AS IT STRENGTHENED SEVERAL DAYS AGO. CONVENTIONAL AND MICROWAVE SATELLITE DATA SHOW THAT THE LOW-LEVEL CENTER IS NOW COMPLETELY EXPOSED TO THE WEST AND SOUTHWEST OF A SHAPELESS CLUSTER OF DEEP CONVECTION. DVORAK FINAL-T AND CI NUMBERS ARE NOW 3.5/4.5 FROM TAFB AND SAB...BUT BOTH AGENCIES WERE CONSTRAINED BY THE DVORAK RULES AND ACTUALLY HAD DATA T-NUMBERS OF 3.0. IN ADDITION...**THE LATEST UW-CIMSS ADT 3-HOUR ESTIMATE IS 3.1 WITH A CI OF 3.6. THEREFORE... RICK IS DOWNGRADED TO A 60-KT TROPICAL STORM.**

CIMSS has a strong partnership with NOAA in the GOES-R program. CIMSS began instrument trade studies in 2000 to define to imager and sounder instrument specifications for the next generation of GOES to meet the user requirements. CIMSS is active in the GOES-R Algorithm Working Group (AWG) activities, developing algorithms and writing Algorithm Theoretical Basis Documents (ATBDs) for various required products. Many of these algorithms are based on research CIMSS has conducted over the last 5 years. CIMSS is also developing proxy data sets and models 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 temporal and spatial scales.

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 has a strong national and international reputation for developing new methods of analyzing satellite observations. NOAA and CIMSS scientists continue to work side-by-side in developing new applications that support aviation hazards. CIMSS is developing these analysis methods for turbulence, volcanic ash and convective initiation that can be adapted to the GOES-R ABI instrument. 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 conduct research that supports 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. Working closely with NOAA, CIMSS scientists perform trade studies on the spectral coverage/resolution, spatial resolution, temporal resolution and radiometric resolution.

CIMSS is active in the international effort to calibrate the world's environmental satellites: Global Space-based Intercalibration System (GSICS). One of the goals of this undertaking is ''to improve the use of space-based global observations for weather, climate, and environmental applications through operational intercalibration of the space component of the World Weather Watch's (WWW) Global Observing System (GOS) and Global Earth Observing System of Systems (GEOSS)". Intercalibration of broadband geostationary imagers with a high-spectral-resolution instrument such as AIRS and IASI (and eventually CrIS on NPOESS) represents a major step in reaching the goals set forth by GEOSS and the World Meteorological Organization (WMO). 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.

In addition to supporting the next generation geostationary weather satellite, CIMSS scientists work closely with the NOAA/ASPB scientists stationed in Madison to support the next generation polar satellite instruments, including NPP/NPOESS. We support calibration/validation activities, and cloud and sounding algorithm work.

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 6 of the 21 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. Three graduate students participated in the CoRP 2009 symposium held on the City College of New York, with Chian-Yi Liu receiving one of the presentation awards. This past year Zhenglong Li finished his PhD on "Improvements and Applications of Atmospheric Soundings from Geostationary Platform." The work demonstrated the quality and utility of soundings derived in the presence thin high clouds or low opaque cloud.

NOAA grants to CIMSS also supported undergraduate student research projects. For example, Annie Lenz, conduct research on transverse bands and clear air turbulence and in January 2009 received the American Meteorological Society's Father Macelwane Award, which recognizes an original undergraduate student research paper. She is currently attending graduate school at Purdue. In spring 2009 CIMSS supported undergraduate Sarah Monette, who is now a graduate student at UW-Madison continuing her research on overshoot tops as identified in satellite images.

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]. One hundred and seventeen new GOES-related "mini-cases", with many showing displays from AWIPS, are on the CIMSS Satellite Blog. 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). 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 Direct Broadcast Conference and the Education Symposium at the 2009 AMS Conference in Phoenix. CIMSS broadened this education effort in 2009 by facilitating a G6-12 teacher workshop held in conjunction with the Federation of Earth Science Information Partners (ESIP) summer conference which partnered regional science teachers with a national network of remote sensing researchers. We collaborate with NOAA on our on-line education activities on climate change.

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:

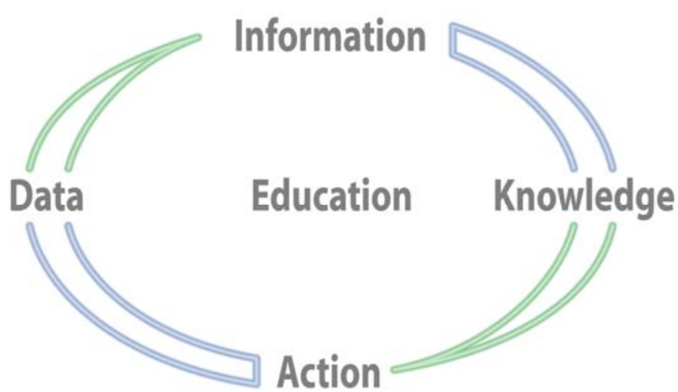
- Foster collaborative research among NOAA, NASA, and the University in those aspects of atmospheric and earth system science that exploit the use of satellite technology;
- Serve as a center at which scientists and engineers working on problems of mutual interest can focus on satellite-related research 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, 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 1st geostationary sounder) and GOES-8/12 design, testing, and checkout are now assisting with similar activities in GOES-R. In addition to bringing "corporate memory" to this new GOES program, 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. This year the National Climate Data Center stationed a research scientist at CIMSS to further build collaborations. CIMSS hopes 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 NPOESS Integrated Program Office (IPO), supporting the instrument design and algorithms of the next generation operational imager and sounder on polar satellites (NPP/NPOESS).

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 5 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.

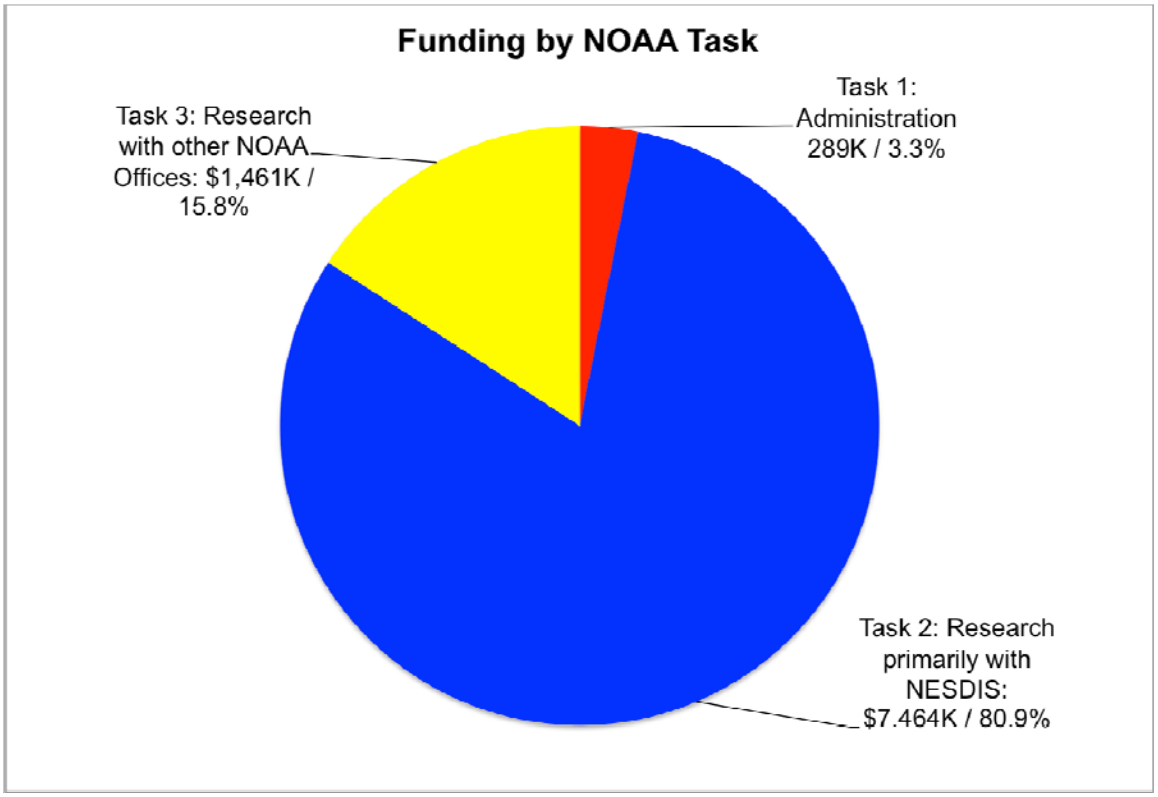
3. NOAA funding to CIMSS in FY2009, summarized by Task, NOAA Strategic Goal and CIMSS Research/Education Theme

In 2008, funding to CIMSS through this Cooperative Agreement totaled $8.4M. The following tables and graphics show the distribution of these funds by Task, by NOAA Strategic Goal and by CIMSS Research and Outreach Theme.

Funding by NOAA task

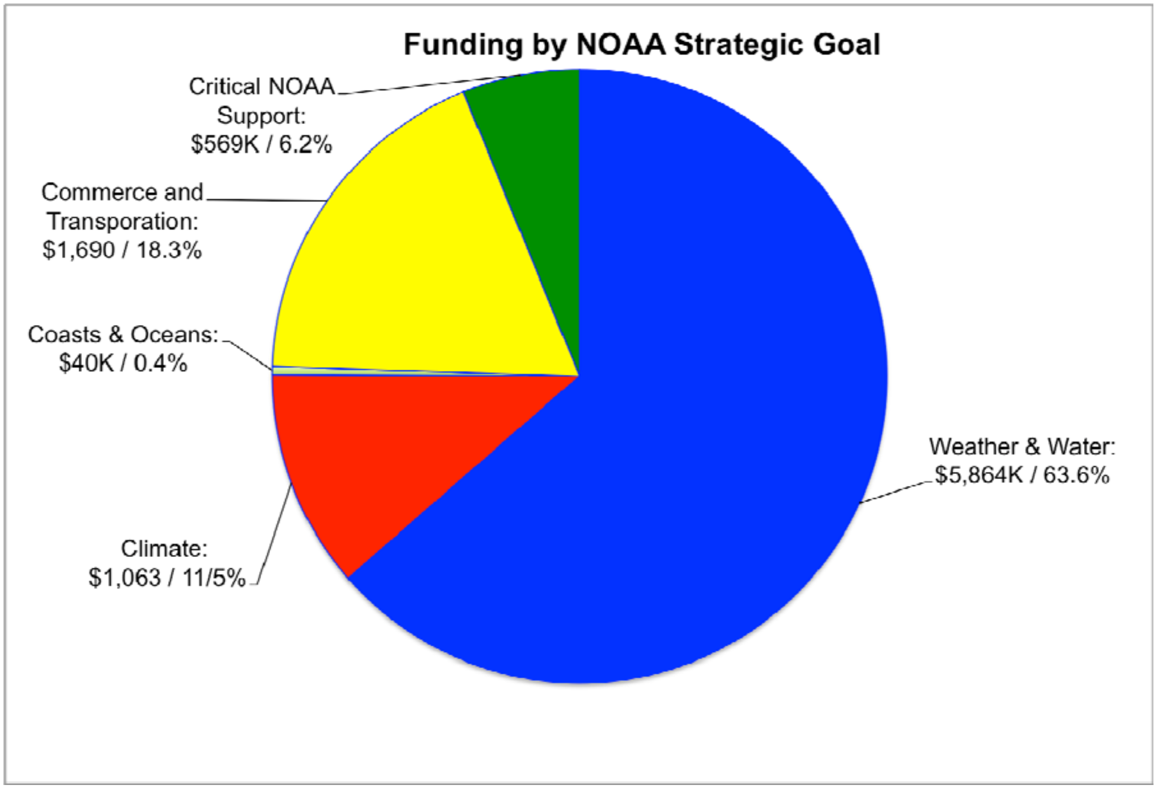
CIMSS Task	Funding in dollars	Percentage
Task 1: Administration	$ 289,000K	3.1%
Task 2: Research primarily with NESDIS	$ 7,476,000K	81.1%
Task 3: Research with other NOAA Offices	$ 1,461,000K	15.8%
	$ 9,226,000K	

Note: Integrated Program Office (IPO) funding through the Cooperative Agreement is split between Task 2 and Task 3, based on topic.



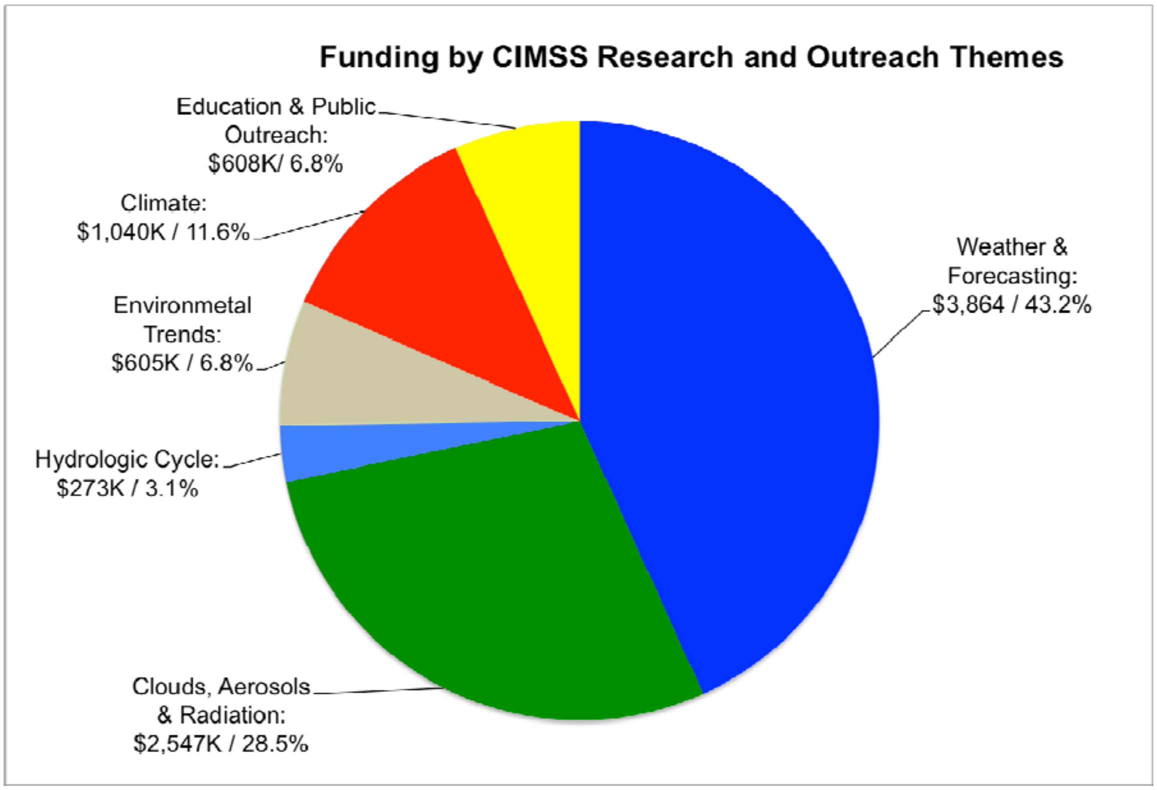
Funding by NOAA Strategic Goal

NOAA Strategic Goal	Funding in dollars	Percentage
Weather and Water	$ 5,864,000	63.6%
Climate	$ 1,063,000	11.5%
Coasts and Oceans	$ 40,000	0.4%
Commerce and Transportation	$ 1,690,000	18.3%
Critical NOAA Support	$ 569,000	6.2%
	$ 9,226,000	



Funding by CIMSS Research and Outreach Themes

CIMSS Theme	Funding in dollars	Percentage
Weather and Forecasting	$ 3,864,000	43.2%
Clouds, Aerosols and Radiation	$ 2,547,000	28.5%
Hydrologic Cycle	$ 273,000	3.1%
Environmental Trends	$ 605,000	6.8%
Climate	$ 1.040,000	11.6%
Education and Public Outreach	$ 608,000	6.8%
	$ 8,937,000 (Task 1 not included)	



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
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 August 2004. 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, Department of Meteorology, Florida State University
Steve Goodman	Deputy Director, Ctr. for Satellite Appl. and Research, NOAA/NESDIS
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

CIMSS Project Leads: Steven Ackerman, Thomas Achtor
CIMSS Support Staff: Maria Vasys, Leanne Avila, Wenhua Wu, Jenny Stepp
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 1st 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/). On the recently re-designed home page, 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 funds also 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 also provided support for the CIMSS support for the International (A)TOVS Working Group's conferences, ITSC-16 and ITSC-17. 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.

The CIMSS Base grant partially supported the research into and publication of an article on "Using a Publication Analysis to Explore Mission Success". The publication explores the analysis of peer-reviewed journal publications as a measure of research success at CIMSS. The article was published in the Bulletin of the American Meteorological Society, Vol. 90, No. 9, September 2009, pages 1313-1320.

Additional funds were provided to CIMSS in support of graduate student travel to the CORP 6th Annual CoRP Symposium, 8-18 & 19-2009 at CREST in NYC: "Extracting the Maximum Information from Remote Sensing Observations". Mat Sitkowski, Chian-Yi Liu and Aronne Merrelli attended and gave presentations at the meeting.

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

2.1. Validation and Improvement of Convective Nowcasting Products

Task Lead: Wayne Feltz
Support Staff Scientists: Kristopher Bedka, Justin Sieglaff, and Lee Cronce
NOAA Collaborator: Robert Rabin
NOAA Strategic Goals addressed:

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

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 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 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 (233 K or -40° C). Since the category 3 storms are closest to reaching maturity, the lead-time is lowest of the three categories but will also have the lowest false alarm rate.

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 has also requested the N-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 in turn provided us with a list of improvements to implement from in-field operational feedback. More time is needed to conduct thorough validation of signal and incorporate improvements before the product is a viable PSDI candidate. The algorithm methodology has been in development since November 2008 with multiple improvements; however, the algorithm needs more evaluation to make sure we understand when the algorithm performs best with continued optimization from SPC feedback. One goal is to automate and improve POD and FAR numbers using lightning data and eventually use an object tracking methodology to implement radar vs. satellite CI POD and FAR values. NLDN data was collected during the SPC HWT experiment for this validation exercise. Since GOES product validation is ongoing, results will be prepared and described in the subsequent reports.

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*.

Bedka, K. M., W. F. Feltz, and J. Sieglaff, 2009: Nowcasting Convective Storm Initiation Using Box-Averaged Cloud-top Cooling and Microphysical Phase Trends. In preparation, to be submitted to *Journal of Applied Meteorology and Climatology*.

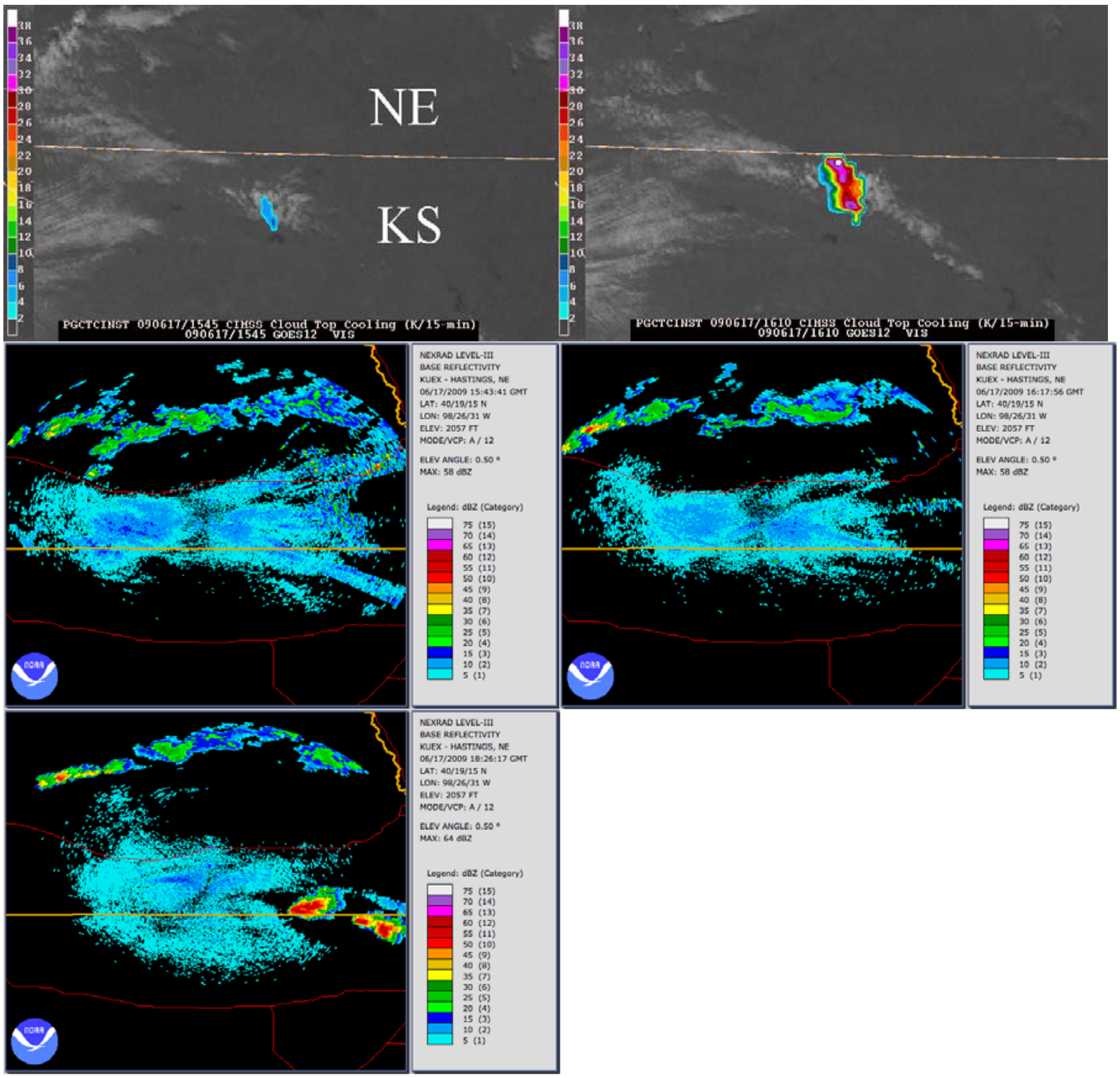


Figure 2.1.1. GOES imager convective initiation nowcast from June 17, 2009 of GOES-12 Imager-derived Cloud Top Cooling (CTC) at 1545 UTC (upper left panel), 1610 UTC (upper right panel). The radar images at the time of the 1545 CI nowcast (middle left), 1617 UTC (middle, right and,1826 UTC (bottom panel).

2.2 Intercalibration

CIMSS Project Lead: Mat Gunshor
CIMSS Support Scientists: Hal Woolf, Jim Nelson
NOAA Collaborators: Tim Schmit
NOAA Strategic Goals Addressed:

- 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:

- Climate

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. CIMSS receives requests from various users confirming the calibration accuracy for both domestic and international geostationary imagers; such requests have come in the recent past from the Navy, OSDPD, STAR, and JMA.

This proposal covered 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.
It was expected that further assessment of the current AIRS gap-filling method would continue.

CIMSS proposed to continue to contribute to NOAA's cal/val efforts especially in terms of cooperating with the international GSICS and partners on that committee.

CIMSS proposed to continue to work with NOAA scientists on issues affecting the GOES-13 Imager 13.3 micrometer band. Prior efforts resulted in a new SRF being provided by the instrument vendor and CIMSS continued to work with NOAA in assessing the feasibility of shifting that SRF an additional amount.

CIMSS proposed to continue maintenance of GEO SRFs. CIMSS provides radiance to brightness temperature conversion coefficients to McIDAS for new instruments. These SRFs are used in fast forward models (CRTM, PFAAST) as well as for intercalibration. The forward model transmittance coefficient files are used in operational processing of most GOES products (retrievals, cloud products, winds, etc).

Summary of Accomplishments and Findings

IASI data were used to test the AIRS spectral gaps filling method. By applying the typical AIRS spectrum's gaps to IASI data a gap-filled, AIRS-like, IASI spectrum can be compared to the unaltered IASI spectrum. It was discovered that the current CIMSS method being employed to address AIRS spectral gaps does not yield optimal results for all atmospheres. While it typically does well in relatively warm, dry, and clear situations, it is not as robust in cloudy or wet atmospheres. One of the scientists working with GSICS from Japan developed a gap-filling method based upon the CIMSS method which is likely an improvement. It is unpublished work and hence documentation is lacking but it is expected that code can be obtained through GSICS. It should be noted that it is unclear yet how much this will affect intercalibration results. While a gap-filled spectrum seems to be a poor substitute at times for actual atmospheric measurements in individual IASI or AIRS channels, when convolving a spectrum with a GOES spectral response function, it seems to have a very small impact.

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 us keep up with work being done in other member-states.

Work continued with the GOES-13 Imager's band 6, the 13.3 micrometer channel. CIMSS contributed to a memo written by Fred Wu of NOAA/NESDIS. To compensate for differences seen in comparisons to AIRS and IASI, the GOES-13 band 6 SRF was shifted further than what was proposed by the instrument vendor, ITT, and became the official SRF. Comparisons of GOES-13 to both AIRS and IASI have taken place with this new official SRF. The new SRF has yielded greatly improved results with GOES-13 now comparing to both AIRS and IASI with a near 0 K temperature difference on average since being implemented operationally by NESDIS. Using the original SRF, GOES-13 was approximately 1.8 K colder than IASI but with the new SRF it is only approximately 0.1 K colder (dates of comparisons cover the entire period GOES-13 has collected data, including during the original checkout period). Figure 2.2.1 shows the evolution of SRFs for this band.

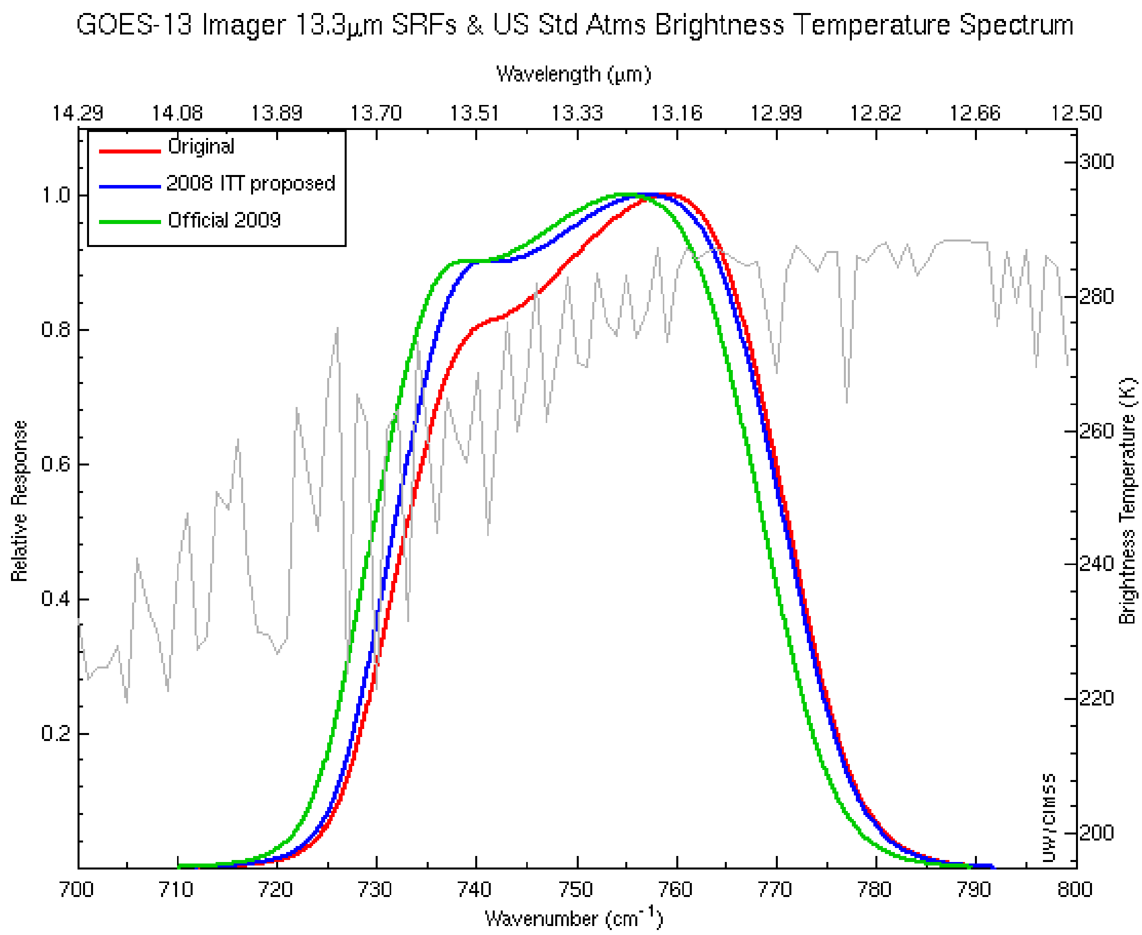


Figure 2.2.1. The GOES-13 Imager 13.3 micrometer band spectral response function (SRF) plotted against a brightness temperature spectrum calculated from the U.S. Standard Atmosphere. The original SRF (red) was replaced in 2008 by the instrument vendor based on their pre-launch lab measurements (blue). On-orbit testing revealed still further disparities in comparison with both AIRS and IASI and NOAA officially shifted the SRF (green) to longer wavelength (shorter wavenumbers).

Intercalibration with IASI data continues to grow. Work is being done to assess the impact of missing IASI FOVs and how best to address them. It has progressed to the point where useful comparisons can be done (as shown with the GOES-13 analysis). A poster presentation of results comparing IASI to the world's geostationary imagers is expected to be made at the GOES User's Conference in November, 2009.

Maintenance continued with GOES SRFs. CIMSS provided the radiance to brightness temperature conversion coefficients to McIDAS for the new GOES-13 SRF. This became part of a new release of McIDAS software that came out earlier this year. Detector averages of these SRFs were also made available for use in generating fast forward model transmittance coefficient files. After being tested at CIMSS these files were eventually sent to NOAA operations to be used in the generation of GOES products.

Publications and Conference Reports

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

Gunshor, Mathew M.; Schmit, T. J.; Tobin, D. C. and Menzel P., 2009: Intercalibration of the world's geostationary imagers with high spectral resolution data. 16th Conference on Satellite Meteorology and Oceanography and 5th Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, Phoenix, AZ, 11-15 January 2009. American Meteorological Society, Boston, MA.

Wu, X.; Schmit, T.; Galvin, R.; Gunshor, M.; Hewison, T.; Koenig, M.; Tahara, Y.; Blumstein, D.; Li, Y.; Sohn, S. and Goldberg, M., 2008: Investigation of GOES imager 13 micron channel cold bias. 2008 EUMETSAT Meteorological Satellite Conference, Darmstadt, Germany, 8-12 September 2008. Proceedings. European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), Darmstadt, Germany, Unpaged.

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

CIMSS Project Leads: Justin Sieglaff
CIMSS Support Scientists: Cory Calvert
NOAA Collaborators: Michael Pavolonis and Andrew Heidinger
NOAA Strategic Goals Addressed:

- 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

In FY07, GIMPAP funded the real-time implementation of GOES-R Advanced Baseline Imager (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.

Summary of Accomplishments and Findings

In FY09, we continued to analyze the time evolution of convective cloud properties for a variety of case studies. One interesting feature that we have noticed with a large number of severe storms is the presence of small ice crystals at or near cloud top. Not only is the small particle signature evident in near-infrared reflectances, it is also often seen in the spectral cloud emissivity slope in the 11 – 13 μm infrared "window." Previous researchers have not exploited the infrared "window" signal of deep convective clouds. It is critical that the information content of the infrared "window" be fully utilized since it is independent of solar zenith angle.

In order to truly understand the relationship between the presence of small ice crystals and trends in storm strength, the source of the small ice crystals needs to be identified. One plausible source is the overshooting convective core, which is most often located in the lower stratosphere. Within the convective core, supercooled liquid water droplets rise very quickly such that they freeze homogeneously near the cloud top. With a minimum amount of aggregation and vapor deposition, the ice crystals cannot grow to larger sizes, and, hence, tend to have an effective radius < 15 μm. However, small ice crystals are not just observed in the convective core, they are observed over large areas atop the storm. At the edge of the overshooting dome, gravity wave breaking can occur due to the very large gradients in potential temperature and specific humidity between the convective core and ambient stratosphere. This gradient is related to the storm intensity. The gravity wave breaking can cause a portion of the overshooting dome, with its small ice crystals, to spread out over the underlying thunderstorm anvil, which is located near the tropopause. While this sequence of physical processes may cause a layer of small ice crystals in the stratosphere to spread out over the underlying anvil, it does not guarantee that the small particle signature will be evident in the 11 – 13 μm "window."

Using a sophisticated radiative transfer model, simulations were performed to verify that a semi-transparent small particle dominated cloud layer in the stratosphere overlying an optically thick anvil layer at the tropopause can cause the small particle infrared "window" signal often observed by GOES for severe storms. In these simulations, the temperature, visible optical depth, and effective particle radius of the optically thick tropospheric anvil cloud were fixed at 216 K, 40, and 30 μm, respectively. The temperature, visible optical depth, and effective particle radius of the overlying stratospheric cloud layer were varied. For clarity, the simulations were performed at high spectral resolution and 11 – 12 μm brightness temperature differences were calculated after applying the GOES-10 spectral response functions. The results do not change significantly if other GOES spectral response functions are applied (including the 13.3 μm spectral response function in lieu of the 12 μm spectral response function).

Results from two sets of simulations are shown in Figure 2.3.1. In the first set of simulations, the stratospheric cloud layer temperature and effective particle radius were set to 216 K (the same temperature as the underlying anvil) and 5 μm, respectively. In the second set of simulations, the stratospheric cloud layer effective particle radius was once again set to 5 μm, but the temperature was set to 206 K (10 K colder than the underlying anvil). In both sets of simulations, the visible optical depth of the stratospheric cloud layer was varied from 0 to 2. The results indicate that the cloud emissivity slope (which manifests itself in the brightness temperature difference) observed for several severe storms by GOES can only be present if the temperature of the stratospheric cloud layer is lower than the temperature of the underlying anvil. In the stratospheric cloud layer, the ambient stratospheric air is generally warmer than the tropopause. The overshooting dome, however, is much colder than the ambient stratospheric air since air parcels continue to cool adiabatically as they overshoot the tropopause. The greater the overshoot, the colder the overshooting dome relative to the tropopause temperature. When saturated air from the overshooting dome breaks away (via gravity wave breaking), it will have a temperature that is lower than the ambient stratosphere. Thus, the stratospheric cloud layer can be colder than the tropopause anvil layer. Mixing with the ambient stratospheric air will eventually increase the temperature of the stratospheric cloud layer in the absence of a cold reservoir (e.g., continued gravity wave breaking from the cold overshooting dome).

In summary, we have determined a possible physical explanation for the deep convective cloud microphysical patterns observed by GOES bi-spectral infrared "window" measurements. While this explanation needs to be tested further using dynamical cloud resolving models, it does imply that the probability of observing the presence of small ice crystals with infrared measurements increases with increasing storm strength (e.g., bigger/stronger updrafts). Stronger updrafts will produce colder overshooting domes and increased gravity wave breaking, resulting in colder stratospheric ice crystal layers. As such, the presence of a small ice crystal layer in the stratosphere, which is observable in the infrared, may be a major precursor of a severe weather event. We will continue to improve our understanding of the spatial and temporal patterns in convective cloud properties.

Publications and Conference Results

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).

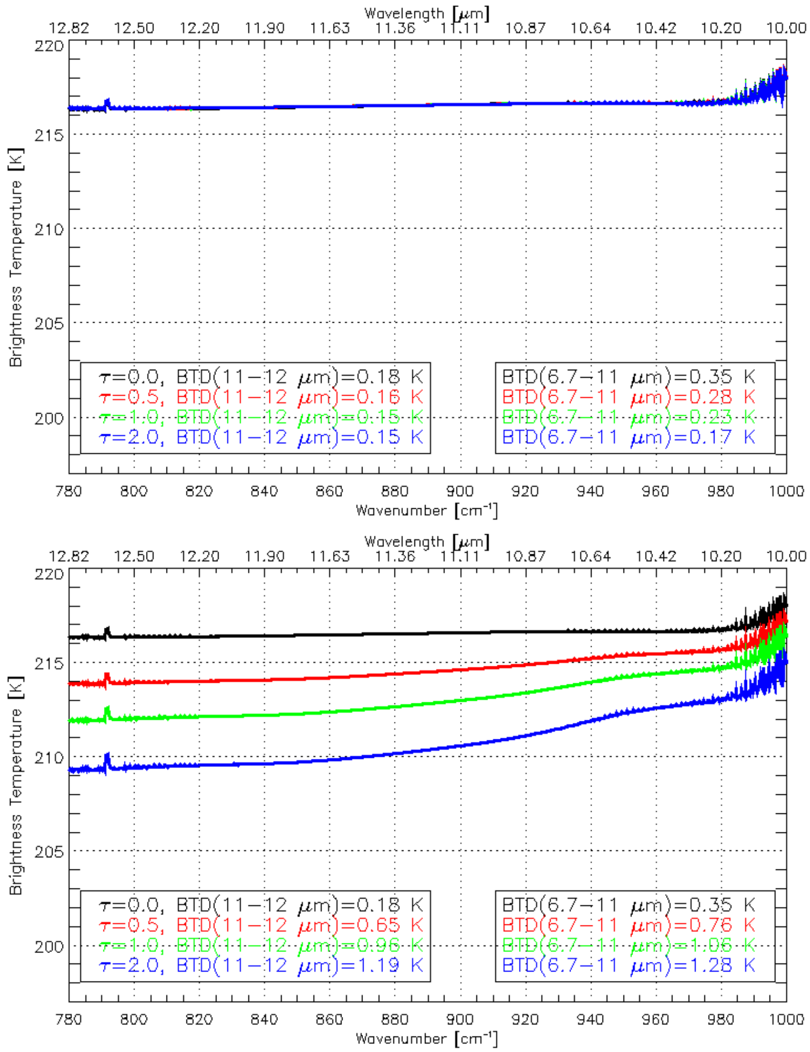


Figure 2.3.1. Simulations were performed to verify that a semi-transparent small particle dominated cloud layer in the stratosphere overlying an optically thick anvil layer at the tropopause can cause the small particle infrared "window" signal often observed by GOES for severe storms. In the simulations shown in this figure, the temperature, visible optical depth, and effective particle radius of the optically thick tropospheric anvil cloud were fixed at 216 K, 40, and 30 µm, respectively. Two sets of simulations were performed. In the first (top panel), the stratospheric cloud layer temperature and effective particle radius were set to 216 K (same temperature as the underlying anvil) and 5 µm, respectively. In the second set of simulations (bottom panel), the stratospheric cloud layer effective particle radius was once again set to 5 µm, but the temperature was set to 206 K (10 K colder than the underlying anvil). In both sets of simulations, the visible optical depth of the stratospheric cloud layer was varied from 0 to 2.

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

CIMSS Project Lead: Christopher Rozoff
NOAA Collaborator: James 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

Improving the forecasting skill of tropical cyclone intensity, including rapid intensification (RI), is a primary goal of NOAA. A particularly dangerous threat to coastal and marine interests is an RI event that is not successfully predicted. Our current forecasting skill of RI is currently limited. Statistical forecast schemes incorporating environment-based and satellite derived predictors appear to offer promising forecasting skill in both tropical cyclone RI and secondary eyewall formation forecasting (e.g., Kaplan et al. 2009; Kossin and Sitkowski 2009). This project has utilized the Statistical Hurricane Intensity Prediction Scheme (SHIPS) and GOES infrared (IR) predictors in conjunction with a Bayesian probability-based forecasting scheme to predict tropical cyclone RI.

As summarized in the 2008 annual cooperative report, the forecasting skill of the Bayes probability scheme is promising. For example, cross validation for the 1989-2007 period showed the scheme was able to detect RI with relatively low false alarm rates and was skillful compared to climatology. A substantial amount of this skill was gained from the use of GOES IR structural predictors, which can indicate important RI signatures such as the formation of an eye or the development of structural symmetry. As such, it is believed that further exploring remotely sensed structural aspects of tropical cyclones will enhance intensity change processes.

Summary of Accomplishments and Findings

In order to exploit the structural detail of tropical cyclones in GOES IR imagery, a principle component (PC) analysis of storm-centered, azimuthally-averaged GOES-IR brightness temperatures over the Atlantic and East Pacific was carried out. The empirical orthogonal modes formed from Atlantic data appear in Figure 2.4.1. Adding the first PC of the azimuthally mean brightness temperatures as a predictor for the standard Atlantic configuration described earlier improves the Brier and Pierce skill scores from 9.8 and 5.8 % to 10.5 and 8 %, respectively. On the other hand, the Eastern Pacific forecasts possess optimal skill by incorporating the first 3 PCs and using the maximum brightness temperature from radii spanning 0 to 30 km rather than the percentage of area from 50 to 200 km radius with brightness temperatures less than -30^{o}C. With these predictors in mind, the Pierce skill score improves to 18.5 % from 8.7%. Thus, the use of simple PC predictors shows how resolving details in cloud structure can substantially improve statistical forecasting. This analysis proved far more fruitful than a Fourier analysis of the inner-core cloud structure. However, higher resolution cloud structure from other platforms such as passive microwave imagery should be studied in regard to its potential predictive properties.

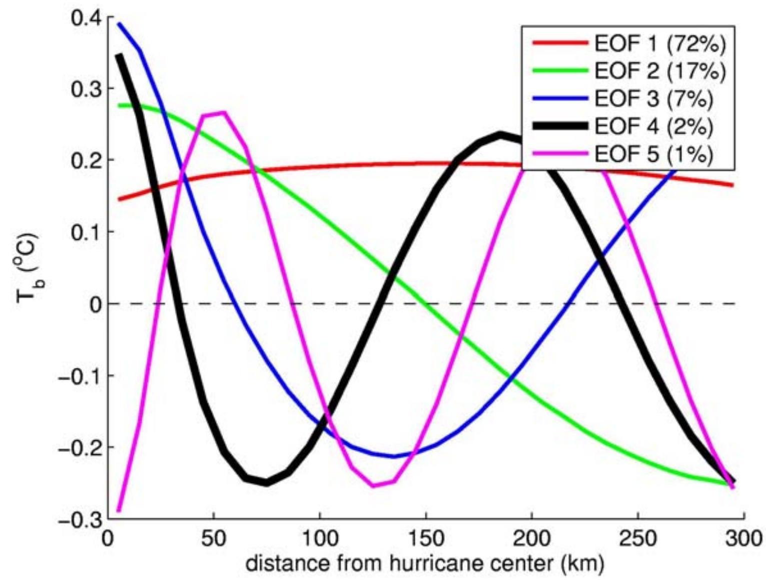


Figure 2.4.1. The five leading empirical orthogonal models (EOFs) determined from hurricane-centered azimuthal mean IR brightness temperatures over the Atlantic Ocean. The percent of variance explained by each EOF is shown beside each EOF in the legend.

Incorporating SHIPS and GOES IR data, we have carried out a comparison between the naïve Bayes classifier developed through this project (trained on the years 1989-2007) and the National Hurricane Center rapid intensity index (RII) that is based on linear discriminate analysis (Kaplan et al. 2009). The predictors used in the comparison are the 12-h persistence, 850-200 hPa vertical wind shear, 200 hPa divergence, the departure of the storm's current intensity from its maximum potential intensity, 850 to 700 hPa relative humidity, ocean heat content, the percentage of pixels in IR imagery with brightness temperatures less than -30°C in the radial region of from r =50 to 200 km, and the standard deviation of GOES brightness temperatures. Figure 2.4.2 shows the Brier skill score (BSS), Pierce skill score (PSS), probability of detection (POD), and false alarm rate (FAR) for three thresholds of RI, including intensification rates of at least 25, 30, and 35 kts per 24 h period. According to the BSS index, the Bayes scheme possesses some skill for only the 25 kts RI threshold (BSS = 9.6%), while the SHIPS-RII scheme only contains favorable BSS numbers for 35 kts. Overall, the results are mixed and the evaluation should be carried out over a much longer time frame (such as through a cross-validation of hindcasts made over the period of 1989 to 2008).

Finally, it has been of interest to explore the potential relationship between RI and secondary eyewall formation (SEF). It has often been conjectured that SEF events often follow RI events. Therefore, we have explored the relationship in the SHIPS data and also by using the Bayes RI forecasting scheme. It turns out RI events often precede SEF, and furthermore, that there is a statistically significant relationship between the Bayesian RI probability and SEF. Atlantic Hurricane Wilma (2005) can help illustrate the relationship. Figure 2.4.3 shows the Best Track intensity through the course of Wilma's lifetime. In terms of maximum surface wind speed, an historical RI event occurs from 18-19 October, which the Bayesian RI scheme (based on data from 1989-2008) can successfully predict/diagnose. Using the environmental and GOES IR predictors described in Kossin and Sitkowski (2009) (which differ from the predictors of the RI prediction scheme in numerous ways), the Bayesian SEF index is also plotted in Figure 2.4.3 for periods when the storm intensity was at least 65 kts. The SEF index correctly identifies the second SEF event, but fails to predict the first SEF event that commenced during the RI event.

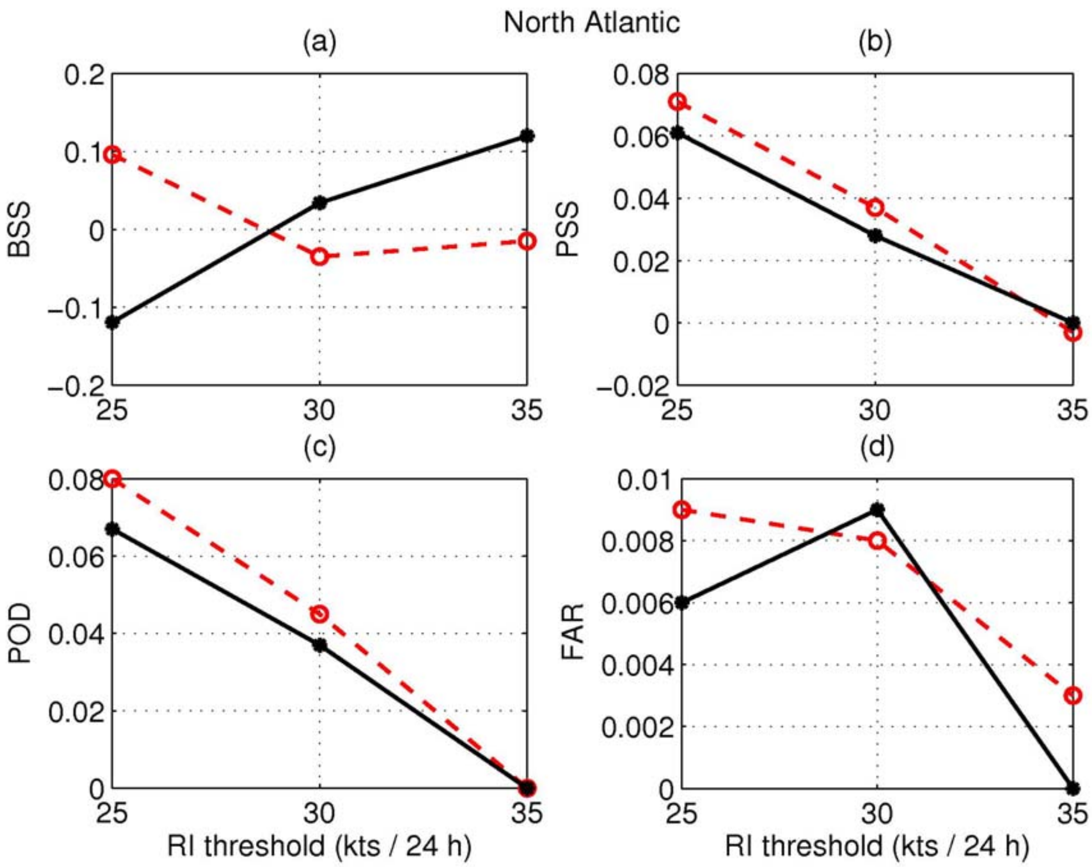


Figure 2.4.2. A comparison of various measures of forecast skill for the 2008 North Atlantic hurricane season, using the Bayes scheme (red dashed) and SHIPS-RII (black solid). The skill quantities include (a) Brier skill score, (b) Pierce skill score, (c) probability of detection, and (d) false alarm rate.

However, using the Bayesian RI index (which turns out to be statistically independent of the predictors used in the SEF scheme) as a predictor in the SEF prediction scheme, the probability of SEF jumps up to 100% at the beginning of the first SEF event. Evaluating the SEF scheme by leave-one-year-out cross validation over the years 1997-2008, we can demonstrate the improvement of the SEF scheme when the Bayesian RI index is used as a predictor. The SEF scheme improves remarkably. The Brier and Pierce skill scores improve from 19.9 and 21.7 % to 22.1 and 34.3 %, respectively. This is because the probability of detection is increased from 24.2 to 38.1 %.

Publications

Rozoff, C. M., and J. P. Kossin, 2009: Hurricane rapid intensification prediction using a naïve Bayes classifier approach. *Wea. Forecasting*, in preparation.

References

Kaplan, J., M. DeMaria, and J. A. Knaff, 2009: A revised tropical cyclone rapid intensification index for the Atlantic and Eastern North Pacific basins. *Wea. Forecasting*, in press.

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

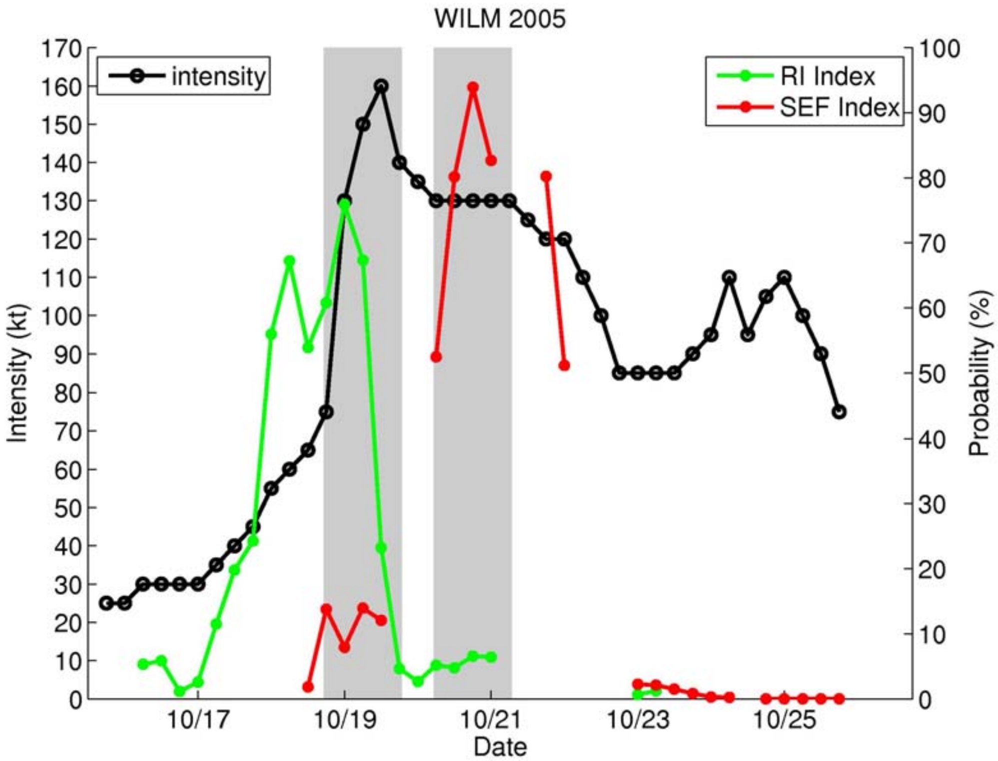


Figure 2.4.3. Evolution of current intensity (solid black line), the Bayes RI predicted probability of RI (green), and the Bayes secondary eyewall formation probability (Kossin and Sitkowski 2009) for Hurricane Wilma (2005). Each gray shaded region depicts a secondary eyewall formation event determined from passive microwave imagery. The secondary eyewall formation model does not assign a probability when intensity is less than 65 kts or when the storm center is over land.

2.5. GOES Single Field-of-view Cloudy Sounding Product Development

CIMSS Project Leads: Jun Li
CIMSS Support Scientist(s): Zhenglong Li, Jim Nelson
NOAA Collaborator(s): Tim Schmit
NOAA Strategic Goals Addressed:

- 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

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

(1) More validation on cloudy SFOV soundings have been performed. In the last year, we have developed an algorithm for retrieving atmospheric temperature and moisture profiles under cloudy situations. According to the GIMPAP technical advisory committee (TAC) general comments on more validation for cloudy soundings, two different data sets of temperature and moisture profiles are used for validation. The first one is the radiosonde observation (RAOB) data set from August 2006 to May 2007, collected by the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Program at Southern Great Plains (SGP) site at Lamont, OK (C1, 36°37' N, 97°30' W). The other data set consists of conventional RAOB measurements over the continental United States (CONUS) from January 2007 to November 2008. Both sets have been spatially and temporally collocated with the GOES-12 Sounder measurements and NCEP GFS forecast profiles to form two match-up databases. The ARM RAOB data are listed separately from the conventional RAOB because they are more frequent (4 times a day), and have better overall quality than the conventional RAOB (Turner et al. 2003). The RAOB/GOES/GFS-ARM match-up database is used as the primary database for validation. However, validation against conventional RAOB is also necessary because it is the only way to assure the algorithm works under different weather and surface conditions. Figure 2.5.1 shows the bias and RMS (root mean square) differences between moisture profiles and RAOBs. The results here are very similar to that using RAOB/GOES/GFS-ARM. Under thin cloud conditions, the largest improvements are in the upper troposphere; both the relative humidity (RH) and the mixing ratio show significant improvements. 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.

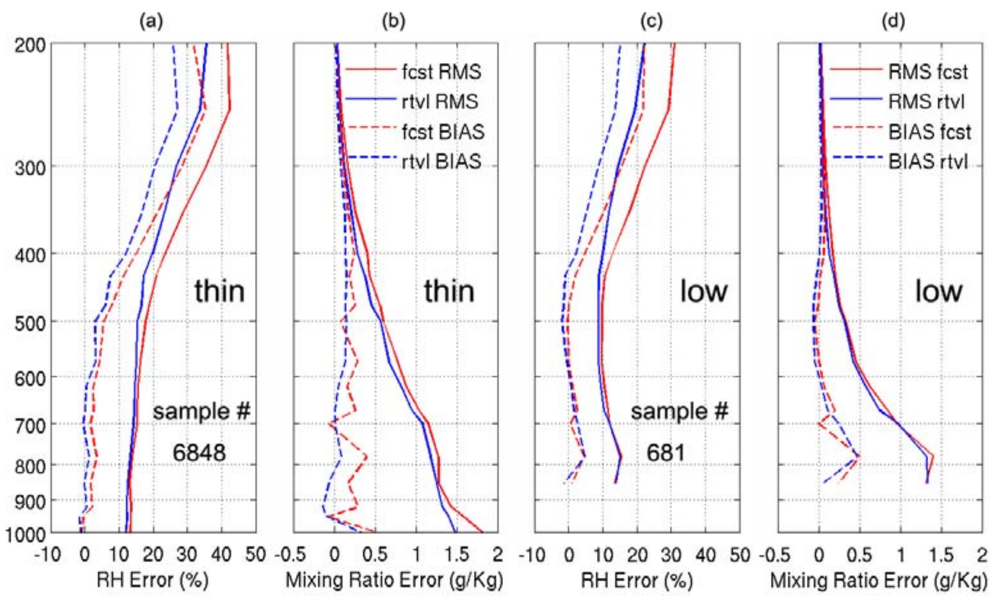


Figure 2.5.1. Validation of moisture profiles using RAOB/GOES/GFS match-up dataset over CONUS: a) relative humidity under thin clouds conditions, b) mixing ratio under thin clouds conditions, c) relative humidity under low clouds conditions, c) mixing ratio under low clouds conditions. The blue lines are retrievals, and the red lines are the GFS forecast. The dashed lines are the biases, and the solid lines are the RMS.

(2) The GOES single field-of-view cloudy sounding algorithm has been evaluated with CALIPSO. 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. Collocated GOES CTH (10 km spatial resolution) and CALIPSO level-2 (version V2.01) cloud product (5 km horizontal resolution),from 0 UTC of 13 April 2007 to 23 UTC of 14 April 2007 have been collected. The GOES CTH product from the CIMSS routine process, which is similar to the operational product, is also included in the comparisons. In total 1056 collocated samples have been found including 471 which are detected to be cloudy by both the GOES-12 Sounder and the CALIPSO. Both the old (CIMSS routine process) and the new (cloudy sounding algorithm) methods agree well with CALIPSO measurements. It appears the new retrievals show slightly better results than the old retrievals; the correlation coefficient is increased from 0.779 to 0.884, the RMS is reduced from 2.75 km to 2.37 km, and the standard deviation (STD) is reduced from 2.56 km to 1.92 km. The GOES cloudy sounding algorithm provides also reasonable CTH in cloudy skies.

(3) Severe storm nowcasting application of GOES cloudy sounding product. We also used the cloudy soundings for storm nowcasting analysis; a busted forecast case is used to demonstrate how the GOES cloudy soundings could be useful in short-term severe storm nowcasting. The GOES cloudy sounding derived products will be used to help avoid a severe storm forecast bust. At 12 UTC on 13 April 2007, the SPC (Storm Prediction Center) issued a moderate (MDT) risk of severe weather over portions of North Central, Northeast Texas, Southern Arkansas and Northern Louisiana. At 20 UTC, the moderate risk is upgraded to high risk (HIGH) (the potential exists for 20 or more tornadoes). However, finally there are only 4 confirmed tornado reports and no single report of wind speeds larger than 80 mph. These reports indicate that the previous high risk of severe storm forecast was wrong. In this case, the derived lifted index (LI) and TPW from the GOES-12 sounding retrievals are compared with the RUC (Rapid Update Cycle) 6-hour forecast and GFS forecast to show how the GOES cloudy sounding retrievals and the derived products could be useful in such a situation. Figure 2.5.2 shows the time sequence of the LI imagery. The LI images at 16, 17, 18, 19, 20 and 21 UTC are shown from the top to the bottom (Figure 2.5.2. (1) – (6)). The LI images from NCEP GFS forecast, the RUC (Benjamin et al. 2004) 6-hour forecast, GOES-12 clear-sky retrievals and GOES-12 clear plus cloudy retrievals are shown from right to left (Figure 2.5.2 (a) – (d)). The LI retrievals are shown in colors, whereas the 11 µm Tb (brightness temperature) values are shown in black/white, most of which are in cloudy regions with cloud optical thickness greater than 2. In this case, the GOES sounding retrievals again show earlier warning signs than the RUC 6 hour forecast and the GFS forecast. Large instabilities smaller than -7.5 K (reds) are revealed at 16 and 17 UTC. The GOES Imager animation (http://www-angler.larc.nasa.gov/armsgp/g8usa.html/) shows the outbreak of the storm occurring around 18 UTC. That gave two hours of early warning compared to GFS forecast and RUC 6-hour forecast. Although the GOES cloudy sounding retrievals do not reveal more large instabilities than the clear-sky ones during the first two hours, it does so in the later times. More importantly, the cloudy sounding retrievals significantly increase the coverage of the GOES-12 sounding product. After the outbreak of the storm (the green X in Figure 2.5.2 (6a) along the boundary between Texas and Oklahoma) at 18 UTC, the RUC successfully predicted the large instabilities to the south of the storm. During the next two hours (20 and 21 UTC), both the RUC 6-hour forecast and the GOES sounding retrievals reveal that the large instabilities (reds) are to the south of the storm and are about 300 km away from the storm.

Publications and Conference Reports

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.

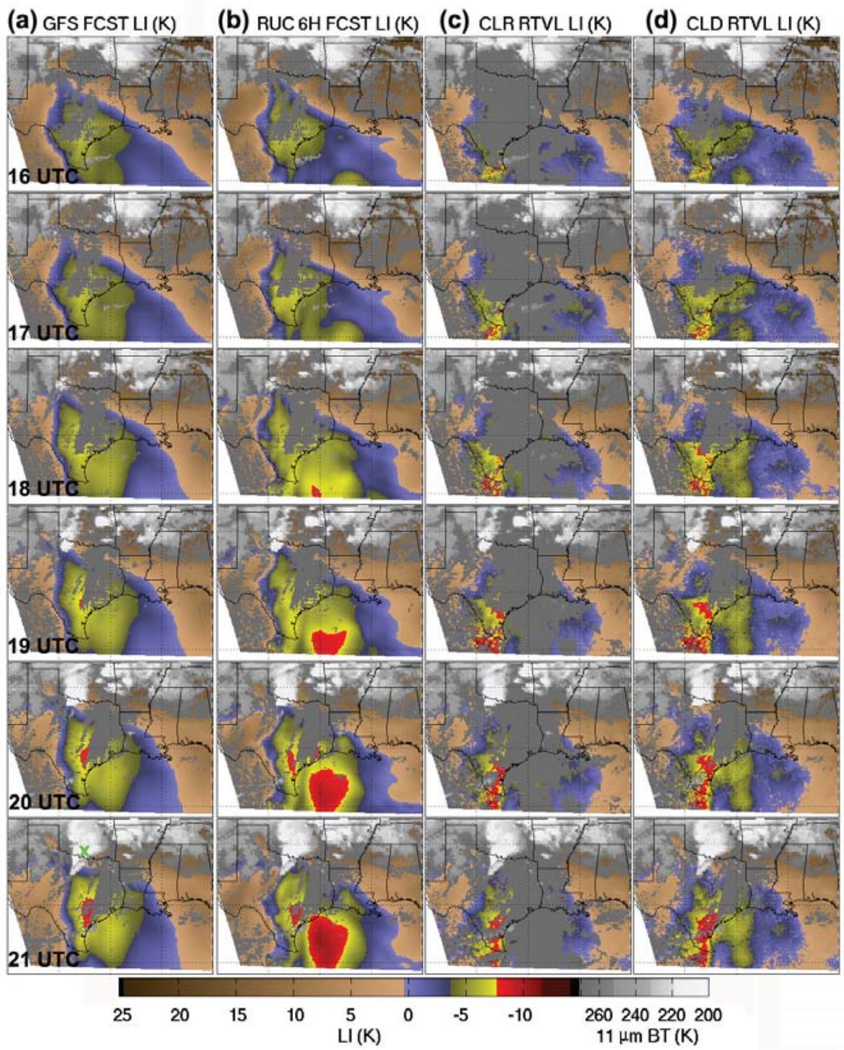


Figure 2.5.2. Time series of LI imagery on 13 April 2007. From top to bottom are 1) 16 UTC, 2) 17 UTC, 3) 18 UTC, 4) 19 UTC, 5) 20 UTC and 6) 21 UTC. From the left to the right are a) the GFS forecast, b) the RUC 6-hour forecast, c) GOES-12 clear-sky retrievals and d) GOES-12 clear plus cloudy retrievals.

Li, Zhenglong, J. Li, P. Menzel, T. J. Schmit, and J. Nelson, 2009: High Temporal GOES Sounding Retrievals in Cloudy Regions and Applications. 89th Annual American Meteorological Society (AMS) Conference, 11-15 January 2009, Phoenix, AZ.

Wade, G. S., J. Li, J. P. Nelson III, Z. Li and T. J. Schmit, 2008: Assessing development of a refined technique for retrieval of vertical profiles of temperature and moisture from the GOES Sounder, with current real-time products. NWA Annual Meeting, Louisville, KY, Oct. 2008.

References

Benjamin, S.G., D. Devenyi, S. S. Weygandt, K. J. Brundage, J. M. Brown, G. A. Grell, D. Kim, B. E. Schwartz, T. G. Smirnova, T. L. Smith, G. S. Manikin, 2004: An Hourly Assimilation-Forecast Cycle: The RUC. *Monthly Weather Review*, **132**, 495 - 518.

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.

Ma, X.L., T. J. Schmit, and W. L. Smith, 1999: A nonlinear physical retrieval algorithm - its application to the GOES-8 /9 sounder. *Journal of Applied Meteorology*, **38**, 501 - 513.

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

CIMSS Project Leads: Justin Sieglaff
CIMSS Support Scientists: Andrew Parker
NOAA Collaborator: Michael Pavolonis
NOAA Strategic Goals Addressed:

- 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.

During FY2009, we focused on three main points, 1) testing the ash algorithms at large viewing angles 2) identifying current shortcomings within the ash detection algorithm and determining how to best mitigate the shortcomings 3) readying a near-realtime system for in-house product evaluation.

Given their temporal resolution, spatial resolution, and spatial coverage, the GOES imagers are vital for monitoring volcanic ash. After a visit to the NWS and USGS in Anchorage, Alaska, we learned that

GOES products are frequently used for monitoring ash plumes over southern Alaska and the Aleutian Island chain despite the large satellite viewing angles. Given the frequent eruptions in this area (Redoubt, 2009, Kasatochi, 2008, and Okmok, 2008 and other smaller eruptions), and the high volume of aviation traffic, it was important to ensure that the GOES products being developed would be useful at large satellite viewing angles. A series of scenes from eruptions of Redoubt in March 2009 were examined and the physical retrievals were in agreement with similar near-nadir Advanced Very High Resolution Radiometer (AVHRR) retrievals despite the high GOES satellite-viewing angle (approximately 70 degrees). Figure 2.6.1 shows an example GOES-11 retrieval for an ash cloud produced by an eruption of Redoubt on March 26, 2009. Volcanic ash retrievals from the Advanced Very High Resolution Radiometer (AVHRR) yields similar results, which gives confidence that the GOES volcanic ash products will benefit high latitude locations, like the Aleutian Islands and southern Alaska.

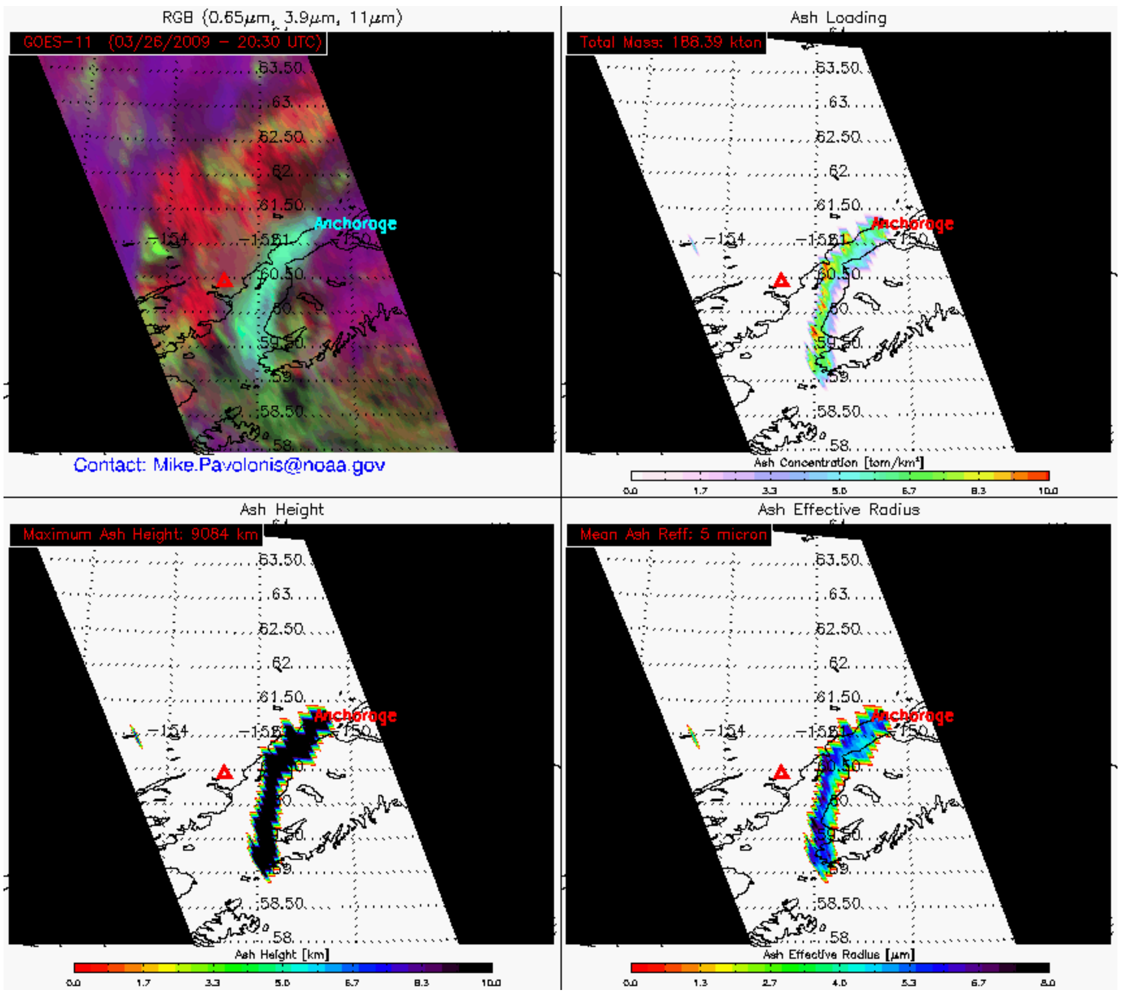


Figure 2.6.1. The upper left panel shows a false-color RGB image of the Redoubt volcanic ash plume near and south of Anchorage, Alaska at 2030 UTC March 26, 2009 as viewed by GOES-11. The coarseness of the image is due to large satellite view angle (near 70 degrees). The ash mass loading (km/ton^2), ash height (km), and ash effective particle size (µm) for this image are shown in the upper, right, lower left, and lower, right panels, respectively.

Despite our best efforts in developing the automated ash detection algorithm, the probability of false alarm is still too large for operational use. The current false alarm rate is about 0.01%. For operational use, a lower probability of false alarm is highly desirable. Exploratory research has indicated that in the absence of high spectral resolution data, advanced spatial techniques are needed in order to reduce the probability of false alarm. The false alarm problem and a potential solution are best illustrated with an example. Our current ash detection algorithm was applied to a 1997 eruption of Soufriere Hills, Montserrat. While the ash detection algorithm was able to capture nearly the entire ash cloud, it also produced several false alarms. Figure 2.6.2 illustrates why false alarms are unavoidable if spectral information alone is used to detect volcanic ash clouds with GOES. During the day, the GOES ash detection algorithm relies on the 3.9/0.65µm reflectance ratio (RAT), the 11 – 12µm brightness temperature difference (BTD), and the 12/11µm absorption optical depth ratio (β). Histograms of RAT and BTD were separately constructed for the volcanic ash cloud (e.g., all pixels that compose the ash cloud) and a meteorological cloud that was producing a false alarm. Notice how the spectral signature of some of the pixels in the volcanic ash cloud overlaps with the spectral signature of pixels in the meteorological cloud. This is why false alarms are unavoidable when relying solely on spectral information. However, the distribution of pixels that compose the volcanic ash cloud has a unique negative BTD tail and the reflectance ratio distribution peaks at very large values, which allows it to be uniquely identified when clouds are treated as objects. With additional effort, a cloud object based approach can be developed and automated. We will continue to perform exploratory research aimed at developing an object-based approach to volcanic ash detection.

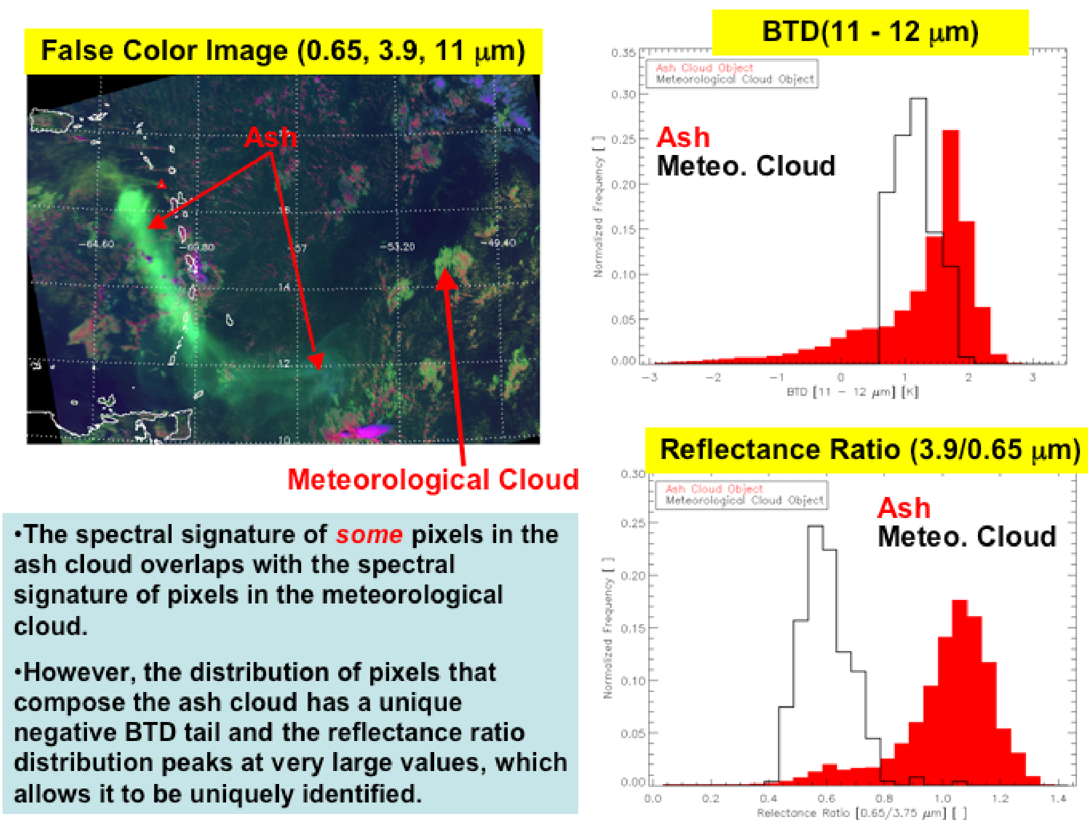


Figure 2.6.2. This figure illustrates that spectral information at a given pixel alone cannot be used to uniquely identify volcanic ash clouds with GOES, but the spectral information from a distribution of pixels can be used to uniquely identify volcanic ash. In this figure, BTD stands for brightness temperature difference.

Publications and Conference Reports

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. To be submitted to *J. Atmos. Sci.*

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. Atmos. Sci.*

2.7. Global Geostationary Fire Monitoring and Applications

CIMSS Project Lead: Chris Schmidt
CIMSS Support Scientists: Jason Brunner, Elaine Prins, Joleen Feltz, and Jay Hoffman
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

The Wildfire Automated Biomass Burning Algorithm (WF_ABBA) is capable of performing fire detection and characterization with a global constellation of geostationary weather satellites, including but not limited to current GOES, Met-8/-9, and MTSAT-1R. The current 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. It is a goal of U.S. and international bodies (IGOS GOFC/GOLD, CGMS, CEOS Constellation Concept) that a single algorithm provide fire data for the various platforms for biomass burning monitoring and inclusion in emissions and aerosols models.

To accomplish these goals CIMSS proposed to expand the GOES WF_ABBA trend analysis around the globe beyond the Western Hemisphere analyses that were produced in past years. CIMSS also proposed to collaborate with the atmospheric modeling community to integrate and assimilate "global" geostationary WF_ABBA fire products into aerosol/trace gas transport models. Additionally, CIMSS proposed to collaborate with Dr. R. Rabin (NOAA/NSSL) and Dr. P. Bothwell (NOAA/NWS, Storm Prediction Center) on applications of RSO GOES fire products in fire weather forecasting through early detection of wildfires, agricultural burning and diurnal monitoring of fire variability. CIMSS proposed continued collaboration with GEOSS, GTOS GOFC/GOLD, CEOS, and CGMS to foster international development and implementation of a global geostationary fire monitoring network.

Summary of Accomplishments and Findings

The GOES WF_ABBA fire monitoring and trend analysis now spans around the globe and currently includes GOES-E/-W over North and South America, Met-9 over Africa and Europe, and MTSAT-1R over Asia and Australia. Figure 2.7.1 shows a composite of processed and saturated fires observed from the GOES Version 6.5 WF_ABBA for Met-9 from September 2008 through June 2009. Enhanced regions of burning are seen over sub-Saharan Africa, Portugal, eastern Europe, and much of Brazil. In Brazil, Met-9 fire results are being compared with the GOES-East and GOES-10 WF_ABBA products. Figure 2.7.2 is a difference plot that shows GOES-East Version 6.1 WF_ABBA detected fires over North America that are unique to the time period 1 October 2007 – 30 September 2008 (fire pixels in yellow) and 1 October 2008 – 30 September 2009 (fire pixels in red). There was an overall increase of 14% in fire activity over North America during 1 October 2008 – 30 September 2009 compared to 1 October 2007 – 30 September 2008. However, in South America there was an overall 6% decrease in fire activity during 1 October 2008 – 30 September 2009 compared to 1 October 2007 – 30 September 2008.

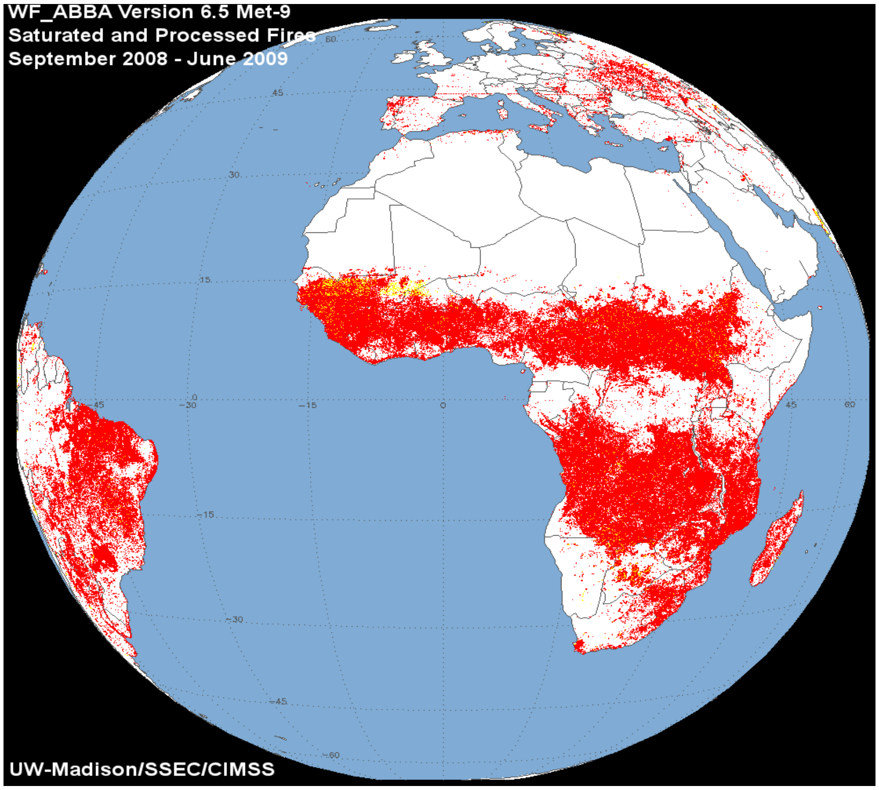


Figure 2.7.1. GOES Version 6.5 WF_ABBA Met-9 detected fire pixels from September 2008 through June 2009. Red pixels indicate processed fires while yellow pixels indicate saturated fires.

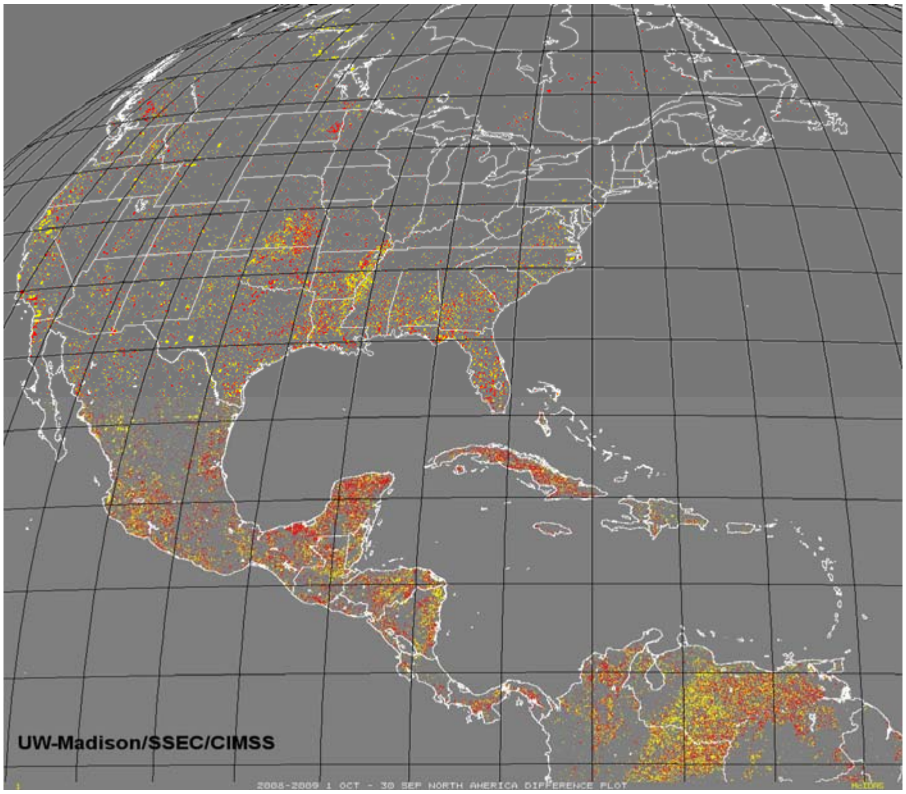


Figure 2.7.2. Difference plot of GOES-East Version 6.1 WF_ABBA detected fires over North America that are unique to the time period 1 October 2007 – 30 September 2008 (fire pixels in yellow) and 1 October 2008 – 30 September 2009 (fire pixels in red).

CIMSS has collaborated with Dr. Rabin and Dr. Bothwell (NOAA/NWS/SPC) on applications of Rapid Scan GOES fire products in conjunction with local meteorological information for early detection of wildfires and diurnal monitoring of fire variability. Dr. Rabin and Dr. Bothwell will test the fire radiative power (FRP) product in real-time in AWIPS during this fall and in the spring of 2010 at NSSL. Figure 2.7.3 shows an image of the FRP product for fires over northern Texas/southern Oklahoma on 9 April 2009 at 2015 UTC. More intense fires (higher FRP values) are denoted by magenta and red colors while less intense fires (lower FRP values) are denoted by green and yellow colors. FRP values range from 500 to 2550 MW. Red also denotes saturated pixels, which prevent a solution for FRP. In those cases FRP is presumed to be high and denoted with the top of the scale. The spacing between the fire pixels is a side-effect of the pixel oversampling by GOES.

The GOES-E/-W 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.

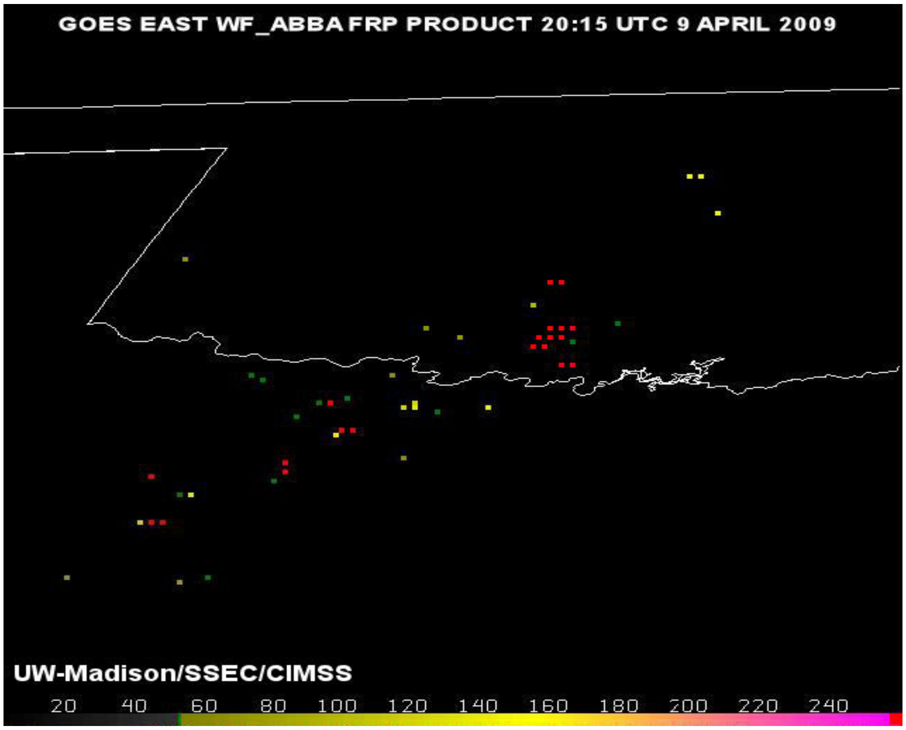


Figure 2.7.3. GOES-East Version 6.5 WF_ABBA fire radiative power product over southern Plains on 9 April 2009 at 2015 UTC. A color enhancement was applied to the product.

CIMSS continues participation in international fire working groups and committees including the GTOS GOFC/GOLD fire monitoring and mapping implementation team, the CEOS Disaster SBA team, and CGMS. CIMSS efforts focus primarily on global geostationary fire monitoring in support of GEO tasks DI-06-13 and DI-06-09. In cooperation with the GOFC/GOLD global geostationary fire monitoring network working group, CIMSS prepared a working paper (NOAA WP-21) submitted to the CGMS-36 Global Space-based Inter-Calibration System (GSICS) panel outlining geostationary satellite data access and characterization needs and issues as they relate to fire monitoring. In response to this paper, CGMS-36 adopted Action 36.03 which states that CGMS agencies with current and/or future geostationary programs were to review CGMS-36 NOAA-WP-21 and complete an assessment on the level of compliance to the recommendations in the working paper by 31 May 2009. This represents the first time that CGMS members have been formally tasked with addressing specific issues and needs related to active fire monitoring.

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, E. M. Prins, J. M. Feltz, J. P. Hoffman, and S. S. Lindstrom, 2009: WF_ABBA Version 6.5: An overview of the improvements and trend analyses of fires from 1995 to present over the western Hemisphere. The 89th AMS Annual Meeting/16th Conference on Satellite Meteorology and Oceanography. Phoenix, AZ. January 2009, Amer. Meteor. Soc., JP7.9.

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*.

Schmidt, Christopher C., E. M. Prins, J. C. Brunner, J. P. Hoffman, S. S. Lindstrom, and J. M. Feltz, 2009: Geostationary detection of fires and the global and long-term datasets of the WF_ABBA. The 89th AMS Annual Meeting/16th Conference on Satellite Meteorology and Oceanography, Phoenix, AZ, January 2009, Amer. Meteor. Soc., J15.4.

2.8. GOES Tropical Cyclone Applications Research

CIMSS Project Lead(s): Chris Velden
CIMSS Support Scientist(s): Tim Olander, Derrick Herndon, Dave Stettner
NOAA Collaborator(s): Jack Beven (NHC), Mike Turk (SAB), Jaime Daniels (STAR)
NOAA Strategic Goals Addressed:

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

CIMSS Research Themes

- Weather nowcasting and forecasting

Proposed Work

This research is being conducted to help advance GOES-derived products as applied to 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 as motivation to continue to innovate and advance GOES product development towards TC applications. The research proposed in this reporting period focused on three areas: Continued science upgrades to the Advanced Dvorak Technique (ADT); further exploration of the consensus TC intensity estimation method (SATCON); and activation of the CIMSS on-line archive of specialized TC satellite-derived products.

Summary of Accomplishments and Findings

Proposal Task 1

Continue the exploration of new and innovative methods for integration into the ADT to improve estimates of TC intensity from GOES.

In this reporting period, we:
1) Explored the potential for other GOES channels. The current ADT algorithm version only employs the GOES IR-Window channel imagery.
2) Analyzed and mitigated known biases in the ADT estimates. Primary example: ADT has difficulty with emerging EYE scenes.

1a) We have continued 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 the last report. In this reporting period, we have written up the results, and just had the paper accepted in 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, and this will be a subject of future investigation for possible applications to the ADT in a follow-on GIMPAP proposal in FY 2010-11.

2a) An important ADT issue has been addressed during this reporting period. The issue 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 involves 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 override 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 validation assessment was positive, with an example shown in the last report. From these results, the scheme is indeed very successful in lowering the errors associated with the ADT estimates. This is indicated in both the hPa and Dvorak Tnum metrics of performance. Transition of this ADT modification is now underway under PSDI funding.

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 continued 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 are then used to assign weights towards a consensus algorithm designed to better estimate TC intensity. An updated statistical analysis (see last 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 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 reporting period was the implementation of the microwave-based ADT, replacing the previous ADT member in the SATCON algorithm. A comparison of 74 cases from 2008 where the ADT-MW was available indicates little statistical improvement to the SATCON even though there is a modest improvement in skill for the ADT-MW versus the ADT. This is likely because the weighting scheme in SATCON has not yet been optimized to make use of the new information. Currently there are not enough cases to produce a robust new weighting scheme for the ADT-MW. Re-processing of cases from 2005 to present is expected to yield sufficient cases for a re-derivation of the SATCON weighting scheme, and this is underway. We will also continue to evaluate SATCON in near real time during the 2009 hurricane season, and will re-evaluate it after the season for potential transition into NESDIS-SAB operations.

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. Therefore, we have 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 went through a beta test mode. The on-line archive site is now active:

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

Publications and Conference Reports

Velden, C., D. C. Herndon, T. L. Olander, and A. Wimmers, 2009: Estimating hurricane strength using multiple integrated satellite data sources. 16th AMS Conference on Satellite Meteorology and Oceanography.

Olander, T. and C. Velden, 2009: Update on the CIMSS Advanced Dvorak Technique. JTWC Metsat Conf.

Herndon, D. and C. Velden, 2009: CIMSS Tropical Cyclone SATellite CONsenus (SATCON) Algorithm. JTWC Metsat Conf.

Olander, T. and C. Velden, 2009: Tropical cyclone convection and intensity analysis using differenced Infrared and water vapor imagery. To appear in *Weather and Forecasting*.

2.9. GOES Atmospheric Motion Vectors (AMV) Research

CIMSS Project Lead(s): Chris Velden and Howard Berger
CIMSS Support Scientist(s): Dave Stettner
NOAA Collaborator(s): Jaime Daniels (STAR)
NOAA Strategic Goals Addressed:

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

CIMSS Research Themes

- Weather nowcasting and forecasting

Proposed Work

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 this as motivation to continue to search out ways to improve GOES AMV product development.

Summary of Accomplishments and Findings

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 continued 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. This work was recently published in the March 2009 volume of the Journal of Applied Meteorology. This 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 will be sent to selected NWP centers interested in the data monitoring and assimilation assessment. We will continue to work closely with the NWP participants in this demonstration for the remainder of this proposed effort, and plan to continue on with the project in a proposed follow-on this GIMPAP effort in FY 2010-11.

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.

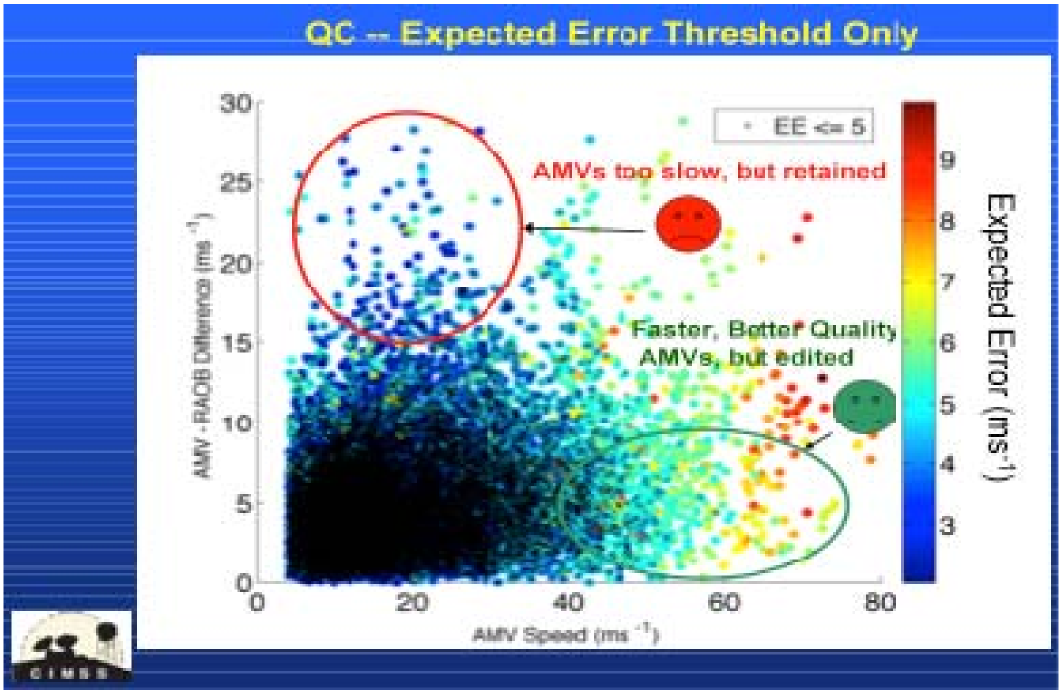
Good progress was made during this reporting period. We continued to test a new regression-based quality indicator referred to as the "Expected Error" (EE - defined and reported on earlier). This index is designed to attach to every vector record and indicate the confidence in the form of an expected vector RMSE. We continued to examine the efficiency of the EE in removing poor AMVs and comparing its skill to the existing Auto-Editor. Preliminary results of considering the EE in tandem with the QI are 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 analysis shows that choosing optimum threshold values will depend on which statistical parameters are most desired to be optimized. It appears it will be quite difficult to match the RMSE and bias statistics of the current AE without losing a significant amount of high and mid-level vectors, at least with the current techniques. Choosing threshold values that reduce the RMSE to the AE value makes sense strictly from a quality standpoint. Allowing some of the faster AMVs back into the dataset helps reduce the speed bias somewhat, and makes sense particularly if it does not increase the RMSE significantly. It appears that mid-range thresholds with QIs >90 and log-EEs ~5 ms^{-1} are the best compromise.

Similar analyses were generated during this reporting period for other spectral bands that are used to generate AMVs, to complete the statistical assessment. The EE and QI quality indicators associated with each AMV estimate are used synergistically in order to optimize the quality and geographic coverage of the final AMV dataset passed onto the user community. The synergistic use of these quality indicators is designed to take advantage of the strengths of each. The EE quality indicator is superior at identifying the quality of relatively slow AMVs, whereas the QI indicator is better at identifying the quality of relatively fast AMVs. These thresholds vary as a function of the channel used to derive the AMW and the speed computed for the AMV. AMVs whose speeds are slower than the indicated speed thresholds are considered high quality if their respective EE quality indicators are less then or equal to the chosen EE thresholds. AMVs whose speeds exceed the speed thresholds are considered high quality AMVs if their respective QI indicators exceed the chosen QI thresholds. AMVs that fail these checks are flagged as possessing poorer quality. See Figure 2.9.1 for an illustration of this finding.

Publications and Conference Reports

Velden, C., and K. Bedka, 2009: Identifying the Uncertainty in Determining Satellite-Derived Atmospheric Motion Vector Height Assignments. *J. Appl. Meteor. & Clim.*, **48**, 450-463.

Berger, H. and C. Velden, 2009: Recent advances in the processing, targeting and data assimilation of satellite-derived atmospheric motion vectors (AMVs). Third THORPEX International Science Symp., Monterey, CA.



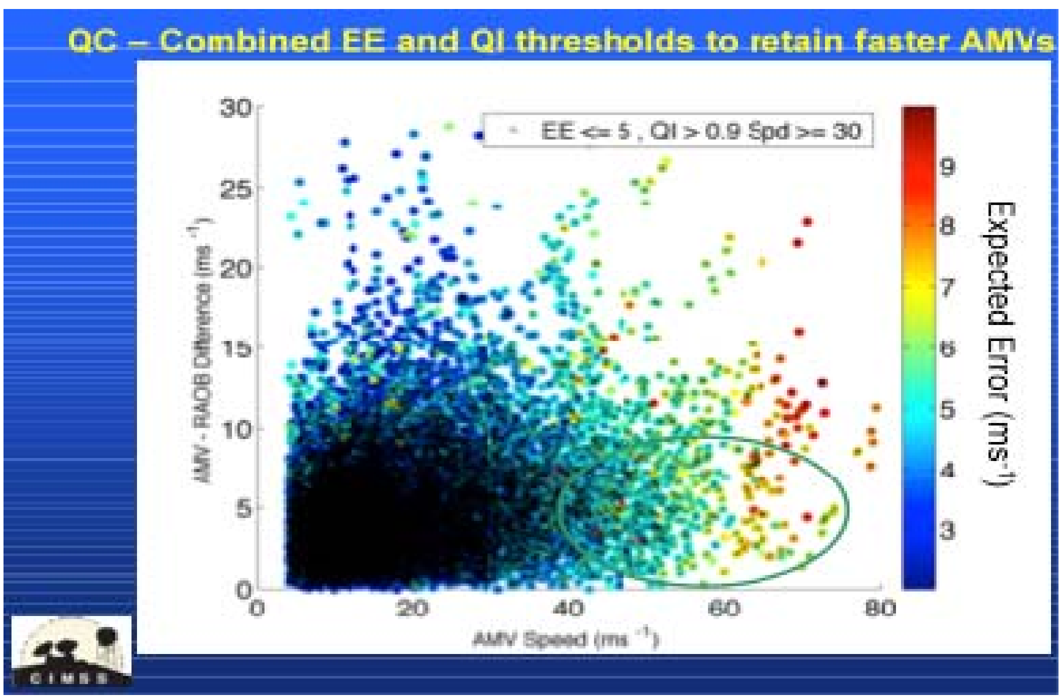


Figure 2.9.1. Top: Scatterplot showing the relationship between AMV speed and vector accuracy vs. collocated rawinsondes for a sample of GOES-12 AMVs. Each AMV-RAOB match is color coded by the assigned AMV EE, and EEs less than 5 (good quality, retained vectors) are marked with black x's. Bottom: Same as top, except the black x's now denote additional quality threshold criterion associated with the AMV speed and QI. The green circle indicates where more high-quality vectors with greater wind speeds are retained by the combined EE/QI thresholding logic.

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

CIMSS Project Lead(s): Scott Bachmeier
CIMSS Support Scientist(s): Jordan J. Gerth
NOAA Collaborator(s): Gary S. Wade
NOAA Strategic Goals Addressed:

- 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
- Education, training, and outreach

Proposed Work

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 (into AWIPS) which sampled cutting-edge research in progress, and could add value to the forecast process. The potential to enhance operations at National Weather Service offices nationwide, by the further creation and deployment of experimental satellite imagery and products into AWIPS, particularly from the Geostationary Operational Environmental Satellite (GOES) Sounder, remains strong. Subsequent training modules can provide a meaningful demonstration of such imagery in AWIPS to forecasters. Current non-operational GOES Imager and new GOES Sounder products from CIMSS/SSEC, undergoing evaluation at NWS Forecast Offices, have shown some positive results to date, and the interest continues to grow.

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 the middle of the next decade, 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 that forecasters only have the best, most pertinent imagery and products available; and,
6) introducing researchers to AWIPS.

Summary of Accomplishments and Findings

An experimental version of the GOES Sounder vertical profile retrieval algorithm [known as Li et al. (2008); see references] continues to be tested with real-time data. This new version uses a better first guess (derived via regression); handles surface infrared emissivity better in the retrieval procedure; and, uses a more reliable background error covariance matrix. Although shown in cases as an improvement over the current Ma-based algorithm [known as Ma et al. (1999); see references], the new version appears to not yet be fully and successfully implemented with current, real-time data in McIDAS (the Man computer Interactive Data Access System), at the University of Wisconsin-Madison Space Science and Engineering Center (SSEC)). Nonetheless, this new version appears 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). {See Figure 2.10.1.} Observed improvements of the new Li et al. (2008) version, including typically much reduced moist biases in the most moist situations, as well as reduction in the amount of cloud contamination permitted around clouds, are unfortunately offset by an observed dry bias with the Li et al. (2008) version profiles, particularly in the lower troposphere. Routine comparison displays of the resulting GOES Sounder Derived Product Imagery (DPI), from both the new Li et al. (2008) version and the older Ma et al. (1999) version, often showed a noticeable lesser lack of deviation from the first-guess for the new Li-based retrievals. These inconsistencies (and opposition to the goal of providing a more robust retrieval, able to more strongly deviate from the guess, especially when the guess is poor) have forced current re-examination of the implementation in McIDAS. Pressure to correct this implementation is increasing, as an immediate high-priority goal of the GOES Sounder team at CIMSS/SSEC is to be able to provide DPI (in AWIPS, following generation in real-time on McIDAS), from this new version of the sounding algorithm, for next spring's (2010) activities of the GOES-R Proving Ground initiative (to be held in Norman, OK). [This development and promotion of the newer GOES Sounder Products is increasingly falling under the efforts of the GOES-R Proving Ground.]

As the new Li-based algorithm DPI are being produced correctly from McIDAS, these "improved" DPI {including total precipitable water (TPW), lifted index (LI) stability, and total column ozone (TCO)} will be added to the CIMSS data stream and fed into AWIPS. {See Figure 2.10.2.} This preliminary offering from CIMSS of the new DPI to forecasters will precede their eventual distribution from NESDIS operational channels - first, from StAR OPDB (Operational Products Development Branch) [J. Daniels], and then OSDPD PIB (Product Implementation Branch) [C. Holland].

Two(2) in-person group collaboration/training events were held with the NWS Forecast Office in Sullivan, WI (KMKX). On 27 Jan 2009, several NWS KMKX staff, along with the new Meteorologist-In-Charge (MIC) S. Brueske, visited CIMSS and learned about the new satellite products which CIMSS was providing to AWIPS via LDM. {See Figure 2.10.3} The theme for the meeting was: "Catering to the satellite needs of operational meteorology". [The presentations are available at: ftp://ftp.ssec.wisc.edu/pub/jordang/talkpost/others/27jan2009/index.html.] On 17 Feb 2009, several CIMSS and ASPB staff visited the NWS KMKX office and continued the dialogue, with more of the NWS staff, working on a meeting theme of: "Building on a collaborative foundation for success in operational satellite meteorology". [The presentations are available at: ftp://ftp.ssec.wisc.edu/pub/jordang/talkpost/others/17feb2009/index.html.]

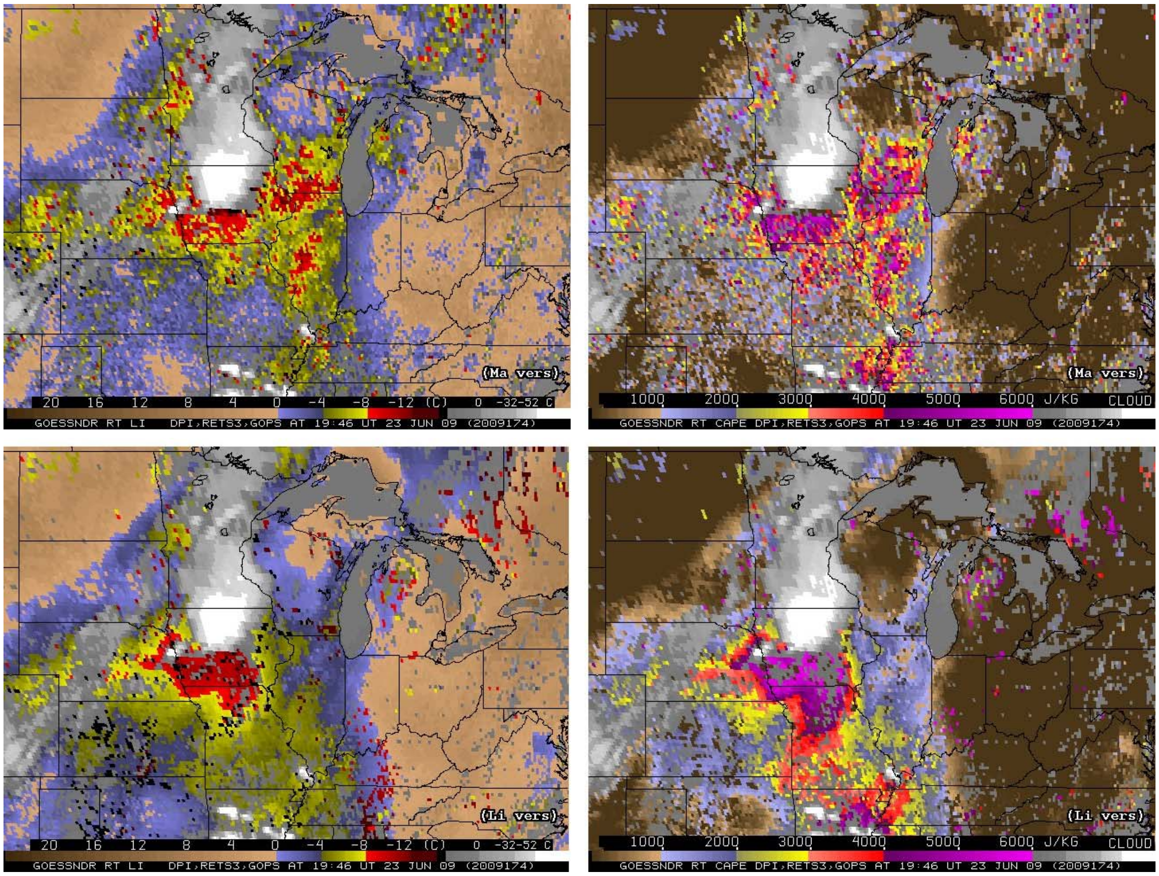


Figure 2.10.1. During monitoring of current weather at the Cooperative Institute for Meteorological Satellite Studies (CIMSS), specifically the chances for severe convection across Iowa and southern Wisconsin on the afternoon of 23 June 2009, it was noted how recent developments in retrieval processing of GOES Sounder data influenced the discussion. Due to ongoing research through GIMPAP, a new version of the retrieval algorithm (known as Li (2008)), which has been developed and implemented at CIMSS, continues to be assessed and compared with the previous (and current operational) algorithm (known as Ma (1999)). Very extreme, and unreasonable, values of moisture and instability are often evident in portions of the Ma (1999) Derived Product Imagery (DPI), such as around cloud regions; such deficiencies are much mitigated within the Li (2008) DPI. Furthermore, on 23 June 2009, the Ma (1999) DPI showed extreme instability across southern Wisconsin and southern Iowa, while the Li (2008) DPI showed much less instability across southern Wisconsin, which was much more in agreement with only one solitary, weak severe event being reported in Wisconsin (the Milton "tornado").

One(1) in-person collaboration/training event was held with C. Siewert at the NWS Storm Prediction Center (SPC) in Norman, OK on 28-29 May 2009. Siewert is the newly hired (by the Cooperative Institute for Mesoscale Meteorology Studies (CIMMS)) satellite focal point, stationed at the SPC, working for the GOES-R Proving Ground project. Although an appropriate large group setting was not workable during the visit, G. S. Wade did have a lengthy discussion with Siewert as they discussed the presentation on: "Advancing geostationary infrared sounding, and its application". [The presentation is available at: /ftp://ftp.ssec.wisc.edu/pub/garyw/GOES-Sndr-ovrvw-SPCvisit-20090529gsw.ppt.]

Thirty-three (33) live tele-training sessions were presented during the year (Oct 2008-Sep 2009) of the following VISIT (Virtual Institute for Satellite Integration Training) lessons, which address the use of GOES imagery in the forecast process: “Water Vapor Imagery and Potential Vorticity Analysis”, “Interpreting Satellite Signatures”, “The Enhanced-V”; “Mesoscale Convective Vorticities”, “CRAS Forecast Imagery in AWIPS”, and “TROWAL Identification”. These VISIT lessons were done with a variety of NWS Forecast Offices.

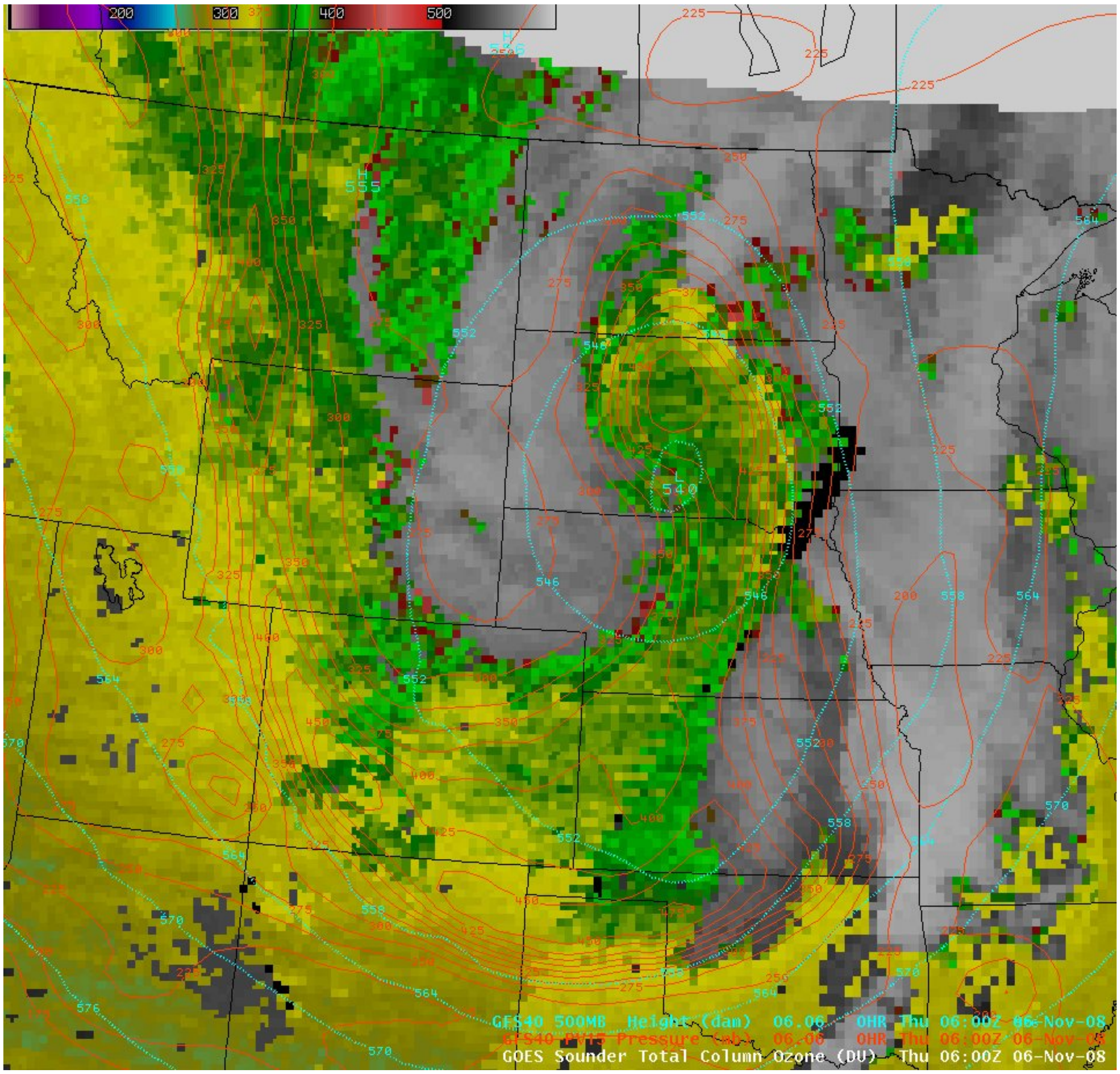


Figure 2.10.2. GOES Sounder total column ozone Derived Product Image (DPI) at 06 UTC on 06 Nov 2008, with the overlaid Potential Vorticity (PV) Anomaly from the GFS40 analysis valid at the same time, all displayed in AWIPS. Note the larger ozone totals in the vicinity of the PV max across South Dakota, indicative of the lowering of the tropopause.

One hundred and seventeen (117) new GOES-related “mini-cases”, with many showing displays from AWIPS, were added to the CIMSS Satellite Blog [http://cimss.ssec.wisc.edu/goes/blog]. {See Figure 2.10.4}

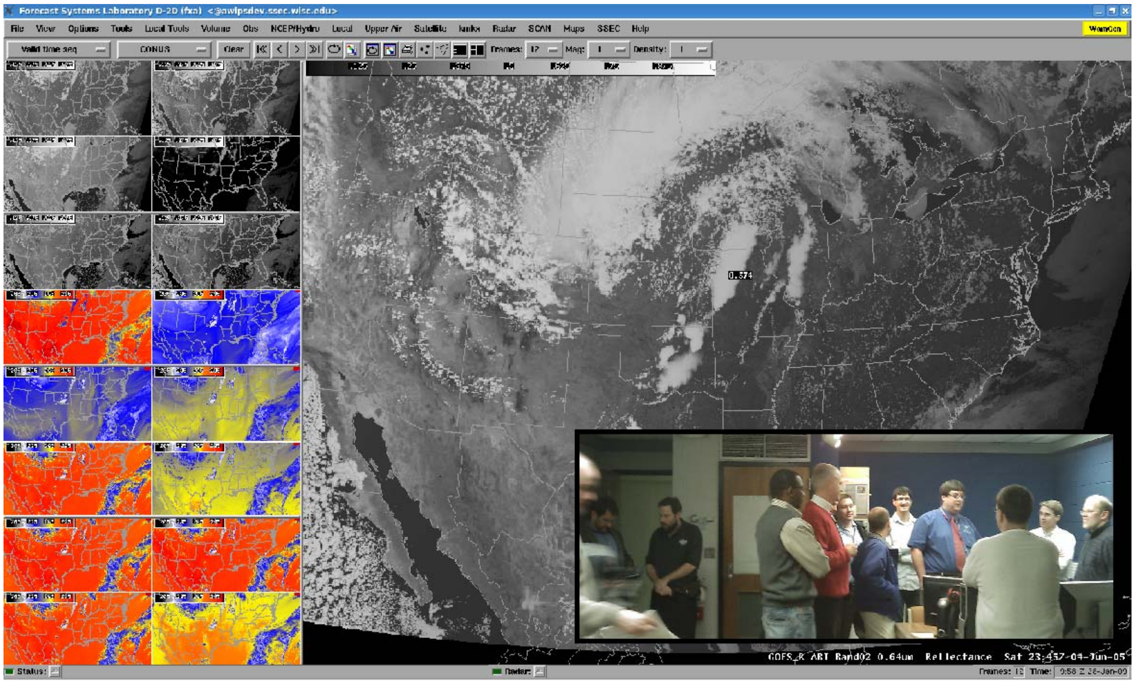


Figure 2.10.3. The lower right insert shows CIMSS and ASPB research and development staff hosting visitors from the NWS Sullivan (MKX) Forecast Office at their meeting in Madison, WI on 27 Jan 2009, congregating around a real-time AWIPS workstation at CIMSS. The background imagery is an example, shown in the AWIPS environment, of all the spectral bands for the GOES-R Advanced Baseline Imager (ABI), simulated from a high resolution model analysis of a case study from 04 Jun 2005. Demonstrations of what GOES-R data are anticipated to be like are already being shown at CIMSS within the AWIPS format.

Dozens of new NWS AFDs (Area Forecast Discussions) mentioning either CRAS and/or MODIS products, provided in AWIPS by CIMSS, were continuing to be noted, adding to the current total (to date) of nearly 300 references. 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.

Publications and Conference Reports

A poster presentation was planned for the 33rd National Weather Association (NWA) Annual Meeting, which was held in Louisville, KY on 13 Oct 2008. Unfortunately, the inability to actually use requested and planned FY2009 project funding in the first quarter for federal travel prohibited attendance at the meeting. Despite the loss of the opportunity to engage meeting participants in a discussion of the early results and attempts to provide improved GOES Sounder profile products (which eventually are destined for AWIPS), the poster was still displayed (but without an author present). The poster, “Assessing development of a refined technique for retrieval of vertical profiles of temperature and moisture from the GOES Sounder, with current real-time products” by Wade, G. S., J. Li, J. P. Nelson, Z. Li, and T. J. Schmit, showed early results of implementing the new version of the GOES Sounder retrieval algorithm developed by J. Li and Z. Li.

An oral presentation was given by R. M. Aune, at the 23rd Weather and Forecasting / 19th Numerical Weather Prediction Conference, sponsored by the American Meteorological Society (AMS), in Omaha, NE. The talk given on 03 Jun 2009 was titled "Using the GOES Sounder to Nearcast Severe Convection"; described results of the severe weather nearcasting system under development at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) in collaboration with Ralph Petersen of CIMSS; and is available at: https://confex.webex.com/cmp0305l/webcomponents/docshow/docshow.do?isPluginInstalled=yes&siteurl=confex&rnd=0.6899189091577589.

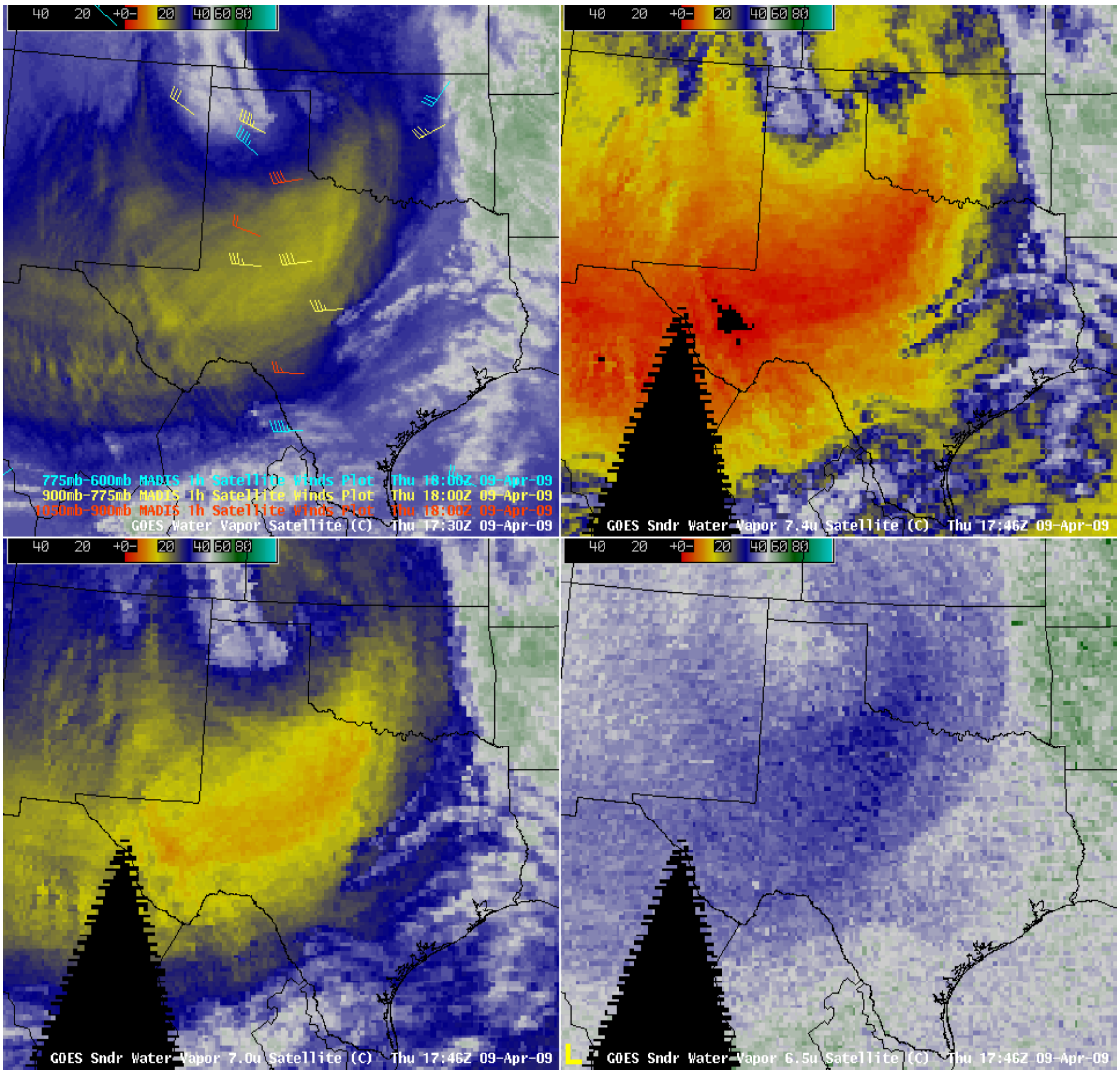


Figure 2.10.4. An AWIPS 4-panel display is shown, from 18 UTC on 09 Apr 2009, of the GOES Imager and GOES Sounder water vapor bands, illustrating a distinct, deep signature of dry air that was rapidly descending from the middle troposphere to the surface, over Texas -- this dry air helped wildfires in Texas to grow very quickly on that day. This descending dry air signature was especially evident on the Sounder 7.0 µm band imagery, lower left panel, and the Sounder 7.4 µm band imagery, upper right panel. The fact that the dew point temperature at Winston, Texas dropped from +7º F (-14C) at 12:06 pm to -20º F (-29C) at 3:06 pm local time (as winds gusted to 48 mph (21 m/s)) was an indicator of how remarkably dry this air mass was on that particular day.

References

Ma X. 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

Li, Z., J. Li, W. P. Menzel, T. J. Schmit, J. P. Nelson III, J. Daniels, and S. A. Ackerman, 2008: GOES sounding improvement and applications to severe storm nowcasting. *Geophys. Res. Let*., **35**, LO3806

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

3.1 Polar Winds from MODIS

CIMSS Project Leads: Dave Santek, Chris Velden
CIMSS Support Scientist: Rich Dworak
NOAA collaborator: Jeff Key
NOAA Strategic Goal Addressed:

- Serve society's needs for weather and water

CIMSS Research Theme:

- Clouds, aerosols and radiation

Proposed Work

Geostationary satellite radiance measurements have been used to generate cloud-drift winds in the low- and mid-latitudes of the western hemisphere for more than two decades. Fully automated cloud-drift wind production from GOES became operational in 1996, and wind vectors are routinely used in operational numerical models of the National Centers for Environmental Prediction (NCEP). Unfortunately, GOES is of little use at high latitudes due to the poor viewing geometry.

The objective of this project is to generate wind vectors over the polar regions from polar-orbiting satellites. Of primary interest are the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on NASA's Terra and Aqua satellites and the Advanced Very High Resolution Radiometer (AVHRR) on NOAA and Metop satellites. We have developed an experimental wind product that can be used in numerical weather prediction systems, and have helped transition the product to NESDIS operations. Under this PSDI funding, we continue to evaluate, improve, and extend the product suite.

The project Principal Investigator at CIMSS is Christopher Velden. David Santek performs the analyses and oversees the implementation and modification of McIDAS and heritage wind generation software for use with MODIS. Rich Dworak assists in data analysis and research activities. Jeff Key, NOAA/NESDIS, works on the project in collaboration with CIMSS scientists, and is the NESDIS point of contact for the project.

Summary of Accomplishments and Findings

Over the past year we have continued the real-time generation of the polar winds product from the MODIS (Terra and Aqua satellites) and the AVHRR onboard the NOAA-15 through -19 and Metop-A satellites. The data are made available to users via anonymous FTP. The polar winds product is routinely generated by CIMSS for scientific research. The MODIS winds product transitioned to NESDIS operations in 2005; the AVHRR winds product transitioned to NESDIS during 2009. We continue to work with our STAR and OSDPD colleagues on code differences and any discrepancies that arise between the CIMSS and OSDPD winds.

To improve the winds product, enhancements to the process and corrections to coding errors are made as identified either at CIMSS or NESDIS. Three significant activities that occurred during the past year:

1. We provided assistance to NESDIS in their effort to transition the mixed-satellite winds product into operations. The mixed-satellite product derives wind information from alternating passes of Terra and Aqua, rather than using a single satellite. This improves the timeliness of the product and expands the winds coverage further south.
2. The wind generation code was changed to incorporate a surface pressure grid and to make better use of surface elevation information. This corrected anomalies observed in the height assigned to some low-level wind vectors.
3. The processing of NOAA-19 AVHRR data was added.

Eleven numerical weather prediction centers worldwide continue use the MODIS winds in their operational systems: the Joint Center for Satellite Data Assimilation (JCSDA), the European Centre for Medium-Range Weather Forecasts (ECMWF), the NASA Global Modeling and Assimilation Office (GMAO), the U.K. Met Office, the Canadian Meteorological Centre (CMC), the Japan Meteorological Agency (JMA), the U.S. Navy's, Fleet Numerical Meteorology and Oceanography Center (FNMOC), Deutscher Wetterdienst (DWD; Germany), Meteo France, the Australian Bureau of Meteorology, and the National Center for Atmospheric Research (NCAR).

Publications and Conference Reports

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

Santek, D., 2009: The impact of satellite-derived polar winds on lower-latitude forecasts. Accepted for publication in *Mon. Wea. Rev*.

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

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

3.2 Automated Volcanic Ash Detection and Height Determination from the AVHRR

CIMSS Project Leads: William Straka
CIMSS Support Scientists: Justin Sieglaff
NOAA Collaborator: Michael Pavolonis and Andrew Heidinger
NOAA Strategic Goals Addressed:

- 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

Volcanic ash poses a large threat to aviation. As such, volcanic ash forecasters and analysts would benefit from automatic and near real-time ash detection and height estimates, which would help improve the accuracy and timeliness of advisories and forecasts. Volcanic ash products that are currently in operations are imagery based and qualitative. Since these products are qualitative, an analyst only looks at them in select regions where volcanic eruptions are thought to be possible. Thus, an unexpected volcanic eruption, even if detectable with current methods, can be missed. In this project, we proposed to take existing experimental methods for quantitatively detecting volcanic ash and estimating its height and implement them into the operational Advanced Very High Resolution Radiometer (AVHRR) processing system, CLAVR-x (The Extended Clouds from AVHRR processing system). This project is focused on implementing and refining the volcanic ash algorithms in CLAVR-x to produce reliable global results on a real-time basis prior to a full operational implementation later in the project.

Summary of Accomplishments and Findings

CLAVR-x was modified in order to accommodate a cloud object based volcanic ash detection algorithm and an optimal estimation technique for retrieving the ash cloud height and mass loading. In addition, a separate program, which ingests the CLAVR-x results and issues an automated warning, if warranted, was created. This program along with the updated version of CLAVR-x will be delivered to the Office of Satellite Data Processing and Distribution (OSDPD) in the Fall of 2009 for pre-operational implementation. The updated version of CLAVR-x was successfully tested on a non-operational test computer in OSDPD. Example output from the latest version of the AVHRR volcanic ash algorithms is shown in Figure 3.2.1.

Further, a McIDAS-X (Man-computer Interactive Data Access System, Version X) Abstract Data Distribution Environment (ADDE) server designed to interpret volcanic ash output from CLAVR-x was developed and tested. The volcanic ash products are remapped to the correct projection and then output to an Advanced Weather Interactive Processing System (AWIPS) compliant netCDF files. These files can be viewed in AWIPS and the Interactive Calibration of Four Dimensions (IC4D) display system. IC4D is a new forecast system being developed by the National Weather Service (NWS) Meteorological Development Laboratory and is being tested at the Alaska Aviation Weather Unit / Volcanic Ash Advisory Center (AAWU/VAAC) in Anchorage, Alaska. An example of the AVHRR volcanic ash mass loading product as viewed in AWIPS is shown in Figure 3.2.2.

Publications and Conference Reports

Heidinger, A.K. and M.J. Pavolonis, 2009: Nearly 30 years of gazing at clouds through a split-window: Part I: Methodology. *Journal of Applied Meteorology and Climate*, **48**(6), 110-1116.

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. To be submitted to *J. Atmos. Sci.*

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. Atmos. Sci.*

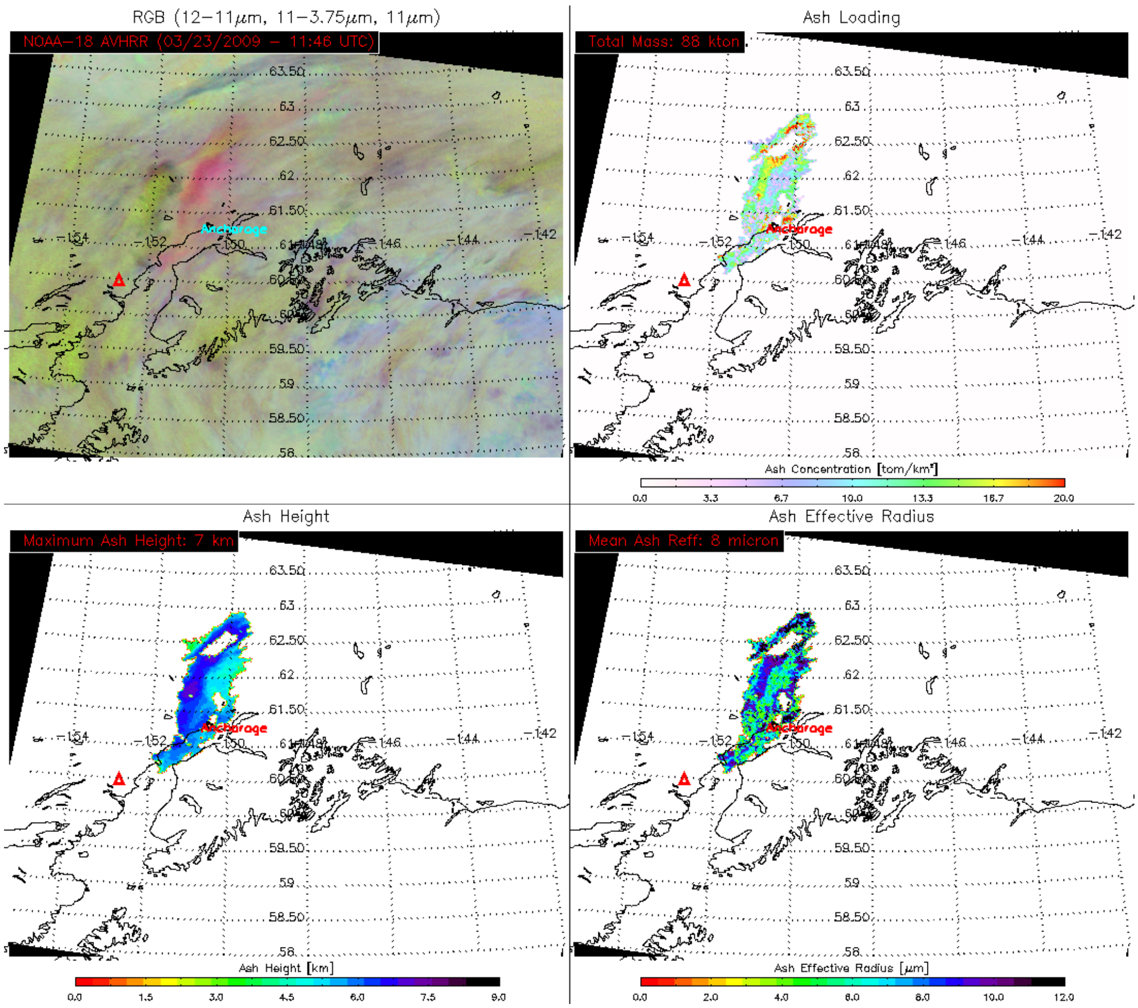


Figure 3.2.1. The AVHRR volcanic ash products are shown for an ash cloud produced by an eruption of Mount Redoubt, AK on March 23, 2009. A false color image, the ash mass loading, the ash cloud height, and the ash effective particle radius are shown in the top/left, top/right, bottom/left, and bottom/right panels, respectively.

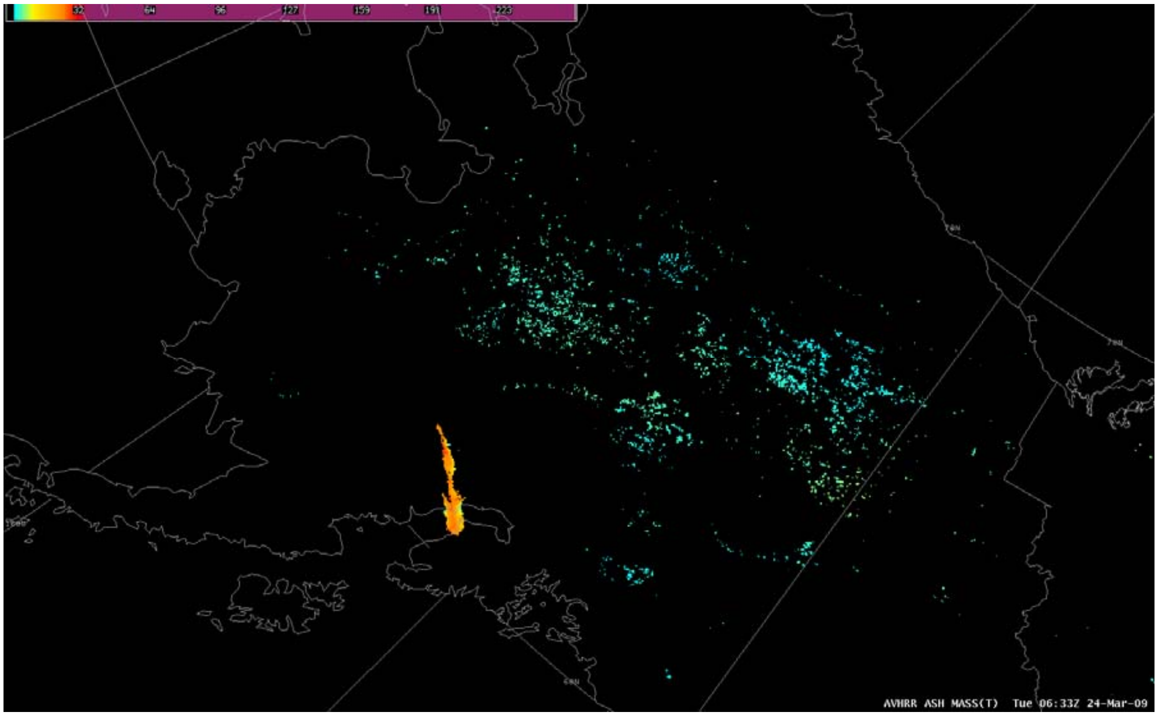


Figure 3.2.2. The AVHRR volcanic ash mass loading product from March 24, 2009 at 0633 UTC as viewed in AWIPS.

3.3. GOES-O Wildfire ABBA

CIMSS Project Lead: Chris Schmidt
NOAA Collaborators: Gilberto Vicente (NOAA/NESDIS/OSDPD), Brad Pierce (NOAA/NESDIS/STAR), Deyong Xu (NOAA/NESDIS/OSDPD)), Ivan Csiszar (NOAA/NESDIS/STAR)
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

The G-PSDI project for fires is a combination of two upgrades for the Wildfire Automated Biomass Burning Algorithm (WF_ABBA): the GOES-O update and support for Global/RSO processing. The WF_ABBA, Version 6.0, became an Operational product at NESDIS in 2001, providing fire detection and characterization on a half-hourly basis for GOES-East and GOES-West. An upgrade, Version 6.5, was proposed to implement support for fire processing of all data, including Rapid Scan Operation (RSO) and Super Rapid Scan Operation (SRSO) data from GOES, as well as data from supported international satellites such as Meteosat-8/-9 and MTSAT-1R. This support for international satellites was in response to SPSRB requirement 0405-7 Global geostationary Fire Monitoring System, the Global Earth

Observation System of Systems (GEOSS) activities and the Group on Earth Observations (GEO) 2006 work plan (items DI-06-13, DI-06-09), and the GOFC-GOLD Fire Objective: "To develop an operational global geostationary fire network providing observations of active fires in near real-time." The other upgrade that was made a part of this project was to add support for GOES-O (now GOES-14) to the WF_ABBA, continuing a series of such upgrades as new GOES satellites have come online. Both upgrades were to be provided through Version 6.5 of the WF_ABBA. Additionally, the WF_ABBA was to have a five minute latency.

Summary of Accomplishments and Findings

The WF_ABBA Version 6.5 meets the goal of processing all of the data from the requested geostationary satellites capable of fire detection. Figure 3.3.1 shows the full disk metadata and fire masks for the scans nearest 17:45 UTC on 3 September 2009. The metadata and fire mask contains a pixel by pixel representation of the fires (too small to see in the figure) and codes for all other pixels that inform the user that the pixels were water (blue), opaque cloud (white), areas that were blocked out or excluded due to solar interference, non-Earth pixels, etc (gray and black), or pixels that were determined to be fire-free (green). CIMSS and NOAA (through Ivan Csiszar) have continued to provide updates on the GEOSS request for global fire detection through the Committee on Earth Observation Satellites (CEOS), most recently in September 2009.

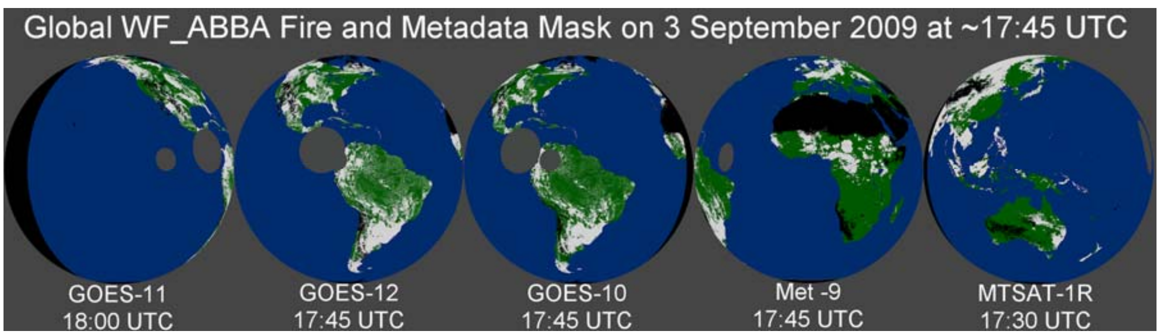


Figure 3.3.1. WF_ABBA v65 metadata and fire masks for the full disk scans nearest 17:45 UTC on 3 September 2009. Water pixels are blue, opaque clouds are white, areas that were blocked out or excluded due to solar interference, non-Earth pixels, and others unusable to the algorithm are gray or black, and pixels that were determined to be fire-free are green. Fire pixels are too small to be seen in this figure.

The transfer of WF_ABBA Version 6.5 (v65) to Operations has been underway during the last year. Testing of v65 on NESDIS computers began in November 2008 in an account assigned to CIMSS. The WF_ABBA supported the required satellites (Met-8/-9, MTSAT-1R, GOES-8 through -13), was able to process all available data as soon as it was available, and could, if given adequate computational resources, meet the 5 minute latency requirement. Initial testing revealed important differences between the configurations of the Abstract Data Distribution Environment (ADDE) servers at NESDIS versus those available to CIMSS via SSEC. SSEC provides a single dataset containing all of the data from each satellite, whereas at NESDIS data is distributed into different sectors, each with its own dataset. The sectors are defined geographically and for GOES cover full disk, northern hemisphere, continental or Pacific US for GOES-East and GOES-West respectively, and southern hemisphere. MTSAT-1R also has sectors at NEDIS, covering full disk, northern hemisphere, and southern hemisphere. Meteosat is provided as full disk only. The sectors overlap temporally and spatially – a GOES full disk image is available in all four datasets, but only the full disk dataset contains the entire image scanned by the satellite. A "Northern Hemisphere" scan by GOES-East is also in the CONUS dataset but not in the full disk dataset. The overlap and the fact that the GOES schedule can vary substantially created a challenging scenario for a product tasked with processing all data. The initial solution was to request that

NESDIS also create a dataset that contains all of the data from a given satellite, as SSEC does. This option was not pursued. The solution was to configure the WF_ABBA to examine the datasets in order of precedence. For GOES-East the order is full disk, northern hemisphere, continental US, and southern hemisphere. This allowed the WF_ABBA to capture all images and avoid processing a subsector of a larger image. The checks had to be made every minute as GOES can have a flexible schedule with SRSO images coming in every minute. The same technique was applied to MTSAT-1R, but due to its fixed schedule data could be looked for 3 times an hour.

In early February 2009 the software package was provided to the OSDPD PAL. Feedback on the package was provided to CIMSS in May 2009, at which point some bugs and several "retrofit" issues were identified that required additional development and testing time. Issues included changing the format and location of the log files, creating a status file for the WF_ABBA that mimicked the file created for other Operational products, and retrofitting the code for the Operational computer systems, their backups, and the Critical Infrastructure Protection (CIP) machine at Wallops. In July and August 2009 CIMSS addressed the bugs, log file changes, and retrofits.

In late August a new problem was identified, which caused the targeted date of presentation to the Satellite Product Service Review Board (SPSRB) to be pushed back from October to November at the earliest. The new problem related to the number of ADDE calls to the Operational satellite data servers for the GOES satellites. Due to the need to check up to four datasets once a minute, and given that checking each dataset required four calls to the server, this led to too many ADDE calls for one product, potentially causing problems for other Operational products. CIMSS worked with the OSDPD PAL to determine ways to reduce the number of ADDE calls. Testing of a solution was underway at the end of the reporting period.

Basic support for GOES-14 is part of the WF_ABBA v65. A maintenance update may be needed once the science test is completed and actual data has been run through the algorithm. The science test is scheduled for November 2009.

3.4 Product Quality Assurance and Science (PQAS) Support for Operational GOES Imager and Sounder Products

CIMSS Project Leads: J. P. Nelson III, C. S. Velden
CIMSS Support Scientists: A. J. Schreiner, S. T. Wanzong
NOAA Collaborators: G. S. Wade, T. J. Schmit, J. Daniels
NOAA Strategic Goals Addressed:

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

CIMSS Research Themes:

- Weather nowcasting and forecasting

Proposed Work

This project supports GOES Imager and Sounder data quality assurance and science algorithm maintenance, as well as the implementation of various algorithm enhancements to GOES Imager and Sounder products software. Work done involves aspects of both computer software and hardware. Examples of work conducted under this project include: a) repairing problems that arise concerning the CIMSS GOES Sounder and (or) Imager research products, such as modifying software to handle special atmospheric or computing environment conditions, and b) making changes to algorithm software to improve the final product. Work supported via this project is vital to maintaining and improving the quality of all the GOES Imager and Sounder research products that CIMSS makes available to the meteorological community via the following Web sites:

http://cimss.ssec.wisc.edu/goes/rt/
http://cimss.ssec.wisc.edu/tropic/real-time/atlantic/winds/winds.html

This report covers the period 01Oct2008 through 30Sep2009. As such, results related to both the 2008 and 2009 Product Systems Development and Implementation (PSDI) proposals are relevant, but should emphasize the 2009 PSDI proposal.

During 2008, both the retrievals and winds processing software was scheduled to be upgraded from the previous 42-level to a higher-resolution 101-level atmosphere. Furthermore, a new GOES temperature/moisture retrieval algorithm was to be made available to STAR personnel for testing, prior to operational implementation, and the GOES Sounder cloud mask algorithm was to be improved. The CIMSS Retrievals/Clouds Archive (CRCA) was slated to become a reality, and improved product validation software was proposed. Monitoring of computer hardware, making our Imager and Sounder software more robust, and adding software and files to the SSEC CVS repository were among other items proposed for 2008.

During 2009, improvement of the spatial resolution of the upper air first guess grids used for much of the GOES Imager and Sounder processing from 1.0 X 1.0 degrees to 0.5 X 0.5 degrees was proposed. An improvement in the approach used to derive surface emissivity for GOES temperature/moisture retrievals was also proposed (Seemann et al. 2008). The basic themes of improving product validation software, monitoring of GOES Imager and Sounder computing hardware, making Imager and Sounder software more robust, etc. were also discussed. In terms of GOES winds development, improved quality control (QC) was emphasized, and a superior QC approach was slated for implementation, with the eventual goal of replacing the existing Recursive Filter auto-editing routine.

Summary of Accomplishments and Findings

Between 01Oct2008 and 30Sep2009, significant progress has been achieved toward accomplishing a number of the above goals. Both the transition from a 42-level to a 101-level atmosphere and the improved CIMSS Sounder cloud mask have been implemented within certain cloud-specific GOES Sounder software running at CIMSS. However, in other Sounder software development, the implementation of the new 101-level temperature/moisture retrieval algorithm with the same improved cloud mask has proven to be more difficult than expected, and has taken longer than hoped, but a majority of the work has in fact now been completed and migrated to Washington, D.C. Extensive correspondence between CIMSS and Washington personnel is ongoing to get a fully-working version of the new software implemented at both sites . After successful testing, this software will be migrated to NESDIS operations.

Progress has been made towards migrating the upper air first guess from 1.0 X 1.0 to 0.5 X 0.5 degrees resolution, but more work remains. Work on implementing the improved surface emissivity approach for GOES retrievals has not yet begun. Early in the reporting period, work on the CIMSS Retrievals/Clouds Archive (CRCA) was performed. CRCA has proven to be very useful internally at CIMSS, but still needs to be made available to outside collaborators, such as personnel in Washington, D.C.

In the realm of Atmospheric Motion Vectors (AMV) development, the quality control module of the processing software at CIMSS was updated with recent upgrades based on research supported by GIMPAP and GOES-R that shows that the log of the Expected Error (EE) quality indicator is a superior metric to the EE alone. We have also shown that the logEE is most effective in combination with the existing QI to identify the most likely high-quality vectors. This new AMV quality control logic has been included in upgrades and made available to NESDIS, and will eventually supercede the existing Recursive Filter auto-editing routine.

Work on improving the vertical resolution of the background model in the AMV processing code has progressed. All routines up to the Recursive Filter step have been modified to include the 26 level GFS background guess. We are still debating internally whether to modify the recursive filter software for increased vertical resolution. Lastly, the version of the software at CIMSS has also been modified to include GOES-14 in the processing stream.

Considerable effort has been expended to allow detailed comparisons between different GOES temperature/moisture retrieval algorithms and collocated RAOB data (Figure 3.4.1). In this work, retrievals derived using the legacy physical retrieval algorithm of Ma et al. (1999) are compared with retrievals derived using the physical retrieval algorithm of Li et al. (2008), as well as RAOBs, with all data being collocated in space and time. Both Derived Product Imagery (DPI) and vertical profiles (via meteorological Skew-T diagrams) are used for the comparisons, allowing for complete perusal of atmospheric profiles up to 100mb. Interested parties can view these near –realtime comparisons for a number of south-central U.S. RAOB sites at: http://cimss.ssec.wisc.edu/goes/realtime/scus/begin-scus.html

North-central U.S. comparisons are also available at a companion Web site (replace “sc” with “nc” in the above Web address).

In other work, McIDAS-X, Fortran and UNIX assistance was provided to various CIMSS personnel. Hardware-related problems were also dealt with, in concert with SSEC Technical Computing: 1) getting one of the CIMSS processing computers running again on 26 January2009, 2) installing a new disk on the same computer in early March 2009, and 3) working with Technical Computing to schedule computer operating system upgrades. On one occasion, new versions of coefficient files needed for radiative transfer calculations were implemented in place of flawed files. By the end of the reporting period, much work had been finished toward creating UNIX makefiles for all CIMSS operational GOES Imager and Sounder software, and development of a related script to interface with all of the makefiles at one time was in process. This software is very useful for interracting with programs individually, and should prove invaluable if/when a system recovery is needed from a catastrophic disk failure. Finally, in terms of outreach activities, meteorological data was provided to scientists at NASA/GSFC-Wallops Flight Facility and Florida State University, and to students at Plymouth State University.

References

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

Ma, X. 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.

Seemann, S.W., E. E. Borbas, R. O. Knuteson, G. R. Stephenson, and H.-L. Huang, 2008: Development of a global infrared land surface emissivity database for application to clear sky sounding retrievals from multi-spectral satellite radiance measurements. *J. Appl. Meteor. Climatol.*, **47**, 108-123.

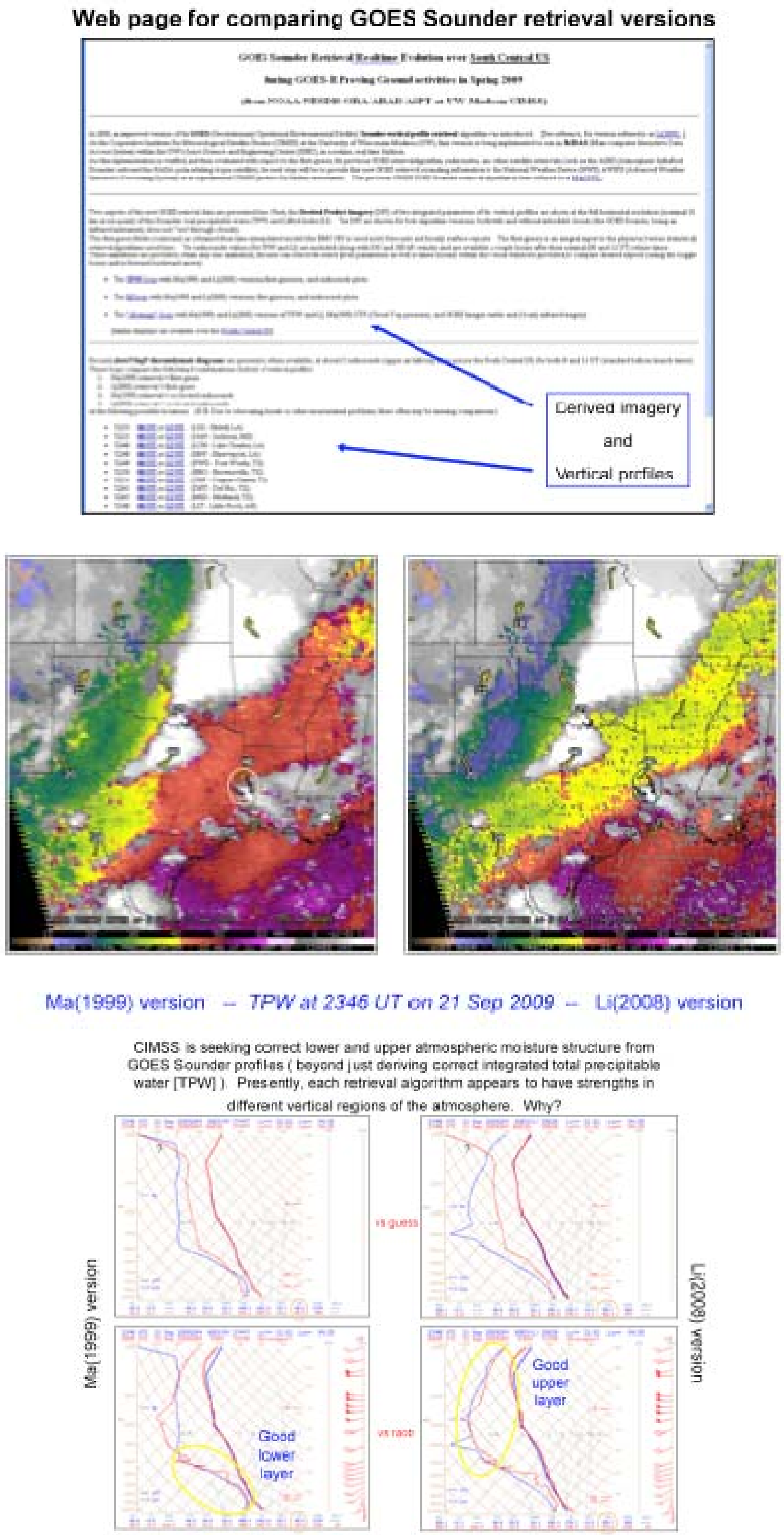


Figure 3.4.1. Examples of the types of comparisons available from CIMSS via the Web page http://cimss.ssec.wisc.edu/goes/realtime/scus/begin-scus.html.

3.5 Operational Implementation of the CIMSS Advanced Dvorak Technique (ADT)

CIMSS Project Lead(s): Tim Olander and Chris Velden
CIMSS Support Scientist(s): John Sears
NOAA Collaborator(s): Mike Turk (SAB), Jack Beven (NHC)
NOAA Strategic Goals Addressed:

- 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 and is the method upon which the ADT is based. 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) delivering ADT Version 7.2.3, which was based on feedback from SAB and improvements incorporated by CIMSS, and 2) readiness for an updated version (8.1) of the ADT that will be delivered in October of 2009. The new version will include 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. SAB analysts have provided thorough feedback regarding the performance of the ADT during the 2008 and 2009 TC seasons. This feedback has led to several improvements within the ADT algorithm and the development of the automated scripting routines developed for NOAA operations. For example, the ability to utilize all WMO Regional Specialized Meteorological Center (RSMC) official TC forecasts for initial analysis positioning has been implemented, along with several smaller requested items such as the utilization/output of different wind speed estimate values, improved identification of land features (over which the ADT is not designed to work) through the implementation of a new topography file and algorithm logic, and updating the ADT documentation. A major new thrust in ADT development during this reporting period has been the integration of an innovative method to utilize PMW data to augment the IR-based analyses. The basic research for this modification was conducted under other NOAA funding, however, the impending delivery of v8.1 that includes this new capability necessitated preparation for this data stream at the SAB site. CIMSS helped facilitate this preparation by supplying code and implementation support so the data streams and ADT algorithm "hooks" will be in place when v8.1 is installed in the next reporting period.

Publications and Conference Reports

Olander, T., C. Velden, and A. Wimmers, 2009: An update on the Advanced Dvorak Technique (ADT), Tropical Cyclone Coordinators Conference, Pearl Harbor, HI, April 27-28.

References

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

4. Ground Systems Research

4.1. Ground Systems Support of CIMSS Satellite Validation Infrastructure

Task Leads: Wayne Feltz and Erik Olson
Support Staff Scientist: Bruce Flynn and Joe Garcia
NOAA Strategic Goals addressed:

- Serve society's needs for weather and water information

Proposed Work

The University of Wisconsin – Madison 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.

Future plans include acquisition of a CIMEL sun photometer for monitoring Aerosol Optical Depth (AOD). 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) which collects, archives, and displays near-realtime data from various instruments on SSEC rooftop and lake Mendota buoy.

A new computer and data server named Tahiti was acquired through ground system funding to support rooftop instrument data archive and server. The system has eight cores, 16GB of RAM, 650GB of RAID-5 table space, and 100G of RAID1 cache space (Figure 4.1.1). Efforts to enter metadata as well as some of the data streams into the RIG database are underway (Figure 4.1.2). The server was purchased (tahiti.ssec.wisc.edu) and installed in the SSEC Data Center to consolidate database operations and quicklook generation. Rooftop instrument tower data (temperature, relative humidity, wind, and solar flux measurements) are being served via CF compliant NetCDF format and stored on an archival system (Figure 4.1.3).

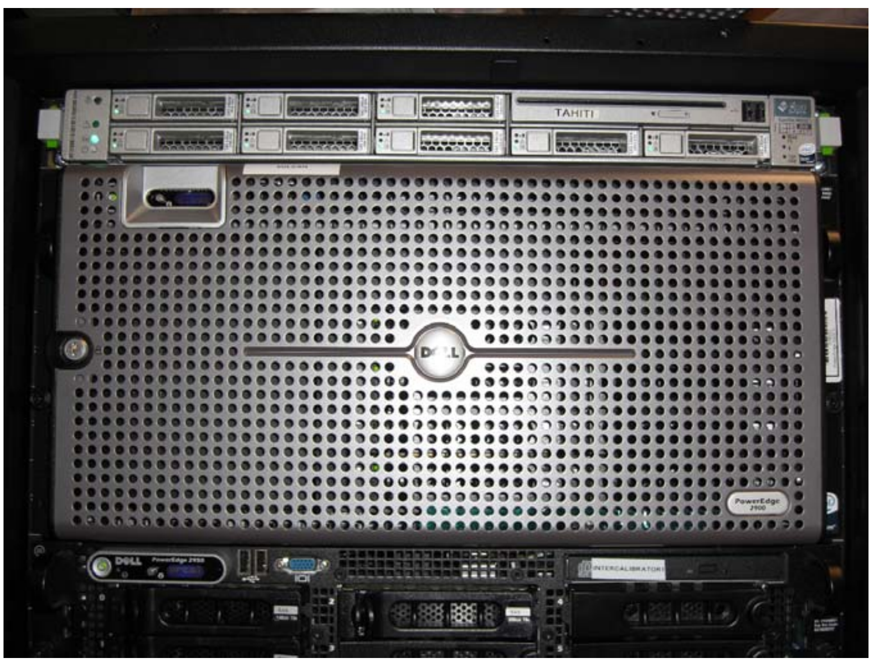


Figure 4.1.1. Picture of tahiti.ssec.wisc.edu computer and data server.

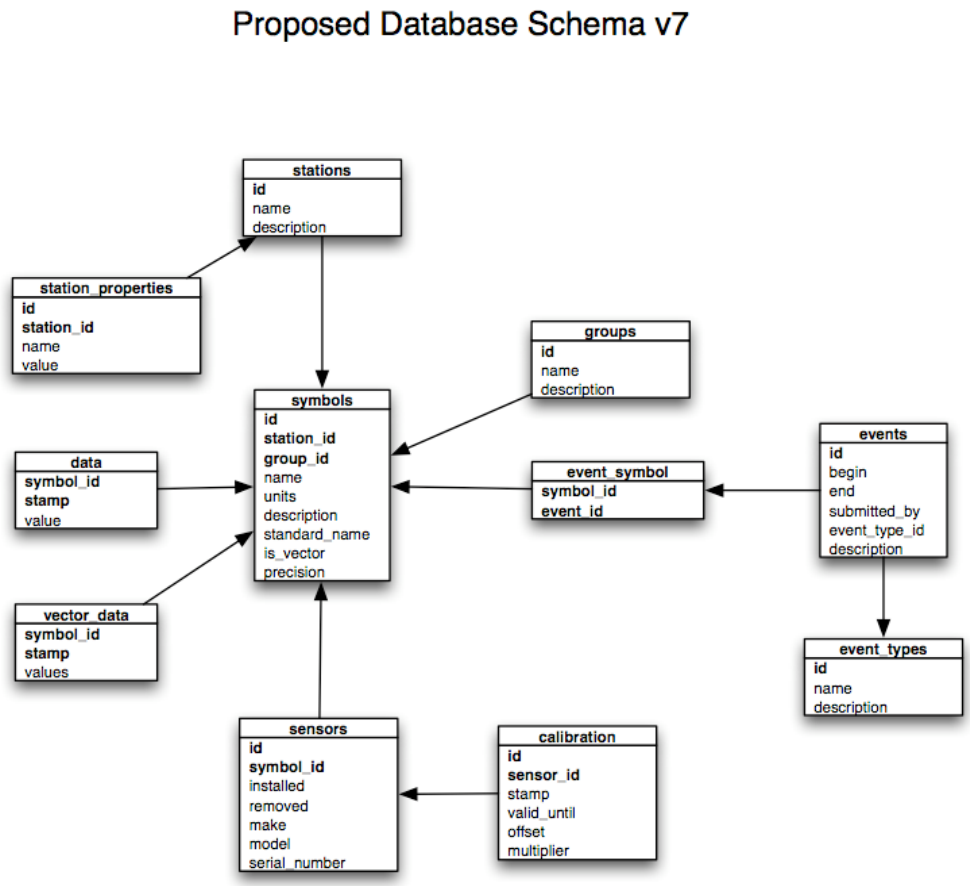


Figure 4.1.2. Schematic of database organization on Tahiti.

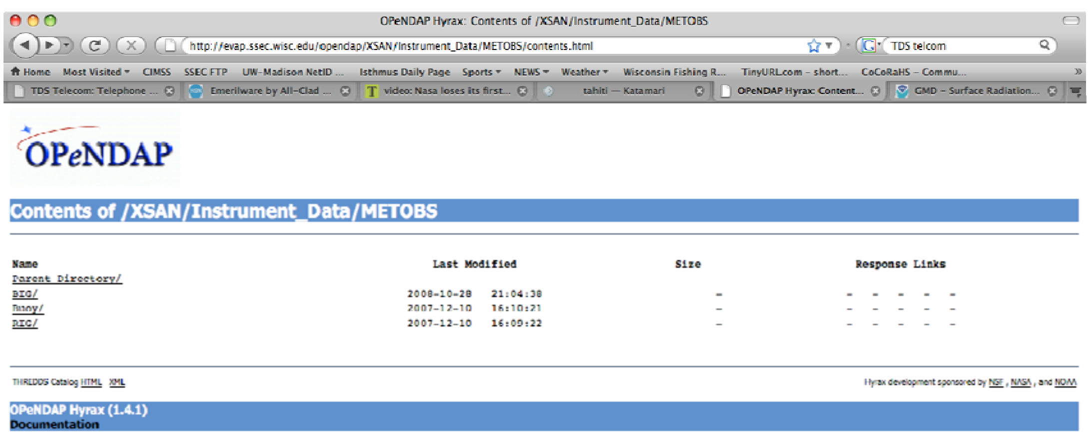


Figure 4.1.3. Picture of OPeNDAP data archival webpage allowing access to CF compliant NetCDF formatted data that can easily be brought into Matlab, IDL, or McIDAS-V validation tool.

A diagram of GAMIS data flow is shown in Figure 4.1.4 essentially showing data flowing from rooftop instruments to various computing nodes, archival system, and quicklook pages.

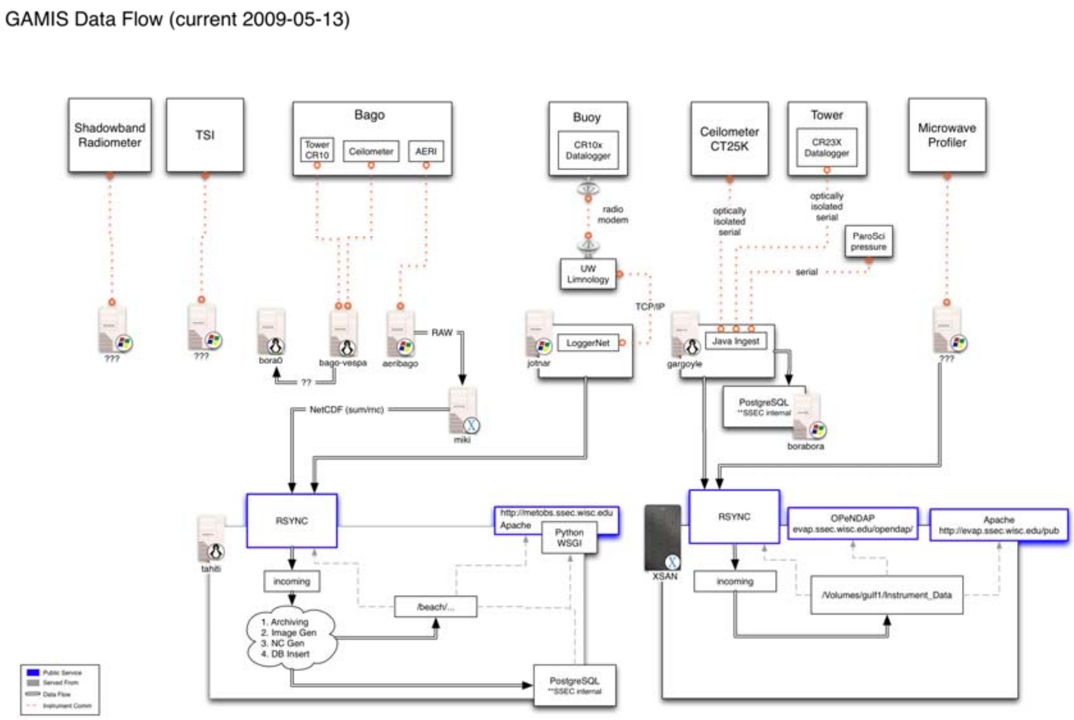


Figure 4.1.4. A diagram indicating GAMIS flow of data from instruments to computer servers, archival system, and final display.

A near real-time quicklook interface (Figure 4.1.5) for rooftop data 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.

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

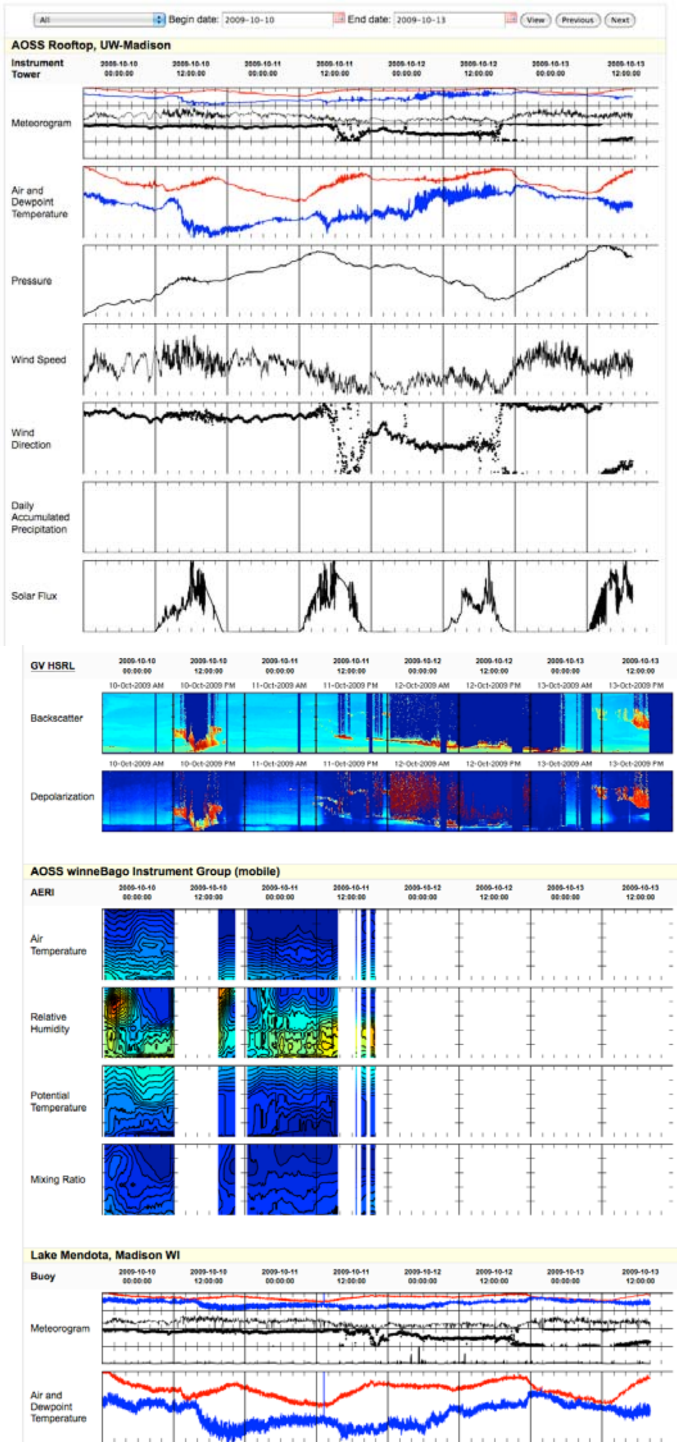


Figure 4.1.5. Example of quicklook interface to AOSS rooftop data.

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

CIMSS Project Lead(s): Scott Bachmeier
CIMSS Support Scientist(s): Jordan J. Gerth
NOAA Collaborator(s): Robert M. Aune, Gary S. Wade
NOAA Strategic Goals Addressed:

- 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
- Education, training and outreach

Proposed Work

Since 2006, CIMSS has been successful in developing and maintaining an in-house, fully-functional Advanced Weather Interactive Processing System (AWIPS) for the purpose of transitioning products from the research environment to operations in AWIPS network Common Data Format (NetCDF), and providing training to National Weather Service (NWS) forecasters which use relevant examples from their primary forecast preparation and weather data visualization tool.

Well established in 2009, CIMSS sought to augment this ground systems project with the goal of continuing the in-house AWIPS network via:

- Continued maintenance of the existing AWIPS hardware;
- Software upgrades to the latest AWIPS operational build;
- Upgrading the primary AWIPS-ready data distribution server;
- The purchase and integration, as needed, of additional dedicated processing machines for producing AWIPS-ready data prior to distribution via the established data servers;
- Preparing a plan for phasing out and modifying existing AWIPS hardware as migrated AWIPS "II" launches in late 2010 with new required hardware specifications;
- Documenting successful methods of AWIPS development; and
- Adding Advanced Very High Resolution Radiometer (AVHRR) processing capabilities and leveraging existing research to operations connections for distribution of AVHRR imagery and products to the field.

Summary of Accomplishments and Findings

Due in large part to continued software and hardware upgrades and adequate support, the CIMSS AWIPS network has remained healthy and viable in 2009, supporting the CIMSS research enterprise. AWIPS at CIMSS has contributed heavily to the success of several CIMSS projects which have research to operations objectives and product transition to NWS operations components, including:

- 2.1. Improvement and Validation of Convective Initiation and Mesoscale Wind Applications
- 2.10. Using AWIPS to Expand Usage of GOES Imagery and Products (including those from the GOES Sounder) in NWS Forecast Offices
- 5.4. Nearcasts - Filling the Gap Between Observations and NWP Using Dynamic Projections of GOES Moisture Products
- 8. CIMSS Participation in the Development of GOES-R Proving Ground
- 12. VISIT Participation
- 13. SHyMet Activities
- 17.5. International Polar Orbiting Processing Package (IPOPP) for Direct Broadcast Users

Knowledge of the AWIPS software at CIMSS has contributed to dozens of products successfully transitioned to NWS field offices in an experimental capacity, influencing 268 documented forecast decisions at 37 offices since July 2006. Imagery and products transitioned to date include:

- Channels and products from the MODerate resolution Imaging Spectroradiometer (MODIS) which have a wide range of implications from vegetation and snow cover assessment to sea surface temperature determination;
- GOES Convective Available Potential Energy (CAPE) and Total Column Ozone (TCO);
- Synthetic forecast infrared window and water vapor imagery from the CIMSS Regional Assimilation System (CRAS);
- Other CRAS output parameters comparable to the National Centers for Environmental Prediction (NCEP) operational models;
- Cloud-top cooling for convective initiation potential;
- Short-term total precipitable water predictions via a Lagrangian model for assessing convective instability; and
- Mesoscale atmospheric wind vectors derived from GOES.

In order to accomplish these research-to-operations exercises, prepare for the expansion of this effort in the future under the next generation of AWIPS, and assure a reliable and consistent delivery of AWIPS-ready products to the field through the mitigation of single points of failure, the following changes were made to the CIMSS local AWIPS network in 2009:

- Jordan Gerth coordinated a transition with NWS Regional Headquarters technical contacts to change the experimental data feed to originate from technology-current, industry-standard redundant servers at CIMSS running the latest version of the Local Data Manager (LDM);
- Jordan Gerth upgraded AWIPS servers and workstations to Operational Build 9.0 (OB9.0) and 9.1 (OB9.1) software, which was able to run on existing hardware supporting RedHat Enterprise Linux 5;
- Documentation was updated and revised to assure AWIPS servers and workstations could be restarted with ease in the event of a system failure or unexpected power failure;
- Jordan Gerth evaluated the latest migrated AWIPS "II" Task Orders and reviewed changes in the software architecture as it will apply to the research to operation activities with NWS operations, and hardware upgrades for existing AWIPS workstations;
- A new server was installed to handle and process incoming AVHRR data for AWIPS readiness.

In addition, a Weather Event Simulator (WES) was maintained and upgraded to the latest version. The WES allows for the display of AWIPS-formatted data in displaced real-time. Forecasters at NWS offices are often required to evaluate one or more WES cases as part of their annual training. CIMSS has used their WES capability leveraged with knowledge of AWIPS to prepare a case of synthetic GOES-R Advanced Baseline Imager (ABI), which is ready for initial testing in the field. The case will ready the field for the increased spatial, spectral, and temporal resolution of data resulting from the GOES-R series.

The current hardware configuration of the AWIPS network at CIMSS consists of three redundant data servers. One primary server handles connections with the NWS for serving data to the field and ingests Satellite Broadcast Network (SBN) data from the LDM, feeding the local AWIPS workstations. The secondary server, which can immediately support NWS connectivity if the primary fails, has been prepared to process AVHRR imagery and products for NWS operations. A tertiary server exists to run N-AWIPS (National AWIPS), the version of AWIPS used in the national centers, specifically the National Hurricane Center and Storm Prediction Center. An additional server not part of the redundant set runs and produces AWIPS-ready CRAS forecasts on domains for the continental United States, Alaska, and Hawaii. There are five workstations which run AWIPS and receive data from the primary server, in addition to a development AWIPS workstation which maintains a separate SBN data ingest and a WES, discussed previously. Through the capability of separate testing from the local network, the development AWIPS workstation allows for the implementation of new operational software builds and software modifications to other workstations without interruption of local or transmitted data, or server downtime.

As CIMSS continues a successful effort to infuse satellite-based imagery and products to NWS operations via AWIPS, CIMSS is mindful of upcoming changes to the software as part of the AWIPS migration project which will require a reassessment of the data formatting and delivery mechanisms. There is a plan to implement the migrated AWIPS "II" software on all local data servers and workstations by the middle of 2010, and transition all current experimental products to an AWIPS "II" format by the end of 2010, consistent with NWS schedules for national delivery of AWIPS "II" to the field offices.

5. GOES-R Risk Reduction

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

CIMSS Project Leads: Jason Otkin and Allen Huang
NOAA Strategic Goals Addressed:

- 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 radiances impacts the accuracy of atmospheric analyses and affects the skill of short-range numerical model forecasts. Multiple observation system simulation experiments (OSSEs) will be performed to examine the data impact on simulated cloud properties as well as to provide guidance concerning the optimal assimilation of infrared radiances.

Summary of Accomplishments and Findings

Accomplishments during the past year include enhancing our data assimilation capabilities and beginning the first OSSE case study. All of our data assimilation activities employ the Data Assimilation Research Testbed (DART), which is an ensemble Kalman filter (EnKF) based data assimilation system. In order to incorporate several conventional observation types within the assimilation experiments, programs were written to generate simulated METAR, radiosonde, and aircraft observations from the "truth" WRF model simulation performed last year. Realistic errors based on the instrument accuracy specifications were added to each of the simulated observations. Further, in an effort to realistically represent the observation density for each data type, simulated observations were only generated for existing METAR and radiosonde station locations and for aircraft pilot reports contained within corresponding MADIS data files.

In order to assimilate simulated ABI infrared radiances, significant modifications were made to the DART code. A new module was written to provide an interface between DART and the Successive Order of Interaction (SOI) forward radiative transfer model. To fit within the DART framework, it was necessary to combine the original SOI subroutines, functions, and modules into a library that could be accessed from within DART. A new module was also written to extract the appropriate atmospheric and land surface data from the model state vector and convert this data into the proper format for ingest into the radiative transfer model. This module also includes a subroutine to calculate the effective particle diameter for each hydrometeor species. It is important to note that now that the basic radiance assimilation capability has been added to DART, that this framework can be modified with minimal effort to assimilate observations from other sensors.

Numerous sensitivity tests were performed to evaluate how several tunable parameters in the data assimilation system, such as the covariance localization radius and the covariance inflation factor, influence the results from the first OSSE case study, which tracks the evolution of a large mid-latitude cyclone and two thunderstorm complexes. Overall, it was found that the best results were generally achieved when minimal covariance inflation (2%) and a medium-ranged localization radius (~800 km) were used. Additional tests showed that increasing the ensemble size from 32 to 40 members produced a more accurate analysis due to a better representation of the background error covariance matrix.

Several assimilation experiments were performed using these settings. Each ensemble member contained 12-km horizontal grid spacing and 37 vertical levels. The initial ensemble containing balanced initial and lateral boundary condition perturbations was created at 00 UTC on 03 June 2005 and then integrated for 24 hours. Conventional observations from the truth simulation were then assimilated once per hour during the following 12 hours in order to produce a realistic ensemble for the final assimilation experiments, which began at 12 UTC on 04 June. Four assimilation experiments were subsequently conducted in which simulated conventional observations and/or ABI band 11 (8.5 μm) radiances from the truth simulation were assimilated once per hour until 00 UTC on 05 June. The simulated radiances were coarsened to ~50-km resolution prior to assimilation. Both clear and cloudy radiances were assimilated in the "B11 ALL" case whereas only clear-sky radiances were assimilated in the "B11 CLEAR" case. Conventional observations, including radiosondes, surface METARs, and aircraft pilot reports, were assimilated in the "CONV" case. Finally, both conventional observations and clear and cloudy-sky radiances were assimilated in the "CONV B11" case.

In order to evaluate the impact of the infrared radiances on the cloud fields, data from the assimilation experiments were remapped to the truth domain and then both datasets were interpolated to isobaric surfaces. Standard statistical measures were then computed for each dataset. Figure 5.1.1 shows vertical profiles of RMSE for the "total" cloud hydrometeor field (i.e., the sum of the cloud water, rain water, pristine ice, snow, and graupel mixing ratios) for both clear and cloudy grid points in the truth simulation. Cloudy grid points were simply defined as those containing a cloud water path greater than zero. It should be noted that due to differences in cloud placement, the prior assimilation analysis will contain clouds at some grid points identified as clear in the truth simulation and vice versa. Ideally, after assimilation, the posterior analysis will no longer contain clouds within the clear areas or clear skies where there should be clouds, but this is very difficult to attain in practice. Inspection of Figure 5.1.1a reveals that the assimilation of both clear and cloudy-sky 8.5 μm radiances in the "B11 ALL" case generally reduces the RMSE for cloudy grid points, particularly in the upper troposphere, which indicates that the Ensemble Kalman Filter is able to extract valuable information about the cloud field from the cloudy radiances. The smaller errors are primarily due to a better representation of the snow mixing ratio field (not shown). Radiance assimilation has an even larger impact on the clear grid points (Figure 5.1.1b), where there is a substantial reduction in the RMSE at all levels relative to the conventional only case. It is apparent that the radiances are able to more easily remove the erroneous cloud cover at these grid points. The reduction in the RMSE in the "B11 ALL" case relative to the "B11 CLEAR" case indicates that the cloudy radiances act as an additional constraint on the clear areas, possibly by changing the large-scale flow or by simply improving the evolution of the existing cloud cover (which may then no longer advect into the clear regions, thereby reducing the errors).

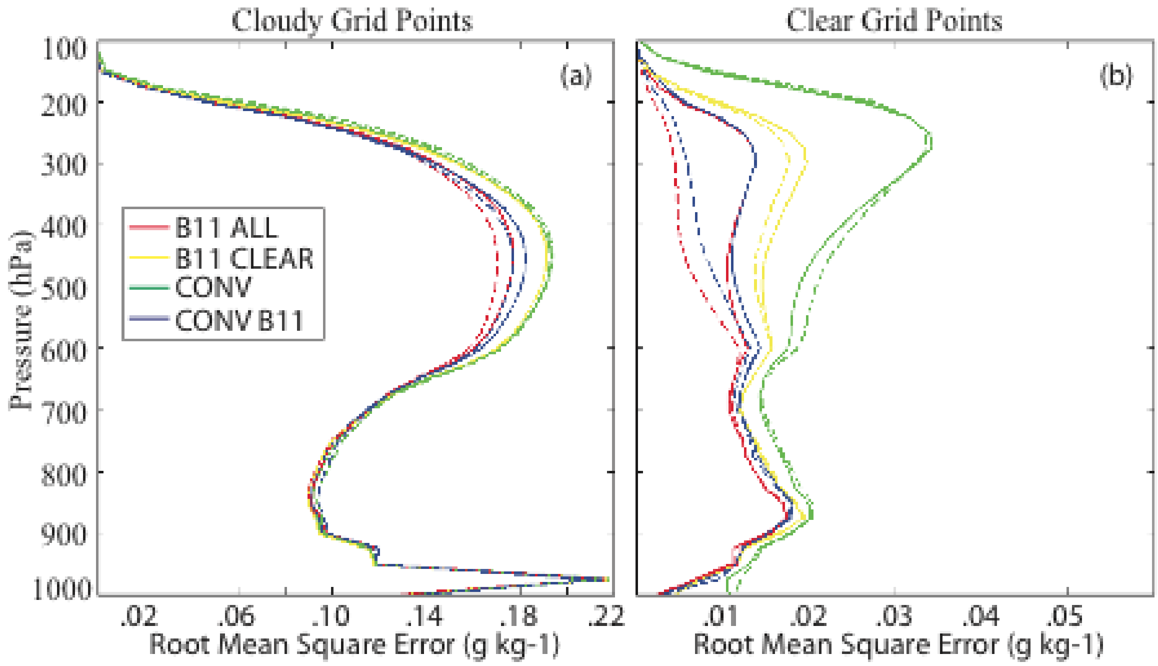


Figure 5.1.1 Vertical profiles of domain-averaged prior (solid) and posterior (dashed) root mean square error (RMSE; g kg^{-1}) for the total cloud hydrometeor mixing ratio (sum of the cloud water, rain water, ice, snow, and graupel mixing ratios) for the (a) cloudy and (b) clear "truth" grid points as defined in the text.

5.2. Hurricane Wind Structure and Secondary Eyewall Formation

CIMSS Project Lead: Christopher Rozoff
NOAA Collaborator: James 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

Tropical cyclones, particularly intense ones, often produce eyewall replacement cycles where an outer eyewall forms outside of a primary eyewall. The consequences of this process include temporary weakening but a widening of the low-level wind field. It is therefore of interest to improve the forecasting skill of such events, particularly before landfall.

The focus of this project has transitioned over the course of time. In earlier work, a Bayesian probabilistic scheme for forecasting secondary eyewall formation (SEF) was designed to incorporate environmental and GOES IR satellite data about storm structure (Kossin and Sitkowski 2009). Both environmental and remotely sensed structural features have provided skillful value to the SEF forecasting algorithm. Of particular interest was the importance was the principle component analysis of azimuthally averaged radial profiles of GOES IR brightness temperatures, which indicated the importance of a structure that resembled a dynamical signal of a hurricane moat (e.g., Rozoff et al. 2008). With the benefits of satellite information demonstrated in Kossin and Sitkowski (2009), this project has evolved to further explore the potential utility of increased spectral and spatial resolution satellite data that will be available with GOES-R ABI for detecting important structures related to tropical cyclone structure change. The cloud structure observed in satellite imagery can reveal important details about the storm dynamics and diabatic heating distributions. In the interest of exploring the potential utility of ABI in revealing forecasting insight into important dynamics and cloud processes in tropical cyclone SEF and structural changes, we are analyzing MSG-SEVIRI data and simulated ABI data from numerical simulations of tropical cyclones.

Summary of Accomplishments and Findings

A manuscript describing the results of the North Atlantic and Eastern North Pacific secondary eyewall formation (SEF) climatology and forecasting scheme has now been published (Kossin and Sitkowski 2009) and has been recognized as a Paper of Note by the Senior BAMS editor. The climatology includes the distributions of hurricane location, intensity, environmental conditions, and time of year associated with SEF events. Cross-validation has proven skillful when measured against climatology. Currently, a real-time prototype of the Bayes algorithm is being transitioned into operations at the National Hurricane Center via the Joint Hurricane Testbed project.

Encouraged by the analysis of MSG-SEVIRI data during an SEF process in North Atlantic Hurricane Helene (2006), we have conjectured that considerable forecast skill in the Bayesian scheme of Kossin and Sitkowski (2009) may be added through the analysis of the “shortwave” (3.9 μm) channel brightness temperatures. The shortwave imagery in Helene shows a strong warming within the region that becomes the outer eyewall, which is consistent with the enhanced subsidence that typically occurs in the radial region inside of an outer eyewall. As such, we have examined shortwave data over the North Atlantic Ocean from GOES and Meteosat imagery contained in the HURSAT dataset (Knapp and Kossin 2007; Kossin et al. 2007) over the years 1997-2006. Specifically, we compiled azimuthally averaged radial profiles of 3.9 μm brightness temperatures for all storms over this time period, one for daytime hours and another dataset covering all hours of the day. From there, a principle component analysis was performed on the azimuthally averaged radial profiles of each dataset. The first four empirical orthogonal functions (EOFs) explained a substantial portion of the variance in both cases. It turns out the data restricted to daylight hours provides substantial improvement to the forecasting skill of the Bayesian SEF algorithm as nighttime data is rather noisy. Close examination of various channels of the high resolution simulated ABI channels in MSG data covering Hurricane Helene continues.

The CIMSS forward radiative transfer modeling system has been used to compute simulated radiances for each ABI band in a Hurricane Katrina (2005) simulation, which offers the ability to connect information in the high spectral resolution ABI data and products to actual dynamics and diabatic heating in tropical cyclone simulations. We have an idealized tropical cyclone simulation in WRF that produces an eyewall replacement cycle (Figure 5.2.1a) and plan to apply the forward radiative transfer code to closely examine the potential ability to infer important aspects of the diabatic heating that can be obtained in ABI data. Diabatic heating is one of the most critical aspects of SEF (e.g., Rozoff et al. 2009) since it is intimately involved in the genesis and maturation of an outer eyewall (Figure 5.2.1b). This effort is expect to yield new insight into how advanced infrared and visible imagery can improve our ability to capture important tropical cyclone structures that are essential in tropical cyclone intensity forecasting.

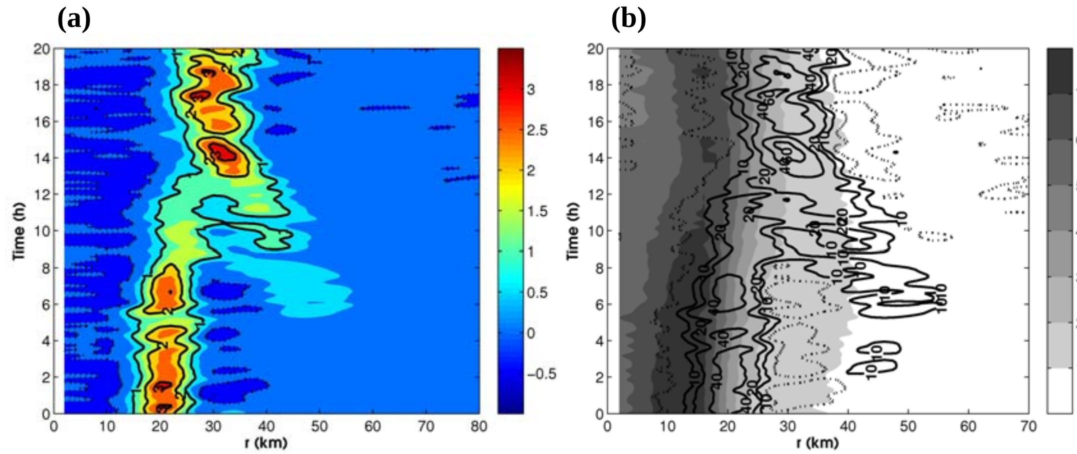


Figure 5.2.1. Various fields illustrating the evolution of an eyewall replacement cycle in a WRF tropical cyclone simulation. (a) Radius-time Hovmoller diagram of vertical motion (m s^{-1}) at z = 5 km on the third day of the simulation. (b) Inertial stability parameter $([\langle f\rangle + \langle \zeta\rangle][\langle f\rangle + 2\langle v\rangle/r])^{-1/2}$ at z = 0.5 km (shaded; units of 10^{-3} s^{-1}) and condensational heating (contoured; K h^{-1}) at z = 4 km.

Publications

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., J. P. Kossin, and D. S. Nolan, 2009: Dynamical mechanisms for secondary eyewall formation in a high-resolution mesoscale model simulation of an intense tropical cyclone. *Mon. Wea. Rev.*, in preparation.

References

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

Kossin, J. P., K. R. Knapp, D. J. Vimont, R. J. Murnane, and B. A. Harper, 2007: A globally consistent reanalysis of hurricane variability and trends. *Geophys. Res. Lett.*, **34**, L04815, doi:10.1029/2006GL028836.

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., W. H. Schubert, and J. P. Kossin, 2008: Some dynamical aspects of tropical cyclone concentric eyewalls. *Q. J. R. Meteorol. Soc.*, **134**, 583—593.

Rozoff, C. M., J. P. Kossin, and D. S. Nolan, 2009: Dynamical mechanisms for secondary eyewall formation in a high-resolution mesoscale model simulation of an intense tropical cyclone. *Mon. Wea. Rev.*, in preparation.

5.3. GOES-R risk reduction study – GEO/LEO synergy for sounding

CIMSS Project Leads: Jun Li, Allen Huang
CIMSS Support Scientist(s): Elisabeth Weisz, Zhenglong Li, Jinlong Li
NOAA Collaborator(s): Tim Schmit, Chris Barnet
NOAA Strategic Goals Addressed:

- 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

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 polar-orbiting satellites for improved soundings. According to the GOES-R risk reduction (R3) technical advisory committee (TAC) guidance for 2009, we will use the GOES Sounder and AIRS (Atmospheric Infrared Sounder) to emulate the ABI and LEO (low earth orbit) hyperspectral IR sounder for GEO/LEO synergy study. Radiosondes and forecast analysis will be used to evaluate the improvement of combined GEO/LEO over that from either system alone.

Summary of Accomplishments and Findings

(1) The CIMSS hyperspectral IR sounding retrieval (CHISR) algorithm has been developed for soundings at full spatial resolution. Using full spatial resolution soundings from LEO satellites is the first step in the GEO/LEO synergy. Usually the operational product from LEO advanced sounder is based on IR/microwave (e.g., AIRS/AMSU, CrIS/ATMS) radiances and the spatial resolution of operational sounding product is 3 by3 of IR footprint, which is good for global numerical weather prediction. However, high spatial resolution is the requirement for GEO soundings; for better soundings from combined GEO/LEO, it is very important to derive full spatial resolution soundings from the LEO advanced IR sounder radiance measurements. The purpose of CIMSS hyperspectral IR sounding retrieval (CHISR) algorithm is to derive full spatial resolution soundings from IR radiance measurements in both clear and cloudy skies. We have improved the cloudy InfraRed (IR) radiative transfer model (RTM) initially developed under the joint efforts between University of Wisconsin-Madison and Texas A&M University (Ping Yang). The improved version includes surface emissivity contribution, and more importantly, version contains analytical Jacobians calculations in cloudy skies (derivative of cloudy radiance to a variable) for temperature and moisture profiles, and for cloud parameters (cloud optical thickness, cloud particle radius and cloud-top pressure). Thus sounding profiles under cloudy conditions can be derived very efficiently. This cloudy IR RTM has been used in hyperspectral IR single FOV cloudy sounding retrieval, cloudy total column ozone (TCO) retrieval, cloud-top property retrieval using IR radiances, etc. Per request from the Texas A&M University (Ping Yang) and the AIRS (Atmospheric InfraRed Sounder) RTM team at University of Maryland – Baltimore County (Sergio DeSouza-Machado), this improved cloudy IR RTM has been made available to the research community for various applications. For instance, STAR/NESDIS (Dr. Chris Barnet) is planning to implement the cloudy RTM into the AIRS retrieval algorithm, according to Sergio DeSouza-Machado.

(2) The CIMSS hyperspectral IR sounding retrieval (CHISR) algorithm has been developed. CHISR algorithm has been developed for deriving full spatial resolution soundings from advanced sounders like AIRS under both clear and cloudy skies. CHISR enables us to gain important information on atmospheric thermodynamic structures such as the vertical structure of the temperature within the hurricane eye. The full spatial resolution cloudy soundings within the hurricane eye (Hurricane Monica 2006) have been

provided to Stephen L. Durden at JPL to be used in hurricane intensity (SLP) estimation; he found improved hurricane SLP from AIRS over that estimated from MODIS. Figure 5.3.1 shows one example of cloudy temperature and moisture profiles (right panel) from Hurricane Monica's eye; note that the eye is also cloudy.

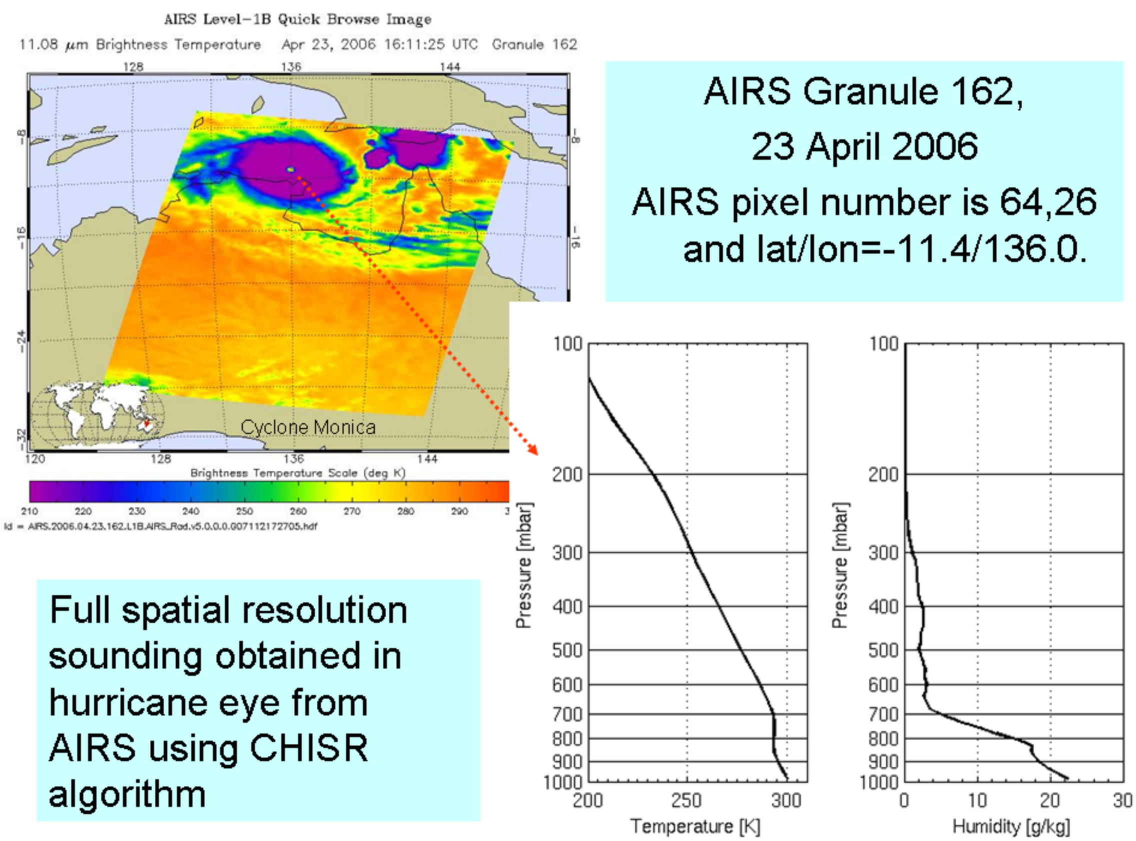


Figure 5.3.1. Single footprint cloudy temperature and moisture profiles (right panel) from Hurricane Monica eye, along with an AIRS brightness temperature at a window channel (left panel).

(3) The GEO/LEO synergy algorithm is under development for soundings (Use GOES Sounder to proxy ABI, and AIRS to proxy CrIS). Since there is no sounder on the GOES-R, ABI is used to continue the current GOES Sounder legacy atmospheric product (Schmit et al. 2008). ABI can provide measurements with high spatial and temporal resolution, however, due to the limited spectral channels, ABI can only provide atmospheric temperature and moisture profiles with coarser vertical structures. Therefore a combination of high temporal resolution ABI and high spectral resolution advanced IR sounder from polar-orbiting satellite is very important for mesoscale application of profiles. We have used the current GOES Sounder and AIRS for algorithm development. AIRS is remapped to the GOES footprints, and soundings are produced by combining GOES Sounder and AIRS: If the AIRS retrieval is found for a given GOES Sounder field-of-view (FOV), then the AIRS sounding is used as the first guess in the GOES single FOV physical retrieval; then the GOES sounding containing AIRS information is used as the first guess for the next time step GOES process until new AIRS sounding is found. The upper panel of Figure 5.3.2 shows the conceptual diagram of the AIRS/GOES combination. The lower central two panels show the water vapor mixing ratio (g/kg) first guess at 920 hPa for 08 UTC and 11 UTC on 24 February 2007, respectively. The left panel shows the relative humidity (RH) profile retrieval from GOES+AIRS and from GOES alone for the footprint indicated in the center panels where AIRS sounding is available,

whereas the right panel shows the RH retrievals at the same footprint, but where the sounding retrieval containing AIRS information from the previous time step is used as the first guess. Combining AIRS and GOES provides enhanced vertical structure. A process will be developed for combining GOES Sounder and AIRS to proxy ABI and CrIS data. More validation will be conducted to evaluate the improvement of combined GOES and AIRS retrievals.

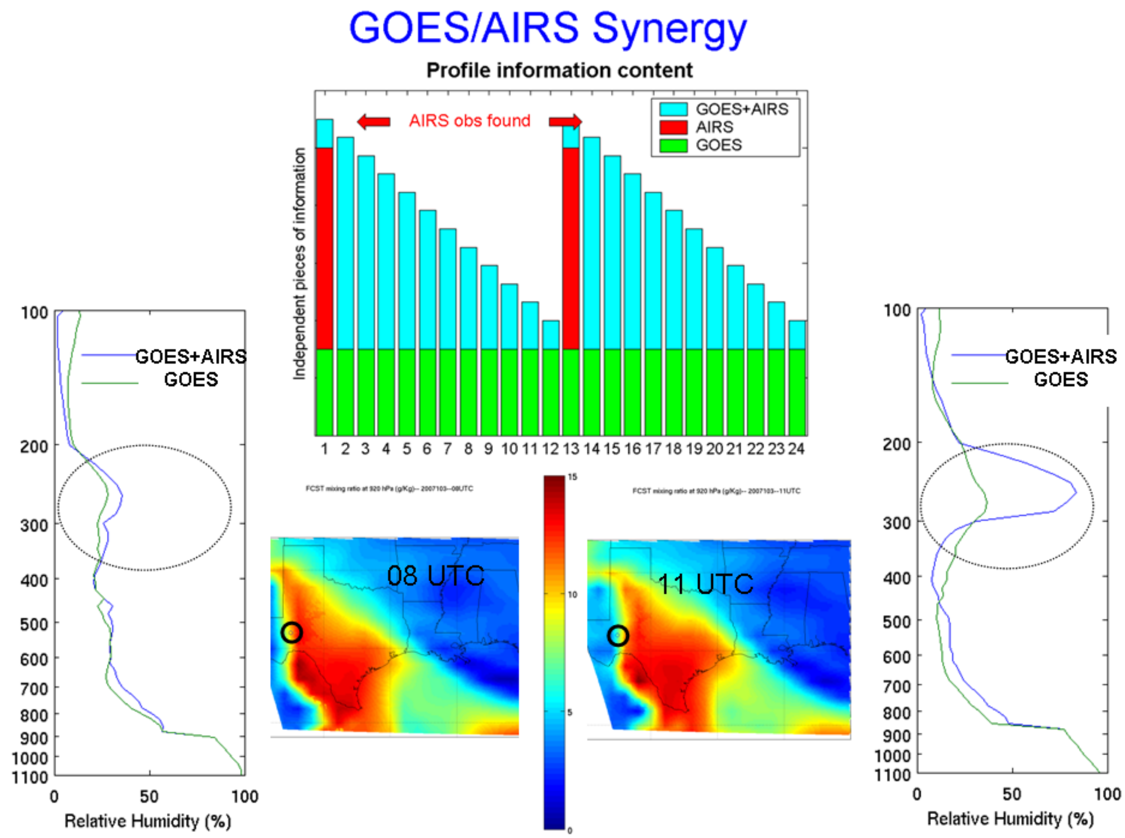


Figure 5.3.2. Conceptual diagram of AIRS and GOES combination on sounding information content, along with RH profiles from GOES alone and combined GOES and AIRS at one footprint for 08 UTC and 11 UTC, respective. The date is 24 February 2007.

(4) GEO IR radiance bias adjustment using LEO advanced IR sounder has been applied. The GOES Sounder radiance bias can be removed with the help of AIRS. Collocated AIRS and GOES Sounder radiances in clear skies can be used for the bias removal of GOES sounder measurements. Since the AIRS instrument possesses high spectral resolution with high radiometric accuracy the radiance differences between collocated AIRS and GOES Sounder are due to (a) GOES Sounder radiance calibration biases, and (b) the viewing angle differences between AIRS and GOES. The angle effects can be corrected by comparing AIRS and GOES radiances; the radiance difference after the angle correction represents the GOES Sounder radiance bias that can be removed before retrieval. An algorithm has been developed for estimating GOES radiances with the help of AIRS. Further research is ongoing to evaluate the impact of radiance bias adjustment with AIRS.

Publications and Conference Reports

Li, Zhenglong., 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.D.Atmospheres*, **114**, D09216, doi:10.1029/2008JD010596.

Li, Zhenglong, J. Li, P. Menzel, T. J. Schmit, and J. Nelson, 2009: High Temporal GOES Sounding Retrievals in Cloudy Regions and Applications, 89th AMS annual meeting, 11 - 15 January 2009, Phoenix, AZ.

Li, Zhenglong, 2009: Improvements and Applications of Atmospheric Soundings from Geostationary Platform, Ph.D. dissertation, University of Wisconsin-Madison. p134

References

Schmit, T. J., J. Li, J. J. Gurka, M. D. Goldberg, K. Schrab, Jinlong Li, and W. Feltz, 2008: The GOES-R Advanced Baseline Imager and the continuation of current GOES sounder products. *J. of Appl. Meteorol. and Climatology*, **47**, 2696 – 2711.

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

CIMSS Project Lead: Ralph Petersen
NOAA Collaborator: Bob Aune
NOAA Strategic Goals Addressed:

- 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 overall goal of this continuing 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 GOES satellites. The NearCasting system uses a trajectory-based approach which preserved large gradients and maxima and minima observed in the GOES data, as well as using successive temporal data to revalidate/revise previous projections every hour. Because basic system development has reached sufficient maturity, the broad objective for 2009 was directed at performing product improvement and real-time testing in selected NWS/WFOs. Through this work, WFOs and some NCEP Service Centers (e.g., SPC, AWC) will improve their very-short-range forecasts and the GOES-R program will have examples showing the benefit of temporal and spatial improvements available when GOES data are used effectively. Results using EUMETSAT SEVIRI data as surrogates for GOES-R ABI data will also be transferable to European Meteorological Services.

Summary of Accomplishments and Findings

The majority of the effort during this year has focused on real-time testing and subjective evaluation of the NearCast products, including a variety of additional case studies using both GOES and SEVIRI data. Recognizing that convective destabilization is only one of many possible thermodynamic indicators of the timing and location of near-future development of convection, 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. Major efforts were also made to remove instabilities in the NWP-based wind fields used to initialize the NearCast trajectories which lead to the rapid development of areas of excessive divergence/convergence. Theoretical examination of the Lagrangian form of the divergence equation showed that the cause of this rapid growth was being forced by excessive deformation in the initial wind fields (both shearing and stretching). Filtering methods have been developed to control this problem and to potentially extend the useful range of the Lagrangian NearCasts out to at least 9 hours.

Milestones *(Status in Parentheses)* for 2009 include:

- Expand WFO training and testing (Ongoing)
  - Expand to Great Plains areas (In planning – data on NWS/CR server)
- Obtain NWS/Scientific Services Directors endorsement (Completed)
  - Perform Heavy Precipitation Tests (Completed)
- Expand development of VISITview-based forecaster and system operator training tools (In progress)

Additional new tasks added at no additional cost to the program included:

- Involvement of FAA Weather Research Programs for aviation applications (Discussions underway)
- Testing with EUMETSAT SEVIRI data over Europe at GOES-R ABI surrogate(Ongoing)
  - Tests successful for major tornadic event in Poland completely missed by all available NWP models
- Assess limitation of centralized & distributed computing (In planning)
- Speed processing of GOES retrievals to extend usefulness of NearCasts (Completed)
  - Remove single-points-of-failure from 24/7 system at CIMSS (Ongoing)
  - Coordinate initial local NearCasting system implementation at a WFO (In planning)
- Extend NearCast accuracy and extend beyond 6 hours by limiting growth of Convergence/Deformation emanating from initial wind fields (Theoretical basis Completed/Implementation Ongoing)
- Design verification plan using McIDAS-V (Ongoing-Coordinating with ongoing McIDAS-V/GOES-RRR efforts
- Expanded evaluation base to include SPC and EUMETSAT (Ongoing)
- Enhance output types to emphasize GRIB-II digital formats and AWIPS/N-AWIPS graphical formats (Completed)
  - Web page operational, including NearCast archive

Efforts for the year have focused both on useful delivery of real-time products and scientific expansion of the products. All milestones were met or are near completion. Most notable were: 1) providing NearCast products in real-time; 2) expanding the number of output parameters; and 3) briefings on the NearCasting system and products to additional NWS/WFOs, GOES Program management, NWS/HQ personnel, NCEP's SPC and EUMETSAT members/collaborators. Highlights follow:

Real-time 24/7 processing NearCast production commenced on March 30, allowing detailed monitoring of localized severe weather cases. One such case occurred on February 10, 2009 (see Figure 5.4.1). The experimental NearCasting model, initialized with two layers of vertically integrated water vapor retrieved hourly from the operational GOES-12 sounder, successfully identified an area of high severe weather risk in Central Oklahoma five hours prior to the outbreak of tornadoes. These observations are projected forward six hours to identify areas of atmospheric destabilization, i.e., drying aloft over moistening below. The NearCasts showed areas of instability developing and then moving over Oklahoma City at the time of the tornado formation. The second area of instability predicted by the NearCasts over east-central Texas was associated with damaging wind reports. For this case forecasters had expected the strongest convection to form in far southeastern Oklahoma.

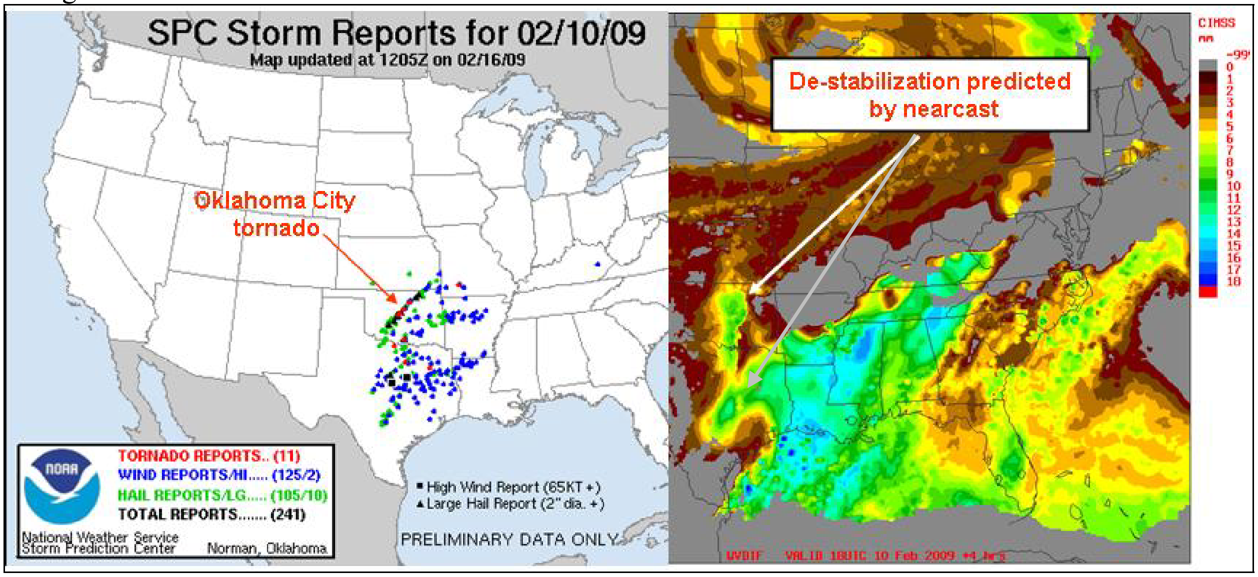


Figure 5.4.1. Example of the utility of NearCasts for GOES low (900-700hPa)- and mid (700-300hPa)-level GOES moisture information for a case on February 10, 2009. Vertical Moisture gradients derived from NearCasts on right (green areas show large vertical moisture gradients - a necessary condition for convective instability), verifying storm reports on the left.

Output for the NearCasting system was enhanced to allow detailed monitoring of localized severe weather cases of not only low- and mid-level moisture and vertical differences, but also multiple levels and vertical gradients of equivalent potential temperature (θ_E). One such case of isolating areas conducive to rapid development of convection occurred on July 9, 2009 (see Figure 5.4.2). The experimental CIMSS NearCasting model successfully identified an area of high severe weather risk in NW Iowa six hours prior to the outbreak of convection. The CIMSS NearCasting model is initialized with two layers of vertically integrated water vapor and temperature retrieved hourly from the operational GOES-12 sounder. These layers are projected forward six hours to identify areas of atmospheric destabilization, i.e., dry/cold (low θ_E) air overlaying warm/moisten air (high θ_E) below. It should be noted that although convective instability (larger negative $\partial\theta_E/\partial Z$) is a necessary condition for rapid development of deep convection, convection will only occur in areas with both convective instability *and* sufficient low-level lifting (convergence) to release the instability. The example also shows that although the majority of the stability information comes from the GOES moisture data, important additional information is also provided by the detailed temperature observations. These and other event and the utility of the NearCast are also discussed on the CIMSS blog (http://cimss.ssec.wisc.edu/goes/blog/archives/2153).

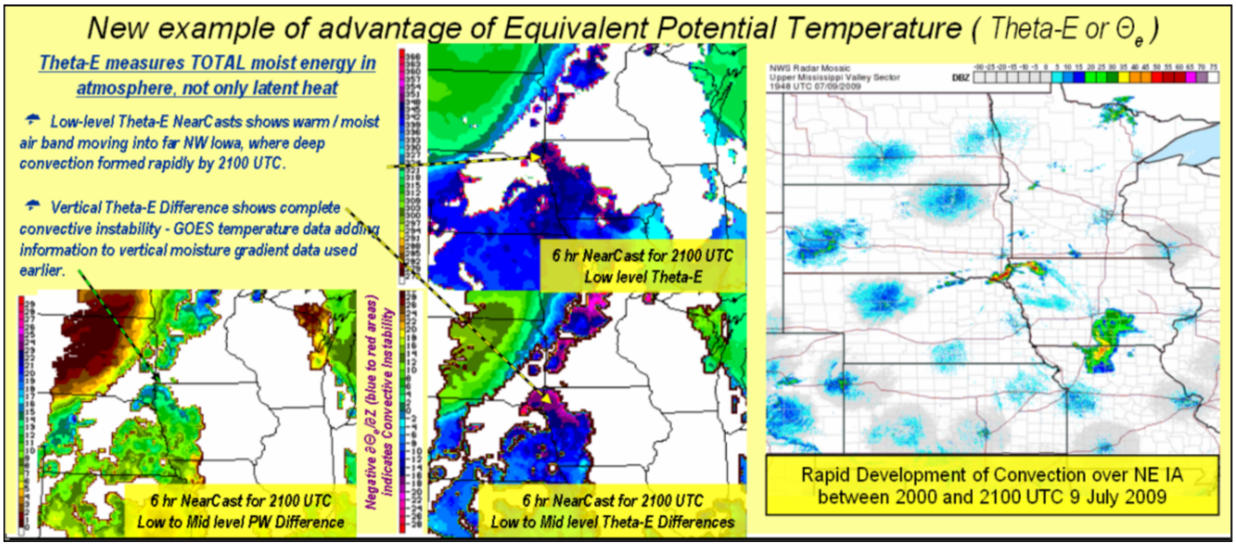


Figure 5.4.2. Example of the utility of NearCasts of GOES convective instability information for a case on July 9, 2009. NearCasts and discussion of moisture and θ_E fields on left, verifying radar reports on the right. NearCasts showed the strongest convection to form in NW Iowa. Later NearCasts also correctly predicted subsequent movement of storm into south-central MN. Watch areas was centered over west-central IA, where NWP guidance forecast heaviest precipitation, but little occurred.

To expand the accuracy, area coverage and temporal range of the NearCasting products, major effort has been made in controlling the growth of divergence/convergence during the short-range prediction cycles. The growth of divergence/convergence in the elementary Lagrangian scheme used in the NearCast model is produced by a combination of 1) strong *ageostrophic* flow and 2) excessive *deformation* (both the stretching and shearing components – each of which can increase during the forecasts as a function of the strength of the opposite component) in the model's initial wind fields, which are obtained from the operational RUC. Using a combination of idealized and real cases, methods to restrict the growth of convergence and divergence have been developed using differently configured high-pass filters for both the geopotential fields (to limit ageostrophy) and the initial wind gradients (necessary to limit deformation). These filtering techniques are expected to be incorporated into real-time system during the next quarter. There impact should be 3-fold: 1) increasing the accuracy of the forecast locations of both low- and mid-level of local moisture features, 2) reducing the number of 'data gaps' that form in the longer-range NearCast images by limiting the movement of parcels away from each other, and 3) extending the useful length of the NearCast products by 2-3 hours.

Although not shown here, experiments have also been run using SEVIRI Global Instability Index (GII) data as a surrogate for future GOES-R ABI retrievals. NearCasts were run for an un-forecasted F-2 tornado event in southern Poland. A wider variety of stability parameters were obtained than done using the real-time system. The results showed not only that Convective Instability (large negative vertical θ_E gradients) developed and moved to within 25 km of the location of the tornado in NearCasts initialized 6 hours prior to the event (other stability indices, e.g., Lifted Index, corroborated this prediction), but also that the lapse rate in the area of the tornado changed became stable and rapidly destabilized immediately before the tornado. In addition, the surface front just downstream of the tornado intensified during the period, potentially contributing to the lifting required to release the Convective Instability in the area. The additional output parameters will be included in the real-time processing for the US in the near future.

The GOES NearCasting products are being sent in GRIB-II format to the Central Region data server where NWS/WFOs can access for forecasting use in their local AWIPS systems. The GRIB-II data are also being used by the SOO at NWS/WFO/MKX to develop forecasters training tools. To speed up the availability of the NearCasting products to forecasters, GOES retrieval processing at CIMSS has also been divided into sectors, allowing the sounding products over the CONUS to be available nearly 30 minutes earlier. This has allowed the perishable NearCasts to be available to forecasters one half hour earlier. Subjective evaluation of the products at NWS Sullivan has been very positive. The system was also chosen to be evaluated at NSSL/SPC next spring.

Real-time NearCasts can also be viewed on the web at http://cimss.ssec.wisc.edu/model/nrc/. The web images are generated using the NWS/NCEP N-AWIPS software system. In addition to producing high quality graphics, these products can be directly included into operational workstations at AWC and SPC.

Publications and Conference Reports

Formal Presentations

Petersen, R., R. Aune, 2009: Optimizing the impact of GOES sounder products in very-short-range forecasts – Recent Results and Future Plans. AMS Satellite Conference, January 2009, Phoenix, AZ.

Aune, R., R. Petersen, 2009: Using the GOES sounder to NearCast severe convection. AMS Numerical Weather Prediction Conference, June 2009, Omaha, NE.

Petersen, R., R. Aune, 2009: Optimizing the Impact of Geostationary Satellite Products in very-short-range forecasts – Recent Results and Future Plans. EUMETSAT Satellite Conference, September 2009. Bath, UK.

Informal Presentations

Petersen, R., R. Aune, 2009: An objective NearCasting tool that optimizes the impact of GOES Derived Product Imagery in forecasting isolated convection - at NWS/WFO/MKX, March 2009.

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

CIMSS Project Lead: Todd Schaack
NOAA Collaborator: Brad Pierce
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Weather nowcasting and forecasting

Proposed Work

This project uses the WRF-CHEM [Grell et al. 2005] regional chemical model coupled to the RAQMS global chemical analysis [Pierce et al. 2007] to evaluate the impacts of GOES-R ABI like Total Column Ozone (TCO) retrievals on AQ forecasts. Spinning Enhanced Visible and Infrared Imager (SEVIRI) measurements are used as ABI proxy data. Linking global RAQMS ozone analyses with ozone predictions from the WRF-CHEM regional model provides a first guess for SEVIRI TCO assimilation studies. WRF-CHEM regional AQ predictions, initialized with ozone analyses with and without SEVIRI TCO, will be used for AQ forecast impact studies.

FY09 activities focused on conducting August 2006 RAQMS/WRF-CHEM/National Center for Environmental Prediction (NCEP) Gridpoint Statistical Interpolation (GSI) SEVIRI total column ozone retrieval assimilation experiments and evaluation of the impact of SEVIRI total column ozone assimilation through comparison with measurements from WMO ozonesonde and surface networks. The CRTM will be used to generate synthetic radiances and brightness temperatures from combined WRF-CHEM tropospheric and RAQMS stratospheric chemical and meteorological analyses. The synthetic radiances will be used to develop a radiance based observation operator for the SEVIRI statistical total column ozone retrieval [Jin et al. 2008]

Summary of Accomplishments and Findings

NESDIS SEVIRI fire emissions have been incorporated into WRF-CHEM emissions preprocessor. NESDIS African Biomass Burning (BB) emissions are consistently larger than WRF BB emissions during the time period considered (Figure 5.5.1) leading to increased tropospheric ozone production.

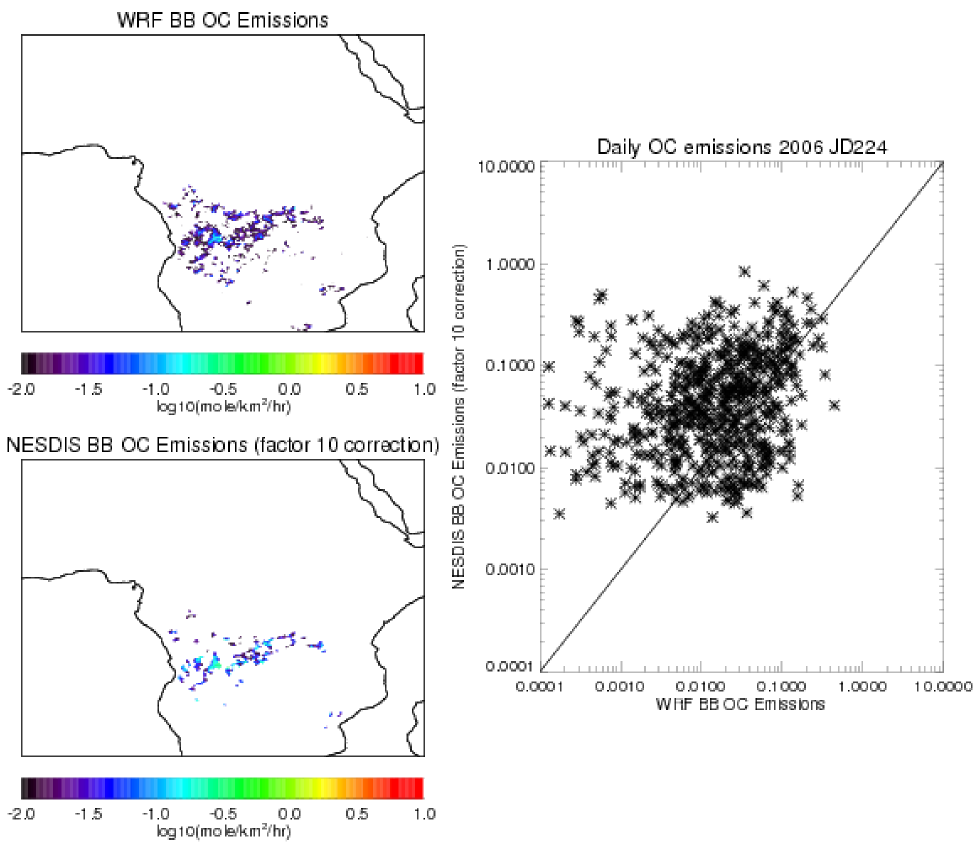


Figure 5.5.1. August 11th, 2006 WRF Biomass Burning (BB) Organic Carbon (OC) emissions vs. NESDIS BB OC emissions.

Algorithms for bias correction and cloud clearing have been developed for SEVIRI TCO retrievals. Enhancements in SEVIRI TCO near cloud edges required additional cloud clearing. Hourly averaging of 15 minute clear SEVIRI TCO retrievals reduces artifacts associated with cloud edge effects. Diurnal and spatial bias corrections were developed to remove scan angle and zenith angle dependencies in SEVIRI TCO. The bias corrections were based on differences between RAQMS TCO analyses (constrained with stratospheric ozone profiles from the Microwave Limb Sounder) and cloud filtered SEVIRI data (Figure 5.5.2).

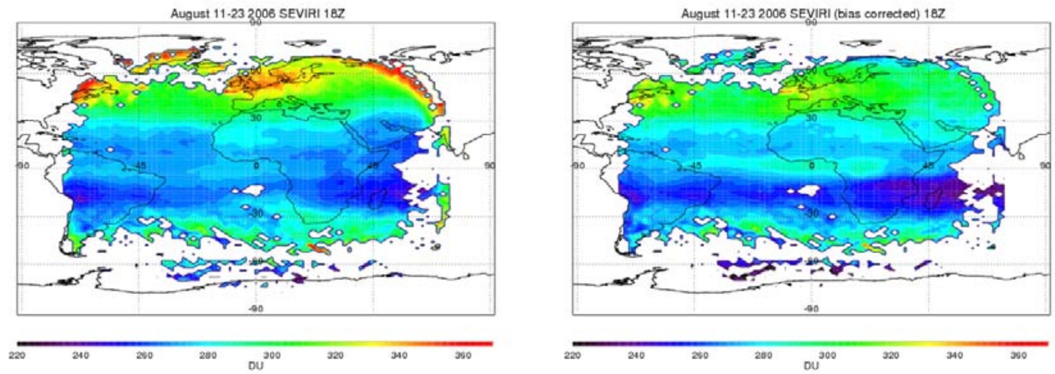


Figure 5.5.2. August 11-23, 2006 18Z SEVIRI (left) and Bias Corrected SEVIRI (right) TCO.

WRF-CHEM SEVIRI Statistical Digital Filter (SDF) assimilation studies have been completed and results have been compared to SHADOWS ozonesonde data to determine the optimal approach for assimilation of SEVIRI TCO. Assimilation of bias corrected SEVIRI TCO has the largest impact on WRF-CHEM tropospheric ozone. However, lack of a lightning NOx source within WRF-CHEM was found to lead to significant underestimates of upper tropospheric (200mb) ozone over Africa which precluded further assimilation studies using GSI. The RAQMS lightning NOx parameterization has been incorporated into WRF-CHEM and testing of the implementation through comparisons with the RAQMS NOx distribution has been completed. SDF-Bias corrected SEVIRI ozone assimilation studies have been re-run with new lightning NOx parameterization. Addition of lightning NOx removes the 200mb bias in NO2 found in previous comparisons with RAQMS, and results in significant increases in upper tropospheric ozone and reduces the low bias in the assimilated ozone compared to Shadows ozonesonde measurements (Figure 5.5.3).

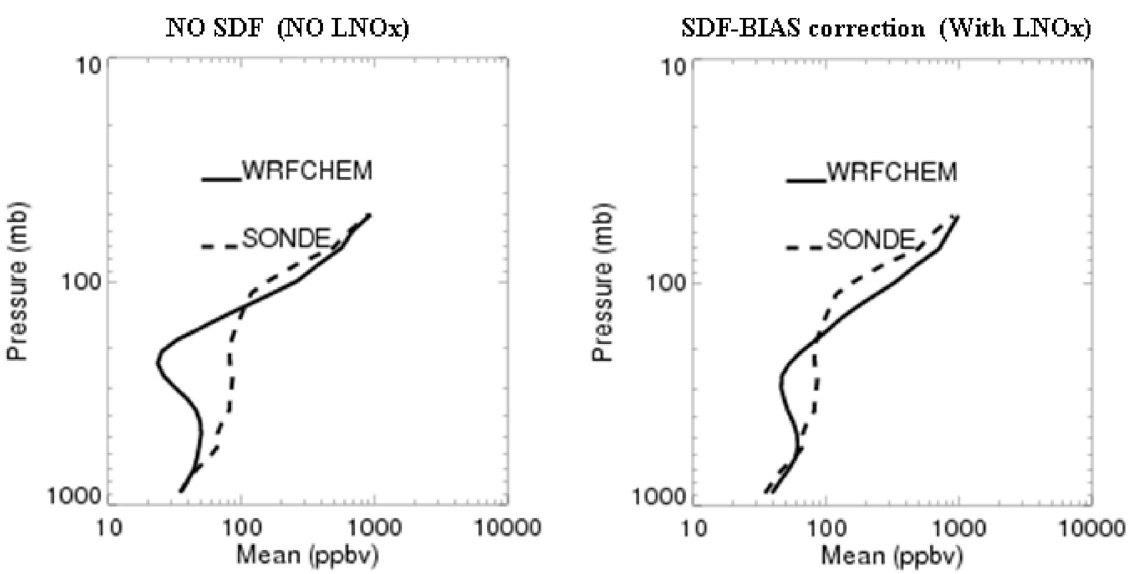


Figure 5.5.3. WRF-CHEM/ozonesonde comparison without SDF SEVIRI assimilation and no lightning NOx (left) and with SDF Bias corrected SEVIRI ozone assimilation and lightning NOx (right).

Initial tests of the WRF-CHEM SEVIRI TCO analyses using the GSI assimilation system has been evaluated through comparisons with WRF-CHEM SDF TCO analyses. Assimilation experiments show that GSI TCO analysis is very sensitive to assumed vertical profile of ozone forecast error variance. Vertical profiles of the forecast error variance used in the NCEP Global Forecasting System (GFS) global GSI assimilation has been adapted for WRF-CHEM regional TCO assimilation studies (Figure 5.5.4).

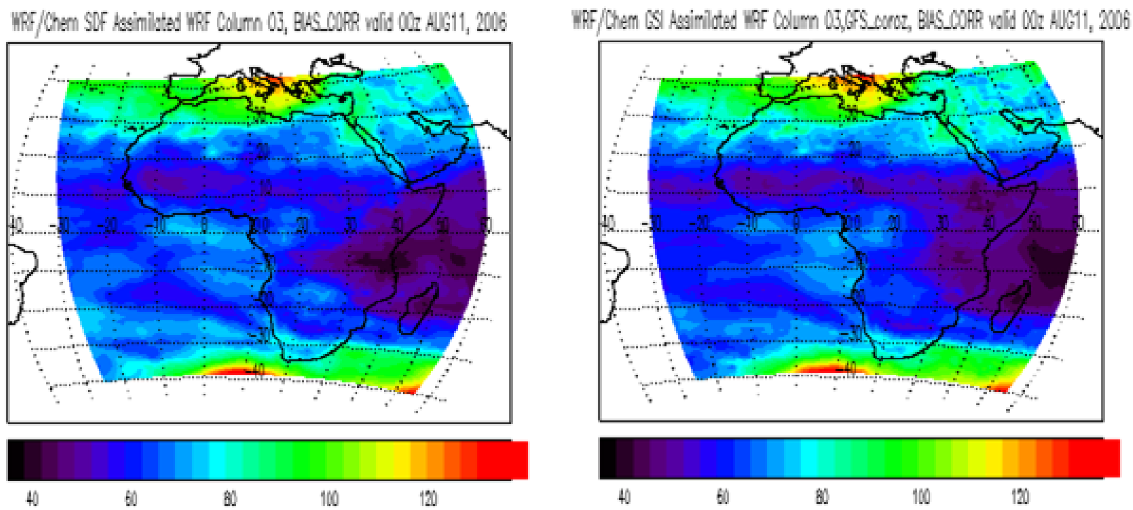


Figure 5.5.4. WRF-CHEM GSI (right) and SDF (left) TCO analysis valid 00Z August 11, 2006.

References

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

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.

5.6. Algorithm Development, Data Analysis and Visualization Capabilities for the GOES-R Program

CIMSS Project Leads: Tom Rink, Tom Achtor
CIMSS Support Scientists: Jun Li, Elisabeth Weisz, Ralph Petersen
NOAA Collaborator: Tim Schmit

Proposed Work

Identify and work with selected CIMSS GOES-R Risk Reduction teams to identify how McIDAS-V can provide interactive visualization and data analysis capabilities to support their research.

Summary of Accomplishments

LEO/GEO Retrieval Synergy

The McIDAS-V development team has been working with the GOES-RRR GEO/LEO Sounding Synergy project to enable interactive visualization in McIDAS-V of the 3-dimensional (3D) structure of retrieval parameters such as water vapor (Figure 5.6.1). AIRS or IASI spectral band imagery can be displayed and overlaid with many data types and products. The analysis power of McIDAS-V is demonstrated in the figure as we show the result of differencing the AIRS 3D moisture retrieval field with the ECMWF forecast 3D moisture field. The transect can be moved anywhere within the image to display this difference field and the probe can provide single gridpoint readout.

We continue to work with the LEO/GEO synergy team to develop and advance analysis capabilities to validate accuracy of retrieval products and visualize them in informative and unique settings.

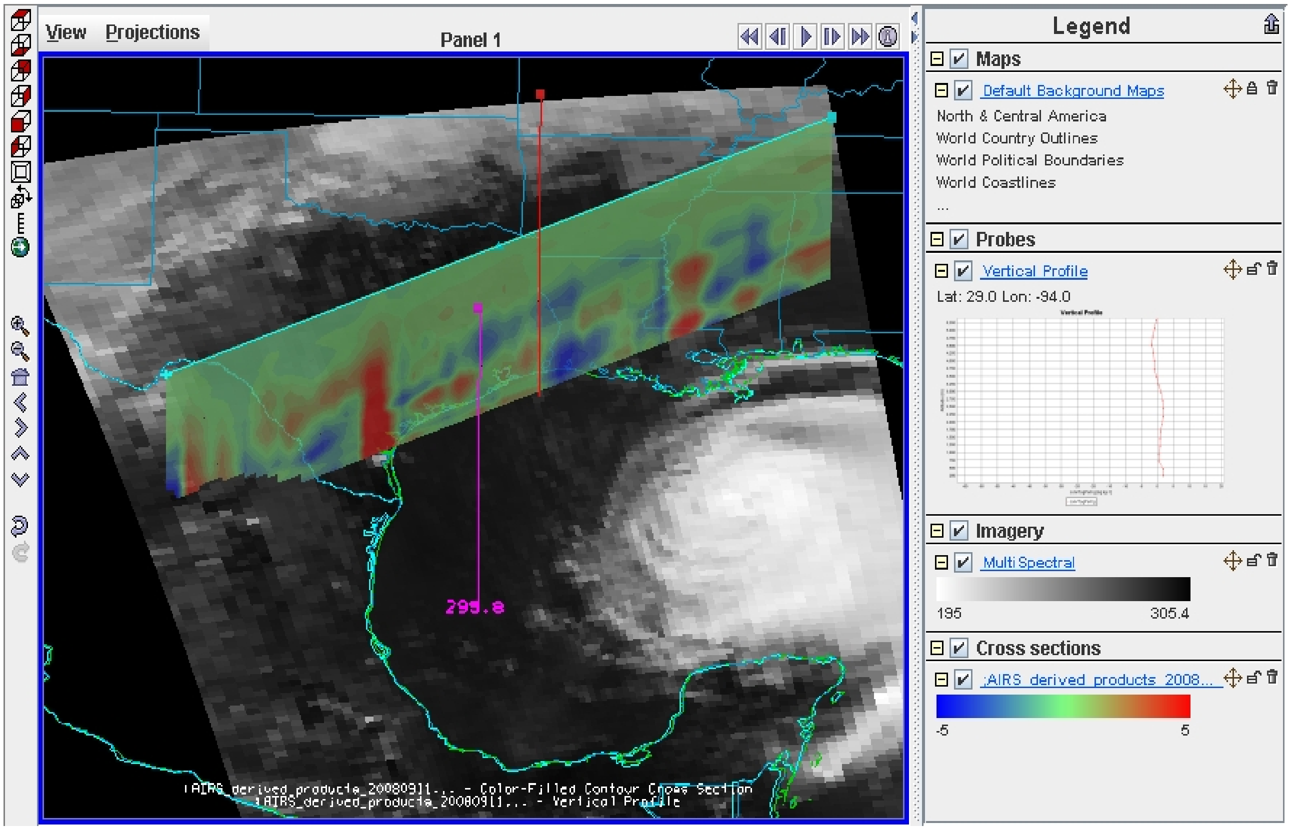


Figure 5.6.1. AIRS L1B window channel (grey-scale) and 2D dragable-in-display slice of ECMWF-AIRS SFOV water-vapor retrieval (color-scale). Values from the slice are re-sampled from the 3D difference field and auto-updated as the slice is dragged in space demonstrating the powerful interactive and data integration capabilities of McIDAS-V.

McIDAS-V Capability Development

An important element for GOES-R Risk Reduction researchers is the capability to display and analyze their experimental results and products. The McIDAS-V development team is continuously working to add capability to the software to support their research needs. Figure 5.6.2 is an illustration using McIDAS-V of the improved signal in fire detection that the high spatial and spectral resolution of the ABI imager will provide.

Another example of McIDAS-V development to allow scientist product validation is provide in Figure 5.6.3, which demonstrates the use of 3D displays with interactive slicing to compare CALIPSO with an AIRS L1B derived cloud density.

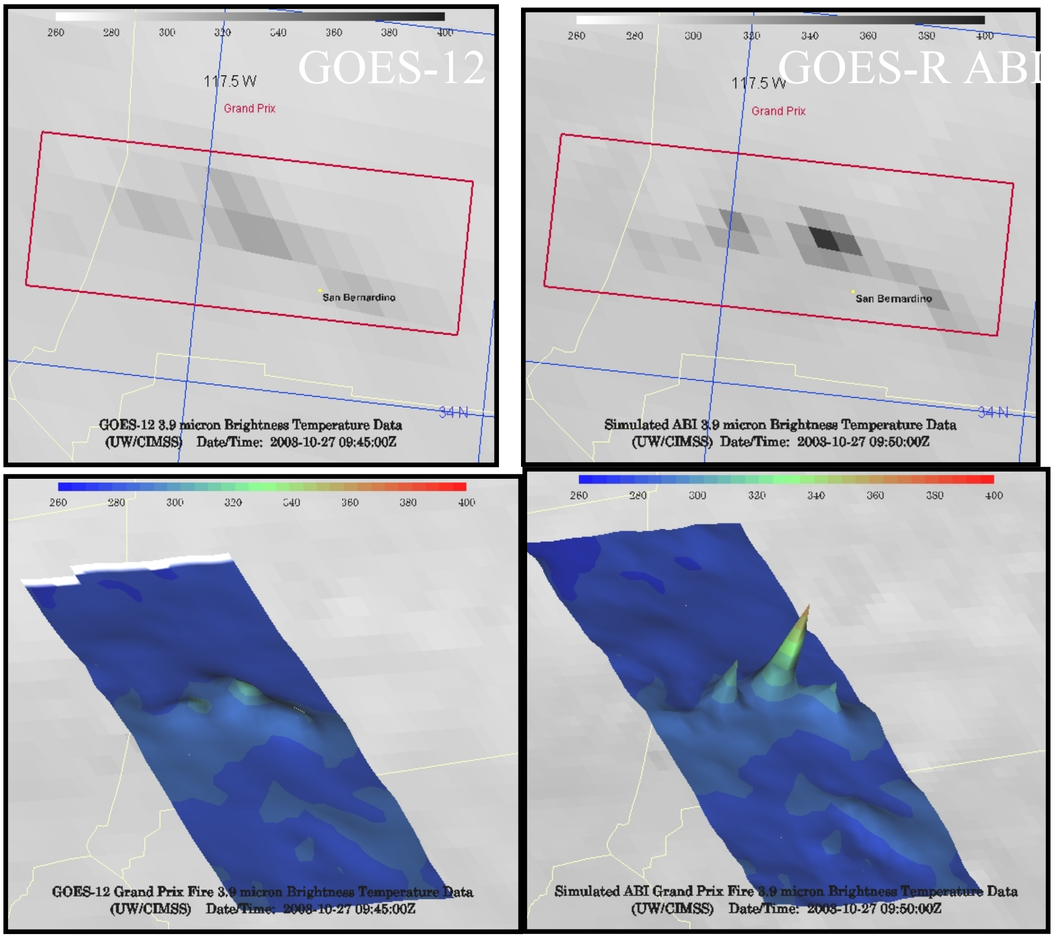


Figure 5.6.2. Combined 2D/3D displays showing more defined peak in the higher resolution data making it easier to pick out individual hotspots. Also, higher saturation temperature in ABI reveals that the fire is near 370K. Courtesy Joleen Feltz (CIMSS)

NearCasting

The McIDAS-V development team has held discussions and initiated a plan of action to employ advanced visualization to help the NearCasting group investigate and display the spatial and temporal correlations between forward trajectory predictions and convection events.

Conference Reports

AGU, December 2008
AMS, January 2009
GOES-R Annual Meeting, July 2009

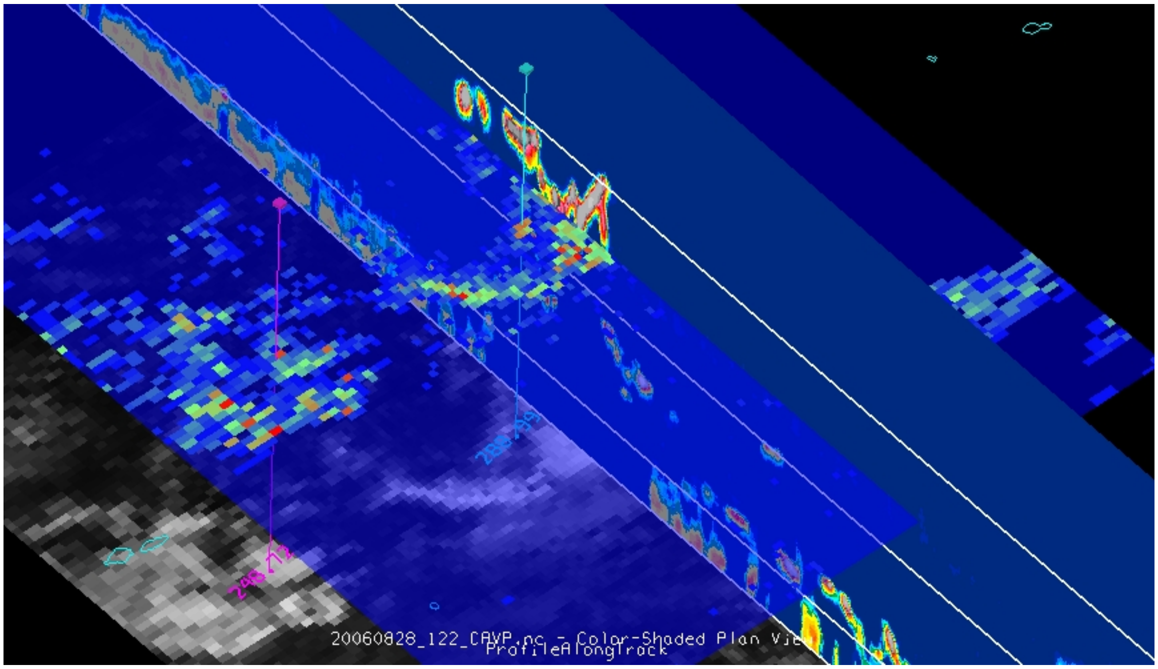


Figure 5.6.3. CALIPSO and AIRS derived cloud field using McIDAS-V

5.7. GOES-R Education and Public Outreach

CIMSS Project Leads: Steve Ackerman, Margaret Mooney
NOAA Collaborators: Tim Schmit, Nina Jackson
NOAA Strategic Goals Addressed:

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

CIMSS scientists continue to participate in student and teacher workshops that advocate for using satellite observations in education; this includes maintaining, updating and distributing the CIMSS *Satellite Meteorology for Grades 7-12* on-line course and CD. We leverage this activity with other funded activities at CIMSS, including programs from NASA and NSF. Updated course CDs were freely distributed at the Education Symposium at the 2009 American Meteorological Society Conference and the ESIP Teacher Workshop in July 2009.

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

CIMSS Project Lead(s): Tom Greenwald and Allen Huang
CIMSS Support Scientist(s): Jason Otkin, Yong-Keun Lee, Eva Borbas, Justin Sieglaff
NOAA Collaborator(s): Tim Schmit
NOAA Strategic Goals Addressed:

- Serve society’s needs for weather and water information

CIMSS Research Themes:

- Weather nowcasting and forecasting

- Clouds, aerosols and radiation

Proposed Work

This project makes substantial use of NWP model simulations and computing infrastructure and software tools developed at CIMSS to generate simulated ABI proxy data sets for use in many GOES-R activities. Past ABI proxy data sets have proven useful to the GOES-R Proving Ground Program, the Algorithm Integration Team (AIT), the GRAFIIR, and the AWG Sounding, Winds, Clouds, and Aviation teams.

Our principal effort involves generating new simulated ABI proxy data sets, improving existing proxy data sets, and providing support to users of these data sets. Continued effort in validating the ABI proxy data sets is an important component of this work as well.

Also included in the proposed work is a new critical path effort ("Improvement of Forward Models for ABI Simulations, Algorithm Development, and Radiance Assimilation") that will enhance forward models through improvements of surface albedo and emissivity databases and ice cloud scattering properties.

Summary of Accomplishments and Findings

Forward Model Development

The IR portion of the CIMSS Solar/IR Radiative Transfer Model was altered to allow for calculation of the ABI thermal band radiances in the presence of aerosols. WRF-Chem model output can now be used to produce simulated ABI proxy data sets for use by the AWG Aerosol, Air Chemistry, and Air Quality Team for testing algorithms.

In addition, we recently switched to the CRTM for producing ABI proxy data sets but only for the IR bands. The code accepts WRF model simulation output (in NetCDF) in the same way as the CIMSS Solar/IR Radiative Transfer Model.

A required deliverable was provided on 30 May to Dr. Fuzhong Weng consisting of the latest forward model source code and documentation ("Users Manual to the Updated Fast Solar/Infrared Radiative Transfer Model.")

Production of Simulated Proxy Datasets

Earlier this year a WRF model simulation covering most of the full disk over the Pacific was run to provide ABI proxy data sets for the GOES west vantage point (called ABI-West). The simulation was run at the Pittsburgh Supercomputer Center (PSC). It was initialized at 06 UTC on 26 June 2008 using 1º GFS data and then integrated for 30 hours on a single 3520 x 3240 grid point domain containing 5-km horizontal grid spacing and 52 vertical levels. Figure 6.1.1 provides an image for a selected ABI band from that simulation. Table 6.1.1 summarizes the data volume for both the model output and ABI proxy data sets.

Another WRF model run, a high-resolution simulation over the central U.S. (ABI-HIRES), was also performed at the PSC to capture two convective storm events. The simulation was initialized at 00 UTC on 19 July 2006 using 20-km RUC data and then integrated for 30 hours on two nested domains containing 2500-m and 500-m horizontal grid spacing, respectively. Figure 6.1.1 shows a simulated ABI IR image for that simulation. Table 6.1.2 summarizes the data volume for both the model output and ABI proxy data sets.

Table 6.1.1. Model data (top) and simulated ABI proxy (bottom) data sets produced for the ABI-West WRF model simulation. IR refers to ABI bands 8-16.

Domain	File Size per Output Time (GB)	Total Dataset Size (TB)	Spatial Resolution (km)	26 June 2008		27 June 2008	
				12-21 UTC	21-00 UTC	00-03 UTC	03-12 UTC
				Temporal Resolution (minutes)			
Fulldisk	33 GB	4.9 TB	5	15	5	5	15

Domain	Satellite Data Type	Temporal Resolution (minute or hour)	Spatial Resolution (km)	Time Period (UTC)	File Size per Output	Total Dataset Size
Fulldisk	ABI IR	30-minute	2	12 on 26th to 12 on 27th June	1.7 GB	83 GB

Table 6.1.2. Model data (top) and simulated ABI proxy (bottom) data sets produced for the ABI-HIRES model simulation. IR refers to ABI bands 8-16.

Domain	File Size per Output Time (GB)	Total Dataset Size (TB)	Spatial Resolution (km)	19 July 2006	20 July 2006	
				06-00 UTC	00-02 UTC	02-06 UTC
				Temporal Resolution (minute)		
Outer	2.1 GB	0.6 TB	2.5	5	5	5
Inner	17 GB	6.2 TB	0.5	5	1	5

Domain	Satellite Data Type	Temporal Resolution (minute or hour)	Spatial Resolution (km)	Time Period (UTC)	File Size per Output	Total Dataset Size
Inner	ABI IR	15-minute	2	06 on 19th to 06 on 20th July	610 MB	58 GB

Data Distribution

Selected simulated ABI proxy data sets were provided to the GRAFIIR team to show the impact of instrument errors on atmospheric soundings, derived winds, and cloud retrievals.

WRF model output and simulated ABI proxy data sets were delivered to the AIT for CONUS and the mesoscale domain for 0600 UTC 4 June 2005 to 0600 UTC 5 June 2005. The WRF model data set included surface, cloud, and atmospheric variables to serve as a "truth" data set to evaluate the ABI retrieval algorithms. The ABI proxy data consisted of all 16 bands every half hour. All bands were remapped to 2 km resolution except bands 1-3 and 5, which were at 1 km resolution. Significant work was spent providing improved NetCDF files for these data sets by using a projection that is currently supported by the NetCDF libraries, which will allow these files to be read directly by McIDAS-V without the need for latitude and longitude arrays in the files.

A required deliverable was provided on 30 May to Dr. Fuzhong Weng consisting of full-disk single-band ABI proxy data files (bands 8-16) for the ABI-West simulation (centered at 137 W) every 30 min from 12 UTC 26 June 2008 to 12 UTC 27 June 2008.

Validation

Our main validation efforts used CloudSat data to evaluate last year's full-disk WRF model simulation over the MSG domain and selected MODIS data to verify the ABI proxy data sets for the WRF model simulation over CONUS for June 2005. When compared against MODIS data using the methods presented by Otkin et al. (2009), the CONUS ABI proxy data sets (IR bands only) were shown to agree well with the observations in terms of the shapes of the brightness temperature probability distributions and in 2D joint histograms of brightness temperature differences. The CloudSat-WRF model study is ongoing. A manuscript titled "Evaluation of Midlatitude Clouds in a Large-Scale High-Resolution Simulation using CloudSat Observations" is in preparation and will be submitted in the near future.

Critical Path

The latest version of the UW/CIMSS Global IR Land Surface Emissivity database was incorporated into the CIMSS Solar/IR Radiative Transfer Model.

The UW/CIMSS High Spectral Resolution Global IR Land Surface Emissivity database was updated using improved MODIS MYD11 surface emissivity products. Independent evaluation of the database was undertaken using the recently released North America ASTER Land Surface Emissivity Database (NAALSAD). Results show the mean emissivities from the UW/CIMSS database agree to within 1% of the ASTER observations (see Figure 6.1.2). This database was also validated against surface emissivity measured from the Jaivex ARIES aircraft over the SGP ARM Cart Site on 19 April 2007 during nighttime under clear sky conditions. The altitude of the flight was 3000 ft producing a 50m foot print size. Over 4000 very high spectral resolution emissivity spectra between 900 and 1200 cm^{-1} wavenumbers (8,3 and 11.1μm) were provided by Stuart Newman (UKMO). The UW/CIMSS database (based on MYD11 Collection 4 data) showed very good agreement (better than 0.5%) with the aircraft measurements.

Publications and Conference Reports

Borbas, E., 2009: Recent updates and validation of the UW/CIMSS High Spectral Resolution Global IR Land Surface Emissivity Database (talk), ITWG 2nd Emissivity Workshop, Toulouse, France, 9-11 June.

Otkin, J. A., T. J. Greenwald, J. Sieglaff, and H.-L. Huang, 2009: Validation of a large-scale simulated brightness temperature dataset using SEVIRI satellite observations. *J. Appl. Meteor. Clim.*, **48**, 1613-1626.

Otkin, J. A., J. Sieglaff, T. Greenwald, and H.-L. Huang, 2009: New Large-Scale Model-Derived Proxy ABI Datasets Available for GOES-R Research and Demonstration Activities, AWG Annual Meeting, Adelphi, MD.

Otkin, J. A., T. Greenwald, J. Sieglaff, M. Gunshor, K. Bah, T. Schmit, H.-L. Huang, and S. Wanzong, 2009: High-resolution simulated ABI datasets used for GOES-R research and demonstration activities. 10th Annual WRF User's Workshop, Boulder, CO.

Otkin, J. A., T. Greenwald, J. Sieglaff, M. Gunshor, K. Bah, T. Schmit, H.-L. Huang, and S. Wanzong, 2009: High-resolution simulated ABI datasets used for GOES-R research activities. 19th Conf. on Numerical Weather Prediction, Omaha, NE.

Otkin, J. A., J. Sieglaff, T. Greenwald, and Y.-K. Lee, 2009: Using satellite observations to validate a large-scale high-resolution WRF model simulation. 16th Conf. on Satellite Meteorology and Oceanography Conference, Phoenix, AZ.

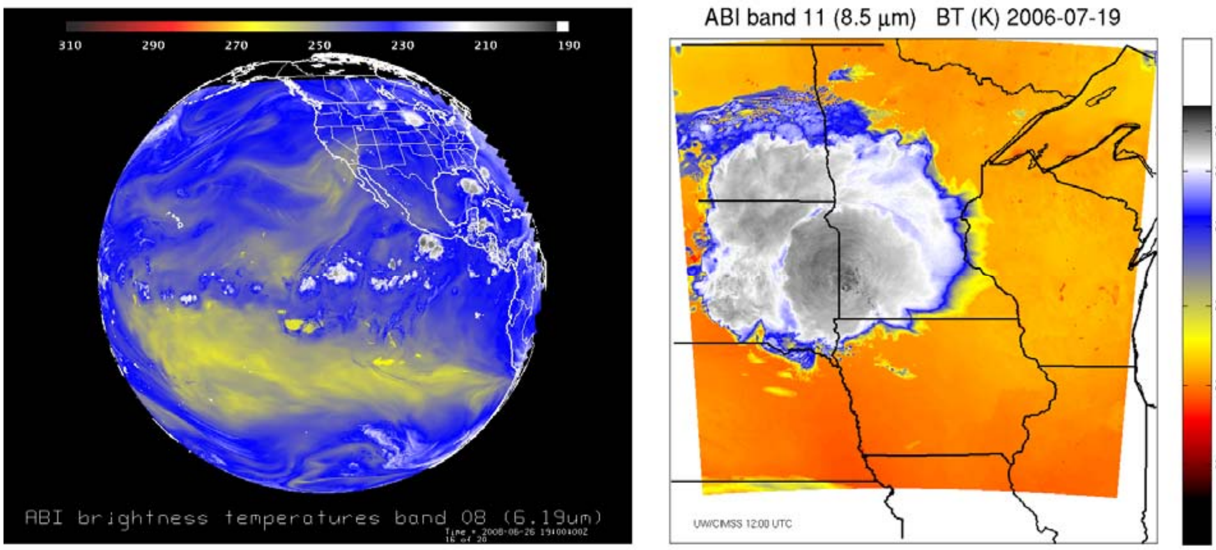


Figure 6.1.1. Examples of the latest simulated ABI proxy data sets: (left) band 8 for the ABI-West simulation for 1900 UTC 26 June 2008 and (right) band 11 for the ABI-HIRES (500 m) simulation at 1200 UTC 19 July 2006.

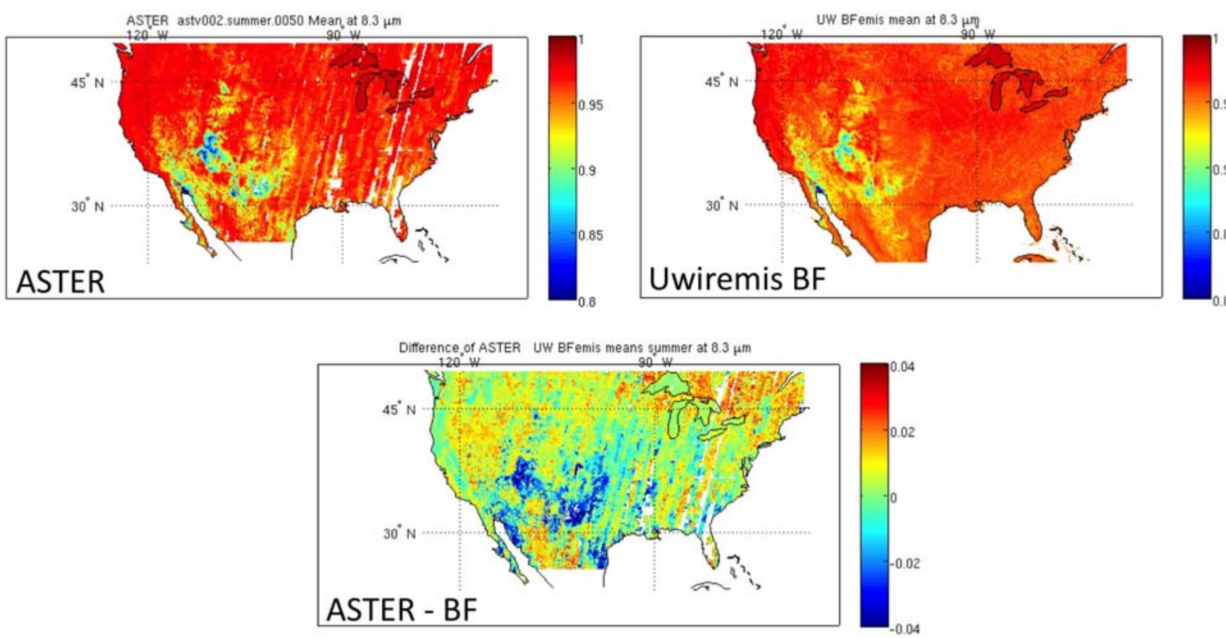


Figure 6.1.2. The mean summertime 8.3 µm surface emissivity map of NAALSAD (left top), UW/CIMSS High Spectral Resolution Global IR Land Surface Emissivity database (right top; based on Collection 4 MODIS MYD11 data) and their difference (bottom).

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

CIMSS Project Leads: Allen Huang, Mat Gunshor
CIMSS Support Scientists: Ray Garcia, Graeme Martin, Jason Otkin, Eva Schiffer, Justin Sieglaff, Steve Wanzong, Hong Zhang
NOAA Collaborators: Tim Schmit
NOAA Strategic Goals Addressed:

- Provide critical support for the NOAA mission

CIMSS Research Themes:

- Weather nowcasting and forecasting
- 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 2009

1. Develop expanded features of GRAFIIR to model ABI calibration, navigation, sensor component, and total system throughputs.
2. Improve analysis function of GRAFIIR to include other ABI products to extend the study of sensor impacts on products not already analyzed.
3. Design Review preparation.
4. Provide support and datasets to assist application team members in evaluating and testing of their product algorithms.
5. Respond to proposed changes in ABI instrument specifications to assess their potential effects on products.
6. Interface with visualization team and AWG science teams to utilize better visualization tools with the eventual goal of being able to visualize all steps of algorithm (inputs, intermediary steps, and outputs).

Milestones and Deliverables

1. Demonstrate end-to-end functionality on sample simulations such as increased noise, a spectral response shift, co-registration errors, or jitter using AWG algorithms on framework and provide sample datasets to AIT.
2. GRAFFIR design review presentation to AWG.
3. Produce diagnostics statistics to assess change in product performance for available algorithms (those integrated into framework). Demonstrate version 1 diagnostic tools for available algorithms to AIT.
4. Assessment of computing needs required to run sample simulations that yield high fidelity product performance statistics.

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 20-24 July 2009. 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. This has been used 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 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.

When testing the installation of a processing framework, the epsilon value can be set to be so small that it will only register differences considered to be above machine precision, since the computations in many algorithms are done with real numbers and involve complex steps and it is common for small differences to show up when the algorithms are run on different machines. Epsilon can also be set to zero, if one does not expect to see any difference between two files or if it is necessary to know how often two files differ absolutely.

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 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 Integrated Modeling Master Plan (still in draft form) in terms of assessing the potential impact on Level-1B and Level-2+ products of an ABI waiver.

GRAFIIR's ability to respond to an instrument waiver was tested at the end of the fiscal year. The ABI visible (0.64 micrometer) band may have a noise performance issue. Proxy Team 500-m ABI simulations for this band have been used to simulate a variety of noisy-data scenarios and multiple presentations have been done via phone-conference to demonstrate some of the possible effects of the discussed noise on the imagery product (Figure 6.2.1). As of the end of the fiscal year, there was not an official waiver request put forth by the vendor on this issue, but this exercise has given the government and its partners an opportunity to test and refine the system put in place so far.

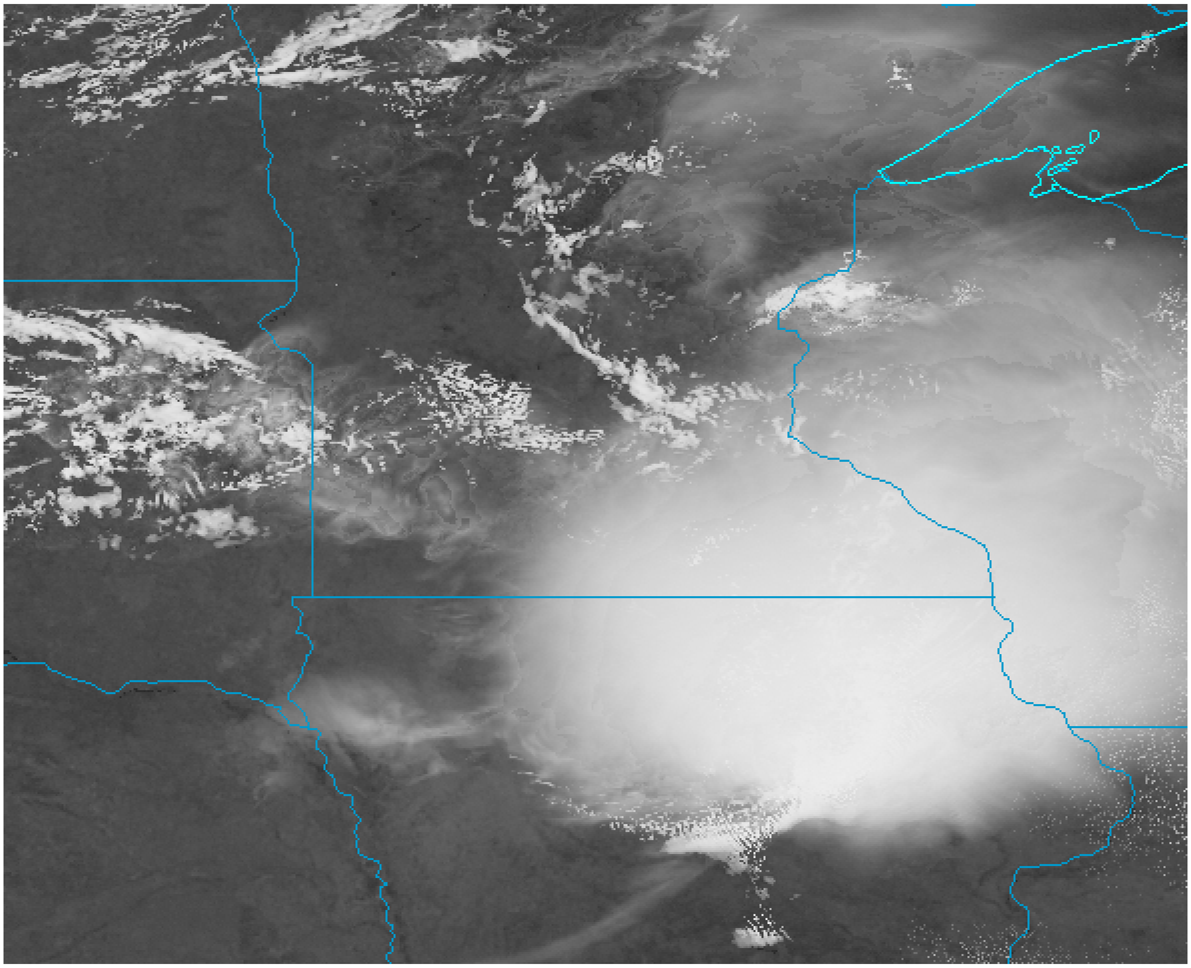


Figure 6.2.1. Nominal noise at spec value (signal to noise ratio of 300:1 at 100% albedo) was added to this ABI band 2 (0.64um) visible channel data using a 500-m simulation which was not remapped (to retain the 500-m resolution). The image is a simulation of 17:30 UTC on July 19, 2006. The noise added is not visibly apparent in the imagery product with this enhancement (typical user enhancement) or at this magnification. The noise is most easily seen when zoomed into the Lake Superior area, which is in the northeast (upper right) corner of the image, north of Wisconsin.

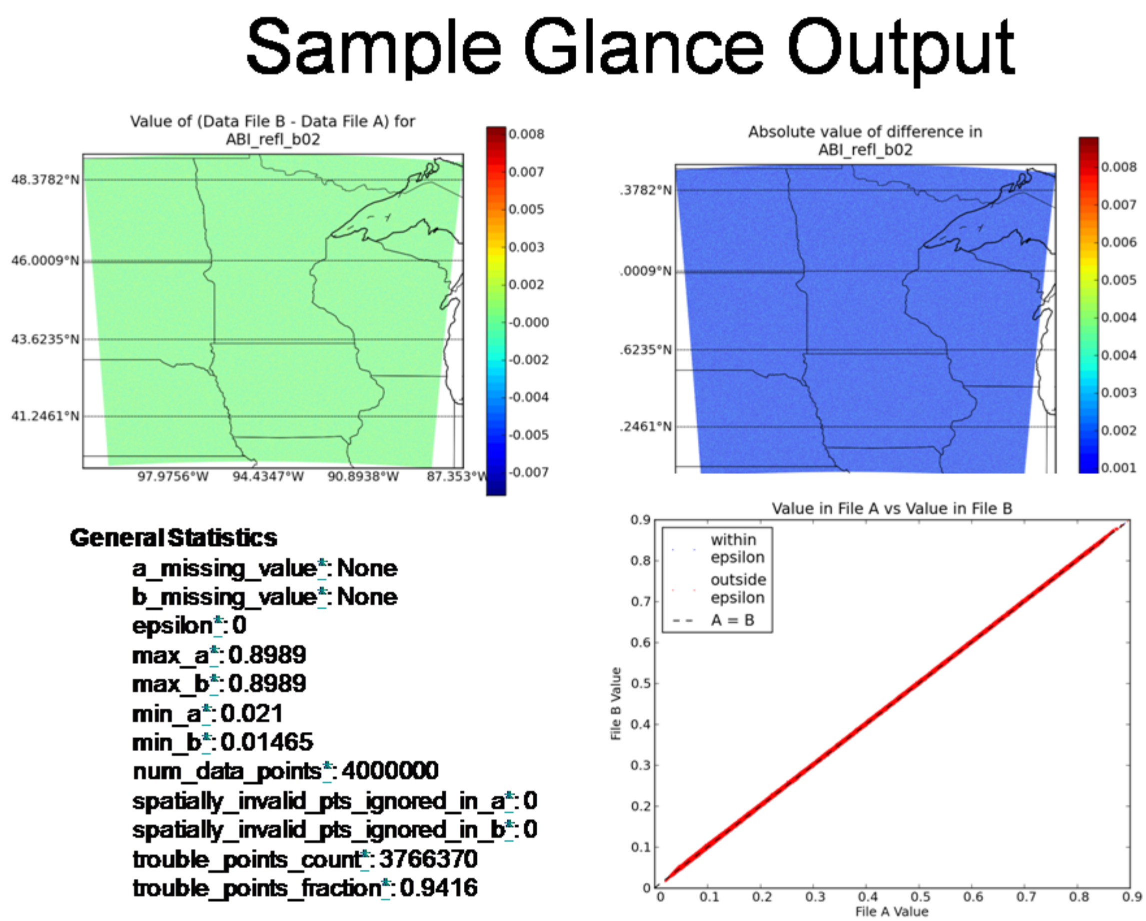


Figure 6.2.2. Sample output from Glance demonstrating the difference between noise added at the 300:1 signal to noise ratio (SNR) versus 200:1. Noise was added to the ABI band 2 (0.64um) visible channel reflectance factor data shown in Figure 6.2.1. The top left panel is the difference image (300:1-200:1). The top right panel is an image of the absolute value of the differences (300:1-200:1). The bottom left panel contains some of the statistics generated with the report. In this case, the fraction of data points that exceeded the threshold of epsilon=0 were 0.9416, meaning 94.16% of the pixels were different between the two files. The bottom right panel is a scatter plot of the differences (File A is the 300:1 SNR file, File B is the noisier 200:1 SNR file).

6.3. AIT Technical Support

CIMSS Project Leads: R.K. García, G.D. Martin, T. A. Demke, R.E Holz
CIMSS Support Scientists: W. Straka III, E.R. Olson, G. Quinn, F. Nagel
NOAA Collaborators: M. Pavolonis
NOAA Strategic Goals Addressed:

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

Proposed Work

1. Develop and support a uniform algorithm testbed, Geocat (Geostationary Cloud Algorithm Testbed)
2. Assist in the integration of AWG algorithms into this testbed in support of GOES-R AWG needs

3. Support Geocat users with documentation, bug fixes, feature enhancements and design improvements
4. Track and manage inter-algorithm dependencies in support of software integration and documentation
5. Advise the Algorithm Integration Team on framework design and implementation, based on experience of working directly with AWG scientists
6. Support the integration of Geocat into larger ensemble testing environments such as GRAFIIR
7. Author any necessary tools to support algorithm development, testing and verification
8. Develop computationally efficient algorithms to collocate GEO and POLAR satellite observations

Summary of Accomplishments and Findings

Product verification activities

In cooperation with the GOES-R AIT team in Washington, the CIMSS AIT team worked extensively to verify preliminary products from integrated algorithms. These efforts provided critical and timely feedback resulting in software patches and dataset corrections, allowing validation activities on products to proceed. Activities included visualization of the data in McIDAS-V, to verify that the data was being written out correctly from the AIT Framework, as well as comparisons of datasets generated by the AIT Framework and Geocat, which is used locally to validate algorithms. The figures below show examples of the comparison images that are used to pinpoint and analyze areas of difference between output generated by Geocat and the AIT Framework, and by different versions of the AIT framework. The images were generated with the dataset comparison tool *glance* (see below).

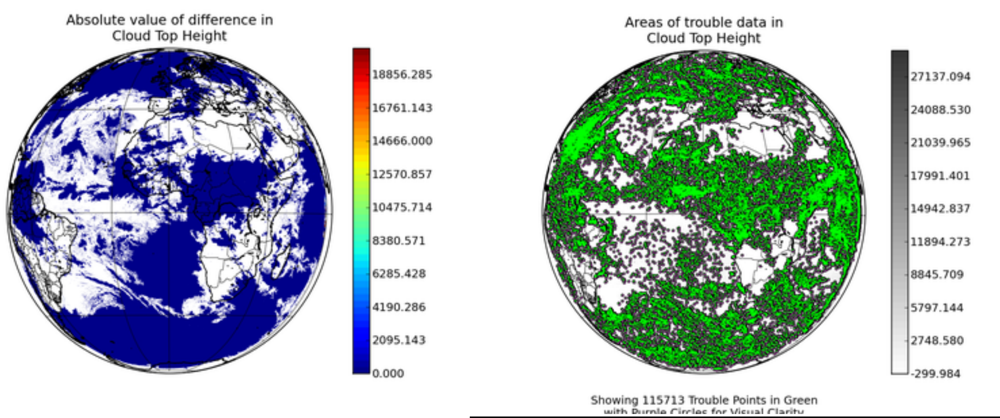


Figure 6.3.1. An example comparison between the AIT framework and Geocat output for Cloud Top Height at 0000Z on day 237 of 2006. The left image shows the absolute difference between the two files and the right image indicates the location and areas of significant difference.

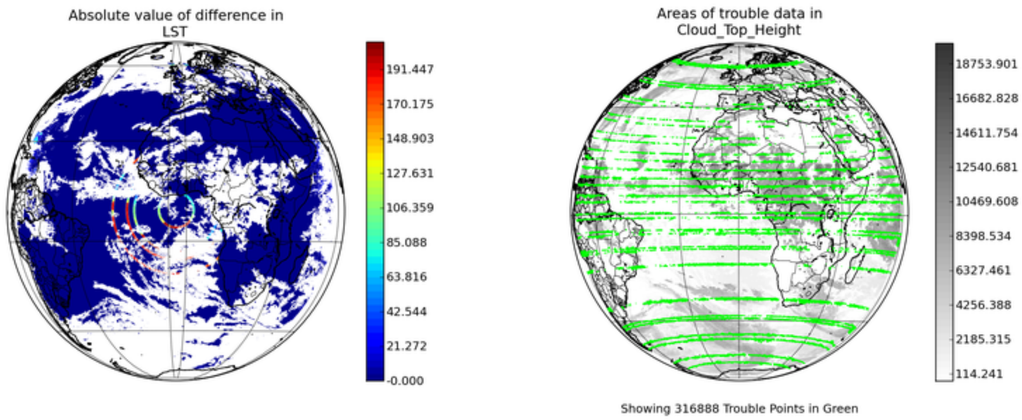


Figure 6.3.2. An example comparison of netCDF3 and netCDF4 output from the AIT framework, showing the absolute difference in the AWG sounding team product LST (left), and the locations of trouble points in the AWG cloud team product Cloud Top Height (right). The banding in the Cloud Top Height image is indicative of different numbers of scan lines being processed in each segment.

Geocat release

Geocat version 0.7 was released to the Geocat user community along with an updated Geocat manual, and updated test and ancillary datasets. Included in this release were support for the V3 clouds algorithm, per-algorithm external build dependencies, MODIS white sky albedo, scattering angle calculation, enhanced 3D variable support, Intel Fortran 11 compatibility, new output variables, new RTM utility routines, viewing angle correction for emissivity, and various bug fixes.

Geocat continuing development

Geocat development is ongoing and is responsive to algorithm developers' needs. Experimental features currently available in the development version of Geocat and expected to be in the next release of Geocat include the ability to spatially interpolate NWP data on–the-fly, support for variable NWP forecast times, extension of available input datasets for aerosol optical depth calculations, and fast model interface changes to support sounding algorithm integration.

Other Geocat activities include user support and direct assistance with algorithm integration.

Verification tool development

Leveraging open-source tools, CIMSS AIT has created and is expanding development of a verification reporting tool to be shared across GOES-R integration testing, called *glance*. This tool automatically generates concise and configurable HTML summary reports that graphically and statistically show correspondence and significant areas of difference between huge datasets generated by GOES-R algorithms. The functionality includes verification across disparate file formats. It has proved crucial to rapidly identifying and addressing problems in generated test datasets. Figure 6.3.3 shows a set of comparison images produced by *glance*.

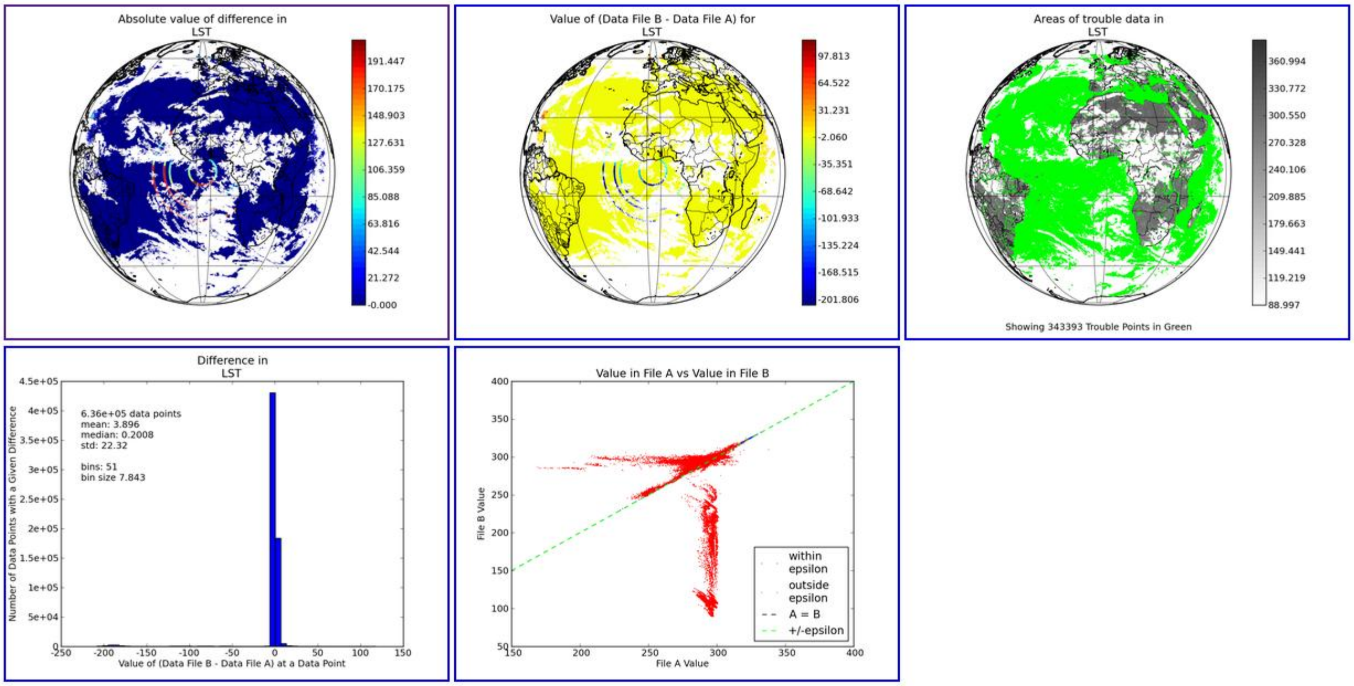


Figure 6.3.3. Comparison images produced by glance. The top row is (from left to right), Absolute different ce, Difference, trouble points. The bottom row (from left to right) is a histogram of the trouble points and a scatterplot of the trouble points.

Scalable testing using computing clusters

In support of GRAFIIR and GOES-R AIT, the CIMSS AIT group has created modular scripting libraries for adaptively handling the huge data volumes required in order to process GOES-R proxy data using Geocat (and eventually the AIT Framework) reliably using clusters. This involves the automatic identification, translation and distribution of ancillary and auxiliary data needed by algorithms, storage and cluster management, and making efficient use of pre-existing third party job management systems (queues). This automation library will be expanded to include the *glance* reporting tool to allow large-scale end-to-end testing activities on modest cluster hardware with short turn-around times for tens of thousands of simulated scenes.

Algorithm integration activities

CIMSS AIT continued work supporting the integration of algorithms to the GOES-R AIT Framework, including coding standards work, unit and subsystem testing, and supporting scientists with programming and tool questions.

Framework development support & migration

In order to address Project Office requirements of algorithm implementations, to permit compatibility between algorithm development frameworks (Geocat) and prototype operational frameworks (AIT Framework), and to permit further evolution of framework implementations allowing new algorithms and capabilities, CIMSS AIT began work on specifying application programming interfaces (APIs) to be implemented by Geocat and the AIT Framework in order to allow algorithms to migrate more efficiently between research and operations without necessitating expensive wrapping and partial re-coding. These efforts will be continued during FY09.

Infrastructure maintenance
During 2009, it has increasingly become necessary to proactively upgrade storage and computing facilities at CIMSS in order to support proxy data and algorithm development work. Substantial planning work was required to assess replacements for our four-year-old systems, address large-scale back-up capability for critical datasets, and simplify and streamline use of large-scale systems by science staff.

Collocation
We are developing collocation software to spatially collocate MODIS, AIRS, CrIS, and IASI with geostationary satellites (GOES, SEVIRI). To meet this goal we will port legacy collocation software developed at CIMSS over the past 30 years to a maintainable software library. The resulting software package will be modular and capable of collocating new sensors as they become available. We recently published the collocation framework that provides the core of the software being developed. We are currently developing the capability to collocate geo-stationary and polar orbiting observations in real-time. This new capability will provide for operational combined polar and geo retrievals.

Management and milestones
Activities involving managing documentation, schedules, milestones, and coordinating with other agencies continued during FY2008.

Publications and Conference Reports
Nagle, F. W., and R. E. Holz, 2009: Computationally efficient methods of collocating satellite, aircraft, and ground observations. *Journal of Atmospheric and Oceanic Technology*.

6.4. Total Ozone retrieval from ABI
CIMSS Project Lead: Chris Schmidt
CIMSS Support Scientists: Jinlong Li
NOAA Collaborators: Shobha Kondragunta (NOAA/NESDIS/STAR), Brad Pierce (NOAA/NESDIS/STAR)
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:
- 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 FY09 CIMSS proposed to work with the Algorithm Integration Team (AIT) to perform the Test Readiness Review (TRR), to provide the 80% delivery of the algorithm (software and ATBD), and to develop the Validation Plan.

Summary of Accomplishments and Findings

CIMSS reached all of its major milestones for the ozone algorithm during the reporting period. Version 3 of the ozone algorithm was delivered to AIT well in advance of its deadline. In Spring 2009 CIMSS worked with the AIT to present the Test Readiness Review (TRR), at which it was shown that CIMSS and the AIT generate the same results on their respective development platforms and that the Ozone algorithm can meet its requirements. The differences, representing less than 0.0018% of all pixels in the proxy dataset, were entirely attributable to precision differences between the two pieces of hardware used to create the products. Proxy data for ozone comes from SEVIRI due to the spectral similarities between it and ABI. An example is in Figure 6.4.1, which shows Ozone generated from ABI proxy data from Met-8 SEVIRI on 24 August 2006 at 16:00 UTC. The data was generated by AIT and visualized in McIDAS-V. The clouds have been masked out using the ABI Cloud Mask (as applied to SEVIRI proxy data). The seasonal ozone hole over Antarctica is visible at the bottom of the image.

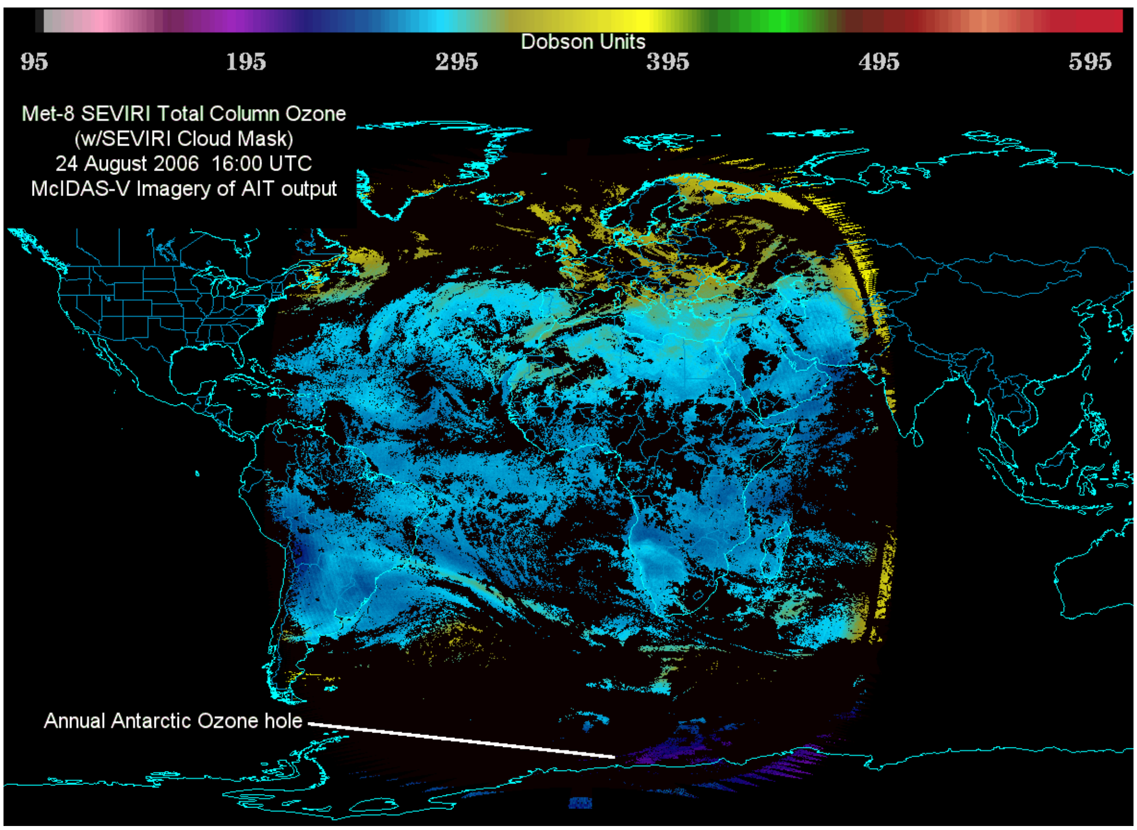


Figure 6.4.1. Ozone generated from ABI proxy data from Met-8 SEVIRI on 24 August 2006 at 16:00 UTC, visualized in McIDAS-V. The ABI Cloud Mask (as applied to SEVIRI data) was used to remove clouds. The seasonal Antarctic ozone hole is visible at the bottom. The data was reprojected to a Mercator projection.

CIMSS developed a Validation Plan that will primarily rely upon 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 proposed validation would be automated and would 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. Work to develop this automated system began in 2009. 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. Ozone was not reported on at the AWG meeting in College park, MD because it is an Option 2 ABI product, though it is being developed on a Baseline Product schedule.

6.5 ABI Cloud Products

CIMSS Project Lead(s): Andi Walther, Pat Heck
CIMSS Support Scientist(s): Corey Calvert, William Straka III, Mike Foster
NOAA Collaborator(s): Andrew Heidinger, Michael Pavolonis
NOAA Strategic Goals Addressed:

- 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

Proposed Work

The GOES-R Cloud Algorithm Working Group (AWG), which consists of researchers from NOAA's 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 retrieval 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 delivered the version 3 (80%) delivery to the NOAA GOES-R Algorithm Integration Team (AIT) routine. The Cloud AWG and the AIT participated in a Test Readiness Review (TRR) in April, where the algorithms provided by the Cloud AWG were validated against the framework.

There have been many presentations showcasing the algorithms developed by the Cloud AWG. At the AMS conference in 2009, a poster was presented comparing the Cloud AWG daytime microphysical properties to MODIS. In March 2009 Andi Walther and Andrew Heidinger participated in the 2009 ESA Satellite Cloud Workshop where the Cloud AWG daytime cloud microphysical algorithm was tested and compared with several US and European microphysical algorithms. Figure 6.5.1 shows an example of the comparisons between the nine cloud microphysical algorithms, including those from the EUMETSAT Climate SAF and NASA Langley, which were presented at the EUMETSAT cloud workshop.

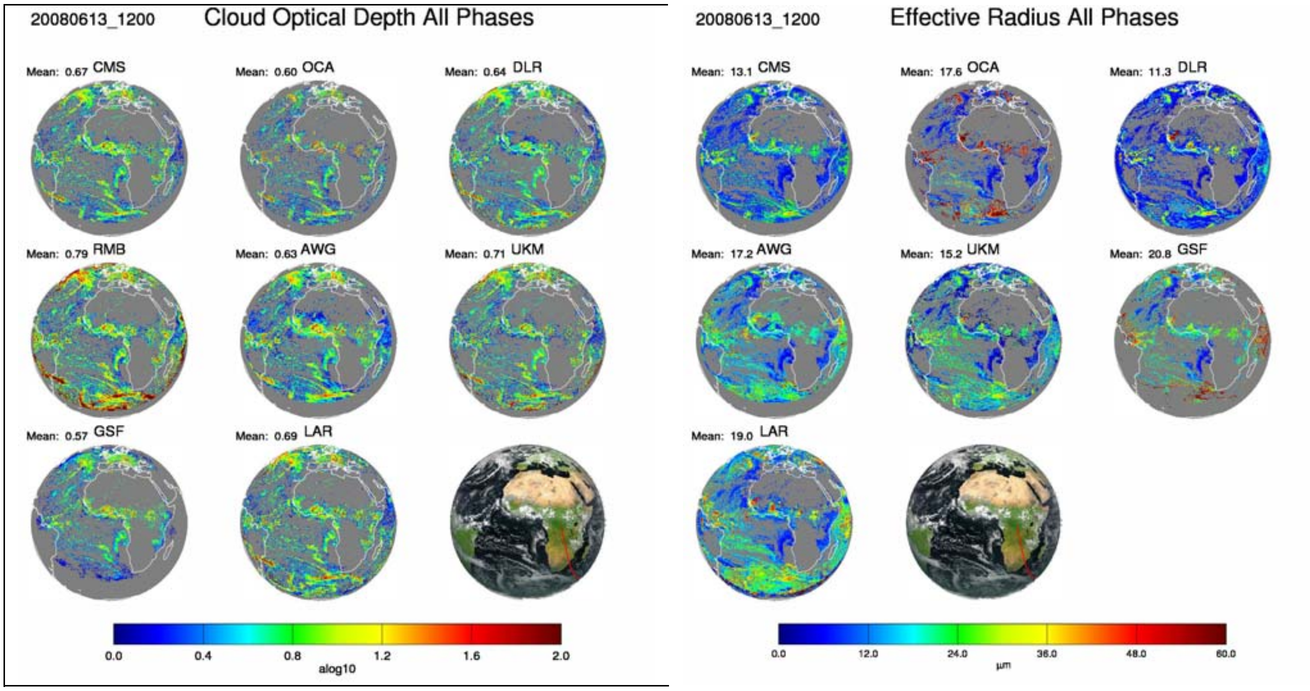


Figure 6.5.1. Comparison of SEVIRI microphysical cloud algorithms. The CIMSS retrieval is labeled with AWG (Algorithm Working Group).

Mike Foster also presented a talk at the 2009 EUMETSAT Meteorological Satellite Conference in Bath, England, detailing a method of extracting statistical moments of liquid water path from the AVHRR satellite sensor for partially cloudy scenes. The same algorithm is used on both AVHRR and GOES-R, though different lookup tables are used. The method described is potentially a valuable tool for generating in-cloud horizontal distributions of liquid water and validation data for numerical models, as well as for analysis of variations in liquid water path and comparison of satellite climatologies.

In July, a number of members of the Cloud AWG participated in the 2009 GOES-R AWG Annual Meeting, where a presentation was made regarding the 80% code delivery and a summary of the various products developed by the Cloud AWG. At the GOES-R Algorithm Development Executive Board (ADEB) in September 2009, responses to the Independent Verification and Validation (IV&V) of the ATBDs were presented. The Cloud AWG also responded to the IV&V's directly to the reviewers. Through these responses, it is hoped that we can continue to improve our algorithms and documentation.

In addition to the various conferences and documents produced during the last year, the Cloud AWG has improved upon each of the algorithms. While the ABI has not been developed at this point, the Cloud AWG is using the SEVIRI instrument onboard the EUMETSAT Meteosat Second Generation geostationary orbiters as a proxy. There has been extensive use of spaceborne lidars, such as CALIPSO, passive microwave satellite sensors, such as the Advanced Microwave Sounding Unit (AMSU), ground lidars and other passive imagers, such as MODIS, as sources for validation and comparison. 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 6.5.2 shows an example of the comparisons done between the daytime cloud optical properties verses CloudSat, MODIS and AMSR-E.

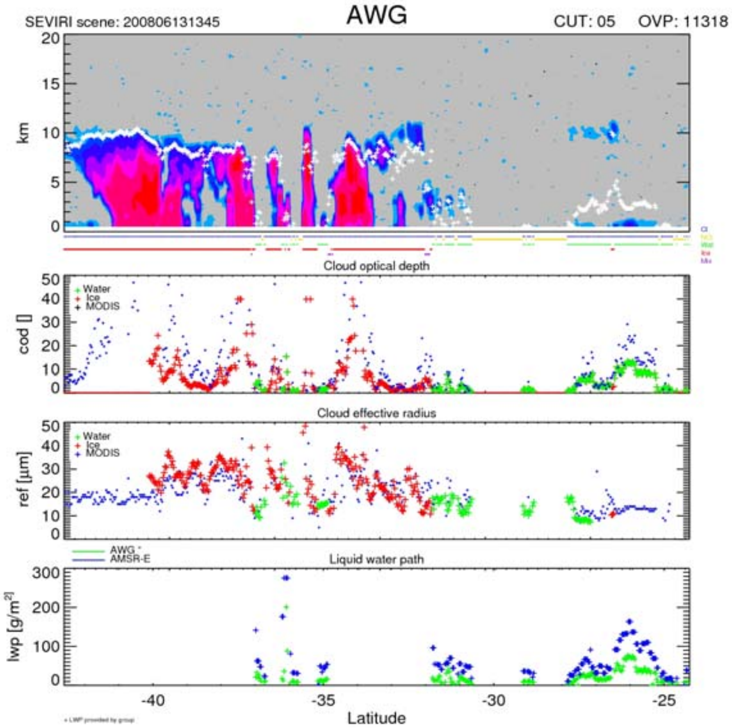


Figure 6.5.2. Validation of AWG retrievals with ATRAIN sensors. The upper panel shows CloudSat reflectivity profile with AWG cloud height product. The color bars below show cloud mask and cloud phase. Second and third panel show comparison of Cloud Optical thickness to MODIS results. Lower image illustrates comparison of Liquid water path to AMSR-E passive microwave measurements.

In addition, the Cloud AWG has worked closely with several other GOES-R AWGs, such as the Winds and SST Algorithm Working Groups, to improve upon the cloud products. The Cloud AWG has also made significant improvements. Some of these improvements have been in response to comments from the various AWGs as well as the IV&V comments. One such example is the inclusion of an additional IR cirrus test to the cloud mask using a combination of the 7.3μm water vapor and 13.3μm channels available on the ABI. The test was based on one of the several steps that make up the Meteosat Cirrus Detection Algorithm (MeCiDA), combining a 15x15 pixel boxcar filter for the 7.3μm brightness temperature (BT) and a single threshold test using the 13.3μm BT. An example of the cirrus test result is shown in Figure 6.5.3.

The Cloud AWG continues to interact with the AIT as well as other AWGs on a regular basis, in order to ensure cloud algorithms are performing to the best of our abilities.

Publications and Conference Reports

William Straka III, A. Walther and A. K. Heidinger, 2009: Evaluation of the GOES-R Algorithm Working Group Cloud Application Team's Daytime Cloud Optical Property Algorithm Applied to the Spinning Enhanced Visible and Infrared Imager (SEVIRI). AMS Satellite Conference, Phoenix, AZ, 11-15 January 2009.

Andi Walther and A. K. Heidinger, 2009: Comparison of Different inversion Techniques for Daytime Microphyiscal Parameter retrievals. 2009 EUMETSAT Satellite Conference, Bath, England, 21-25 September 2009.

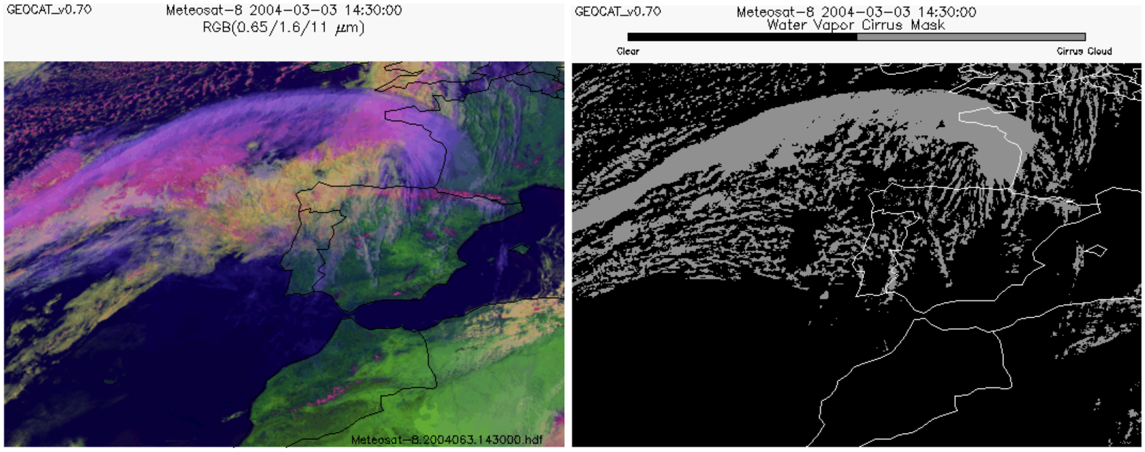


Figure 6.5.3. Example output of the water vapor cirrus test from March 3, 2004 at 14:30 UTC centered over Portugal. The left panel is a 3-channel false color image. The right panel is the binary yes/no output from the water vapor cirrus test.

Andi Walther and A. K. Heidinger, 2009: Aspects of the retrieval of cloud daytime microphysical parameters. ESA Cloud workshop, Locarno, Switzerland, 25-27 March 2009.

Michel Foster, 2009: Development of a multi-decadal cloud water climatology using the AVHRR satellite sensor. EUMETSAT 2009 conference, Bath, England, 21-25 September 2009.

GOES-R ABI Cloud Mask Algorithm Theoretical Basis Document (80% delivery)
GOES-R ABI Cloud Type/Phase Algorithm Theoretical Basis Document (80% delivery)
GOES-R ABI Cloud Height Algorithm Theoretical Basis Document (80% delivery)
GOES-R ABI Daytime Cloud Optical Properties Algorithm Theoretical Basis Document (80% delivery)
GOES-R ABI Nighttime Cloud Optical Properties Algorithm Theoretical Basis Document (80% delivery)

References

Krebs W., H. Mannstein, L. Bugliaro, and B. Mayer, 2007: Technical note: A New Day- and Night-time Meteosat Second Generation Cirrus Detection Algorithm MeCiDA. *Atmos. Chem. Phys.*, **7**, p6145-6159

6.6. Active Fire/Hot Spot Characterization (FIRE)

CIMSS Project Lead: Chris Schmidt
CIMSS Support Scientists: Jay Hoffman, Elaine Prins, Scott Lindstrom, Jason Brunner
NOAA Collaborators: Yunyue Yu (NOAA/NESDIS/STAR), Ivan Csiszar (NOAA/NESDIS/STAR)
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

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 FY09 the task included preparing and delivering the Test Readiness Review (TRR), the 80% Algorithm Theoretical Basis Document (ATBD), the version 3 and 80% code deliveries, and modification of the ABI fire code to address the impacts of sensor characteristics on fire detection/characterization. Additionally, in coordination with NOAA scientists CIMSS proposed to begin 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 Critical Path efforts to take advantage of new features and spectral bands available with GOES-R, and 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. In November and December 2008 CIMSS discovered calibration and navigation bugs in its development system which slowed delivery of the Version 3 fire algorithm. By early 2009 the delivery was made and accepted by the Algorithm Integration Team (AIT). In Spring 2009 CIMSS worked with the AIT to present the Test Readiness Review (TRR), at which it was shown that CIMSS and the AIT generate the same results on their respective development platforms and that the Fire algorithm was able to meet its requirements. Figure 6.6.1 shows fires from the two teams using the same algorithm and data. The differences are entirely attributable to rounding differences between the two pieces of hardware used to create the product.

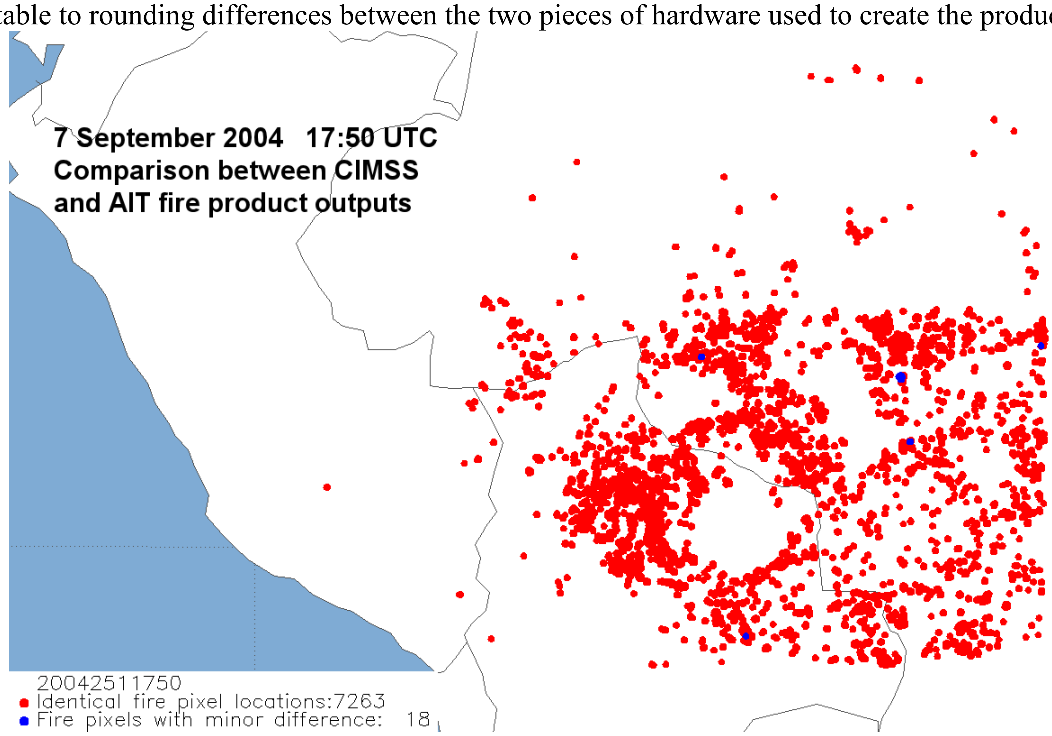


Figure 6.6.1. Comparison between CIMSS and AIT results using the ABI Fire algorithm using data remapped from MODIS (17:50 UTC overpass on 7 September 2004). The data matches almost exactly, with all 18 differences being attributable to 4 differences in rounding on the two difference machines.

CIMSS collaborated with STAR to create the Validation Plan for the ABI Fire algorithm. The 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 MODIS data is remapped to ABI using the tool developed at CIMSS. It was discovered that there appears to be a navigation offset between the ABI data and MODIS data. MODIS fires derived from the same imagery show a very strong match with ASTER, whereas ABI proxy fires are offset by approximately 1.5 pixels to the southeast. This issue was not resolved by the end of the reporting period but is under investigation. CIMSS delivered the 80% code and ATBD to the AIT, which then delivered it to the GOES-R Program Office, on time in September. The delivery included responding to comments from an independent reviewer, which primarily focused on relatively straightforward issues with the ATBD.
The Fire algorithm was part of the presentation about the AWG Land Team's efforts at the annual AWG meeting held in College Park, Maryland. Additionally, monthly progress reports were provided to the Land Team chair, Yunyue Yu, that tracked effort and money spent.

Publications and Conference Reports

Schmidt, Christopher C., E. M. Prins, J. C. Brunner, J. P. Hoffman, S. S. Lindstrom, and J. M. Feltz, 2009: Geostationary detection of fires and the global and long-term datasets of the WF_ABBA. The 89th AMS Annual Meeting/16th Conference on Satellite Meteorology and Oceanography, Phoenix, AZ, January 2009, Amer. Meteor. Soc., J15.4.

6.7. GOES-R legacy atmospheric profile and infrared surface emissivity algorithm development

CIMSS Project Lead: Jun Li
CIMSS Support Scientist(s): Xin Jin, Zhenglong Li, Jinlong Li, Elisabeth Weisz
NOAA Collaborator(s): Tim Schmit, Chris Barnet
NOAA Strategic Goals Addressed:

- 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

Proposed Work

The main focus of this work is to develop the legacy atmospheric profile (LAP) algorithm for GOES-R Advanced Baseline Imager (ABI) (Schmit et al. 2005) data processing. Forecast and ABI InfraRed (IR) radiances are combined to develop the LAP product and the derived products (DPs). The LAP product includes atmospheric temperature and moisture profiles, while the derived products include total precipitable water (TPW), lifted index (LI), convective available potential energy (CAPE), total totals index (TOTO), Showalter index (SI), and K-index (KI). This project will provide science codes to the GOES-R algorithm integration team (AIT) for software implementation and process demonstration, as well as to support algorithm evaluation and validation by using collocated ABI, global numerical weather prediction (NWP) forecast, analysis, radiosondes, ground in-situ measurements, and measurements from polar-orbiting satellites.

Besides the LAP algorithm development, this project also aims to develop the physical algorithm for the IR surface emissivity (SE) product from GOES-R ABI radiances. The algorithm uses high temporal information of ABI observations. The GOES-R ABI SE algorithm is based on the assumption that the surface skin temperature is temporally variable while the IR SE is temporally invariable within a time period, so that ABI radiances from multiple time steps can be used to retrieve temporally variable surface skin temperatures and temporally invariable SE within a time period. The algorithm will be tested with Spanning Enhanced Visible and Infra Red Imager (SEVIRI) radiance measurements.

Summary of Accomplishments and Findings

(1) An Emissivity look-up table has been implemented into the algorithm for LAP product generation over ocean. Prior information on infrared surface emissivity is very important for the LAP product. The CIMSS sounding team has implemented an IR emissivity lookup table over ocean into GOES-R LAP package; the emissivity look-up table is based on the Wu/Smith/Nalli model. The impact of using the IR emissivity model over ocean is evaluated using AMSR-E (The Advanced Microwave Scanning Radiometer - Earth Observing System) total precipitable water (TPW) measurements; it is found that using ocean emissivity look-up tables improves the LAP and DPs over ocean.

(2) The impact of radiative transfer model on LAP product has been evaluated. The CIMSS sounding group continues to test the impact of the radiative transfer model on the LAP products. The Community radiative transfer model (cRTM), Radiative Transfer for TOVS (RTTOV), and Pressure layer Fast Algorithm for Atmospheric Transmittances (PFAAST) are used in the evaluation. Calculations are performed for SEVIRI (Spinning Enhanced Visible and InfraRed Imager). We found that brightness temperatures (BTs) are similar between cRTM and RTTOV for most SEVIRI spectral bands. However, BT differences between cRTM and RTTOV are found for the 7.3 and 13.4 μm bands; we will collaborate with the cRTM group to investigate the BT differences by comparing with LBLRTM calculations. In the retrieval experiment SEVIRI radiance measurements are used in the GOES-R LAP algorithm for August 2006 and evaluated against collocated radiosonde observations (RAOBs); for the RAOB locations see left panel of Figure 6.7.1. The retrieval is performed using both RTTOV and cRTM. The right panel of Figure 6.7.1 shows the relative humidity (RH) retrieval RMSE (root mean square error) when using cRTM (red line) and RTTOV (blue line), respectively. The ECMWF (European Centre for Medium-Range Weather Forecasts) global forecasts are used as the first guess. The RMSE of the first guess (forecast) is also shown (black). A total of 457 comparisons are included in the statistics. It can be seen that both cRTM and RTTOV provide similar retrievals better than the forecast, especially in atmospheric layers between 700 – 300 hPa. cRTM performs slightly better in the boundary layer while RTTOV performs slightly better in the middle tropopause.

(3) The GOES-R LAP version 3.0 algorithm has been delivered. Version 3.0 of the GOES-R ABI LAP algorithm was delivered by CIMSS in early 2009. This delivery the lifted index, total totals, K index, convective available potential energy and Showalter index are all available. In this version the ocean emissivity model is used over ocean. Version 3.0 is able to process both simulated ABI radiances and SEVIRI radiance measurements.

(4) The LAP algorithm has been implemented into GEOCAT. Since the Algorithm Integration Team (AIT) mainframe demonstration system starts with the GEOCAT version, it is very important to implement the LAP algorithm into GEOCAT. The CIMSS sounding team has closely worked with the GEOCAT and AIT teams on the implementation of the LAP algorithm into GEOCAT. The GEOCAT LAP version has been successfully tested with both simulated ABI radiances and SEVIRI radiance measurements.

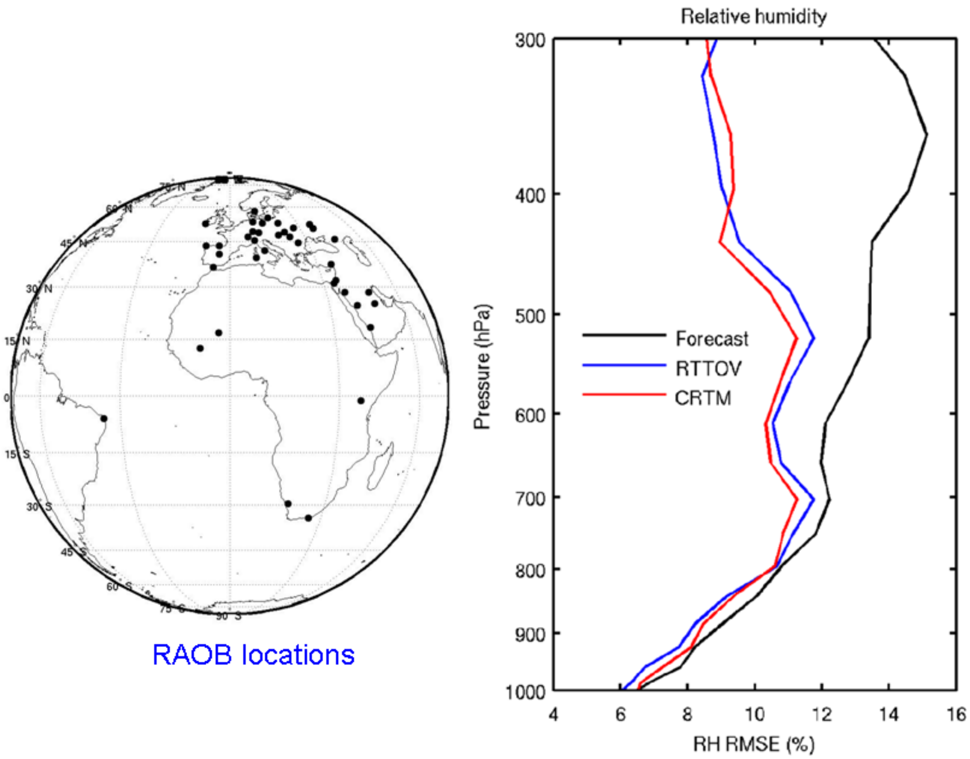


Figure 6.7.1. The RH retrieval RMSE with cRTM (red line) and RTTOV (blue line), respectively. Comparisons are between SEVIRI retrievals and RAOBs for August 2006, a total of 457 comparisons are included in the statistics. The first guess (ECMWF forecast) RMSE is also shown (black).

(5) The GOES-R LAP Test Readiness Review (TRR) has been held. The GOES-R AWG LAP Test Readiness Review (TRR) was held on April 15, 2009. This TRR covered the following products: legacy vertical moisture profile, legacy vertical temperature profile, derived stability indexes, and total precipitable water.

(6) The LAP ATBD (80%) has been delivered and reviewed. The CIMSS sounding team has worked on updating the GOES-R LAP Algorithm Theoretic Baseline Document (ADBT) to meet the 80% requirements; this 80% ADBT has been delivered and reviewed by the Algorithm Development Executive Board (ADEB). Feedback and suggestions from Independent Validation and Verification (IV&V) teams will be used for the 100%ATBD development.

(7) The GOES-R AWG surface emissivity (SE) algorithm design review (ADR) was held. The AWG sounding team is responsible for the SE algorithm development and product generation; Tim Schmit and Jun Li from the sounding team presented the SE algorithm design and the test results. The SE algorithm uses the temporal information of the Advanced Baseline Imager (ABI) infrared radiances for the same clear-sky pixel in a short time period (i.e., several hours to one day). By assuming that the SE is temporally invariable while land surface skin temperature (LST) is temporally variable in a time period, the SE and LST can be retrieved simultaneously from radiances of multiple time steps. The SE product at IR window channels will be developed, and Spinning Enhanced Visible and InfraRed Imager (SEVIRI) radiance measurements are used as proxy data for the algorithm development. Figure 6.7.2 shows the conceptual diagram for the SE algorithm design.

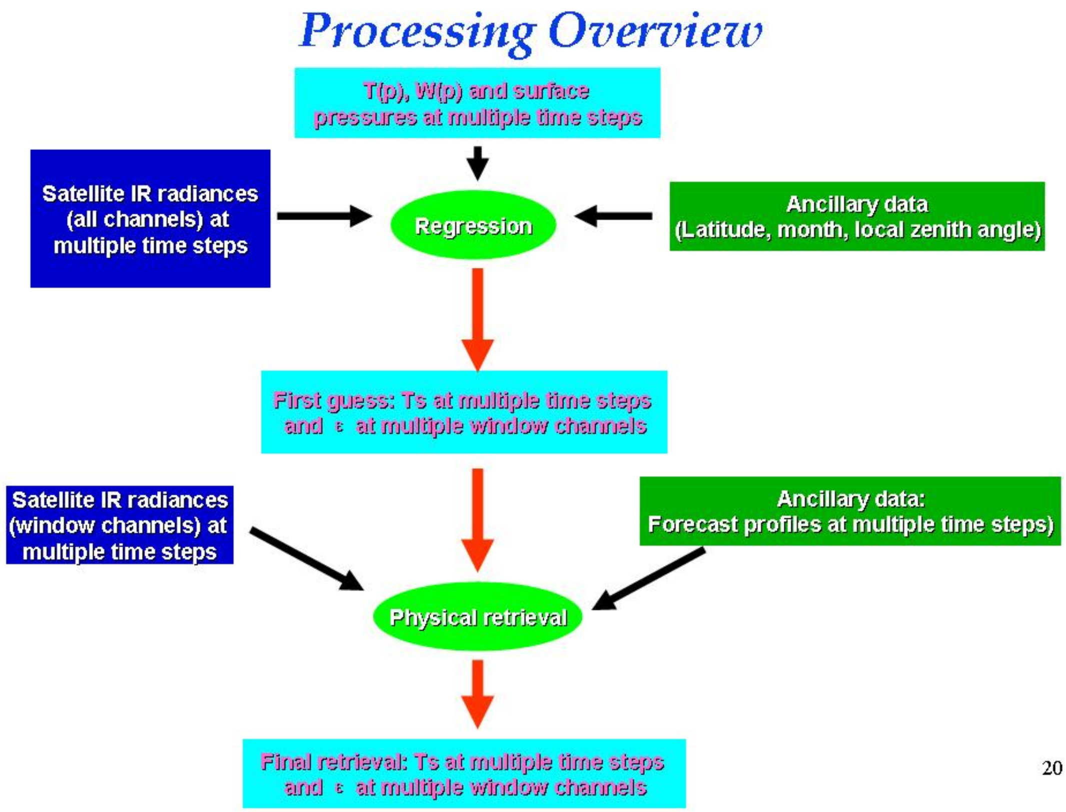


Figure 6.7.2. The conceptual diagram for the SE algorithm design.

(8) The LAP winter validation was conducted using ECMWF analysis. One month (January 2008) spatially and temporally co-located SEVIRI and ECMWF analysis data is used for winter validation of the LAP algorithm. The operational SEVIRI cloud mask product from EUMETSAT is used for clear sky pixel identification. Test results show that the physical retrieval does improve the regression (used as the first guess), while the regression improves the forecast for both summer and winter. Since the regression algorithm uses forecast profiles and SEVIRI radiances as predictors, an improvement from regression over the forecast is expected. The physical retrieval improves the regression since it accounts better for the nonlinearity of moisture with regards to IR radiances. RTTOV9.2 is used as the radiative transfer model in the SEVIRI retrieval experiment.

Publications and Conference Reports

Tim Schmit and Jun Li gave a summary talk on LAP 80%ATBD and algorithm development at the AWG annual meeting held from 20 – 24 July in Maryland.
Xin Jin gave a poster presentation on LAP which is the baseline product at the AWG annual meeting held from 20 – 24 July in Maryland.
Zhenglong Li gave a poster presentation on SE which is an option 2 product at the AWG annual meeting held from 20 – 24 July in Maryland.

References

Jin, X., J. Li, T. J. Schmit, J. Li, M. D. Goldberg, and J. J. Gurka, 2008: Retrieving clear-sky atmospheric parameters from SEVIRI and ABI infrared radiances. *J. Geophys. Res.*, **113**, D15310, doi:10.1029/2008JD010040.

6.8 AWG Winds

CIMSS Project Lead(s): Chris Velden and Steve Wanzong
CIMSS Support Scientist(s): Howard Berger
NOAA Collaborator(s): Jaime Daniels (STAR)
NOAA Strategic Goals Addressed:

- 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 development and automated processing of wind vectors from satellites has its heritage at CIMSS. The work plan research objectives seek to continue this heritage by adapting current methods and algorithms to NOAA's next generation of geostationary satellites, starting with GOES-R. The ABI will provide both traditional and new spectral channels that the CIMSS winds team will employ to test, process and validate using simulated and proxy datasets provided by other members of the GOES-R AWG project. We plan to use locally-available hardware resources initially for software testing, with a phased transition to a collaborative testbed environment as it comes online. The proxy data will leverage off of existing imagery from GOES and MSG/SEVERI. We will also employ ABI simulated imagery for select case studies. The algorithm development, testing and validation will focus on heritage algorithms currently being used in NESDIS operations today to generate winds from satellite imagery (Velden et al. 2005). We will leverage and adapt current algorithms/software to expected ABI characteristics, focusing first on ABI heritage channels (VIS, IR-W, WV) for winds testing. We will then turn our attention to the new spectral capabilities afforded by the ABI for wind derivation. All software development will follow accepted AWG standards, and will be accompanied by documentation such as the Algorithm Theoretical Baseline Document (ATBD). This work will insure the readiness of the CIMSS/NESDIS automated winds algorithm for eventual operational implementation upon the deployment of GOES-R ABI. During this reporting period, CIMSS scientists proposed to help deliver new versions of the GOES-R-adapted winds algorithm and ATBD 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 winds algorithm, including the use of MSG SEVERI data and model-derived synthetic data.

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) Redesign the current operational winds code to meet the AWG standards in terms of documentation, programming language, and embedding it into a GOER-R ABI AWG framework.
2) Test the algorithm performance using simulated and proxy data sets.
3) Address the need for new approaches to vector height assignment and quality control.

In each of these three areas, several important benchmarks have been met during the reporting period in order to satisfy the AWG 80% delivery requirements, including the delivery of the winds algorithm (Version 3), all related documentation (ATBDs and Product Validation Plan), and the evaluation of datasets for assessing the performance and accuracy of the winds. An initial evaluation of the algorithm and winds product using a model simulation proxy data shows that AWG algorithm meets the 80% accuracy requirements in most cases (for example, see Figure 6.8.1). Some issues remain with the clear-sky water vapor tracers, and these will be investigated.

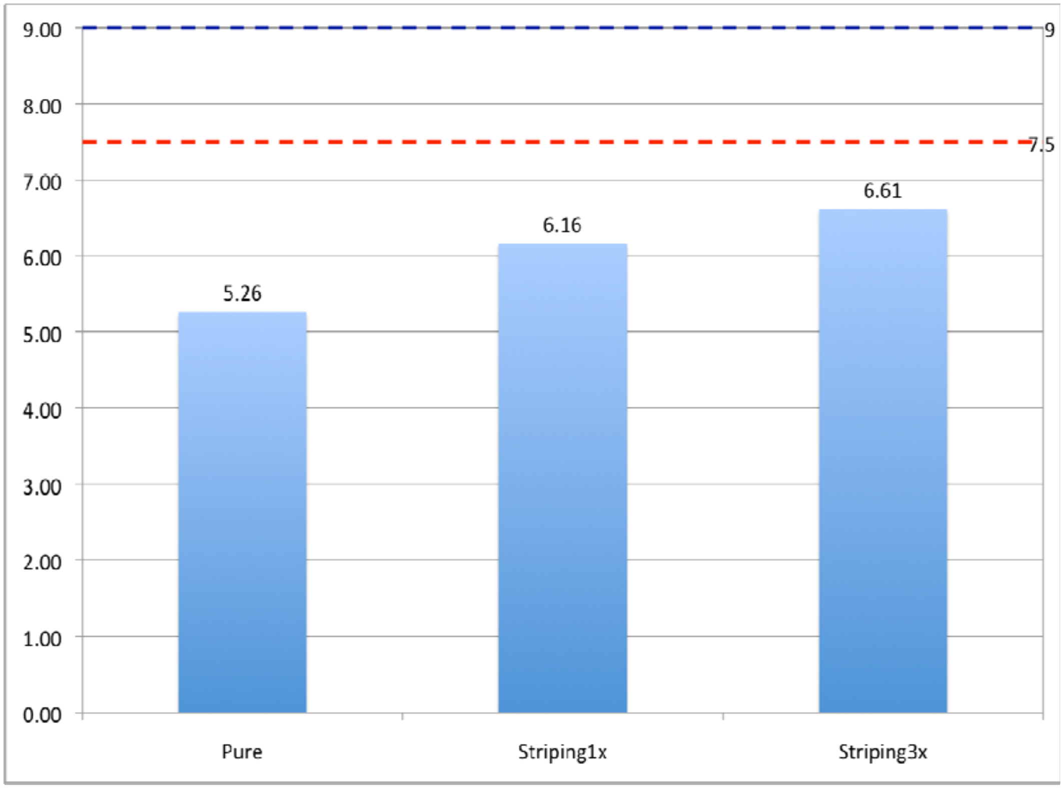


Figure 6.8.1. Performance for IR-Window AMVs produced from WRF simulated fields at 15-min. image intervals. Mean Vector Difference (MVD) accuracy of unaltered ("Pure"), 1 times ABI striping specification, and 3 times striping specification when compared to the WRF model U/V fields ("Truth"). Dashed red line is the accuracy goal for ABI IR AMVs. Although the accuracy is worse (as expected) for both striping effects, it is still within the MVD accuracy tolerance of 7.5 m/s.

Publications and Conference Reports

Wanzong, Steve; Velden, C.S.; Huang, A; Gunshor, M.; Otkin, J.; Greenwald, T.; Daniels, J. and Bresky, W., 2009: Exploring the behavior of atmospheric motion vector (AMV) errors through simulation studies. 2009 EUMETSAT Meteorological Satellite Conference, Bath, United Kingdom, 21 - 25 September 2009.

References

Velden, C.S. et al., 2005: Recent Innovations in Deriving Winds from Meteorological Satellites. *Bull. Amer. Meteor. Soc.*, **86**, 205-223.

6.9 Hurricane Intensity Estimation (HIE) Algorithm

CIMSS Project Lead(s): Tim Olander and Chris Velden
CIMSS Support Scientist(s):
NOAA Collaborator(s): Jaime Daniels (STAR)
NOAA Strategic Goals Addressed:

- 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 80% delivery requirements (completed in September 2009), including the delivery of the HIE algorithm (Version 3), all related documentation (ATBDs and Product Validation Plan), and the delivery of several evaluation datasets for assessing the performance and accuracy of the HIE. An initial evaluation of the HIE using a limited GOES-R ABI proxy data derived from MODIS data (obtained from CIRA) has shown that the ADT meets the AWG HIE algorithm 80% accuracy requirements. Our analyses also show the impact of the improved ABI resolution data on specific TC cases, such as the ability to resolve and provide a more accurate intensity estimate for extremely small TC eye situations, such as observed with Hurricane Wilma in 2005.

Publications and Conference Reports
Olander, T., and C. Velden, 2009: The GOES-R AWG Hurricane Intensity Estimation (HIE) Algorithm, GOES-R Algorithm Working Group Meeting, Adelphi, Maryland, July 19-23.

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 Volcanic Ash
CIMSS Project Leads: Justin Sieglaff
CIMSS Support Scientists: Andrew Parker
NOAA Collaborator: Michael Pavolonis
NOAA Strategic Goals Addressed:

- 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 2009 fiscal year we proposed to begin validation of the Advanced Baseline Imager (ABI) volcanic ash height and ash mass loading algorithm retrievals developed during previous fiscal years.

The volcanic ash height and mass loading retrieval is only applied to pixels that contain volcanic ash, so in addition to validating the retrieval algorithm, validation of the ash detection algorithm is also necessary. This year's proposed work also included several code and Algorithm Theoretical Basis Document (ATBD) deliveries. 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 Spinning Enhanced Visible and InfraRed Instrument (SEVIRI) imager is one such instrument. Since volcanic eruptions are relatively rare, SEVIRI has observed relatively few volcanic clouds since it began service in 2004. To supplement the few volcanic ash scenes viewed by SEVIRI, 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).

The validation effort is composed of two parts, one part verifying the correct detection of ash pixels and one part verifying the accuracy of the ash height and mass loading retrievals. The detection verification statistics are computed by comparing the algorithm to a volcanic ash mask produced via expert manual analysis. The ash detection has been shown to have a skill score that generally exceeds 0.85. Initial validation of mass loading began with null case validation. Eight ash and dust free SEVIRI full disk scenes were validated and the results were well within the requirements, with mean mass loading bias < 0.03 tons/km^2 and standard deviation < 0.8 tons/km^2. For non-trivial validation results, the Cloud-Aerosol Lidar with Orthogonal Polarization (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. The CALIOP observed a volcanic ash plume co-located with SEVIRI observations between South America and Africa from the Chaiten volcano on May 5, 2008 (Figure 6.10.1.1). For this volcanic plume the ash height algorithm retrieval agreed very well with the CALIOP observed cloud height, despite the complicated multilayered nature of the scene. There were 92 co-located SEVIRI ash pixels with CALIOP footprints; the ash height retrievals had a bias of 0.6 km and standard deviation of 0.5 km when compared to CALIOP. Due to the multi-layered nature of the volcanic ash plume, mass loading validation for this plume are unavailable. Similar validation efforts utilizing commonly observed airborne dust scenes have been performed and will continue into the current fiscal year. Future validation will also include Moderate Resolution Imaging Spectroradiometer (MODIS) observations of volcanic ash plumes and airborne dust cases.

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

- Successful Critical Design Review (CDR) – December 2008
- Delivery of 80% Algorithm Theoretical Basis Document (ATBD) and Versions 2 and 3 of the volcanic ash code to GOES-R Algorithm Implementation Team (AIT)
- Successful Test Readiness Review (TRR) – July 2009
- Successful Algorithm Development Executive Board (ADEB) review – August 2009

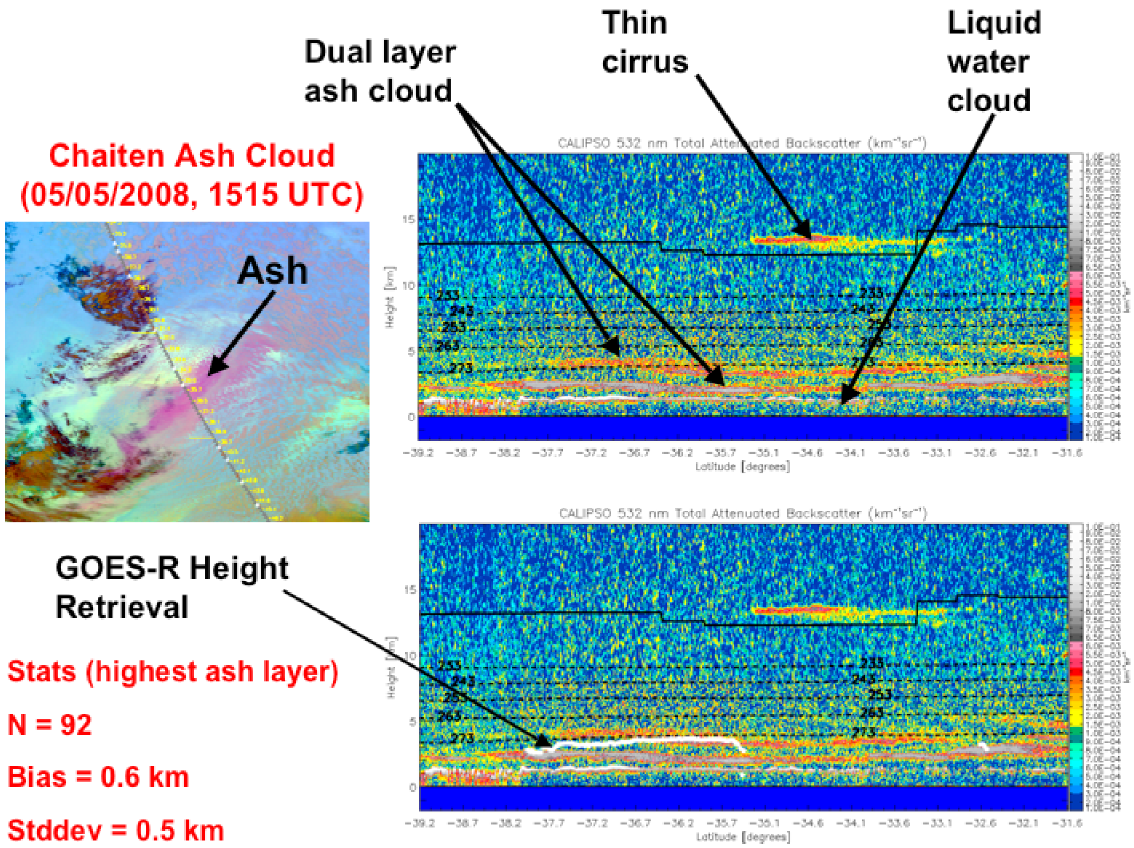


Figure 6.10.1.1. Left panel shows a false-color RGB image from SEVIRI of a volcanic ash plume from the Chaiten volcano over the Atlantic Ocean on 5 May 2008. The CALIOP overpass is plotted over the image. The upper right panel shows the CALIPSO backscatter, the ash cloud layers, boundary layer stratus clouds, and thin cirrus clouds are identified. The lower right panel is the same as the upper right panel, but with the GOES-R ABI ash height retrievals plotted in white.

Publications and Conference Reports

New Automated Methods for Detecting Volcanic Ash and Retrieving Its Properties from Infrared Radiances, M. Pavolonis and J. Sieglaff, AMS Annual Meeting/16th Conference on Satellite Meteorology and Oceanography. Phoenix, Arizona, January 2009 – Oral presentation.

Pavolonis, M. J. and J. Sieglaff: GOES-R Volcanic Ash: Detection and Height Algorithm Theoretical Basis Document (ATBD), Second Draft (80%) submitted June 2009.

Pavolonis, M. J., 2009: Advances in extracting cloud composition information from spaceborne infrared radiances: A robust alternative to brightness temperatures. Part I: Theory. To be submitted to *J. Atmos. Sci.*

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. Atmos. Sci.*

6.10.2 SO_2 Detection

CIMSS Project Leads: Andrew Parker
CIMSS Support Scientists: Justin Sieglaff
NOAA Collaborator: Michael Pavolonis
NOAA Strategic Goals Addressed:

- 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

This year we proposed to make improvements in an automated sulfur dioxide (SO_2) detection algorithm for use with the Advanced Baseline Imager (ABI) aboard the next generation of Geostationary Operational Environmental Satellites (GOES-R). SO_2 is present in many volcanic eruptions, so the ability to reliably detect SO_2 and warn aviation interests is important. Data from the Spinning Enhanced Visible-Infrared Imager (SEVIRI) were used as a proxy for the ABI, and the results of the SO_2 detection algorithm were compared to SO_2 detected by the Ozone Monitoring Instrument (OMI), which is highly sensitive to SO_2. Upon completion of this project, the SO_2 detection algorithm will be ready for operational use with GOES-R.

Summary of Accomplishments and Findings

The SO_2 detection algorithm 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. Based on the information from these optical depth ratios, pixels are assigned a probability of containing SO_2. An example SO_2 cloud from the eruption of Mt. Nyamuragira and results of the SO_2 detection algorithm are shown in Figure 6.10.2.1.

In order to quantify the success of the GOES-R algorithm, SO_2 detected by the algorithm is compared to SO_2 detected by OMI, which is highly sensitive to SO_2. 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 alone is considered false alarm. Combining the probability of detection and the false alarm rate generates a skill score. The OMI-derived SO_2 cloud from the Nyamuragira eruption and the resulting skill score graph are shown in Figure 6.10.2.2. As Figure 6.10.2.2 shows, the accuracy goal of 0.7 is reached at approximately 14 Dobson Units SO_2.

The following additional project milestones were achieved:

- Completed the SO_2 detection Critical Design Review (CDR), December 2008.
- Delivered Version 2.0 of the SO_2 code to the Algorithm Implementation Team (AIT), April, 2009.

Publications and Conference Reports

Pavolonis, M. J.: GOES-R SO_2 Detection Algorithm Theoretical Basis Document (ATBD), First Draft.

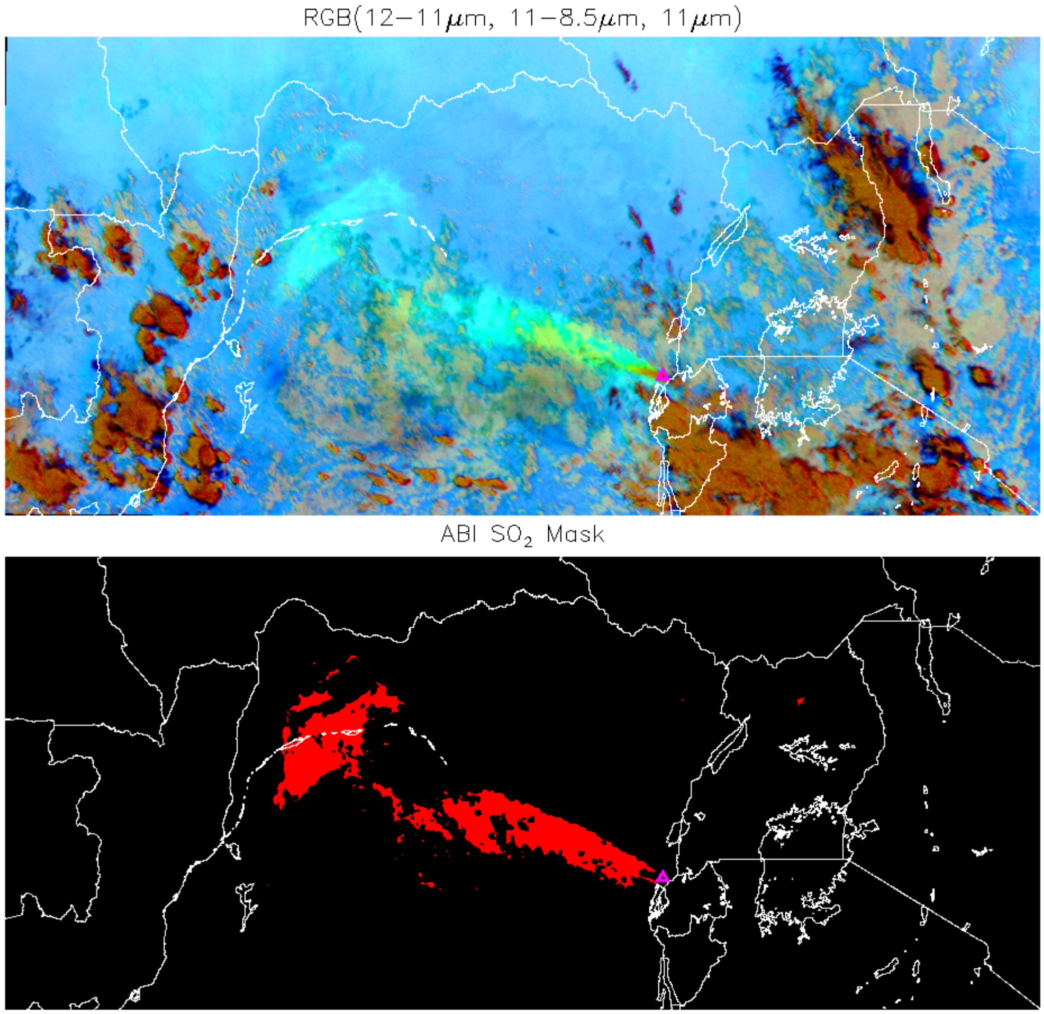


Figure 6.10.2.1. False color image of an eruption of Mt. Nyamuragira in central Africa is shown in the top panel. Light green is indicative of SO_2. Results from the ABI SO_2 detection algorithm for this eruption are shown in the bottom panel. Red indicates pixels in which SO_2 probability is greater than 0.9.

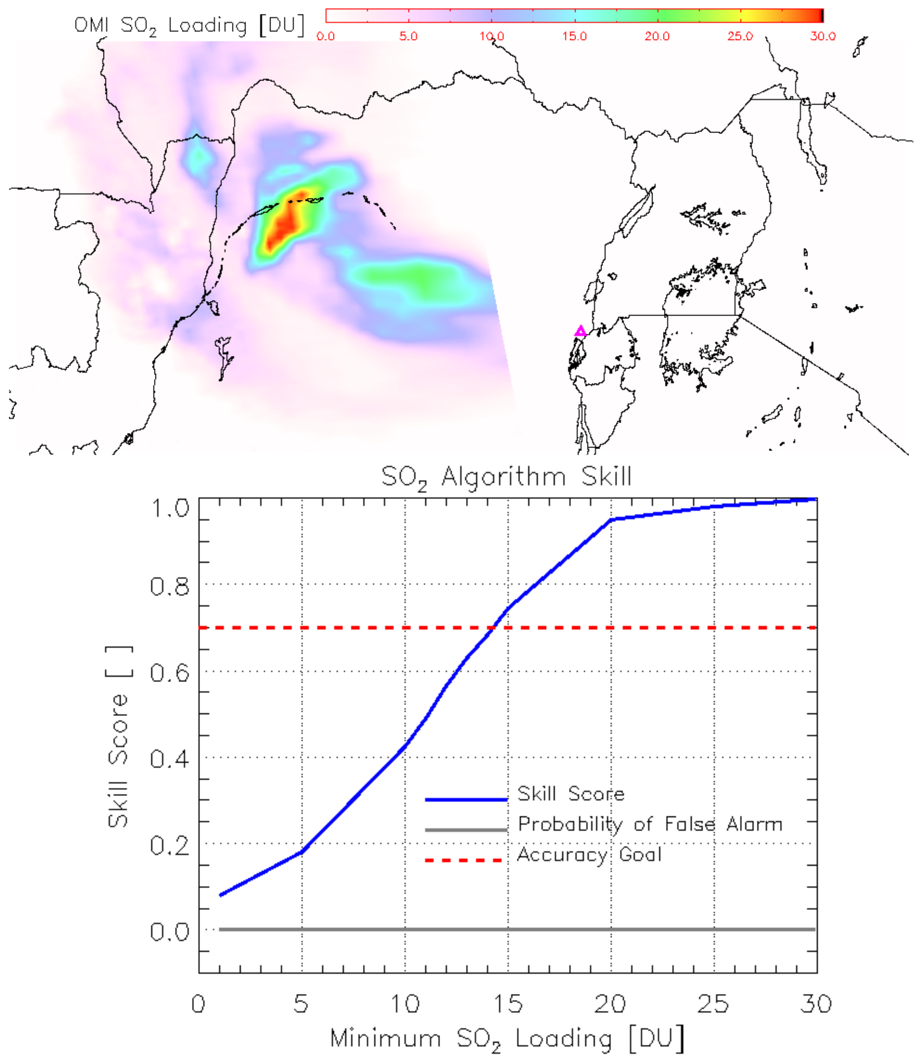


Figure 6.10.2.2. OMI-derived SO_2 from the Mt. Nyamuragira eruption is shown in the top panel. Color bar shows SO_2 loading in Dobson Units (DU). The GOES-R algorithm skill score is shown as a function of the total column SO_2 retrieved by OMI in the bottom panel.

6.10.3 Fog/Low Cloud

CIMSS Project Leads: Corey Calvert
CIMSS Support Scientists: William Straka
NOAA Collaborator: Michael Pavolonis
NOAA Strategic Goals Addressed:

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

CIMSS Research Themes

- Weather nowcasting and forecasting
- Clouds, aerosols and radiation

Proposed Work

The first 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 was based on heritage methodologies used for current GEO imager data, where applicable (nighttime), supplemented with additional spectral information provided by the ABI. We proposed to expand on this original algorithm to further improve the quality of the fog/low cloud algorithm by utilizing the spatial characteristics of the imager data in areas that meet the fog/low cloud criteria. Combining the spatial information with pre-determined look-up tables (LUTs), a probabilistic approach to detection was implemented rather than a binary yes/no mask. The algorithm was ingested into a real-time GOES11/12 processing stream (http://cimss.ssec.wisc.edu/geocat) for continuous evaluation, and additional validation with LIDAR and surface observations will be used for further tuning. In-situ and ground-based data from a fog field experiment sponsored by Environment Canada will provide an additional data source useful for evaluating the algorithm. This project will insure the readiness of the fog/low cloud algorithm for operational implementation upon the deployment of GOES-R.

Summary of Accomplishments and Findings

The basis of the fog algorithm is to use radiometric and spatial information to determine areas of fog/low cloud in the absence of overlapping water or ice clouds. LUTs were created using 3.9μm emissivity (night only), 0.65μm reflectance (day only), and 11μm thermal (both day and night) data from fog/low clouds and non-fog water clouds determined by spaceborne LIDAR and surface observations. Each table returns a probability that fog is present at any given pixel. 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. The spatial uniformity metrics in a 3x3 pixel area are used along with the surface temperature bias and LUT probabilities to determine the overall probability fog/low cloud is present. Examples of the fog probability determined by the algorithm are shown in Figure 6.10.3.1.

The Fog Remote Sensing and Modeling (FRAM) project was conducted from March 16 – May 5, 2009 at the Saint John's International Airport in Saint John's, NL, Canada. The field experiment was organized by Environment Canada. The objective of the project was to collect fog microphysical measurements with the goal of improving fog prediction through increased understanding of fog physics and dynamics. The GOES-R fog/low cloud products were generated in real-time and archived over the field campaign site for the duration of the experiment. These measurements will be used to help characterize and validate the GOES-R fog products.

The following additional project milestones were achieved:

- Completed the fog/low cloud Critical Design Review (CDR), December 2008.
- Delivered Version 2.0 of the fog/low cloud code to the Algorithm Implementation Team (AIT), April, 2009.

Publications and Conference Reports

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

Calvert, C. and M. Pavolonis. The Introduction and Evaluation of a Prototype GOES-R Fog/Low Stratus Thickness algorithm Using SEVIRI, GOES and SODAR Data. AMS Annual Meeting (89th): Fifth Annual Symposium on Future Operational Environmental Satellite Systems – NPOESS and GOES-R. Phoenix, AZ.

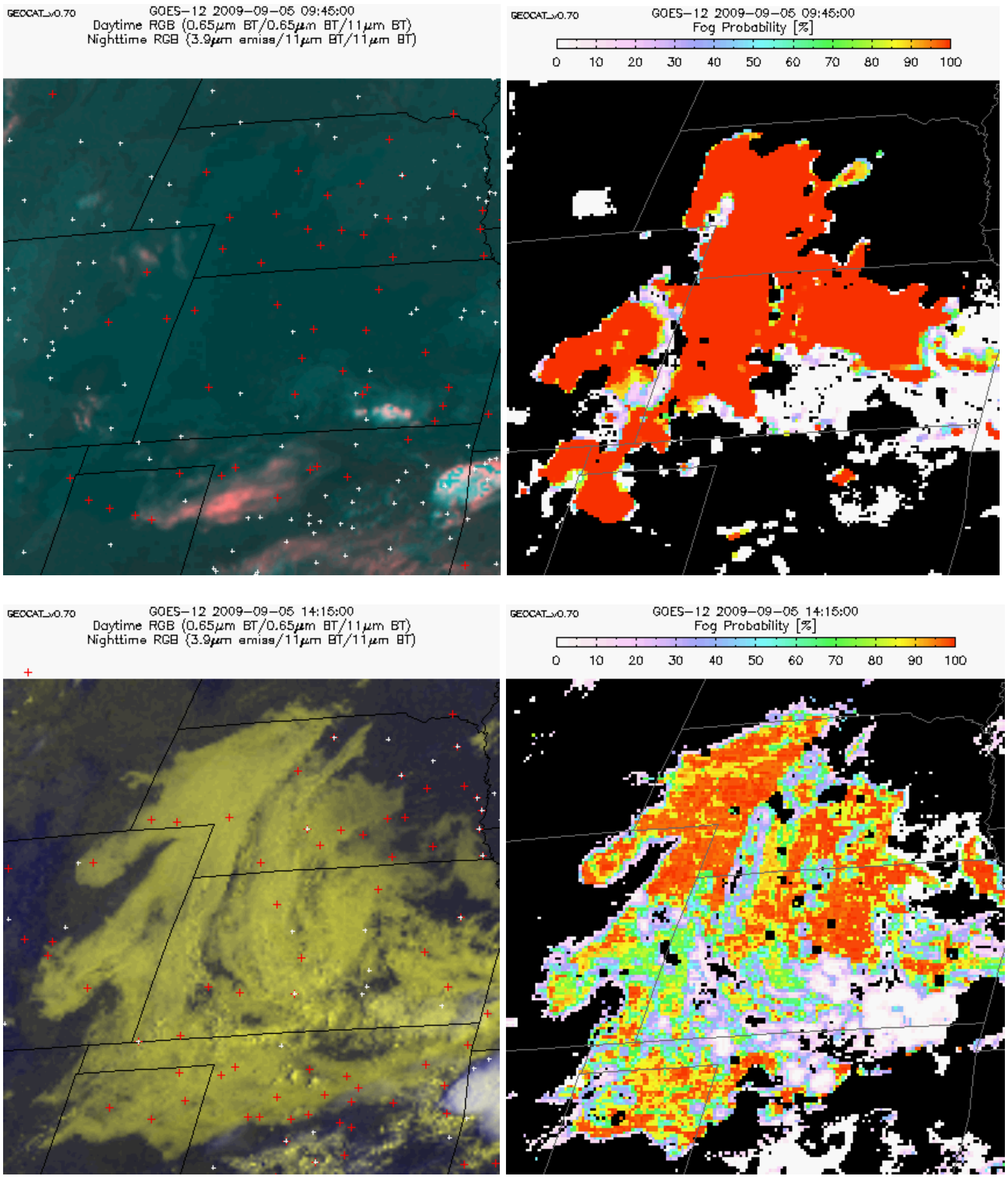


Figure 6.10.3.1. Example output from the ABI fog/low cloud algorithm from September 5, 2009 at 09:45 UTC (top two images) and 14:15 UTC (bottom two images) centered over Kansas. The two left panels are 3-channel false color images. The overlaying red/white crosses represent surface observations reporting fog/non-fog conditions respectively. The two right panels are the fog probabilities determined using the GOES-R fog/low cloud algorithm.

Calvert, C. and M. Pavolonis. The GOES-R Low Cloud/Fog Algorithm: Description and Evaluation. GOES-R AWG & Risk Reduction Review Meeting. Alephi, MD.

6.10.4 Tropopause Fold Turbulence Detection

Task Leads: Wayne Feltz and Anthony Wimmers
NOAA Strategic Goals addressed:

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

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.

Tropopause folds can be located by their association with gradients in moisture, which are evident in the band in the ABI sensitive to upper-tropospheric water vapor. The TFTP automatically detects these gradients in moisture, imposes extra conditions for association with flow instability and presents a distribution of regions of expected turbulence.

The legacy of this product in the scientific literature is as follows. This algorithm uses (and produces natively) the GOES Layer-Average Specific Humidity (GLASH) product described by Wimmers and Moody (2001) for resolving upper-tropospheric moisture. Tropopause folds are associated with moisture gradients above a threshold specified in Wimmers and Moody (2004a), and the tropopause folds themselves are given a uniform width specified in Wimmers and Moody (2004b). Further work verified the application of this method of detecting tropopause folds to observations of aircraft turbulence. Wimmers et al. (2004) showed that pilot reports of turbulence corresponded to a subset of tropopause fold occurrences, and Wimmers and Feltz (2005) showed a similar result with automated aircraft eddy dissipation rate (EDR) data.

The accuracy of the tropopause-folding algorithm was improved by refining the criteria for satellite signatures corresponding to upper-tropospheric turbulence. We now consider gradient feature size, aircraft angle of approach, and distance from the tropopause fold. Also, the algorithm was tested on a 12-month data set of over two million automated, in-situ observations. Further turbulence prediction requirements were refined using model wind data. The algorithm was adjusted to fit more closely with the theory of clear air turbulence due to tropopause folding.

Summary of Accomplishments and Findings

Algorithm development was completed and the tropopause fold algorithm was implemented into GEOCAT, adhering to AIT coding standards. Several Matlab modules were converted to Fortran 90 and they have been made available to other AWG algorithm teams. These include the image smoothing, gradient/laplacian and contouring routines.

The version 2 Tropopause Folding Turbulence Prediction code was delivered to AIT in April 2009 for operational testing. Incremental updates to the code will be delivered as scheduled. Algorithm testing and validation continues with new Eddy Dissipation Rate (EDR) data, which has been received from UCAR in a rigorously quality-checked format and will be processed to help with testing and validation. Validation with EDR data, which is produced at one-minute intervals along commercial airline tracks, required a new conceptualization of the accuracy statistic and an accompanying change to the product requirements. In the new framework, the accuracy is measured as the probability of predicting at least one 1-minute episode of Moderate-or-Greater turbulence over an integrated 16-minute period. This 16-minute period corresponds to a full transect of an aircraft through a tropopause fold.

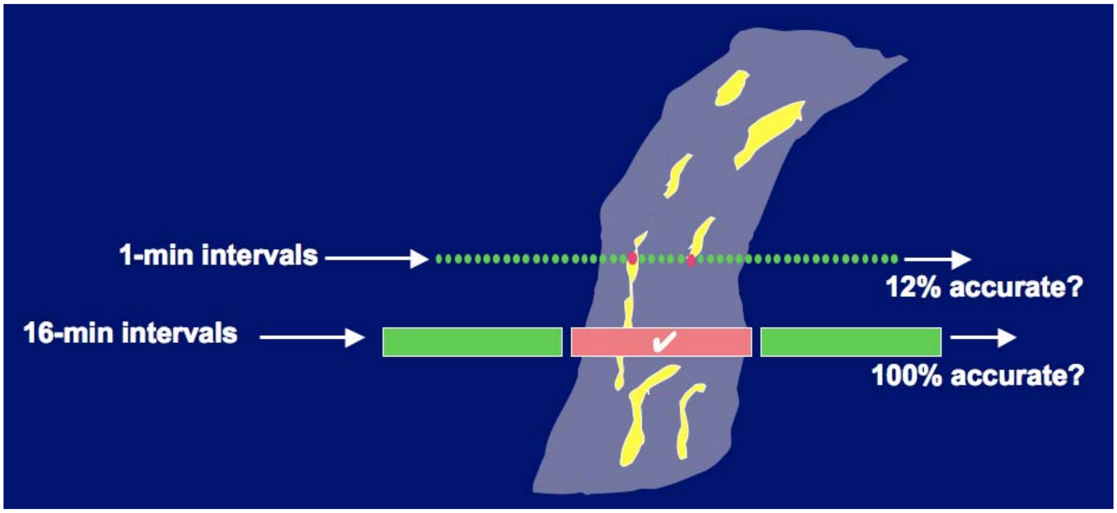


Figure 6.10.4.1. Conceptual diagram of two aircraft passes through a tropopause fold, scaled to the average width of a tropopause fold (shown in gray) and the typical speed of a commercial jet passing through. Areas of short-lived atmospheric instability are shown in yellow. Green segments are "no turbulence" reports and red segments are turbulent reports. The top pass supposes a one-minute interval between observations, and the bottom pass supposes a 16-minute interval between observations.

The TFTP algorithm has also been adapted for use in the UCAR Global Turbulence Guidance (GTG) system, which is being developed to combine model, satellite, and in-situ reports of flight hazards to create a three-dimensional global aviation warning service. By integrating into the GTG system, the TFTP product will complement warnings of other forms of turbulence (convection, shear, mountain waves, etc.) and receive feedback on its contribution from the GTG neural network self-assessments. This will benefit the TFTP product for GOES-R by helping to refine the practices for how it is best used operationally in conjunction with other turbulence products.

Publications and Conference Reports

GOES-R Tropopause Fold Turbulence Detection Algorithm Theoretical Basis Document (ATBD), First Draft submitted August 2008.

Wimmers, Anthony and Wayne Feltz, 2009: Nowcasting aircraft turbulence from tropopause folds operationally for GOES-R. Poster presented at the 16th Conference on Satellite Meteorology and Oceanography, Fifth Annual Symposium on Future Operational Environmental Satellite Systems-NPOESS and GOES-R, American Meteorological Society Annual Conference, Phoenix, 2009.

GOES-R AWG Aviation Team Critical Design Review: Turbulence, Presented by Walter Wolf, Anthony Wimmers, Wayne Feltz, and Shanna Sampson, March 2, 2009.

6.10.5 Overshooting Top and Enhanced-V Detection

CIMSS Project Lead: Wayne Feltz
CIMSS Support Scientists: Kristopher Bedka, Jason Brunner, Rich Dworak, Lee Cronce
NOAA Collaborators:
NOAA Strategic Goals addressed:

- Serve society's needs for weather and water information

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

Proposed Work

This work represents the second 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) 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. A five-year OT climatology shows that OTs occur frequently across the continental U.S. and there are clear diurnal differences in OT activity. Also, 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, lightning is more often observed near OTs and that the minimum IRW brightness temperature (BT) within an OT can be used as an indicator of cloud-to-ground lightning activity.

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. 2009). Such a technique would have some advantages over 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 6.10.5.1), 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 produced severe weather for greater than 90% of all events during summers 2003 and 2004. UW-CIMSS and Kristopher Bedka (SSAI/NASA LaRC) have developed a pattern recognition technique with IRW imagery to objectively detect anvil thermal couplets associated with the enhanced-V signature.

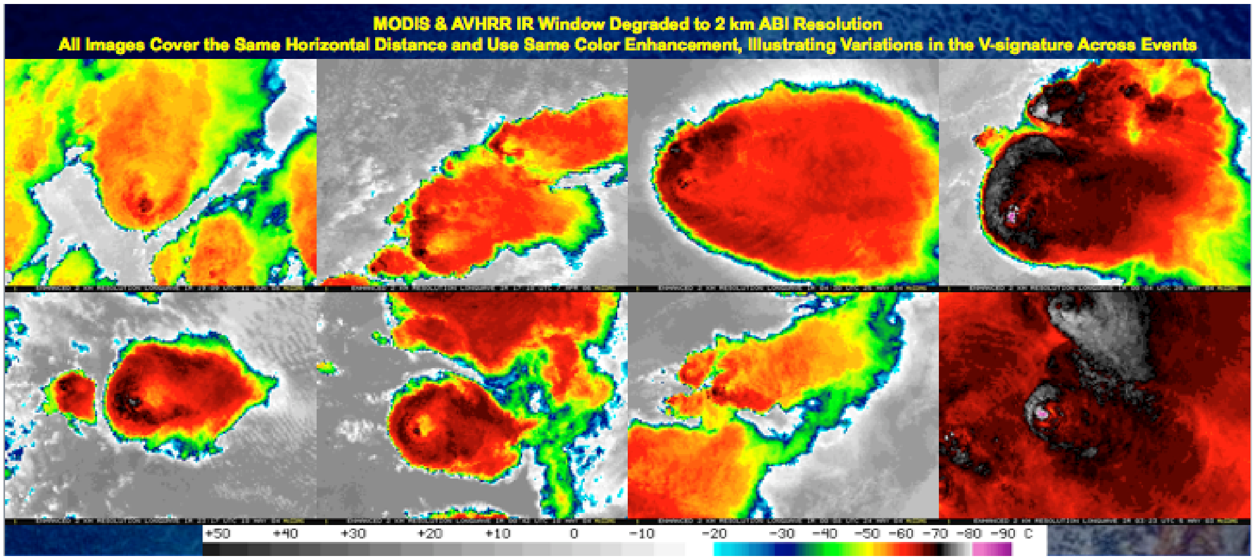


Figure 6.10.5.1. An example of 8 cold (or enhanced)-U/V producing storms in MODIS and AVHRR ~11 µm brightness temperature imagery across the continental U.S. The color enhancement and horizontal distance shown in each panel is identical, illustrating the variability of the enhanced-V signature.

Summary of Accomplishments and Findings

The Algorithm Design Review and Critical Design Review for the enhanced-V and OT product were successfully completed on December 12, 2008 and September 16, 2009, respectively. In addition, the Version 1 enhanced-V and OT product were delivered to the Algorithm Implementation Team in September 2009.

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 6.10.5.2 provides a rare view of an OT producing storm over Mali 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 (HRV) 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 satellite profiles. Figure 6.10.5.3 shows that these satellites passed directly over an OT over the Atlantic Ocean off of the coast 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 again performs well in detecting the ~8 km wide 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. This example, coupled with those shown by Bedka et al. (2009), 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. Please see Bedka et al. (2009) or contact kristopher.m.bedka@nasa.gov for a full description of the IRW-texture algorithm and validation in addition to OT relationships with turbulence and cloud-to-ground lightning.

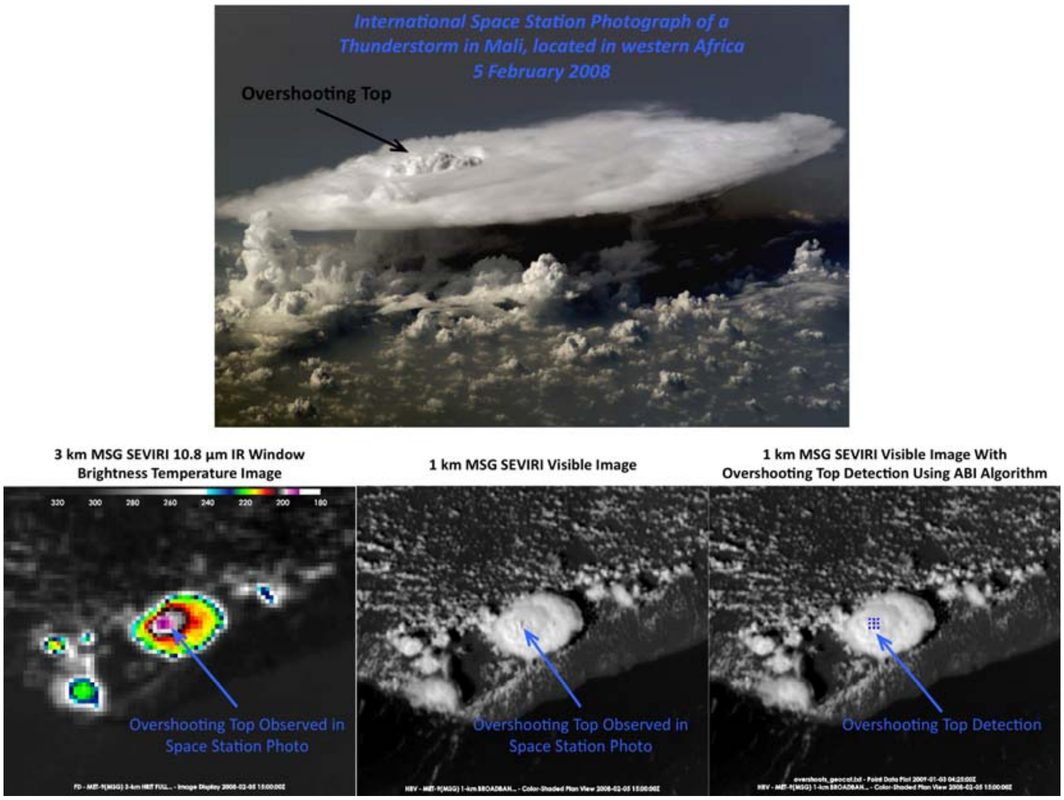


Figure 6.10.5.2. (top) A photograph of an overshooting top producing storm over Mali (western Africa) on 5 February 2008. (bottom panels) (left) 3 km MSG SEVIRI 10.8 µm brightness temperature imagery, 1 km SEVIRI high-resolution visible with (right) and without (center) IRW-texture overshooting top detections.

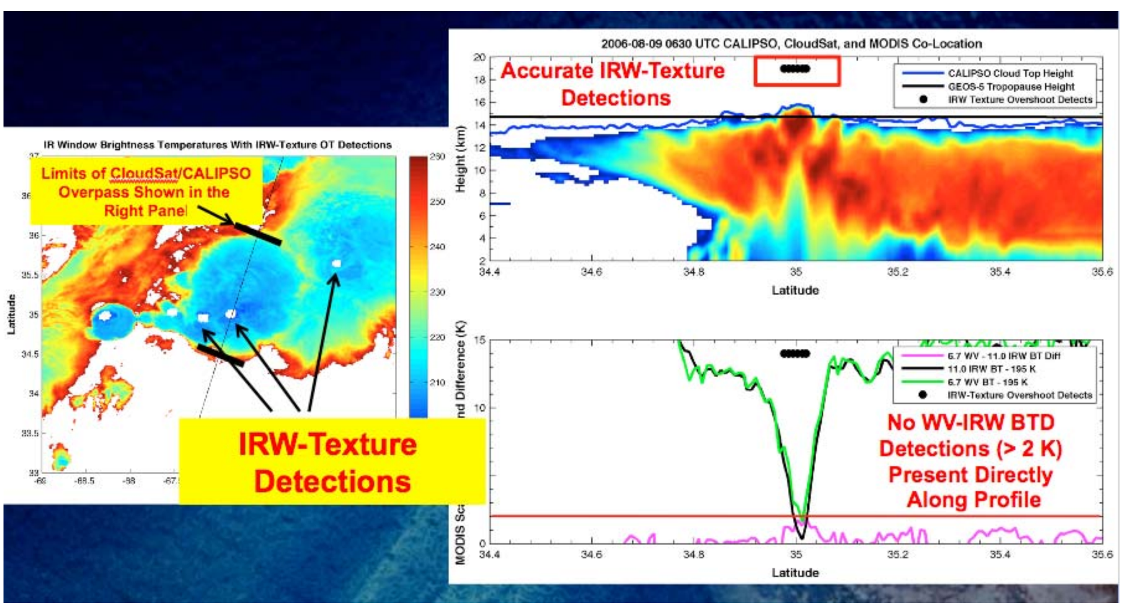


Figure 6.10.5.3. (left) Aqua MODIS 1 km 10.7 µm brightness temperature imagery with IRW-texture OT detections (white dots). (right) IRW-texture OT detections co-located with MODIS brightness temperatures, CloudSat radar reflectivity, CALIPSO cloud top height, and the NASA GEOS-5 model tropopause height analysis.

An example of objective enhanced-V/anvil thermal couplet detection is provided in Figure 6.10.5.4. MODIS 1 km IRW imagery from this 7 April 2006 event shows 5 enhanced-V producing storms. OTs and anvil thermal couplets were detected for 4 of the 5 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 56% and the false alarm rate was 25%. 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. 79% of the storms detected by the algorithm were severe and 64% of the undetected storms were severe, indicating that this algorithm is detecting a larger fraction of the severe storms in our database.

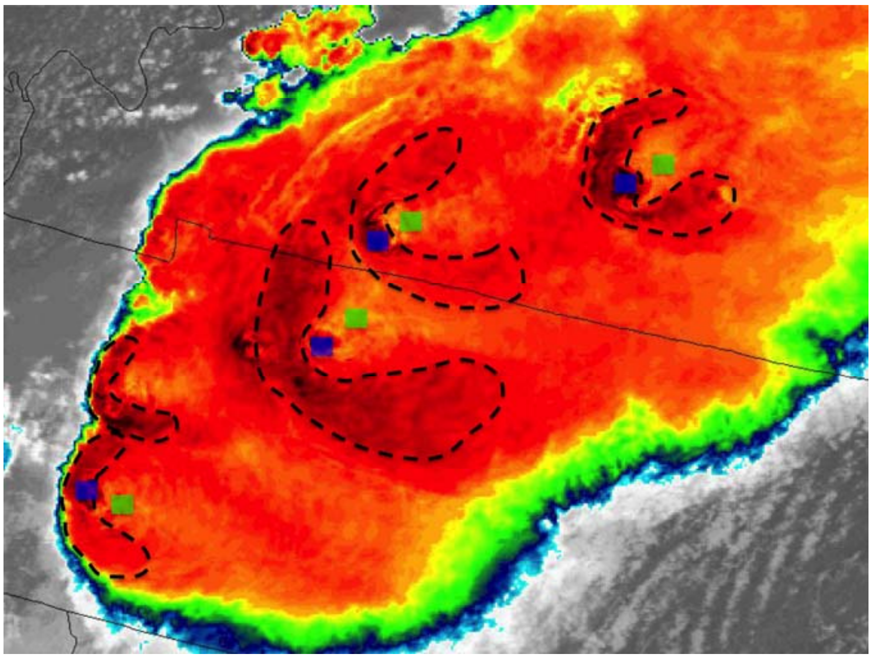


Figure 6.10.5.4. Aqua MODIS 1 km 10.7 μm brightness temperature imagery of a set of enhanced-V producing storms that occurred on 7 April 2006 at 1845 UTC. Five enhanced-V signatures are outlined with a black dashed line. Overshooting top detections are shown with blue squares and anvil thermal couplet 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, 2009: Objective Satellite-Based Overshooting Top Detection Using Infrared Window Channel Brightness Temperature Gradients. Accepted for publication in *J. Appl. Meteor. and Climatol.* (August 2009).

Bedka, K., W. Feltz, J. Sieglaff, R. Rabin, M. Pavolonis, and J. Brunner, 2009: Toward an End-to-End Satellite-Based Convection Nowcasting System. The 89th AMS Annual Meeting/16th Conference on Satellite Meteorology and Oceanography, Phoenix, AZ, January 2009, Amer. Meteor. Soc., J15.2.

Bedka, K., J. Brunner, J. Sieglaff, L. Cronce, W. Feltz, and R. Dworak, 2009: Convection Diagnostic and Nowcasting Activities at UW-CIMSS. World Meteorological Organization, Symposium on Nowcasting and Very Short Term Forecasting, Whistler, British Columbia, September 2009.

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.

6.10.6 Visibility

CIMSS Project Lead: Wayne Feltz
CIMSS Support Scientist: Allen Lenzen
NOAA Collaborator: Brad Pierce
NOAA Strategic Goals Addressed:

- 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). The satellite (MODIS) based boundary layer extinction (AOD/PBL depth) will be regressed against coincident extinction measurements from the Automated Surface Observing System (ASOS). Continental US MODIS 550 nanometer AOD measurements (10kmx10km) and GFS boundary layer depth analyses (0.5^ox0.5^o) will be used as input into the regression analysis. Verification of the GFS boundary layer depth analyses will be done using Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) global positioning system (GPS) radio-occultation (RO) measurements.

Planned activities during FY09 focused on development of statistical regression between MODIS COT/AOD and ASOS extinction measurements for use in the ABI visibility algorithm. This involved:

- Collection of multi-year ASOS high resolution visibility information, MODIS AOD, and GFS boundary layer (BL) height analyses over continental US.
- Co-location of ASOS visibility, MODIS COT/AOD, and BL height data for statistical analysis.
- Regression analysis at ASOS sites to establish statistical relationship between ASOS measurements and (MODIS AOD and COT)/(BL Height).

Summary of Accomplishments and Findings

A test version of the ABI visibility algorithm has been developed within the CIMSS GEOCAT framework. The test algorithm uses ABI AOD retrievals provided by Shobha Kondragunta (NOAA/NESDIS/STAR) using MODIS L1 radiances as ABI proxy data and experimental ABI COT retrievals provided by Andrew Heidinger (NOAA/NESDIS/STAR) using GOES-12 L1 radiances as ABI proxy data. GFS PBL heights have been incorporated into the GEOCAT meteorological data sets and the algorithm has been tested within the GEOCAT framework. Figure 6.10.6.1 shows ABI visibility retrievals for May 01, 2008.

Studies were conducted to assess the visibility product measurement accuracy using the GFS PBL during July 2008. Results are summarized in Figure 6.10.6.2 which shows histograms of the ASOS and MODIS/(GFS PBL) categorical visibility statistics for coincident ASOS measurements. The MODIS/(GFS PBL) based visibility estimates tend to underestimate the frequency of clear (visibility>30km) cases and overestimate the frequency of low (2km<visibility<10km) and poor (visibility<2km) cases resulting in an absolute accuracy (% of time with categorical error = 0.0) of less than 56%. However, if the ABI precision requirement for visibility (1.5 categories) is accounted for then the accuracy (% of time with categorical error < precision) is greater than 80% (required accuracy). The mean classification error is less then 0.5 classes and the precision estimate (standard deviation of categorical errors) is 0.77 which is significantly less then the required precision of 1.5 categories.

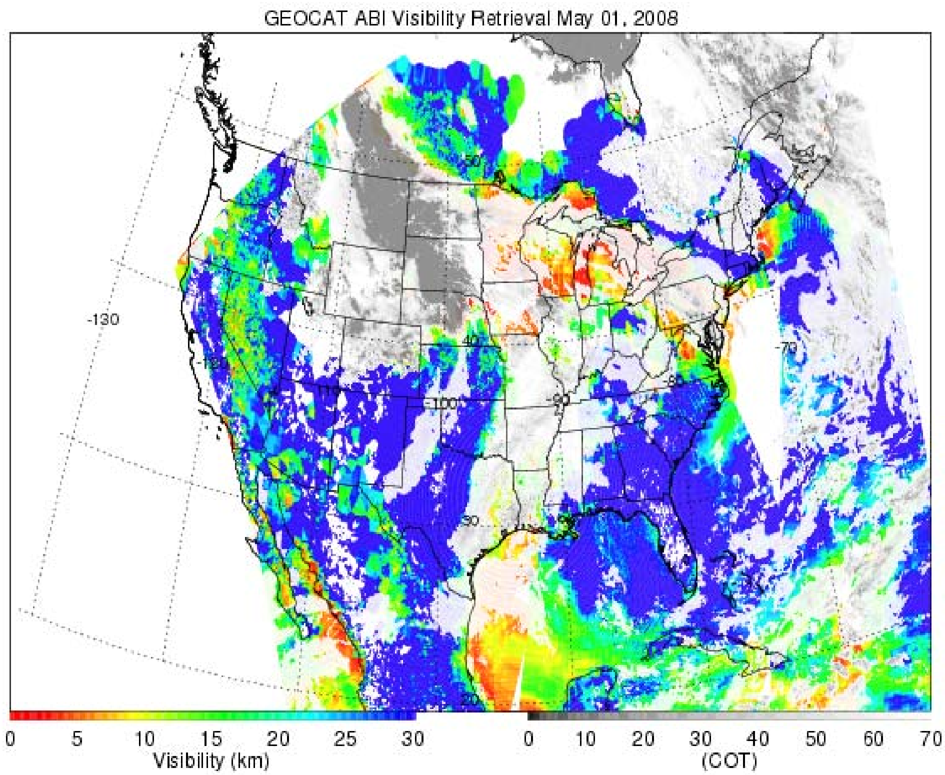


Figure 6.10.6.1. ABI GEOCAT visibility retrievals for May 01, 2008.

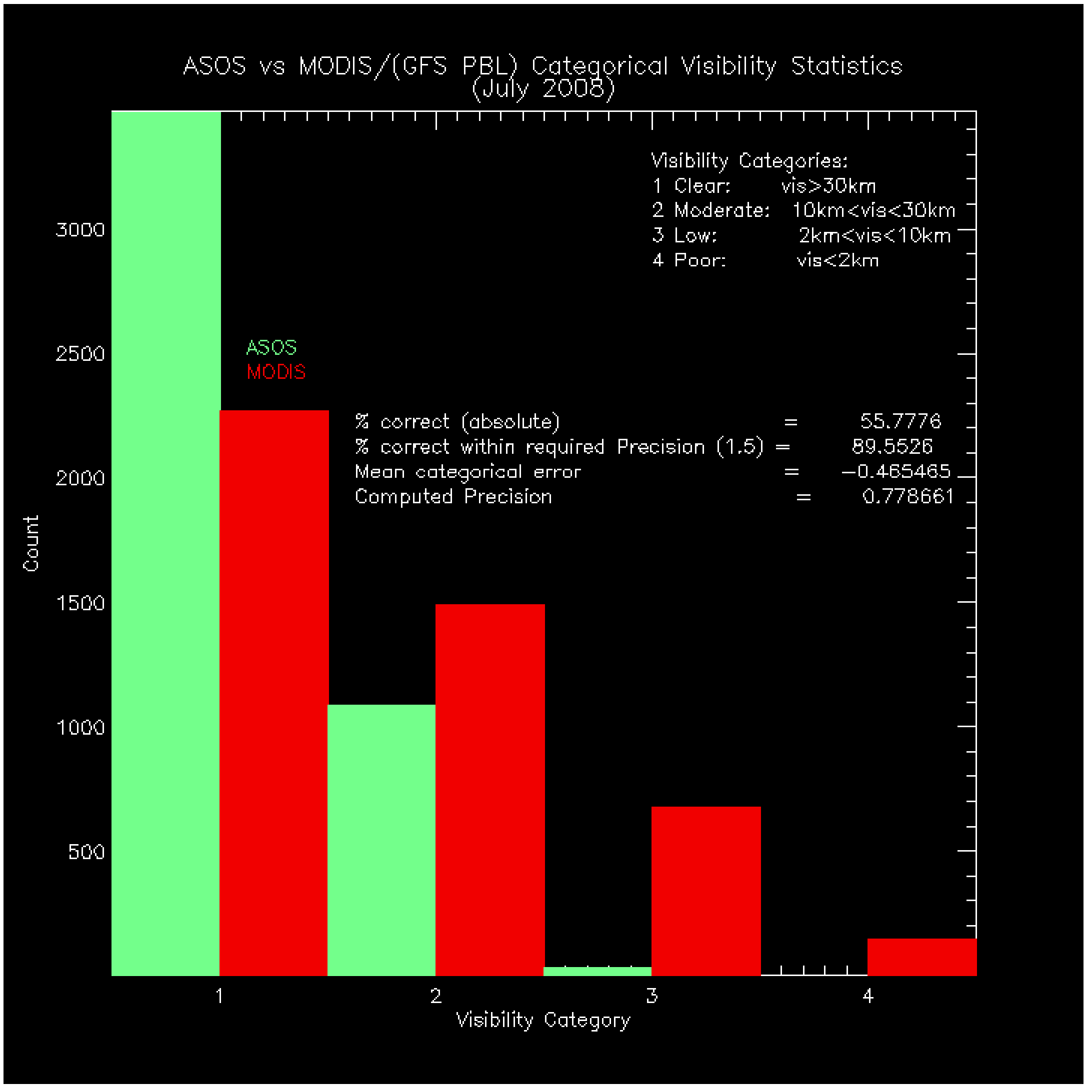


Figure 6.10.6.2. Histograms of the ASOS (green) and MODIS/(GFS PBL) (red) categorical visibility statistics for coincident ASOS measurements during July 2008.

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

CIMSS Project Leads: Xuanji Wang, Yinghui Liu
CIMSS Support Scientists:
NOAA collaborator: Jeffrey R. Key
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.

CIMSS Research Themes:

- Weather nowcasting and forecasting
- Environmental trends

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. Product comparison, validation, and maturity studies are also be done through comparing the products to data from numerical model simulations, submarine cruise sonar measurements, and surface-based measurements 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 2008 to 30 September 2009. The major accomplishment this year was the improvement, validation, and uncertainty assessment of the version 3 algorithms that generate the ice products. We have conducted the Cryosphere Team Critical Design Review (CDR) with the GOES-R AWG AIT in January 2009. In addition, we delivered our Fortran 95 version 3 algorithm code to the AIT for testing on September 3, 2009. AVHRR, MODIS, and SEVIRI data were used as proxy data for the purpose of the algorithm testing, submarine and meteorological station measurements were used for the comparison and validation, maturity study was 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. The updated algorithm combines two existing ice concentration/extent retrieval algorithms and adapts for GOES-R ABI: (1) a group threshold technique from the Earth Observation System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS) snow and sea ice mapping algorithms based on the normalized difference snow index and visible reflectance observations; (2) tie point analysis from the National Polar-Orbiting Operational Environment Satellite System (NPOESS) Visible/Infrared Imager/Radiometer Suite (VIIRS) fresh water ice algorithm. An additional product, ice surface temperature, which is the first step to retrieve ice concentration particularly at night, was developed with the split-window technique developed by Key and Haefliger (1992). Version 3 of this algorithm has been coded in Fortran 95, and has been applied to and 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 AMSR-E sea ice concentration product shows good agreement. Figure 6.11.1b and 6.11.1e are an example of retrieved ice concentration and ice surface temperature for the Great Lakes with MODIS data, respectively.

Ice thickness and age

A One-dimensional Thermodynamic Ice Model (OTIM) has been implemented and further improved based on the theoretical basis of surface energy balance at thermo-equilibrium. Currently version 3 of the OTIM has been coded in IDL and Fortran 95, and implemented and tested by this team and the AIT with proxy data of AVHRR, MODIS, and SEVIRI. Figures 6.11.1d and 6.11.1f show the retrieved ice thickness and ice age for the Great Lakes area with MODIS data. The improved ice thickness/age algorithm has also been compared and validated with numerical model simulations from A Pan-Arctic Ice-Ocean Modeling and Assimilation System (PIOMAS), submarine upward looking sonar ice draft data from Scientific Ice Expeditions (SCICEX) in 1999, and Canadian station measurements from the Canadian Ice Service (CIS) with 11 new Arctic Program Stations starting in 2002. Error sources of the OTIM have been identified and the model uncertainties resulting from model input variables have been quantified. The results of the uncertainty study are shown graphically in Figures 6.11.2 for the reference ice thickness values of 0.3, 1.0, and 1.8 m with those expected uncertainties in the model controlling variables. As the uncertainty study revealed with current satellite product retrieval accuracy, the OTIM is not recommended for use with daytime satellite data. The OTIM is capable of resolving regional and seasonal variations in ice thickness, and is useful for weather and climatological analysis with nighttime data.

Ice motion

The heritage ice motion algorithm developed by Fowler et al. (2004) has been adopted, improved, and implemented at the direct broadcast site in Tromsø, Norway using MODIS data. This approach has been used by the National Snow and Ice Data Center with AVHRR passes routinely. A variety of time steps can be used to track the ice, though the best results are given when using images that are 24 hours apart. One disadvantage to using this technique is that motion is detected in only a small fraction of the area due to cloud cover. The algorithm has been adopted and applied over the Great Lakes with modified map projection. Version 3 of this algorithm has been coded in Fortran 95 and C languages, and has been applied to and tested with proxy data, MODIS data. Comparisons of this algorithm with the Medium Range Forecast Model (MRF) surface winds have yielded positive results, showing that the detected motion is similar to that of the surface wind (Figure 6.11.1c). Validation of the sea ice motion product with motion derived from ocean buoys shows good agreement.

Publications and Conference Reports

Wang, X., J. R. Key, and Y. Liu, 2009: A thermodynamic model for estimating sea and lake ice thickness with optical satellite data. *J. Geophys. Res.*, submitted, September 2009.

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.*, in press, October 2009.

Wang, X., J. R. Key, Y. Liu, 2009: Arctic sea ice and its change over the last two decades of the 20th century (Talk). AMS 10th Conference on Polar Meteorology and Oceanography, 18-21 May 2009, Madison, Wisconsin.

Wang, X., J. R. Key, Y. Liu, 2009: Sea and lake ice characteristics from GOES-R ABI. AMS 89th Annual Meeting/5th Symposium on Future National Operational Environmental Satellite systems NPOESS and GOES-R, January 11-15, 2009, Phoenix Conference Center, Phoenix, Arizona.

References

Fowler, C., W. J. Emery, and J. Maslanik, 2004: Satellite-derived evolution of Arctic sea ice age: October 1978 to March 2003. *IEEE Geoscience and Remote Sensing Letters,* **1**(2): 71-74, doi:10.1109/LGRS.2004.824741.

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

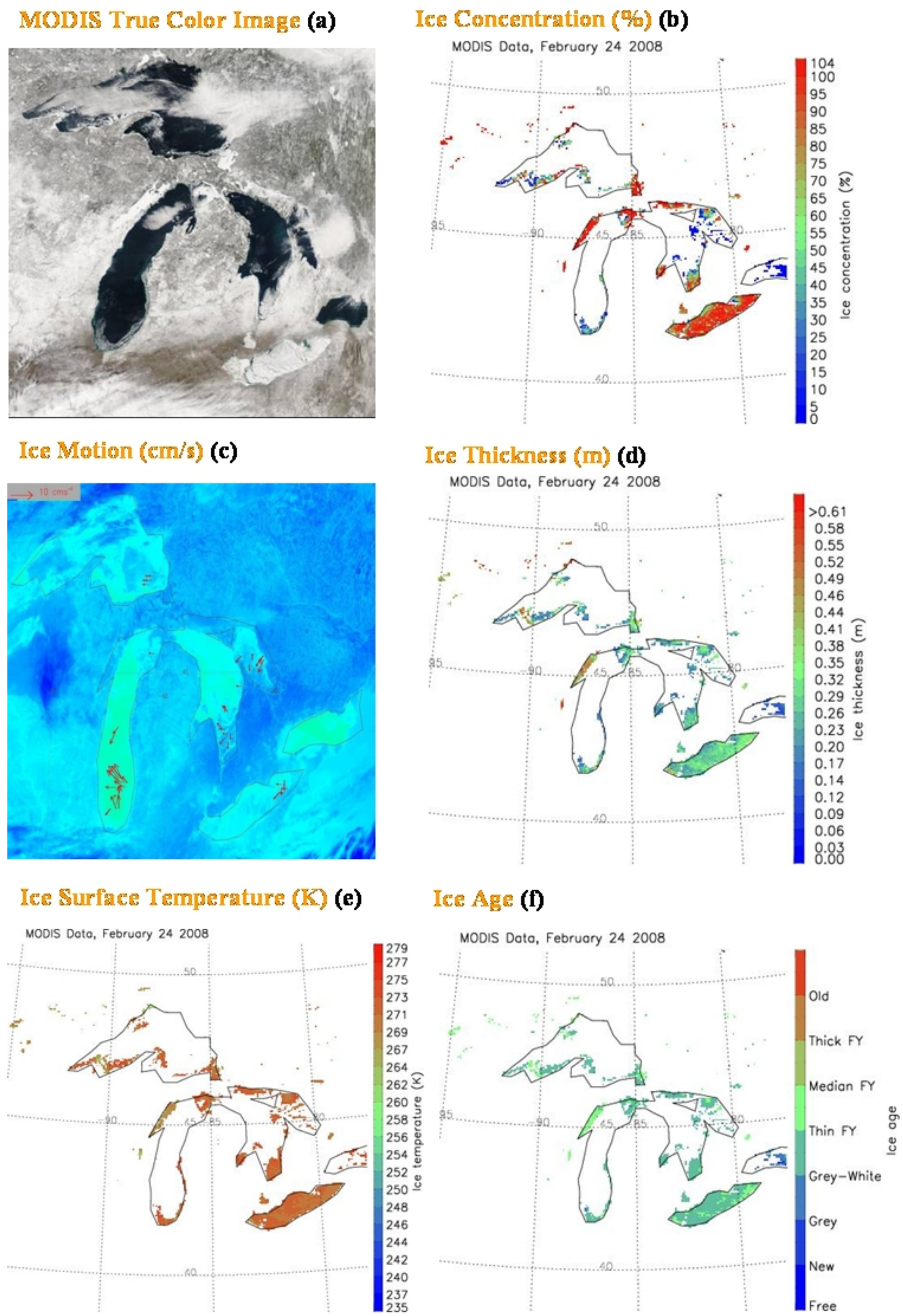
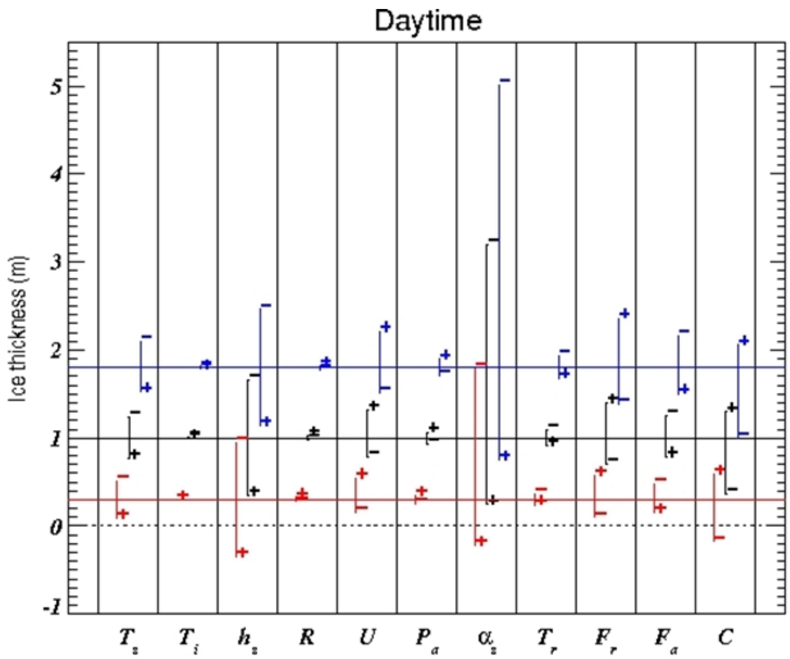


Figure 6.11.1. MODIS Aqua true color image (a) on February 24, 2008 over the Great Lakes, and derived ice concentration (b) in percentage, ice motion (c) in centimetre per second, ice thickness (d) in meter, ice surface temperature (e) in K, and ice age (f) for clear-sky condition only. Ice motion (c) is from February 27, 2003



Variable	Error
T_s (K)	±2.0
T_i (K)	±5.0
h_s (m)	±50%
R (%)	±10%
U (m/s)	±20%
P_a (hPa)	±50.0
α_s (0~1)	±0.10
T_r (0~1)	±0.05
F_r (w/m²)	±20%
F_a (w/m²)	±2.00
C (0~1)	±0.25

Figure 6.11.2. Uncertainty of ice thickness to expected uncertainties in the model controlling variables listed in the table on the right-hand side from satellite retrievals for daytime case with reference ice thickness of 0.3 (red), 1 (black), and 1.8 (blue) meters. Plus signs are the ice thickness values for positive uncertainties in the indicated variables; minus signs show the direction of changes in ice thickness for a decrease in the controlling variable value. The model 11 controlling variables are: surface ice/snow temperature (T_s), ice temperature (T_i), snow depth (h_s), surface air relative humidity (R), surface wind speed (U), surface air pressure (P_a), surface shortwave albedo (α_s), ice slab transmittance (T_r), surface downward shortwave radiative flux (F_r), cloud amount (C), surface residual heat flux (F_a).

6.12 Imagery and Visualization

CIMSS Project Leads: Tom Rink, Tom Achtor,
CIMSS Support Scientists: William Straka, Kaba Bah, Tim Olander, Tom Whittaker
NOAA Collaborators: Tim Schmidt, Gary Wade

Proposed Work

1. Develop interactive multi/hyper-spectral analysis and visualization capability for GOES-R.
2. Define a storage format for ABI calibrated/navigated measurements, adopting community standards and practices for storing data and meta-data wherever possible.
3. Work with GOES-R product framework team to ensure that product output meets the above standards.

Summary of Accomplishments

Much of the capability of the software application HYDRA, a CIMSS project, has been incorporated in the McIDAS-V development environment. Remote sensing scientists work can use basic analysis tools (Figure 6.12.1) with large multi/hyper-spectral datasets .

The use of NetCDF as a storage format for GOES-R was mandated by the Program Office. To support this requirement NetCDF files which follow community conventions for internal structure and metadata

(CF-compliant) have been created for various scene simulations for the ABI instrument (Figure 6.12.2). We also created a CF 1.4 compliant NetCDF files for AIRS derived products. These files can be imported immediately, i.e., without any code development, because McIDAS-V is aware of the structure and semantics of the CF conventions. Work is presently underway to determine the geo-location specification for ABI, known as the Fixed Grid Format (FGF), and how it will be described in terms of current metadata standards.

Very productive iterations occurred between the GOES-R Product Generation Framework and CIMSS regarding the definition of NetCDF files for AWG products. Many AWG framework products can be imported directly into McIDAS-V. We worked with AWG algorithm teams to implement individual team needs for ancillary data and analysis techniques for evaluation and validation. 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 6.12.3).

Other milestones included:

- Participated in Imagery and Visualization CDR
- Supported the AWG Imagery TRR
- Participated in the GOES-R AWG Annual Review in College Park, MD

Training

- Developed training data sets and materials for GOES-R ABI
- Conducted workshops and training sessions on McIDAS-V focusing on satellite data analysis and visualization, including use of ABI data sets.

Conference Reports

AGU, December 2008
AMS, January 2009
SPIE, August 2009
EUMETSAT, September 2009

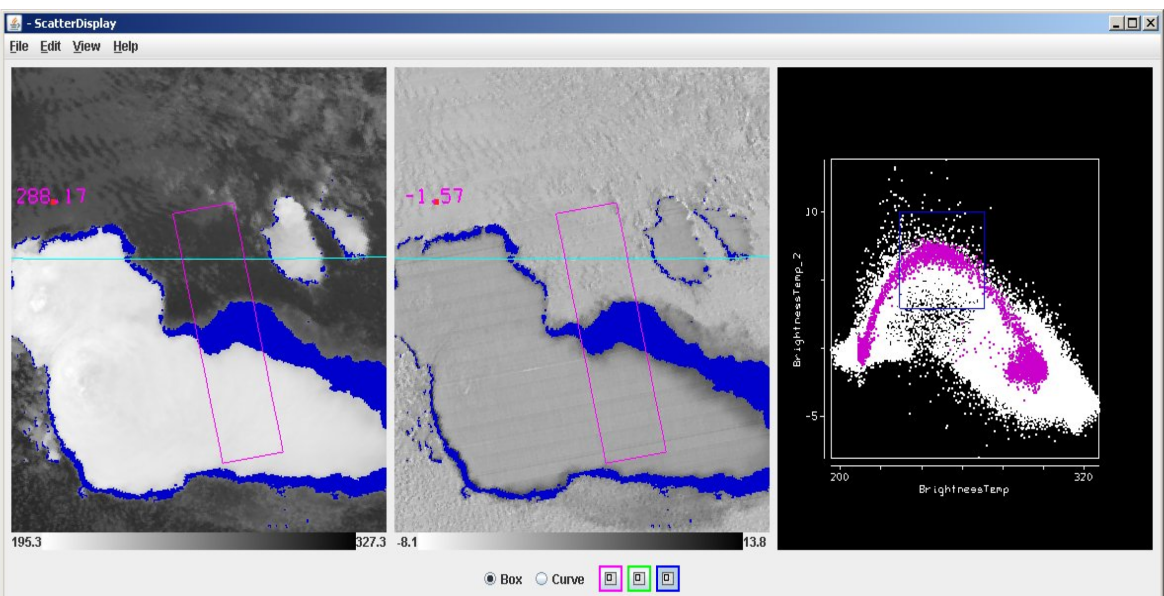


Figure 6.12.1. Example of scatter analysis tool with MODIS.

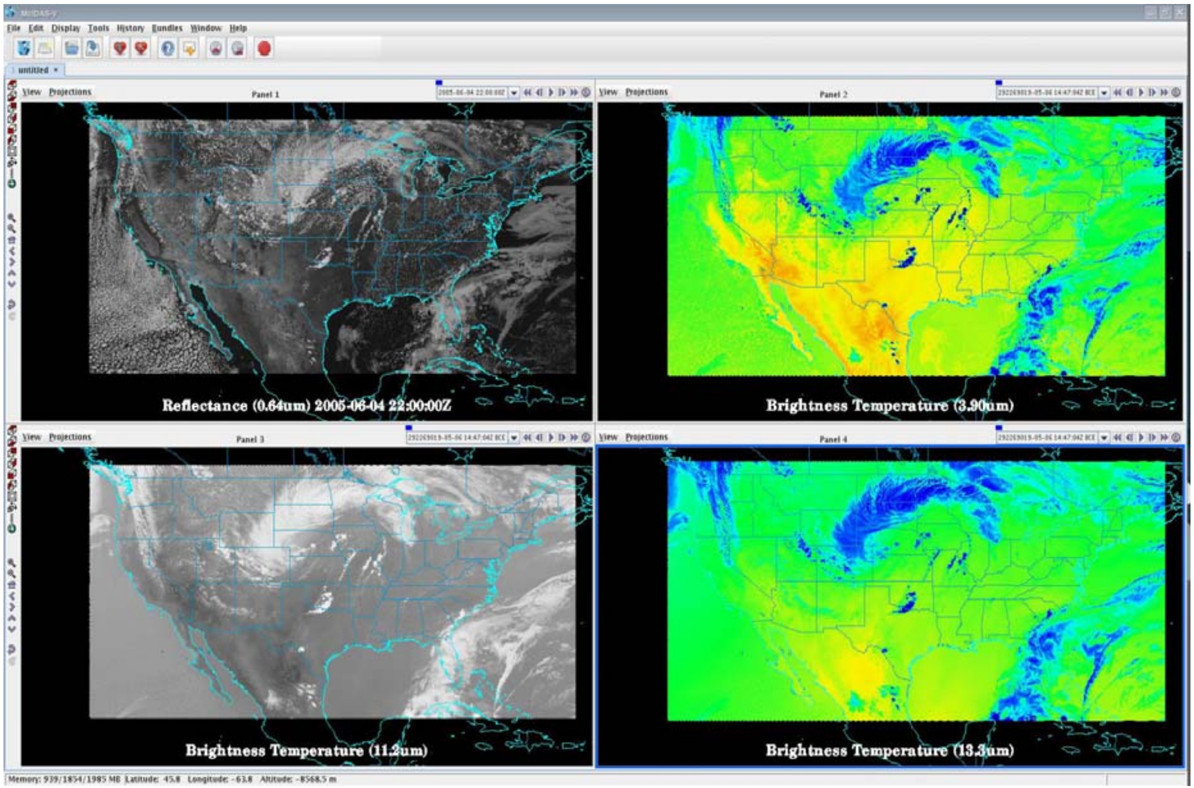


Figure 6.12.2. Simulated ABI bands displayed in McIDAS-V.

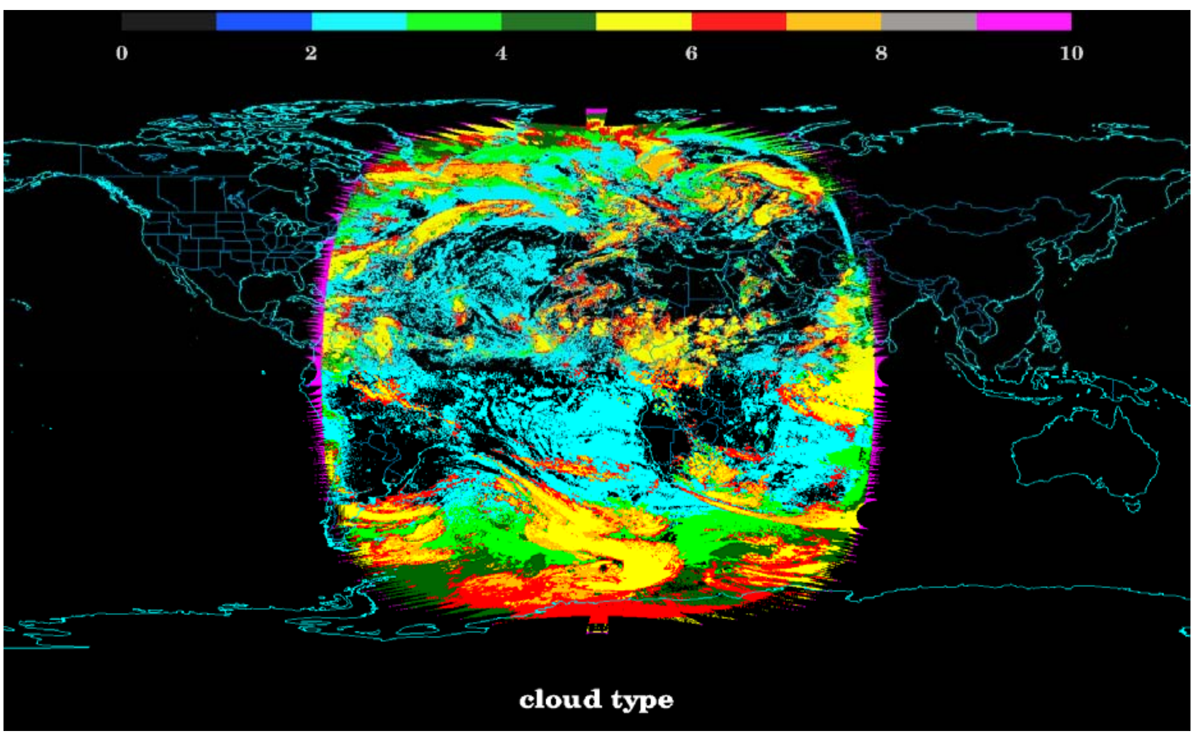


Figure 6.12.3. CIMSS AWG cloud type derived from MET-8 SEVIRI imported and display in McIDAS-V.

6.13. GOES-R Aerosol and Ozone Proxy Data Simulation

CIMSS Project Lead: Todd Schaack
NOAA Collaborator: Brad Pierce
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information

CIMSS Research Themes:

- Clouds, aerosols and radiation

Proposed Work

The main focus of this project is to augment the current GOES-R AWG WRF Advanced Baseline Imager (ABI) proxy data capabilities with proxy data sets for aerosols and ozone over the continental US and Africa. The aerosol and ozone proxy data sets are generated with WRF-CHEM air quality simulations [Grell et al. 2005] coupled to global chemical and aerosol analyses from the Real-time Air Quality Modeling System (RAQMS) [Pierce et al. 2007]. Chemical data assimilation is used to provide observational constraints on the global chemical and aerosol analyses. Output from the coupled RAQMS/WRF-CHEM ozone and aerosol simulations are used to construct simulated radiances using the NOAA Community Radiative Transfer Model (CRTM) [Han et al. 2006]. The addition of aerosol and ozone distributions into the WRF proxy data set will allow generation of synthetic radiances for all ABI bands. This will facilitate the development of algorithms supporting retrievals of aerosol properties (optical depth, aerosol type, effective radius, fine vs. coarse mode fraction), total column ozone, and detection of dust, smoke and SO_2. This work will be conducted in close collaboration with the existing GOES-R WRF proxy data simulation team at CIMSS (Lead, Allen Huang, CIMSS) and with the ABI aerosol retrieval and GOES-R aerosol assimilation activities under the GOES-R Air Quality and Aerosols AWG (Lead, Shobha Kondragunta, NOAA/NESDIS).

FY09 activities focus on validation of the August 24-25, 2006 simulated high resolution (4km) ABI radiances over the continental US and 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 validation. MODIS AOD retrievals will be assimilated within 36km WRF-CHEM simulations to provide improved initial conditions for the high resolution African simulations.

Summary of Accomplishments and Findings

'Beta' versions of the August 24-25, 2006 WRF-CHEM GOES Re-Broadcast (GRB) proxy data sets have been completed and delivered to the imagery team and AIT. The GRB files contain visible reflectances, IR radiances, and IR brightness temperatures in scaled integers (Figure 6.13.1).

Validation of the proxy ABI radiances (using MODIS viewing geometry) has been completed using comparisons with selected MODIS IR and visible radiances. As expected due to the increased complexity and relatively early nature of forward modeling of visible channels, agreement between the MODIS and Proxy IR channels (~3.9 to ~ 13.3 microns) is better than for visible channels (~0.47 to ~2.26 microns). The largest differences between observed and proxy radiances arise from timing and location of deep convective clouds, which result in high visible radiances (due to high reflectivity) and errors in surface emissivity and reflectivity (Figure 6.13.2).

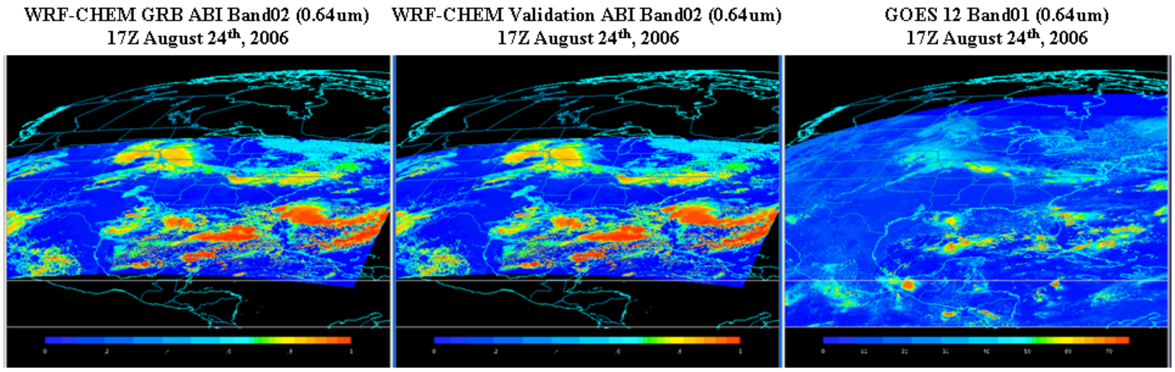


Figure 6.13.1. McIDAS-V visualization of WRF-CHEM GRB scaled integer (left), validation (center), and GOES 12 (right) 0.64 micron reflectance at 17Z on August 24^{th}, 2006.

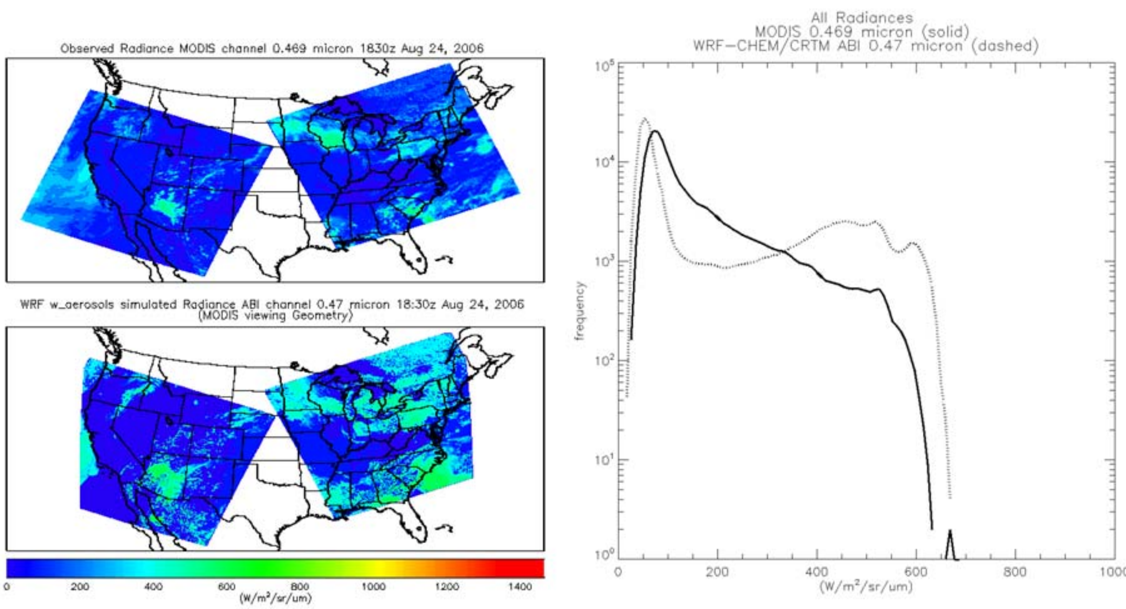


Figure 6.13.2. Comparison of the 0.469 micron band MODIS Terra and Aqua L1 radiances (upper left panel) and 0.47 micron band ABI proxy radiances (lower left panel) and histograms (right panel, MODIS solid, CRTM dash) using MODIS Terra and Aqua viewing geometry for 18:30Z on August 24th, 2006 ($W/m^2/sr/um$)

The 36km WRF-CHEM SEVIRI domain simulation (without aerosol assimilation) has been completed and the Aerosol Optical Depth (AOD) has been compared to MODIS (Figure 6.13.3). Saharan dust loading appears to be well represented while biomass burning aerosols are underestimated over S. Africa, most likely due to clouds limiting the MSG WF-ABBA fire detection.

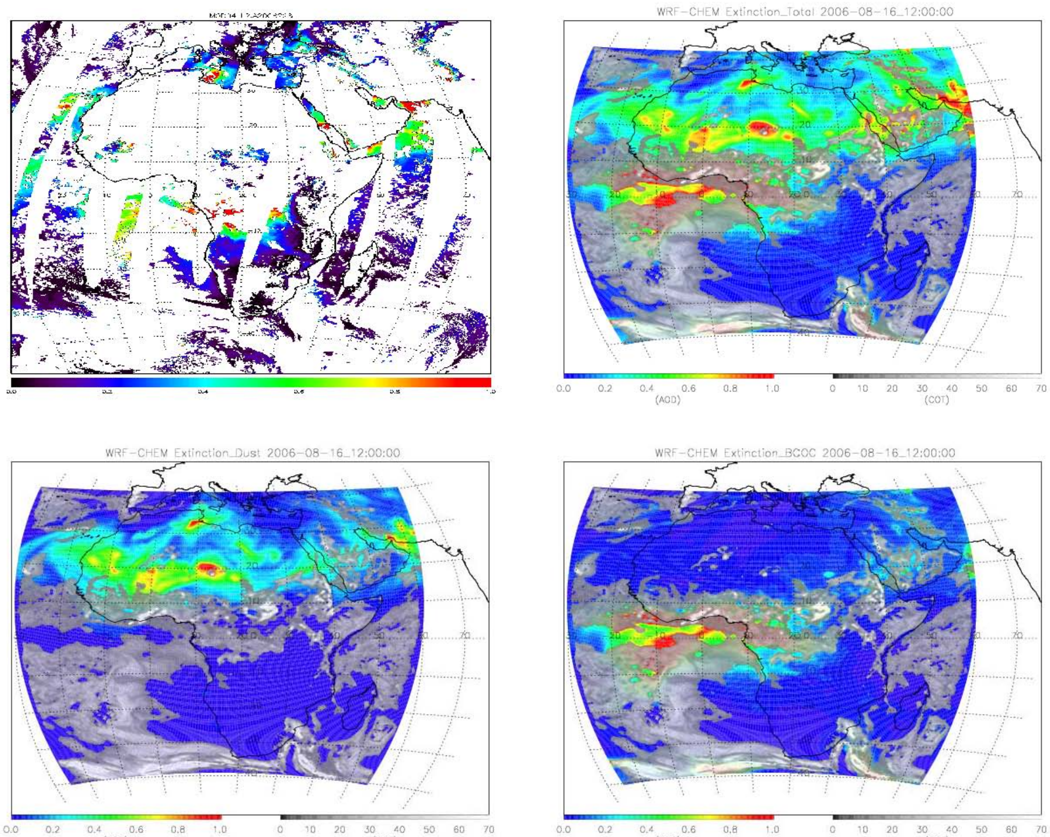


Figure 6.13.3. Comparison between MODIS Aerosol Optical Depth (AOD, upper left) and Total (upper right), Dust (lower left), and Black Carbon/Organic Carbon (BCOC, lower right) from 36km WRF-CHEM Proxy simulation for August 16th, 2006.

Publications and Conference Reports

Schaack, T, R B. Pierce, A. Lenzen, G. Grell, S. Peckham, and J. Otkin, 2009: High Resolution Coupled RAQMS/WRF-Chem Ozone and Aerosol Simulations for GOES-R Research. 10th Annual WRF Users' Workshop, 23-26 June, 2009, Boulder, CO, http://www.mmm.ucar.edu/wrf/users/workshops/WS2009/abstracts/5A-04.pdf

References

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.

6.14. AWG Critical Path GOES-R Cal/Val

CIMSS Project Lead(s): Dave Tobin
CIMSS Support Scientist(s): Mat Gunshor
NOAA Collaborator(s): Tim Schmit, Chanyong Cao, Robert Iacovazzi, X. Wu.
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water
- Understand climate variability and change to enhance society's ability to plan and respond
- Protect, restore and manage the use of coastal and ocean resources through an ecosystem approach to management
- Support the nation's commerce with information for safe, efficient and environmentally sound transportation
- Provide critical support for the NOAA mission

CIMSS Research Themes

- Weather nowcasting and forecasting
- Clouds, aerosols and radiation
- Global hydrological cycle
- Environmental trends
- Climate
- Education, training and outreach

Proposed Work

Project description and potential contribution to GOES-R Program

The proposed work includes participation in the GOES-R Calibration/Validation activities, with primary emphasis on providing input for and review of the GOES-R Calibration/Validation plan. Properly calibrated and characterized sensor radiance and reflectance observations are the basis for all GOES-R products, and therefore a well planned and executed calibration plan is important for many aspects of the program.

Background and Previous Work

CIMSS/SSEC has a long history in satellite design, calibration, inter-satellite calibration, and post-launch satellite validation for both polar and geostationary programs. We have been involved in the calibration and check-out of the GOES sensors since the program's beginning. We are also currently involved in the detailed analysis of the calibration accuracy and performance of the NPOESS Preparatory Project Cross-track Infrared Sounder (CrIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) sensors and in the development of the Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission. These missions are anticipated to provide important observations for on-orbit calibration/characterization of the ABI on GOES-R. More importantly, these sensors are being developed and characterized in a new era of emphasis on calibration accuracy and calibration traceability, and our intimate involvement in these activities provide us with experience and perspective for evaluating and contributing to the GOES-R calibration activities.

Proposed Activities for 2009

We proposed two primary activities for 2009. The first activity is to participate in the review and development of the GOES-R Calibration/Validation plan, with an emphasis on pre-launch sensor testing, calibration algorithms, and post-launch characterization of the infrared radiance observations of the ABI. Our efforts will ensure that the expertise and experiences represented by CIMSS/SSEC in infrared radiance calibration and validation are reflected in the plan. The second smaller activity is the demonstration of some of the key GOES-R calibration tasks using GOES-O Imager and Sounder observations during the NOAA GOES-O science check-out (with GOES-O launch expected in April 2009).

Summary of Accomplishments and Findings
We have obtained version 1.1 of the GOES-R Cal/Val plan and have begun reviewing it, with an initial focus on the radiance observation cal/val activities.

7. High impact weather studies with advanced sounding products
CIMSS Project Lead: Jun Li
CIMSS Support Scientist(s): Jinlong Li, Chian-Yi Liu, Jason Otkin, and Elisabeth Weisz
NOAA Collaborator(s): Tim Schmit
NOAA Strategic Goals Addressed:

- 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

Proposed Work
This proposal is for the University of Wisconsin-Madison to produce a simulated dataset and to conduct high impact weather studies for future GOES satellites using advanced sounding products. Severe weather forecasting requires 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 forecasts and "nearcasts." The unique value of these geostationary high spatial and high spectral resolution observations in high impact weather (convective and tornadic storms, tropical cyclones, etc.) need to be studied and demonstrated using both simulated geostationary advanced IR radiances and full spatial resolution hyperspectral IR sounding data from polar-orbiting satellites.

Summary of Accomplishments and Findings
(1) Simulation has been conducted to demonstrate the unique applications of geostationary advanced infrared (IR) sounder on storm nowcasting. A geostationary advanced infrared (IR) sounder would provide highly accurate breakthrough measurements on the time evolution of horizontal and vertical water vapor and temperature structures. These measurements would be an unprecedented source of information on the dynamic and thermodynamic atmospheric fields, and an important benefit to nowcasting and numerical weather prediction (NWP) services. The International H2O Project (IHOP 2002) storm case has been used to demonstrate the important applications of future geostationary advanced IR sounder for severe storm nowcasting. The geostationary advanced IR sounder provides a critical atmospheric instability index (e.g., lifted index - LI) product before the storm development; during that stage the radar does not provide the needed warning information. The Weather and Research Forecasting (WRF) model has been used to simulate Hyperspectral Environmental Suite (HES)-like data, the Advanced Baseline Imager (ABI)-like data and the radar observations to demonstrate the unique value of high temporal advanced IR sounder for severe storm forecasts by depicting the unstable region before the storm development; it should be mentioned that radar provides also good precipitation information during the storm development. ABI or the current GOES Sounder only provide limited instability information before the storm development due to the limited spectral IR information for vertical atmospheric temperature and moisture profiling. The high spatial and high temporal GEO advanced IR sounder can provide needed instability and warning information hours earlier than the current GOES Sounder or ABI. Figure 7.1 shows the LI from the true field (upper left), HES-like observations (upper

right), ABI/GOES Sounder like observations (lower left), along with the simulated radar image (lower left) at 1300 UTC on 12 June 2002. HES-like provides warning information 4 hours before ABI-like (or GOES Sounder like) and 8 hours before the radar.

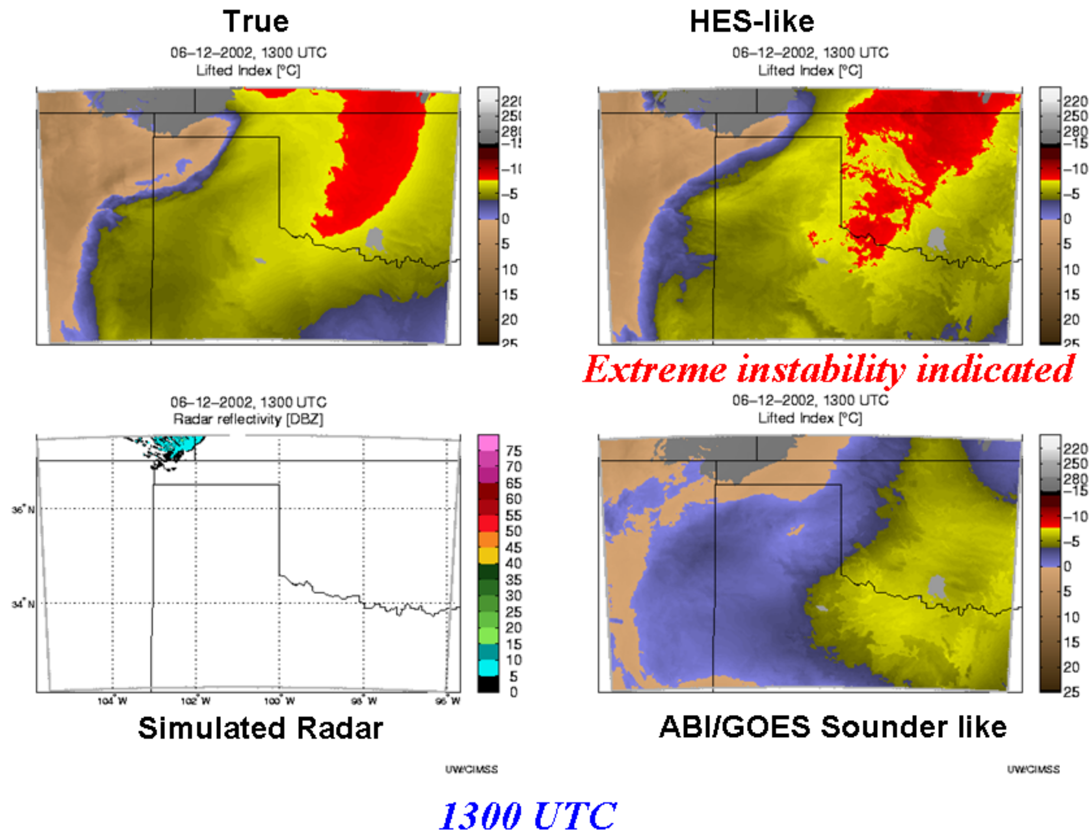


Figure 7.1. The LI from true field (upper left), HES-like observations (upper right), ABI/GOES Sounder like observations (lower left), along with the simulated radar image (lower left) at 1300 UTC on 12 June 2002.

(2) The high spatial resolution advanced sounding product has been studied in regional model for storm forecast. Satellite-based hyperspectral (or advanced) IR sounding measurements are a principal source of water vapor and temperature data over the tropical oceans where conventional *in situ* observations are relatively sparse. Geostationary advanced IR sounder can provide more soundings in clear skies and water vapor tracked wind profiles through frequent observations. The high spectral resolution infrared sounders (AIRS, IASI, and CrIS) from polar-orbiting satellites provide unprecedented capability on global soundings with high vertical resolution and accuracy. They can be used to emulate the high spatial resolution sounding product for geostationary advanced sounder. The CIMSS hyperspectral IR sounding retrieval (CHISR) algorithm has been developed to extract soundings at full spatial resolution from advanced IR sounder radiance measurements, which are critical for improving regional numerical weather prediction and severe storm nowcasting. Hurricanes are one of the major natural hazards; we have applied the soundings retrieved from AIRS to hurricane track and intensity forecast studies. NCAR (National Center for Atmospheric Research) WRF/DART (Weather Research and Forecasting / Data Assimilation Research Testbed) ensemble assimilation is performed at 36 km resolution. Studies shows that the track error for Hurricane Ike (2008) and Typhoon Sinlaku (2008) is reduced significantly when AIRS data are used compared to the control run which includes other observations such as radiosondes, satellite cloud winds, aircraft data, ship, and land surface data, etc. The hurricane intensity forecast is also substantially

improved when AIRS data are assimilated (Li and Liu 2009). It is also found that the full spatial resolution advanced IR water vapor and temperature soundings significantly improve the forecast of the rapid intensification Typhoon Sinlaku (Liu and Li 2009). Figure 7.2 shows the 96 hour forecast for hurricane Ike (2008) using ensemble forecast and full spatial resolutions soundings (right panel), which significantly improve the hurricane path forecast.

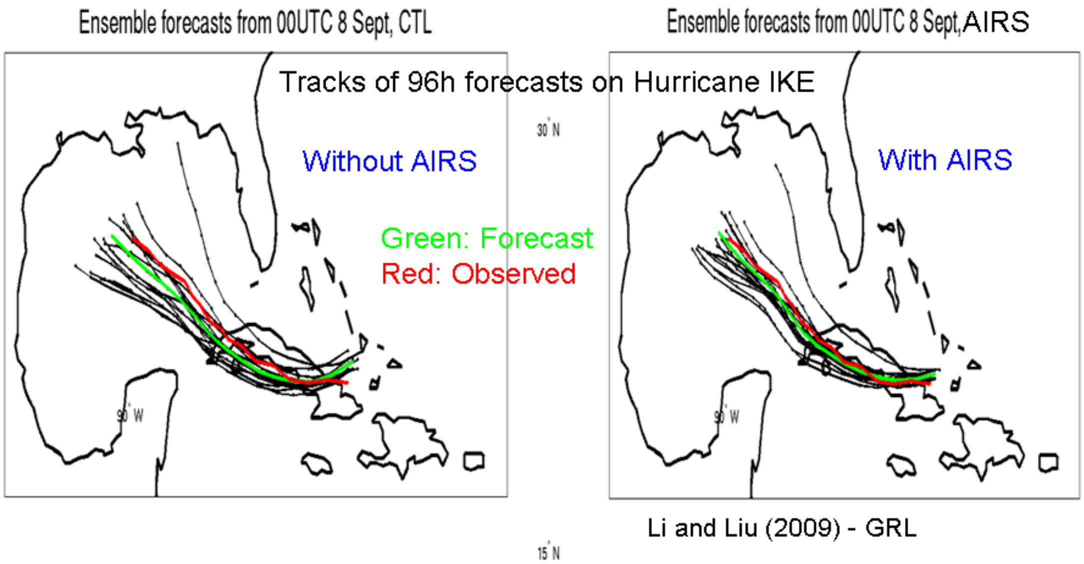


Figure 7.2. The 96 hour forecast for hurricane Ike (2008) using ensemble forecast.

(3) The upper tropospheric storm-scale signatures from advanced IR soundings have been studied. The advanced IR sounder provides atmospheric temperature profiles with good accuracy in the upper troposphere and lower stratosphere (UTLS). We employ both clear and cloudy skies sounding retrievals from AIRS radiance measurements to investigate the UTLS stability in associated with storm-scale weather phenomenon. The case study shows that the atmospheric thermodynamic stability (e.g., Lifted Index) may fail in certain circumstance, while a relative low UTLS stability in terms of the buoyancy frequency is found in the storm vicinity. It demonstrates the advantage of using the clear and cloudy hyperspectral IR sounding retrievals for supporting the short-term forecasting or nowcasting. With an advanced IR sounder in geostationary orbit, temporal evolution of UTLS stability can be very useful for nowcasting the rapid development of storms. More cases are being investigated.

(4) The detection of tropopause-penetrating clouds using advanced IR sounder have been studied. Clouds penetrating the tropopause are associated with deep convection and rapid storm development. Usually brightness temperature from a broad band imager is used to identify over-shooting clouds. With advanced IR sounder radiance measurements, the online/offline technique (Sieglaff et al. 2009, Aumann 2009) can be used to identify deep convective clouds more accurately. Figure 7.3 shows AIRS brightness temperature at a window channel (left) and the penetrating tropopause clouds detected with the online/offline technique (red) and only window IR brightness temperature technique (blue) (e.g., minimum BT), respectively. Hurricane Bill (2009) was used in this study. The high spectral resolution IR sounder is ideal for the online/offline technique; with high temporal information from a geostationary orbit, the advanced IR sounder provides good monitoring of the evolution of clouds penetrating the tropopause.

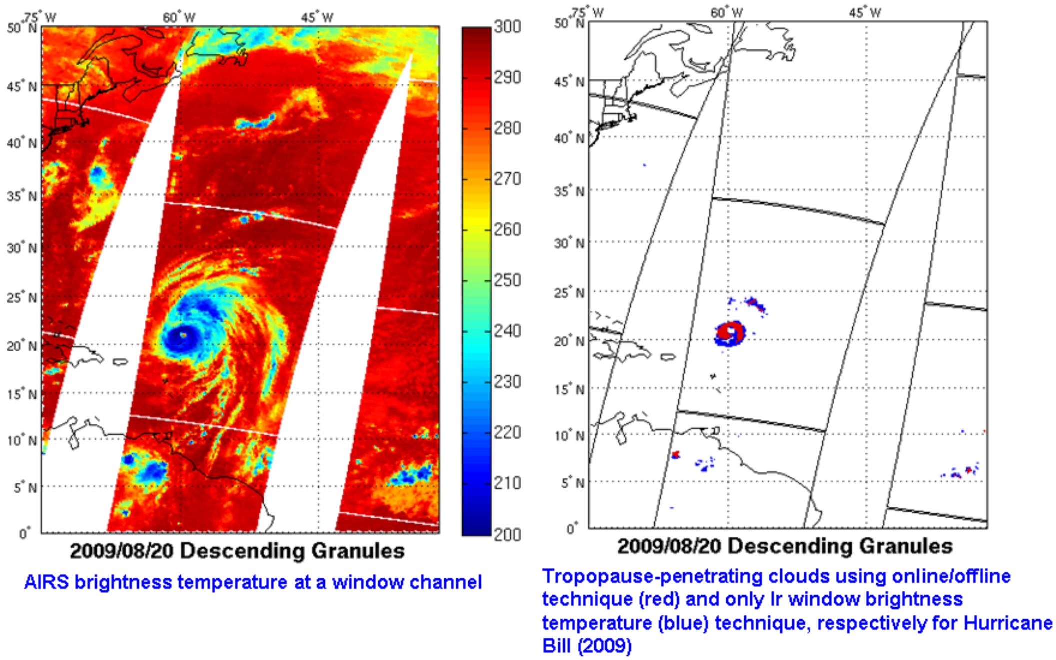


Figure 7.3. The AIRS brightness temperature at a window channel (left) and the penetrating tropopause clouds detected with online/offline technique (red) and only window IR brightness temperature technique (blue) (e.g., minimum BT), respectively, for Hurricane Bill (2009).

Publications and Conference Reports

Li, J., and H. Liu, 2009: Improved Hurricane Track and Intensity Forecast Using Single Field-of-View Advanced IR Sounding Measurements. *Geophysical Research Letters*, **36**, L11813, doi:10.1029/2009GL038285.

Liu, H., and J. Li, 2009: An Improvement in Forecast of Rapid Intensification of Typhoon Sinlaku (2008) Using Clear Sky Full Spatial Resolution Advanced IR Soundings. *Journal of Applied Meteorology and Climate* (submitted).

Revercomb, H., 2009: Advanced IR sounding from geosynchronous orbit: Status and a call for action. EUMETSAT Satellite Conference, 21 – 25 September 2009, Bath, U.K.

Sieglaff, J. M., T. J. Schmit, W. P. Menzel, and S. Ackerman, 2009: Inferring Convective Weather Characteristics with Geostationary High Resolution IR Window Measurements: A Look Into the Future, *J. Atmos. Ocean. Technol.*, **26**, 1527-1541.

References

Sieglaff, J. M., T. J. Schmit, W. P. Menzel, and S. Ackerman, 2009: Inferring Convective Weather Characteristics with Geostationary High Resolution IR Window Measurements: A Look Into the Future, *J. Atmos. Ocean. Technol.*, **26**, 1527-1541.

Aumann, H. H., 2009: Correlation of severe storms identified with AIRS and heavy precipitation with AMSR on the EOS Aqua. IEEE International Geoscience and Remote Sensing Symposium, 12 – 17 July 2009, Cape Town, South Africa.

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

Task Lead: Wayne Feltz and Kaba Bah
Support Staff Scientists: Scott Bachmeier, Scott Lindstrom, Lee Cronce, Jordan Gerth
NOAA Collaborator: Tim Schmit, Gary Wade, Bob Aune
NOAA Strategic Goals addressed:

- Serve society's needs for weather and water information

Proposed Work

In addition to continuing efforts working with the National Weather Service (NWS) offices in preparation for GOES-R Advanced Baseline Imagery (ABI) prior to launch, we are also testing and applying algorithms for new satellite data imagery/products in support of the Storm Prediction Center (SPC) Hazardous Weather Testbed (HWT). We continue to work jointly with NWS forecast offices and SPC personnel in evaluating GOES-R related products, addressing concerns and implementing suggested changes to improve their quality. This will ensure that GOES-R products are useful to NWS forecasters soon after launch. As a result of these activities, the relationship between the CIMSS Proving Ground team and NWS offices is strengthening and participation is expanding.

Summary of Accomplishments and Findings

We have started providing real-time access to University of Wisconsin-Madison Convective Initiation (UWCI) decision support products via N-AWIPS to the Storm Prediction Center (SPC) as part of the Hazardous Weather Testbed (HWT) Spring 2009 Experiment. In addition, the NOAA Satellite Analysis Branch (SAB) and Milwaukee-Sullivan National Weather Service Forecast Office are also receiving the real-time data feed via AWIPS and have provided additional operational feedback. The UWCI decision support products include, instantaneous convective initiation nowcast, instantaneous cloud-top cooling rate, 60-minute accumulated convective initiation nowcast, and 60-minute accumulated cloud-top cooling rate (Figure 8.1). The cloud-top cooling rate is used to infer vertical growth of developing convective clouds. This information can assist forecasters in determining where convection will develop; the satellite signal has been shown to lead significant radar echoes by up to 45 minutes. The convective initiation nowcast assigns categories to cooling clouds identified in the cloud-top cooling product. The categories (pre-CI cloud growth, convective initiation likely, and convective initiation occurring) reflect increased lead-time but higher false alarm to less lead-time but lower false alarm, respectively. The 60-minute accumulated products are 60-minute accumulations of CI nowcasts or cloud-top cooling rates. The 60-minute accumulated products help increase forecaster confidence when continued cooling and continued CI nowcasts occur over multiple satellite scans.

We used high-spectral resolution AIRS data to produce Derive Product Imagery (DPI) near real time over CONUS in the same format as the current GOES sounder. These products are currently being tested in our local AWIPS WES case and work is in progress to make them available to NWS offices via AWIPS. The products that are currently being tested for initial distribution are Convective Available Potential Energy (CAPE), Total Precipitable Water (TPW), Lifted Index (LI), Precipitable Water 01 (Surface -900MB), Precipitable Water 02 (900 - 700MB) and Precipitable Water 03 (900-300MB). Other products such as K-Index will soon follow. Figure 8.2 shows a comparison between the online CIMSS GOES (11/12) derived Precipitable Water on the left to AIRS derived Precipitable Water 02 (upper right) and AIRS Total Precipitable Water (lower right) displayed in AWIPS WES.

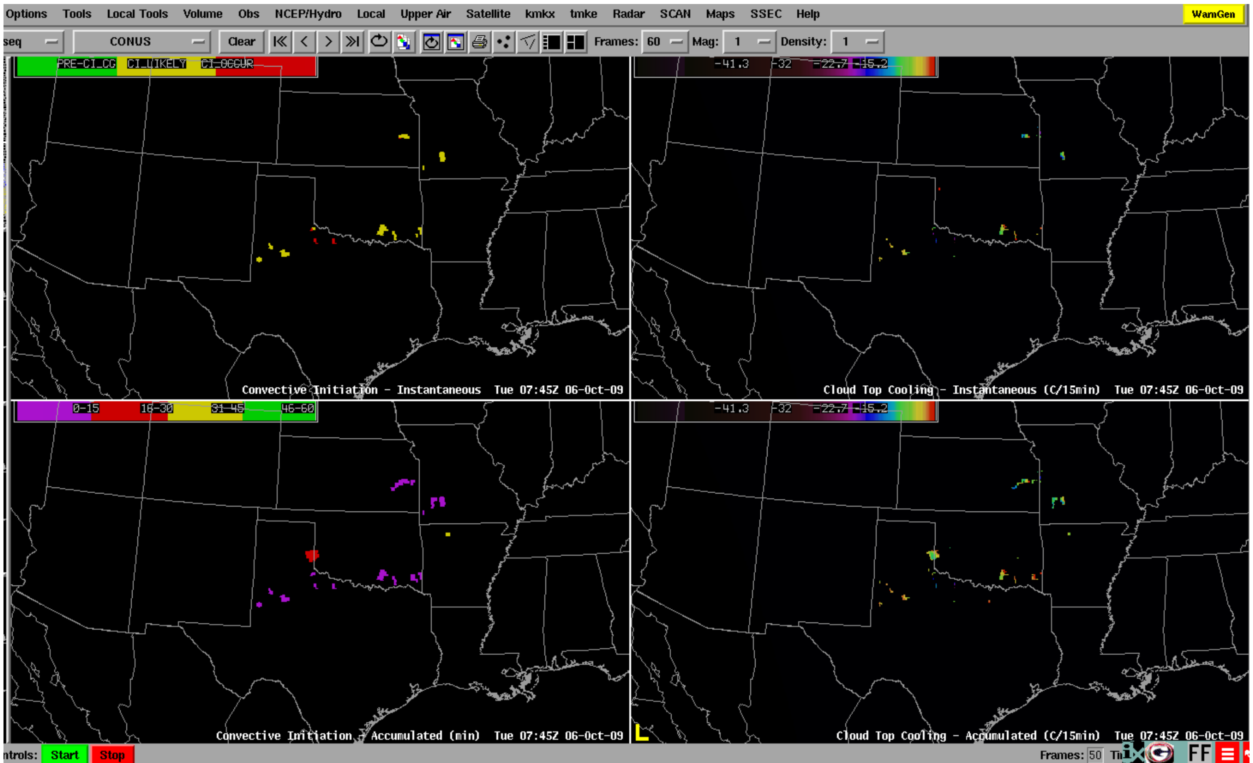


Figure 8.1. UWCI products in AWIPS for October 06th 2009 at 07:45Z. The upper left image is the instantaneous Convective Initiation (CI) Nowcast where convective initiation is likely to occur (yellow) and where convective initiation is occurring (red). The bottom left image shows the 60-minute accumulated CI product. The upper right image shows instantaneous cloud top cooling rate while the bottom right shows the 60-minute accumulated cloud top cooling.

MODIS Products in AWIPS: The number of MODIS products available through AWIPS for additional stability have been extend and made accessible to all NWS offices through the Local Data Manager (LDM). The MODIS stability indices that were recently added are: Lifted Index, Total Totals and K-Index.

CIMSS continues collect feedback from the operational users through visits to National Weather Service (NWS) Field offices, and presentations at meetings of the National Weather Association (NWA). Recently, CIMSS has established monthly visits to NWS Sullivan to assure the flow of products to the field remains uninterrupted, and to answer any questions from the forecasters about the utility of the products in operations. These visits often lead to new ideas about candidate products for furthering research to operations activities.

CIMSS participation in the NWS Storm Prediction Center (SPC) 2009 Spring Experiment has led to additional documented forecaster feedback and adjusting of the GOES-R convective initiation algorithm. A revised product will be presented at the 2010 Spring Experiment with this feedback considered.

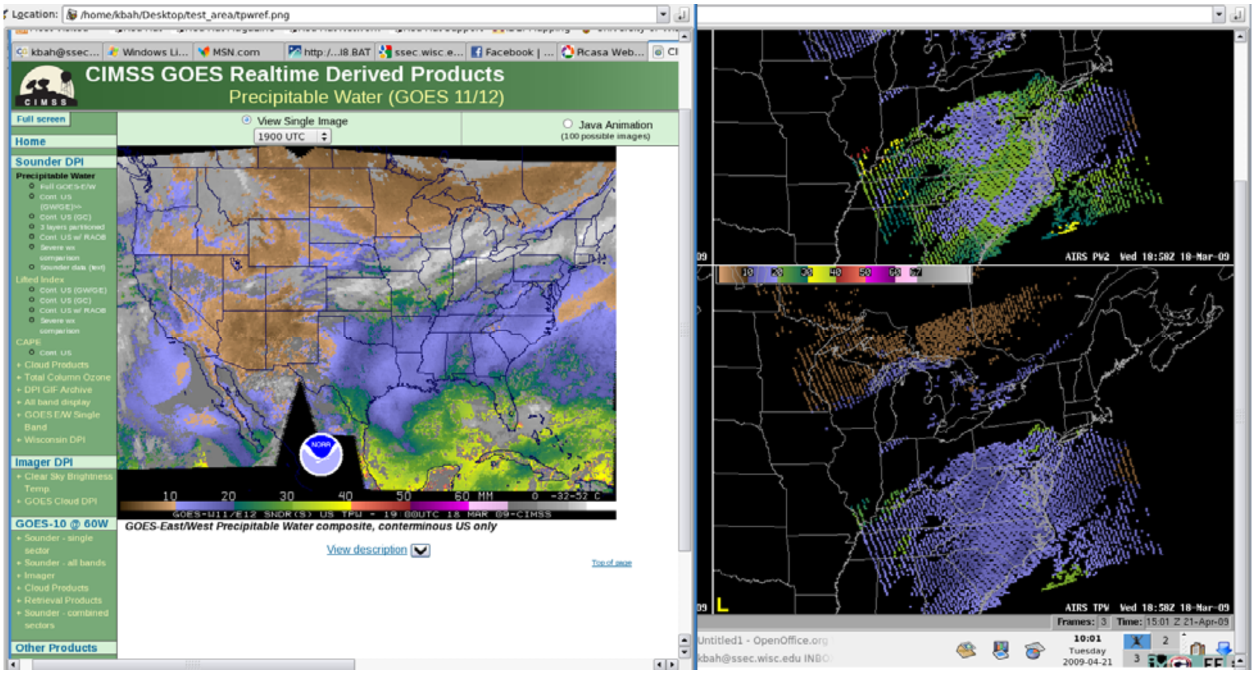


Figure 8.2. Comparison between CIMSS GOES Real time derived Precipitable Water (GOES 11/12) on the left to AIRS derived Precipitable Water 02 and AIRS derived Total Precipitable Water displayed in AWIPS WES.

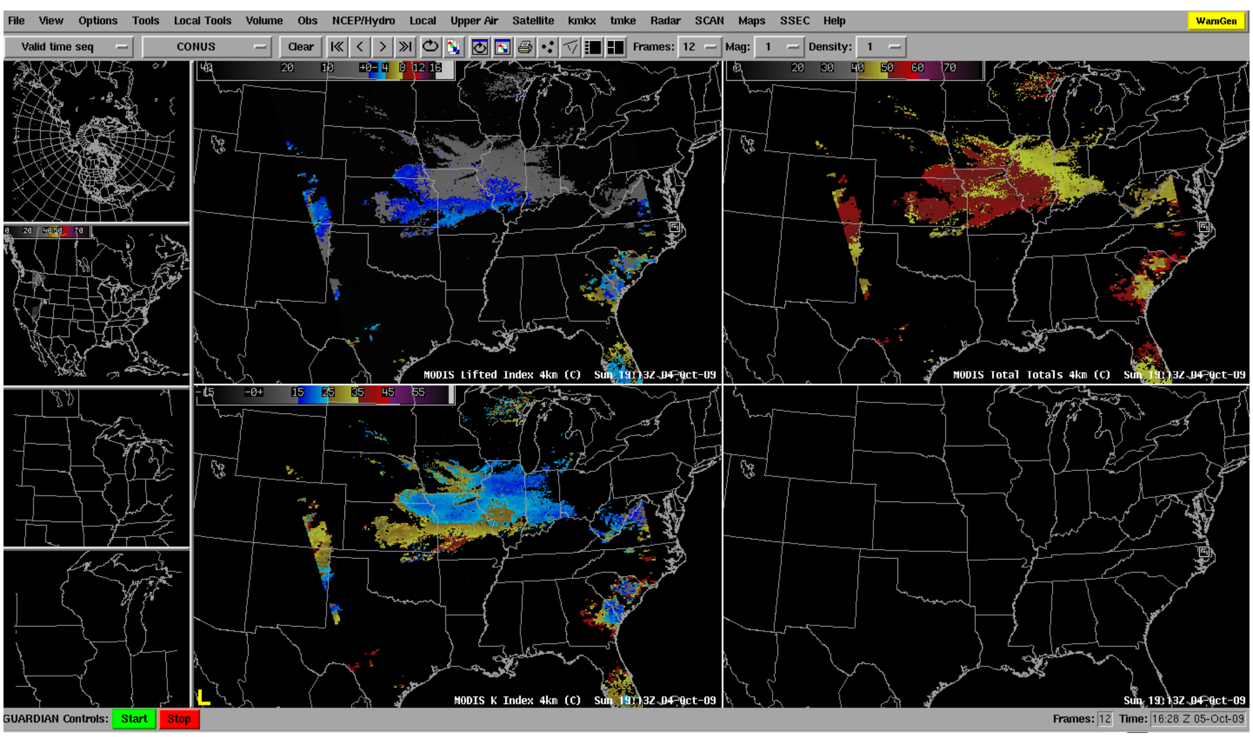


Figure 8.3. MODIS additional stability indices in AWIPS, showing Lifted Index (Upper left), K- Index (lower left) and Total Totals (upper right) .

As part of the strong relationship between the National Weather Service (NWS) Field Office in Sullivan, Wisconsin, and CIMSS that has been fostered through research to operation exercises since July 2006, new management and staff was invited to CIMSS for a one-day workshop in January 2009. The theme of the meeting, "Catering to the satellite needs of operational meteorology", included presentations on CIMSS' mission and goals, the GOES-R Proving Ground, and how the GOES-R Proving Ground will leverage existing mechanisms for research to operations activities in preparation for the next generation of geostationary satellites. Included in the workshop was a demonstration of CIMSS' Advanced Weather Interactive Processing System (AWIPS) and AWIPS II enhancements. The NWS staff also presented on their future service visions, with ensuing discussion surrounding how GOES-R objectives for day-one forecaster readiness fit with the service evolution plan for the NWS.

In February 2009, CIMSS held a one-day seminar at NWS Sullivan for the office meteorologists. The theme of the meeting, "Building on a collaborative foundation for success in operational meteorology," was established to introduce forecasters to the objectives of the GOES-R Proving Ground, as well as to provide a primer on the use of the current GOES Sounder. Additional talks from CIMSS and NOAA scientists showcased new research to operations products, including a Lagrangian model approach to convective nearcasting, and the application of GOES-R convective initiation algorithms to aviation. The seminar was concluded with a discussion between CIMSS and NWS personnel about how to continue tight collaborative ties between the two agencies. NWS Sullivan continues to provide meaningful feedback on CIMSS research to operations products developed via AWIPS.

The GOES-R AWG Proxy Data group at CIMSS has produced an improved CONUS and mesoscale simulation for the convective outbreak on June 4-5, 2005. While the previous dataset was sampled at 2 km spatial resolution for all the 16 ABI bands, the new simulated dataset has 1 km spatial resolution for band01 (0.47um), band02 (0.64um), band03 (0.865um) and band05 (1.378um). In addition, the new mesoscale temporal resolution has also been improved from 5 to 1 minute. This new dataset shows much finer details and is more consistent with the GOES-R ABI resolution . Hence we have upgraded all the simulated ABI data in our WES case to the new improved dataset.

In conjunction with the local NWS office, we have released a beta-01 version of the Weather Event Simulator for the GOES-R simulated ABI data on DVD. Besides data and derived products, this ABI-DVD also contains a beta-01 version of the WES-GUIDE and introductory videos to the GOES-R ABI bands. The WES-GUIDE will help users explore the new dataset and learn about some of the potential uses of the GOES-R ABI bands. This WES-DVD will be distribution to other NWS offices and can also be made available upon request.

As requested by the NWS Miami office, we have developed and integrated the WRF-ARW Hurricane Katrina simulations into our AWIPS WES case for training to prepare forecasters for future ABI hurricane decision support capabilities. Figure 8.5 shows sample images of simulated ABI for hurricane Katrina on 29th August 2005 at 18:00Z.

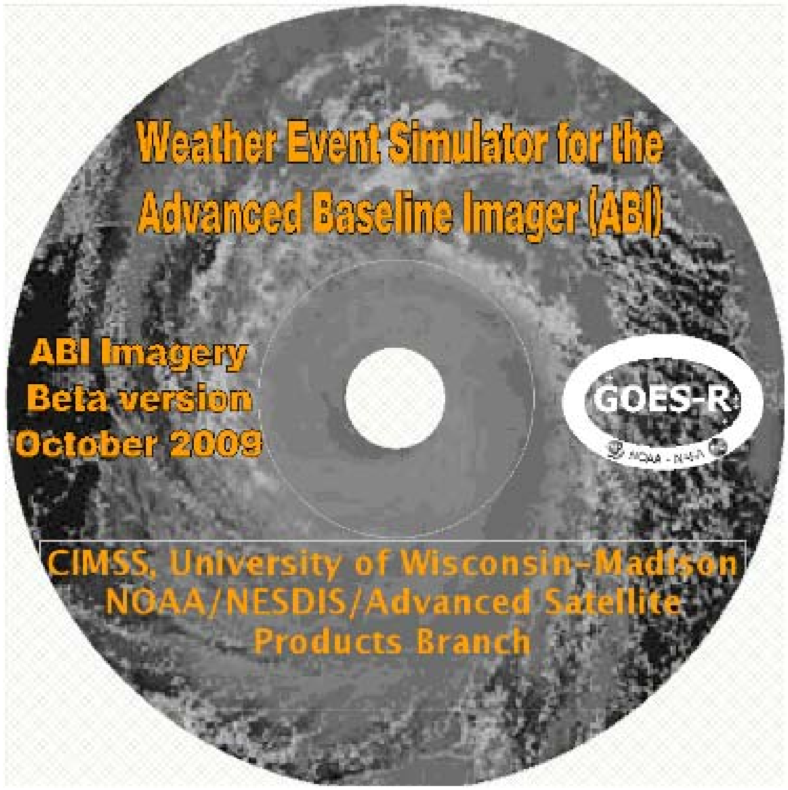


Figure 8.4. DVD cover of the beta version Weather Event Simulator for the Advance Baseline Imager (ABI), showing the simulated hurricane Katrina as seen on the reflective band03 (0.865um).

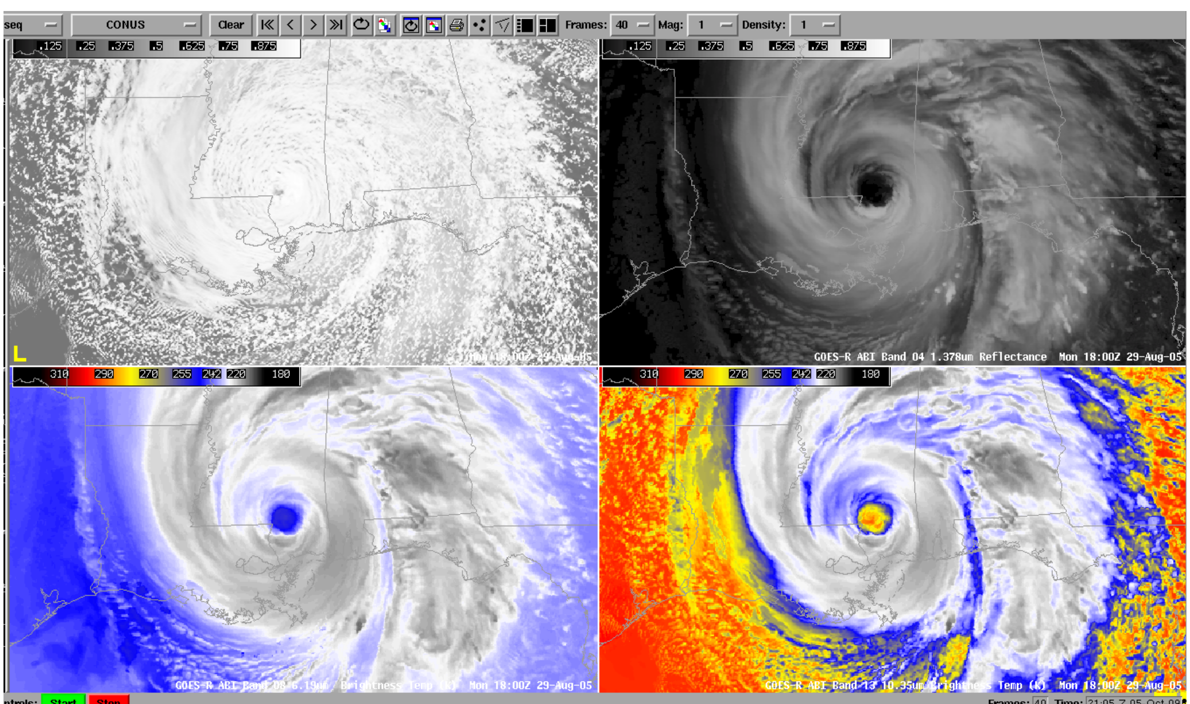


Figure 8.5. Simulated ABI data from the WRF-ARW showing hurricane Katrina on 29th August 2005 at 18:00Z.

The upper images shows reflective band02(0.64um) and band04 (1.38um) while the lower images shows the water vapor band, i.e., band08 (6.19um) and the longwave IR band16 (13.3um).

Included in our WES case are mesoscale simulation of the convective outbreak on June 4-5, 2005 for all the 16 ABI bands with 1minute temporal resolution. At such high temporal resolutions we can closely watch events that can potentially unfold within minutes and at 1km spatial resolution or better for the visible bands.

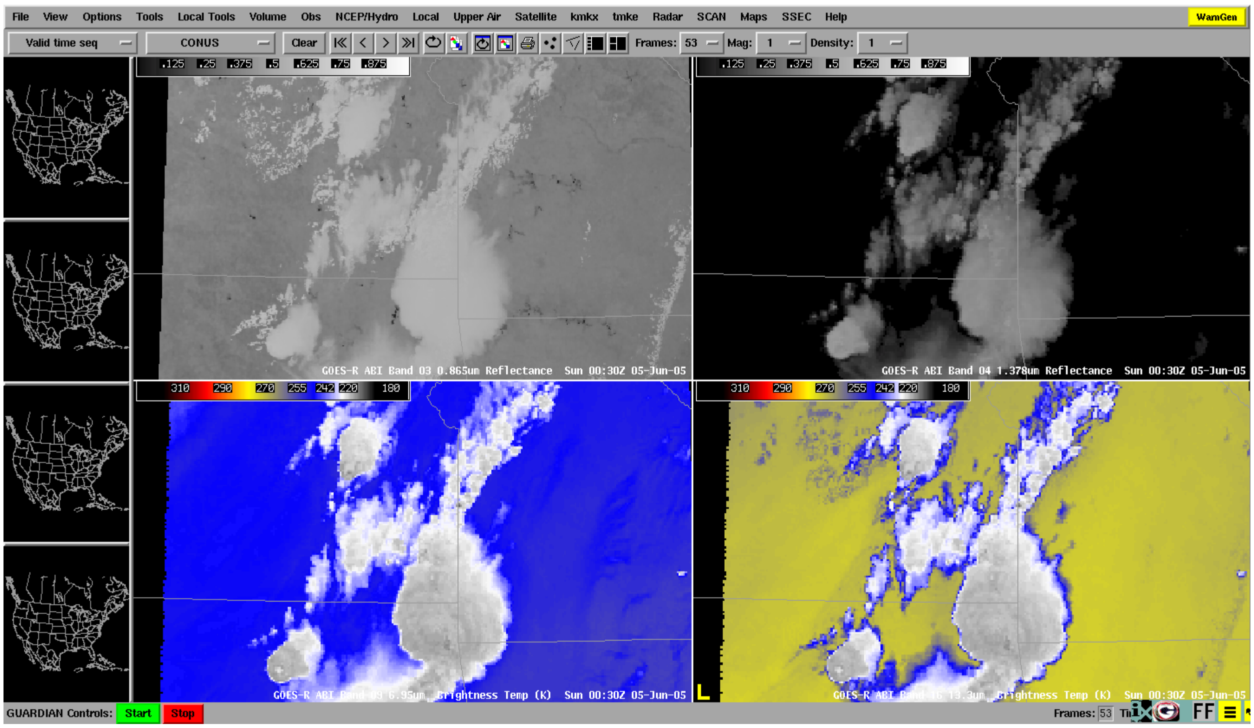


Figure 8.6. ABI mesoscale simulation of the convective outbreak on June 4-5, 2005 at 00:30Z. The upper left images shows the "near-IR" band03 (0.86um), the upper right shows "cirrus" band 04 (1.378um), the "Upper/mid-level tropospheric water vapor" band09 (6.95um) and the "CO_2" longwave IR band16 913.3um).

In addition to the 16 simulated ABI bands, we have included some simple bands differences in our WES case. Figure 8.7, for example shows a band difference between band (08 – 14), i.e., 6.19um – 11.2um. Such a difference shows the location of potentially over-shooting tops which are highlighted by the largest differences. Other differences includes a Normalize Difference Vegetation Index (NDVI) between band(03 -02) i.e., (0.86um -0.64um). Such a difference is used to study vegetation and a sample can be seen in upper left corner of Figure 8.7 below.

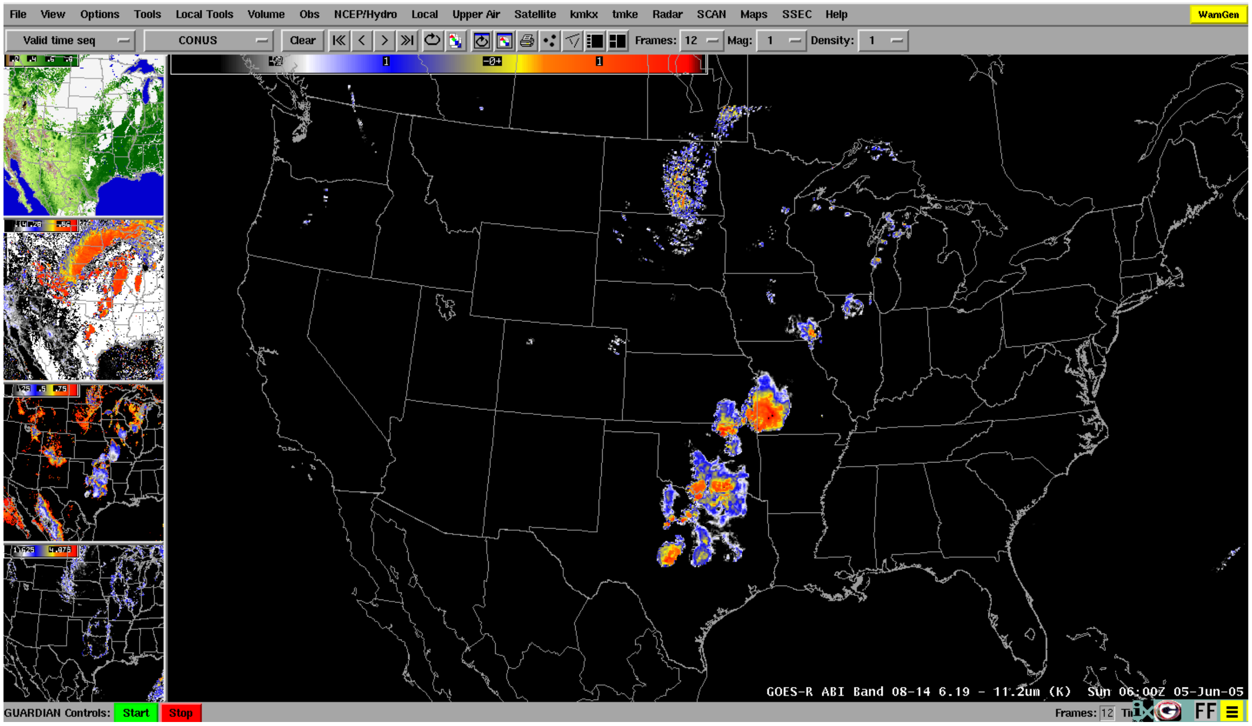


Figure 8.7. A band difference between band (08 – 14), i.e., (6.19um – 11.2um) for the convective outbreak on June 4-5, 2005 at 06:00Z.

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.

Presentations and Conference reports

Bachmeier, S., 2009: CIMSS Satellite Products in AWIPS. 2nd Annual GOES-R Proving Ground Meeting, Boulder, Colorado, 15 May 2009.

Bachmeier, S. and J. Gerth 2009: Satellite Training Activities at CIMSS: Helping to Prepare Forecasters for the GOES-R and NPOESS Era. 16th Conference on Satellite Meteorology and Oceanography, 89th AMS Annual Meeting, Phoenix, Arizona, 10-16 January 2009.

Bah, Kaba and Timothy J. Schmit, 2009: ABI and AIRS retrievals in McIDAS-V. 6th annual McIDAS Users' Group meeting, Madison, WI, 02-04 June 2009.

Bah, Kaba, Jordan Gerth, Jason Otkin, and Timothy J. Schmit, 2009: Operational Uses of Bands on GOES-R Advance Baseline Imager(ABI). 34th Annual National Weather Association Annual Meeting, Norfolk, VA, October 17-22, 2009.

Feltz, W. F., 2009: GOES-R Proving Ground Satellite-based UW Convective Initiation Decision Support Capabilities. 2nd Annual GOES-R Proving Ground Meeting, Boulder, Colorado, 15 May 2009.

Gerth, J., and S. Bachmeier, 2009: Transitioning Satellite Products to National Weather Service Operations, and Future Directions for the GOES-R Era. 16th Conference on Satellite Meteorology and Oceanography, 89th AMS Annual Meeting, Phoenix, Arizona, 10-16 January 2009.

Gerth, J., 2009: How CIMSS Contributes to GOES-R Proving Ground, and Possible Implications for Alaska. High Latitude/Arctic Proving Ground Meeting, Fairbanks and Anchorage, Alaska, 18-20 August 2009.

Pavolonis, M. and J. Sieglaff, 2009: Quantitative Volcanic Ash Remote Sensing at NOAA/NESDIS/STAR and CIMSS. High Latitude/Arctic Proving Ground Meeting, Fairbanks and Anchorage, Alaska, 18-20 August 2009.

Schmit, T., 2009: CIMSS Participation in the Development of a GOES-R Proving Ground. 2nd Annual GOES-R Proving Ground Meeting, Boulder, Colorado, 15 May 2009.

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

CIMSS Project Lead: W. Paul Menzel
NOAA Collaborators: Steven Goodman
NOAA Strategic Goals Addressed:

- Serve society's need for weather and water

CIMSS Research Themes:

- Weather
- Clouds
- Hydrological cycle
- Outreach

Mentoring new PhD

Zhenglong Li finished his PhD on "Improvements and Applications of Atmospheric Soundings from Geostationary Platform." The work demonstrated the quality and utility of soundings derived in the presence thin high clouds or low opaque cloud. The abstract of his thesis reads as follows. In an effort to extend the high temporal resolution GOES infrared (IR) sounding retrievals from clear to cloudy skies, a synthetic regression-based cloudy sounding retrieval algorithm has been developed and applied to GOES-12 Sounder measurements. Comparisons against radiosondes at the Atmospheric Radiation Measurement (ARM) Program at Southern Great Plains (SGP) site from August 2006 to May 2007 and the conventional radiosondes network over the Continental United States (CONUS) from January 2007 to November 2008 both show the retrievals of moisture under thin cloud conditions perform similarly to those under the clear sky conditions. The largest improvements are found in the upper level integrated precipitable water vapor (PW) or PW3. Also in the case of low thick clouds, PW3 is usually improved significantly. In addition, the retrieved cloud parameters are consistent with the false RGB composite images. With the addition of the soundings under low thick or thin cloud conditions, the area without soundings is reduced by 57 % in the selected case. The application to a tornadic storm on 24 April 2007 reveals that the GOES cloudy sounding retrievals are more useful at the early stage of the storm, when nearby clouds are considered thin or broken. The GOES cloudy sounding algorithm reveals more pronounced and extensive convective instability, and it does so earlier than the clear-sky only results. The cloudy sounding retrievals have the potential to provide an earlier warning to forecasters.

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

CIMSS Project Lead: Mat Gunshor
CIMSS Support Scientists: Bob Holz, Steve Dutcher
NOAA Collaborator: Tim Schmit
NOAA Strategic Goals Addressed:

- 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:

- Climate

Proposed Work

The goal of this proposal was to support STAR calibration/validation activities with a retrospective analysis of the GOES Imagers using AIRS and then IASI with intercalibration methods previously developed at CIMSS. 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 (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. This project dovetails with the GIMAP Intercalibration project, a longtime CIMSS project which covers research into new/improved methods, testing new satellite instruments, diagnosing problems on existing instruments, and the analysis and presentation of results. Data for that project are collected in near real time for future analysis. What was proposed here was to look back at approximately five years of AIRS and two years of IASI and coincidental GOES observations.

Due to the late start in FY08 of this project, there was little progress to report on the retrospective study of AIRS vs. GOES in the CIMSS FY08 report. This project also got a relatively late start in FY09 and hence this report will focus more on what was proposed technically in 2008.

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

Over five years of AIRS data were used to intercalibrate operational GOES. This study covered the period from January 2003 through November 2008. GOES-10, -11, -12, and -13 Imagers were all intercalibrated with AIRS, when available, during that time period. The GOES Imager Infrared bands are generally well calibrated, with the exception of the 13.3 micrometer band. This was corrected for GOES-13, because that instrument is still not operational and a new spectral response function was released for it which yields a vast improvement in these results. The GOES-12 Imager 13.3 micrometer band could possibly benefit from a similar spectral response function update. Figure 10.1 shows the results.

Imager:		GOES-10	GOES-11	GOES-12	GOES-13
Shortwave Window	N	186	94	95	17
	ΔT (K)	0.44	-0.09	-0.11	-0.25
	STD (K)	0.26	0.19	0.42	0.31
Water Vapor	N	542	244	622	54
	ΔT (K)	0.55	0.04	0.03	-0.15
	STD (K)	0.21	0.18	0.43	0.28
IR Window	N	561	243	626	65
	ΔT (K)	-0.12	-0.33	-0.19	-0.04
	STD (K)	0.49	0.41	0.66	0.38
"Dirty" Window	N	535	244	-	-
	ΔT (K)	0.16	-0.1	-	-
	STD (K)	0.51	0.35	-	-
CO_2	N	-	-	624	64
	ΔT (K)	-	-	-1.45	-1.62
	STD (K)	-	-	0.68	0.5

Figure 10.1. Intercalibration results spanning nearly 6 years AIRS coverage (GOES-AIRS). Note that these results reflect the second release of the ITT GOES-13 spectral response function for the CO_2 band, not the one that NESDIS released to correct this calibration error. Besides that band, the GOES Imagers seem to be well calibrated in comparisons to AIRS.

Time series plots of GOES-AIRS differences reveal some interesting trends. For instance, the decontamination in July 2007 of GOES-12 can be seen in several bands, most dramatically the water vapor band (not shown). The dirty window (12 micrometer) band on GOES-10 time series plot showed that the calibration in that band had changed after GOES-10 started collecting data in 2007 after being in storage mode (and moved) for much of 2006 (Figure 10.2). Figure 10.3 shows the time series of GOES-12 Imager's IR Window band compared with AIRS. While the mean difference is very small over the study period (-0.2 K, GOES-AIRS) there are several troubling individual cases with differences well over 1 K. These are all removed when we narrow the comparison criteria and only compare cases where the AIRS and GOES actual scan times are within 5 minutes of each other (Figure 10.4).

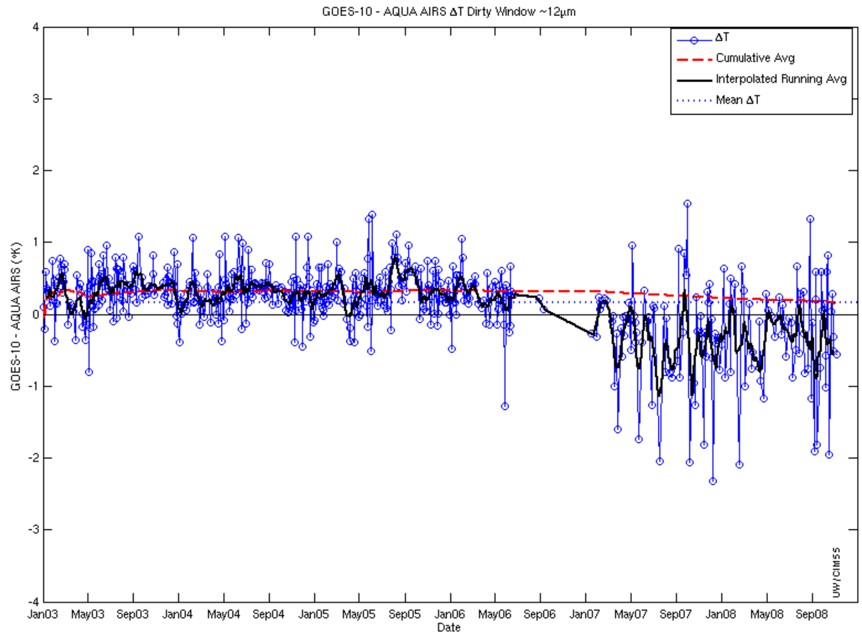


Figure 10.2. Time series of GOES-10 "Dirty" Window (12 micrometer) comparisons to AIRS from January 2003 to November 2008. The break in 2006/07 is when GOES-10 was replaced by GOES-11 and then moved for better South American coverage. Coming out of the break, the comparisons have actually changed sign, though on average remain roughly the same magnitude, with a higher standard deviation.

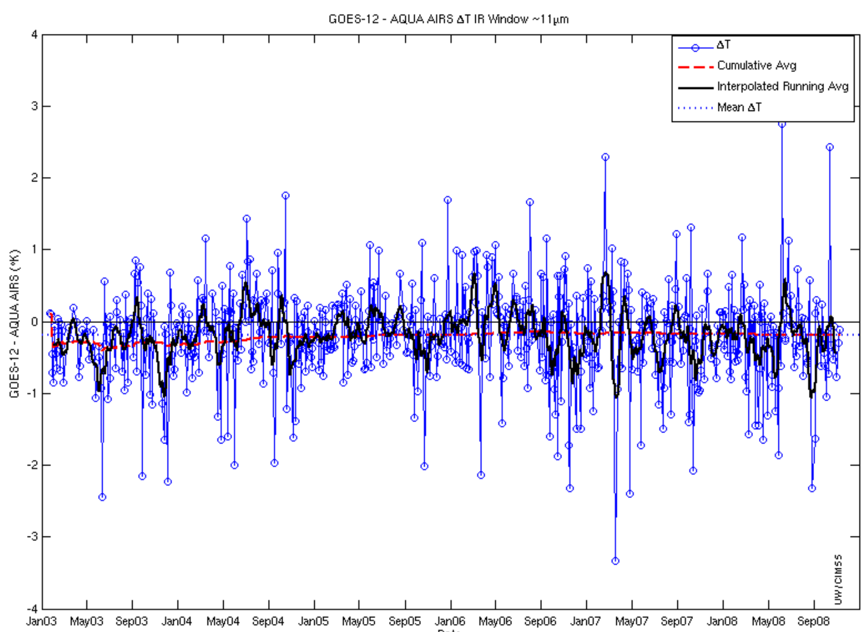


Figure 10.3. Time series of GOES-12 Infrared Window (11 micrometer) comparisons to AIRS from January 2003 to November 2008. The interpolated running average is a running average of +/- 10 cases in either direction, an attempt to find patterns in the data. While the mean difference is small, approximately -0.2 K over the study period, there are many individual cases (outliers) that far exceed this value.

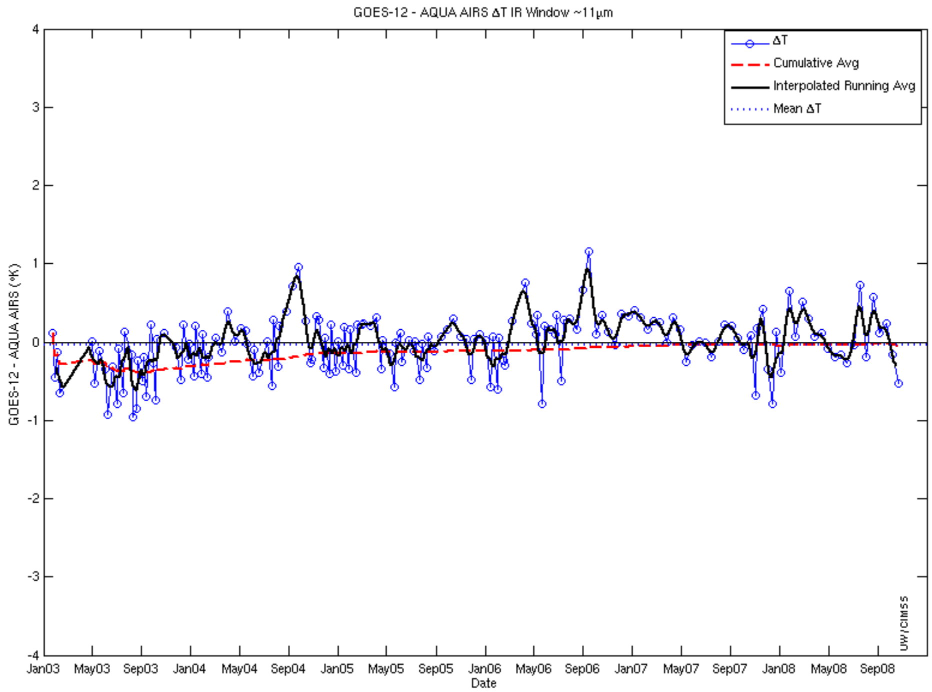


Figure 10.4. Time series of GOES-12 Infrared Window (11 micrometer) comparisons to AIRS from January 2003 to November 2008, with an overpass time difference maximum of 5 minutes applied. The mean difference is essentially 0.0 K, an improvement over the approximately -0.2 K when all cases were considered. The standard deviation about the mean of all cases is lower as well.

This work was presented on a poster at the 2009 AMS 16th Conference on Satellite Meteorology and Oceanography in Phoenix, AZ. It is expected that similar results will be shown with IASI at the AMS annual meeting in 2010.

Publications and Conference Papers

Gunshor, Mathew M.; Schmit, T. J.; Tobin, D. C. and Menzel P., 2009: Intercalibration of the world's geostationary imagers with high spectral resolution data. 16th Conference on Satellite Meteorology and Oceanography and 5th Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, Phoenix, AZ, 11-15 January 2009. American Meteorological Society, Boston, MA.

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

11.1. Assimilating Sea Surface Winds Measured by ASCAT and Evaluating the Impact of ASCAT and WINDSAT/CORIOLIS in the NCEP GDAS/GFS

CIMSS Project Leads: Michael Morgan, Li Bi, and James Jung
NOAA Collaborators: John Derber, Russ Treadon , Zorana Jelenak

NOAA Strategic Goals addressed:

- 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

We propose to work with JCSDA (Joint Center for Satellite Data Assimilation) personnel to evaluate the assimilation techniques and the forecast impact of assimilating the European Organisation for the Exploitation of Meteorological Satellite's (EUMETSAT) new Advanced SCATterometer (ASCAT) in the National Center for Environmental Prediction (NCEP) Global Data Assimilation/Global Forecast System (GDAS/GFS). We plan to develop Quality control (QC) and data thinning procedures required for the assimilation of the ASCAT data. We plan to develop an ambiguity test for ASCAT which will improve the consistency of the ASCAT data with the model background. We will conduct two season assimilation experiments comparing results of assimilating ASCAT with a control experiment. We propose to compare the attributes of using the ASCAT data to the control experiment by computing the geographic distribution of Forecast Impact (FI) along with using NCEP's verification software to quantify forecast impacts. We hope these experiments ultimately lead to operational implementation of ASCAT data in the NCEP weather forecast models. We will start performing initial ambiguity test for WindSat and QuikSCAT retrieved winds if time permits.

Summary of Accomplishments and Findings

A two-season Observing System Experiment (OSE) has been conducted to study the impacts of assimilating the Advanced SCATterometer (ASCAT) surface winds product. The assimilation system and forecast model are a recent version of the National Centers for Environmental Prediction (NCEP) Global Data Assimilation/Global Forecast System (GDAS/GFS) at the current operational resolution. The impacts of assimilating the ASCAT surface wind products are assessed during two seasons by comparing the forecasts through 168 hours of control simulations utilizing all the data types assimilated into the operational GDAS with the experimental simulations using this new surface wind product.

Several aspects of the OSE of ASCAT were completed, including Quality Control (QC) procedures, data thinning, and ambiguity tests, which were necessary for improving Numerical Weather Prediction (NWP) forecasts. Accept/reject quality control criteria based on sea surface temperature was developed and tested. We found that larger RMS errors with the model background occur when the sea surface temperature is below 273 K. These observations are suspected of being contaminated by sea ice. This routine rejects the observations during the thinning process to allow vectors in warmer regions of the thinning box to be used. An innovation vector difference test (observation minus background) has also been developed and incorporated into the ASCAT assimilation procedures. Through various trial and error tests it was determined that innovation differences greater than ~2.5 standard deviations, or 5m/s, for the U or V component were degrading the forecast. These observations are now being rejected. Experiments designed to test the ASCAT data at different thinning resolutions were conducted at 150, 100, and 50 km. Thinning ASCAT data to 100km had the best forecast performance. A vector ambiguity test developed for ASCAT has also been incorporated into the QC procedures. The ambiguity QC was based on comparing the vector difference of the two ASCAT retrieved wind vectors to the GDAS/GFS model 6 hour forecast. Observations where the vector difference of the originally selected vector is larger than its pair, suggesting the wrong direction may have been chosen, are rejected. Less than 2% of the observations are being rejected by this ambiguity check.

Results for a summer season suggest that assimilation of ASCAT data has a neutral to small positive impact as shown by the day 5 anomaly correlation bar chart in Figure 11.1.1. Figure 11.1.2 shows the Forecast Impact (FI) in the 48 hour forecast of 10 meter u and v component of the winds. Positive and neutral Forecast Impacts are still found in most regions of the 10 meter winds at 48 hr.

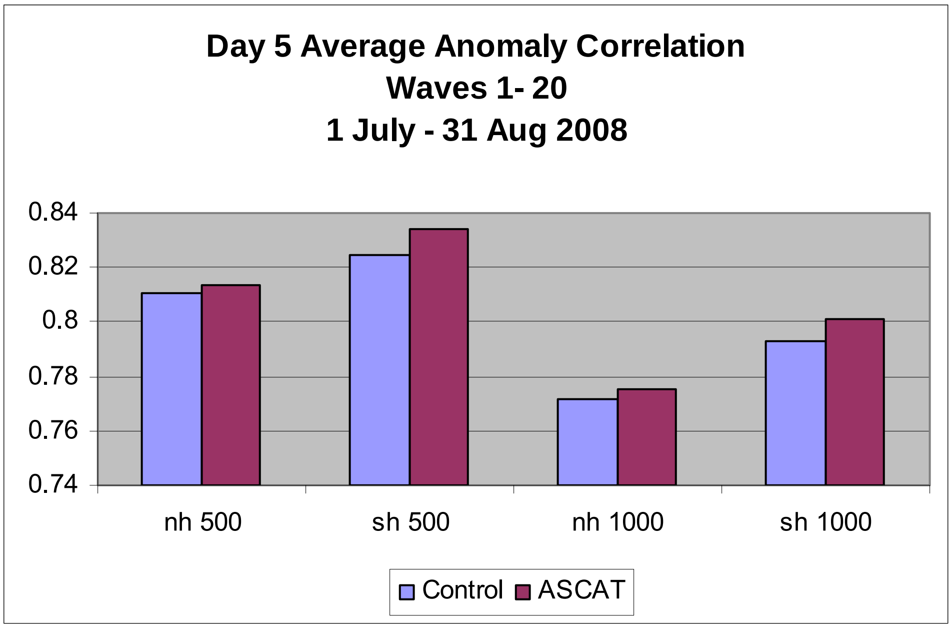


Figure 11.1.1. Anomaly Correlation Scores for day 5 forecasts without ASCAT (Control) and with ASCAT (ASCAT) data for 500hPa and 1000hPa heights in the Northern and Southern Hemispheres.

Publications and Conference Reports

Bi, L., J. A. Jung, and M. C. Morgan, 2009: Assimilating Sea Surface Winds Measured by ASCAT and Evaluating the Impact of ASCAT winds in the NCEP GDAS/GFS. JCSDA 7th Workshop on Satellite Data Assimilation Joint Center for Satellite Data Assimilation, University of Maryland at Baltimore County (UMBC), Halethorpe, MD, May 12-13, 2009.

Bi, L., 2008: A Two-Season Impact Study of ASCAT and WindSat Surface Wind Retrieval in the NCEP Global Data Assimilation System. Department of Oceanic and Atmospheric Sciences, University of Wisconsin-Madison, Ph.D. thesis.

Bi, L., J. A. Jung, M. C. Morgan and J. F. Le Marshall, 2009: A Two-Season Impact Study of the WindSat Surface Wind Retrievals in the NCEP Global Data Assimilation System. Submitted to *Wea. Forecasting.*

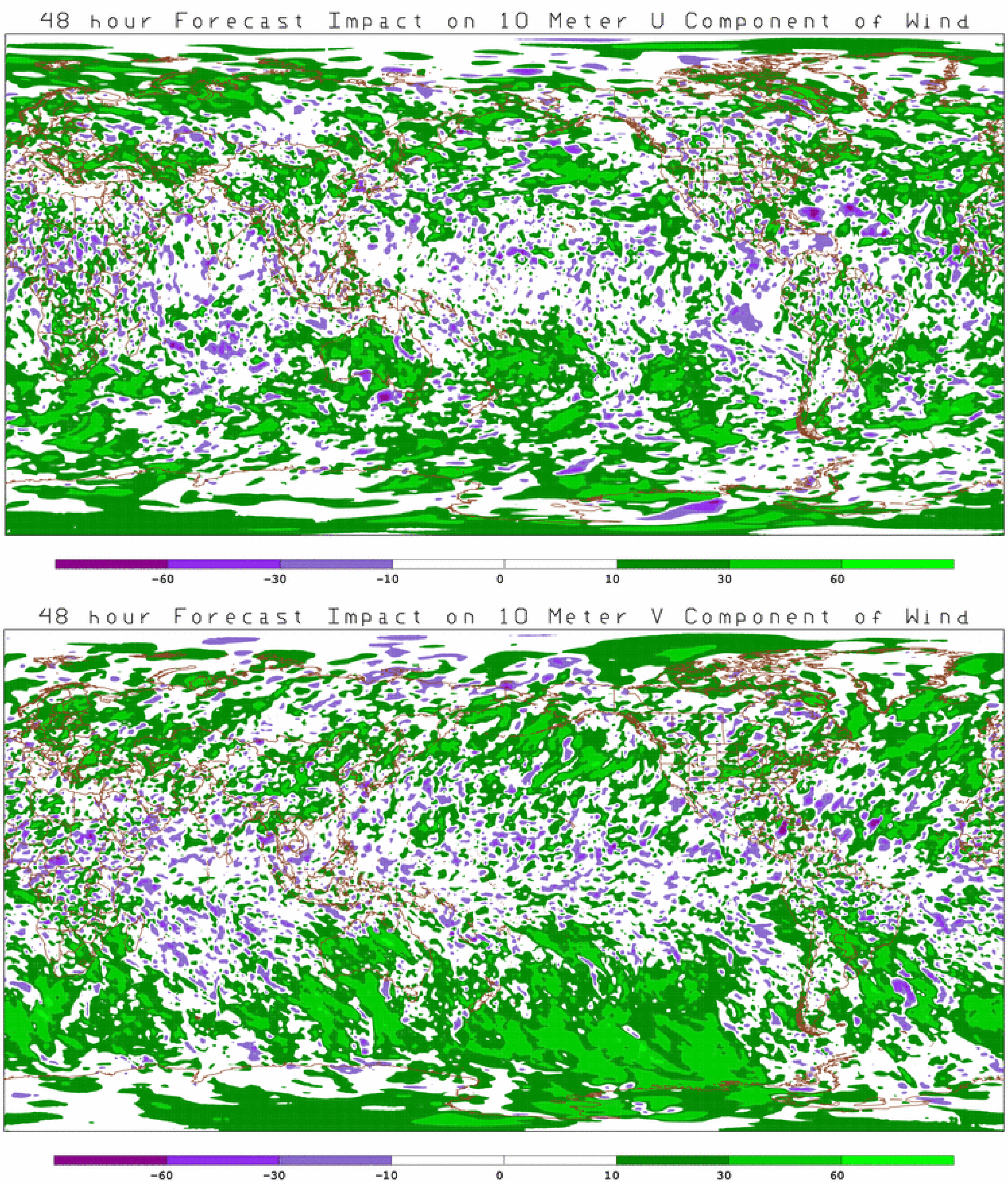


Figure 11.1.2. 48 hour Forecast Impact of 10 meter u and v component of wind.

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

CIMSS Project Leads: James Jung and Li Bi
CIMSS Support Scientist: Todd Schaack
NOAA and other Collaborators: John Derber, Russ Treadon, Paul van Delst, Chris Barnett, Lars Peter Riishojgaard and John Le Marshall
NOAA Strategic Goals addressed:

- 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 have been working with the 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 the AIRS and IASI infrared (IR) 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. Channels which have significant dependencies to water vapor in the stratosphere are not modeled well by the Gridpoint Statistical Interpolation (GSI). The issue of supersaturation and small negative moisture values in the GSI must also be addressed.

We propose to investigate the assimilation of IR water vapor channels into NCEP's Global Data Assimilation System / Global Forecast System (GDAS/GFS). We will take into account the performance (convergence) of the GSI when selecting the water vapor channels to assimilate. We will also investigate ways to reduce the number of supersaturated and negative moisture points within the analysis. Threat scores, and anomaly correlations, from NCEP verification software, along with forecast impact of relative humidity and precipitable water will be used to quantify changes made to the analysis have on the forecast.

Summary of Accomplishments and Findings

The focus this year has been on improving the assimilation techniques of the hyperspectral (AIRS and IASI) water vapor channels. The channels which include strong water vapor absorption spectral lines, and have a narrow spectral response and are sensitive to moisture in the Stratosphere as well as the Troposphere. The IASI and AIRS water vapor channels used were divided into two groups depending on their sensitivity to moisture above the Troposphere. AIRS and IASI both have channels sensitive to moisture in the Stratosphere but IASI, with its narrow spectral bandwidth, is better suited to infer stratospheric moisture. IASI also samples both the longwave and shortwave sides of the water vapor band which should improve the assimilation of water vapor in the lower troposphere, AIRS only samples the longwave side. We have found that by closer screening of the observations, adjusting the model background error and adjusting the water vapor channels assimilation weights, the IASI and AIRS water vapor channels can be used by the analysis and lead to better moisture field forecasts.

Results of incorporating new assimilation techniques and assimilating water vapor channels from AIRS and IASI have shown improvements in the moisture field when compared to simulations using the NCEP operational configuration. Some of these improvements are shown by the average differences in the precipitable water field in the analysis and in the 12 hour forecast. Using the hyperspectral water vapor channels decreased moisture in the Polar Regions (reds) and increased moisture in the tropics (greens) as shown in Figure 11.2.1(a). The precipitable water returns in the Polar Regions after 24 hours but the higher precipitable water values are maintained in the tropics (Figure 11.2.1(b)). Differences in precipitation between the control and the experiment were generally small (not shown) and mostly in the tropics where the inter-tropical convergence zone was active.

Typically, adjustments to the moisture field are short lived due to various interactions with other processes such as precipitation, clouds and radiation. Our initial results are no exception. The Forecast Impact suggests that improvements in relative humidity are evident in the 12 hour forecast (Figure 11.2.2(a)) but are reduced by 24 hours (Figure 11.2.2(b)).

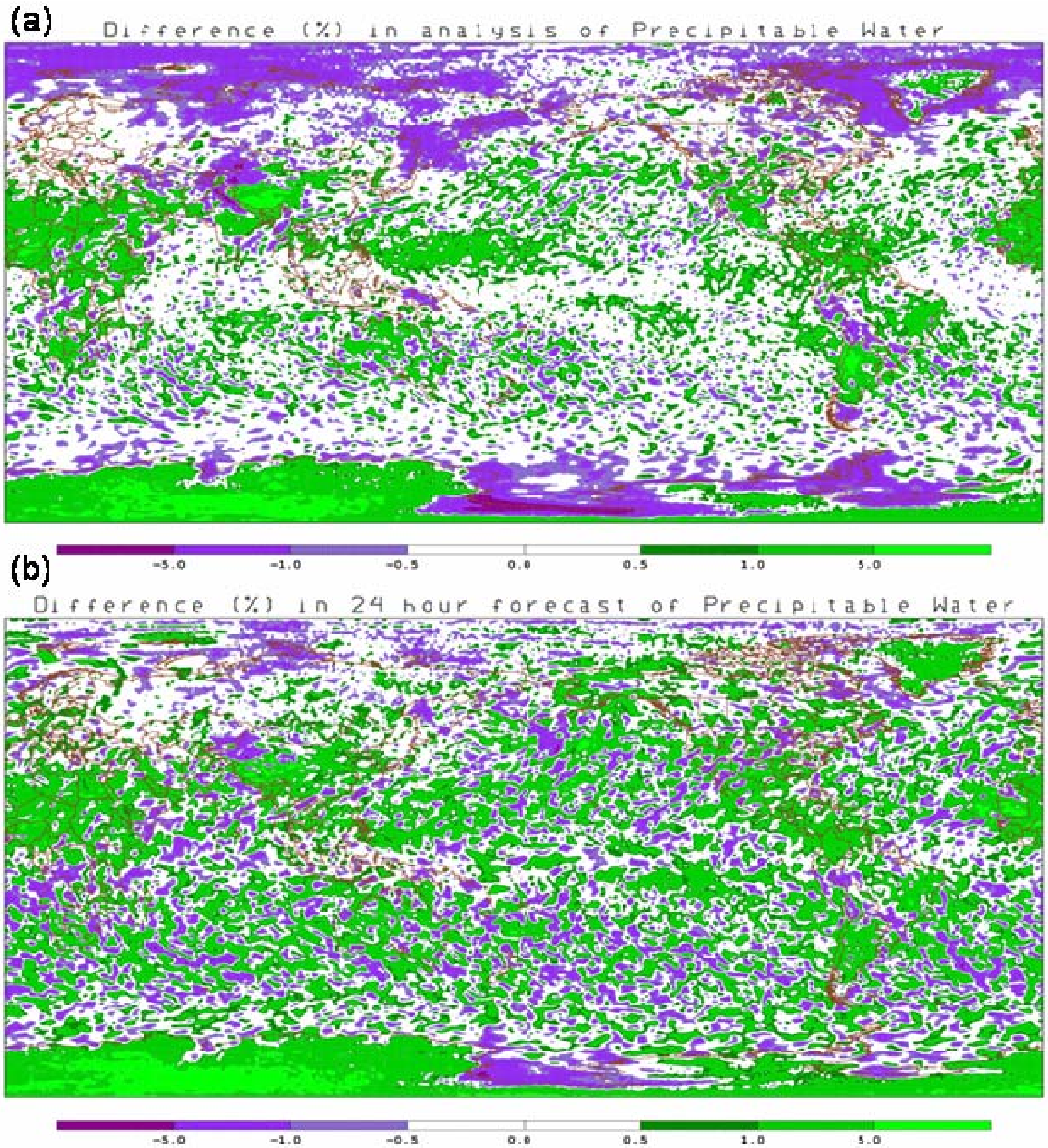


Figure 11.2.1. Geographic distribution of monthly average changes in precipitable water between the control and the experiment for (a) the analysis and (b) the 24 hour forecast. Color bar units are percent [%].

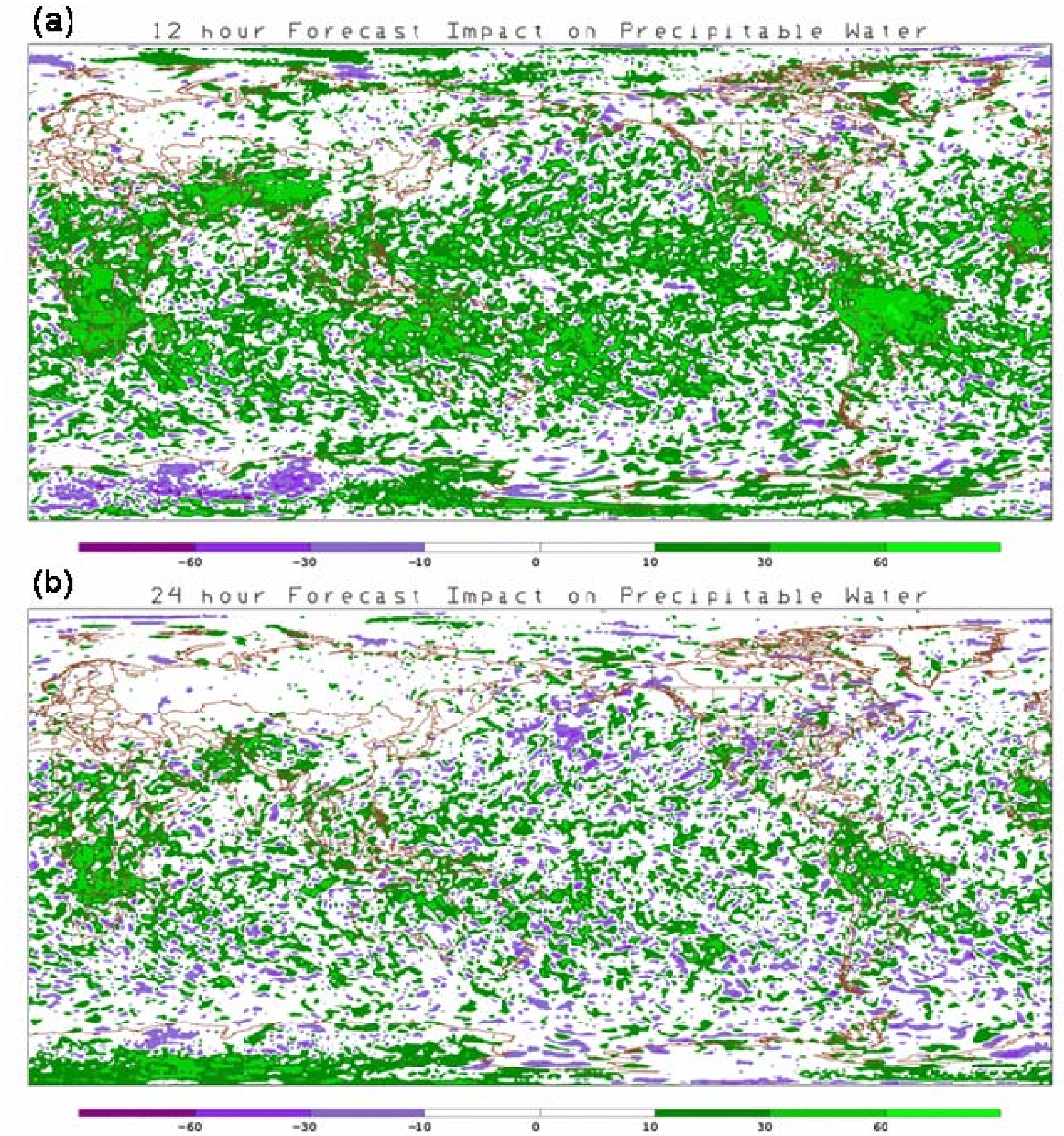


Figure 11.2.2. Geographic distribution of Forecast Impact on precipitable water for (a) 12 hour and (b) 24 hour forecasts. Color bar units are percent [%]

Some of the AIRS and IASI water vapor channels are sensitive to moisture in the stratosphere. When these specific water vapor channels are used to adjust the moisture in the Stratosphere, general circulation features appear in the moisture field. Figure 11.2.3 (a) and (b) depict a large anti-cyclonic circulation in the north Pacific in two layers of the moisture field above the tropopause.

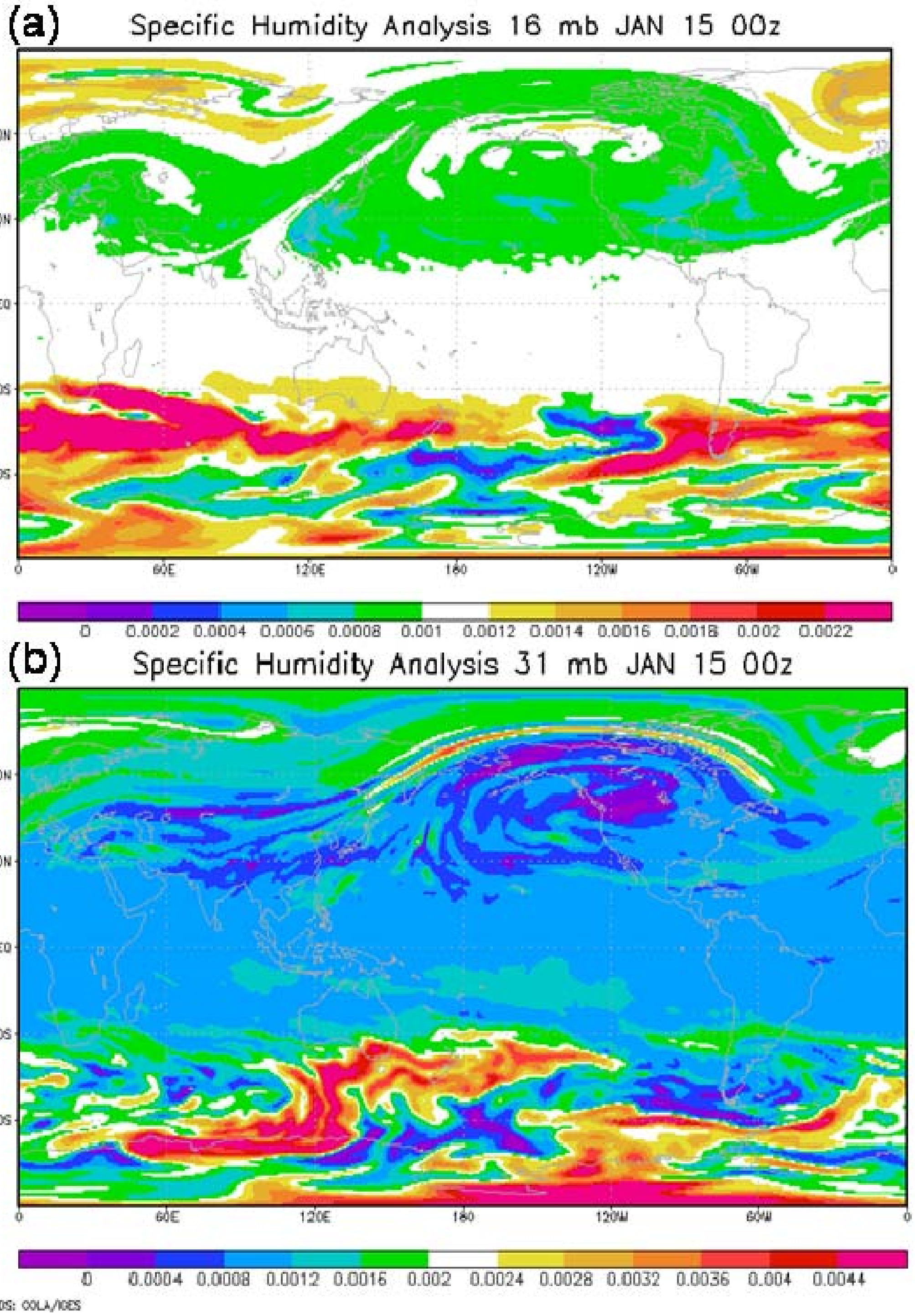


Figure 11.2.3. The specific humidity analysis at (a) 16 hPa and (b) 31 hPa when using some of the AIRS and IASI water vapor channels sensitive to moisture in the stratosphere. Color bar units are g/kg.

The Community Radiative Transfer Model (CRTM) is used by NCEP for data assimilation to simulate the radiance observations. The sea surface emissivity model used by the CRTM is based on work by Wu and

Smith (1997) in which the reflected sea surface emission is taken into account and is treated as lambertian. Work by Hanafin and Minnet (2005) and Nalli et al. (2008a and b) have shown this methodology underestimates the effective emissivity at larger zenith angles due to the quasi-specular reflection of downwelling atmospheric radiance into the sensor field-of-view. The differences between Wu and Smith (1997) and Nalli et al. (2008a and b) model emissivities in the longwave IR window region can be as high as 1%.

The Nalli et al. (2008a and b) model was incorporated into the CRTM by NCEP personnel for comparison to the Wu and Smith model. The Nalli model was implemented as a lookup table of effective emissivities similar to the Wu and Smith model. The ocean surface emissivities studied here are a function of frequency, zenith angle and wind speed. Linear interpolation is performed to determine values between points.

A two season comparison of the two ocean surface emissivity models was conducted using the NCEP GDAS/GFS at the operational resolution. Improvements were noted by the increase in surface channels used over ocean along with a more consistent bias correction at the various scan angles. Improvements in the anomaly correlation stats from using the Nalli et al. (2008a and b) emissivity model were also observed and are shown in Figure 11.2.4.

Other issues are being investigated in relation to the hyperspectral water vapor studies and 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. Some areas of cold temperature biases and lower heights in the stratosphere have also been associated with the assimilation of the hyperspectral water vapor channels. Work is underway to characterize and resolve these. Improvements in characterizing the surface emissivity for all surface types (ocean, ice, land, etc.) are needed to take advantage of the hyperspectral sensors. Other aspects of NCEP's GFS are also being investigated for potential improvements in using the hyperspectral channels such as the CRTM and the forecast model itself by JCSDA and NCEP personnel.

Publications and Conference Reports

Jung, J. A., L. P. Riishojgaard, and J. Le Marshall, 2009: Hyperspectral Infrared Water Vapor Radiance Assimilation. JCSDA 7th Workshop on Satellite Data Assimilation, University of Maryland at Baltimore County (UMBC) Halethorpe, MD, 12-13 May 2009.

Jung, J. A., J. F. Le Marshall, L. P. Riishojgaard, and J. C. Derber, 2009: The Development of Hyperspectral Infrared Water Vapor Radiance Assimilation Techniques in the NCEP Global Forecast System. *ECMWF/EUMETSAT NWP-SAF Workshop on the assimilation of IASI in NWP*, Reading, UK 6-8 May 2009.

Van Delst, P., N. Nalli, J. Jung, and J. Derber, 2009: Implementation of a new infrared sea surface emissivity model in the Community Radiative Transfer Model. 2nd Workshop on Remote Sensing and Modeling of Surface Properties, Toulouse, France, 9-11 June 2009.

Bi, L., J. A. Jung, M. C. Morgan and J. F. Le Marshall 2009: A Two-Season Impact Study of the WindSat Surface Wind Retrievals in the NCEP Global Data Assimilation System. Submitted to *Wea. Forecasting.*

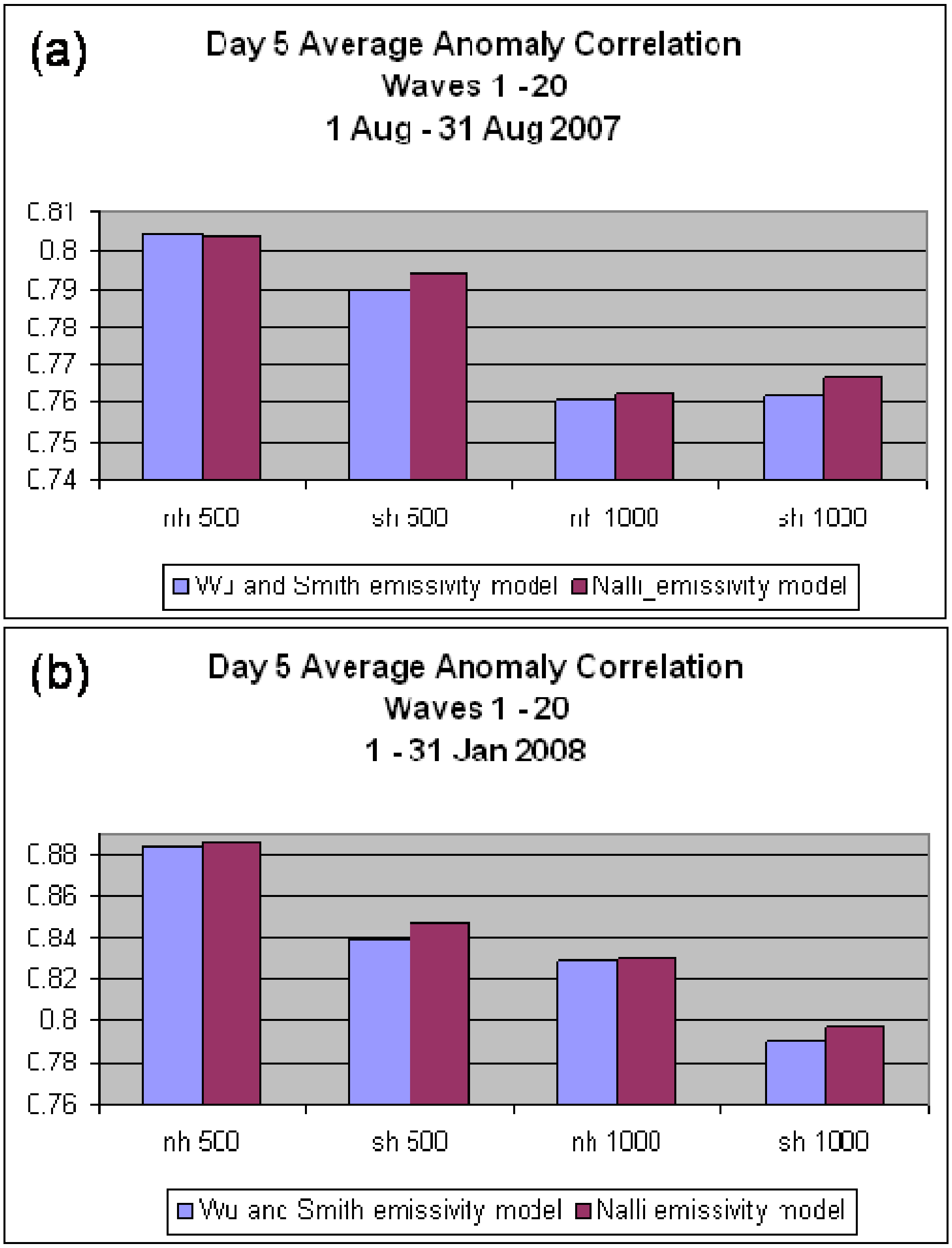


Figure 11.2.4. Monthly average anomaly correlations for the day 5 forecast in the Northern and Southern hemispheres at 500 and 1000 hPa during (a) August 2007 and (b) January 2008.

References

Hanafin, J. A., and P. J. Minnett, 2005: Measurements of the infrared emissivity of a wind-roughened sea surface. *J. Appl. Opt.*, **44**, 398-411.

Nalli, N. R., P.J. Minnett and P. van Delst, 2008a: Emissivity and reflection model for calculating unpolarized isotropic water surface-leaving radiance in the infrared. 1: Theoretical development and calculations. *J. Appl. Opt.*, **47**, 3701-3721.

Nalli, N. R., P. J. Minnett, E. Maddy, W. W. McMillan and M. D. Goldberg, 2008b: Emissivity and reflection model for calculating unpolarized isotropic water surface-leaving radiance in the infrared. 2: Validation using Fourier transform spectrometers. *J. Appl. Opt*., **47**, 4694-4671.

Wu, X., and W. L. Smith, 1997: Emissivity of a rough sea surface for 8-13 µm: modeling and verification. *J. Appl. Opt*., **36**, 2609-2619.

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

CIMSS Project Leads: Ralf Bennartz, Tom Greenwald
CIMSS Support Scientists: Mark Kulie
NOAA Collaborators: Paul van Delst, Yong Chen, Fuzhong Weng, Min-Jeong Kim, Andrew Heidinger
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water information
- 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. Further develop, integrate, and test the Successive Order of Interaction (SOI) forward, tangent linear and adjoint infrared and microwave radiative transfer models within the Community Radiative Transfer Model (CRTM) framework.
2. Determine observation error covariances under cloudy and rainy conditions both in the infrared and microwave separating effects of (1) radiative transfer solvers, (2) approximations in optical properties of clouds and precipitation, (3) cloud overlap assumptions, (4) neglecting three-dimensional radiative transfer and beam filling.
3. Quantify regional and global biases between numerical weather prediction models and observations for different model setups as well as for different cloud microphysical parameterizations.

Summary of Accomplishments and Findings

In close collaboration with JCSDA scientists we have integrated the SOI forward, TL and ADJ models into the CRTM and performed accuracy and speed tests. We are working directly with JCSDA developer team within the NCEP software repository. Our work has shown the SOI is as accurate as the ADA but is 28 to 35% faster, which translates to an overall reduction in the CRTM runtime of 15 to 19% (see Figure 11.3.1). However, situations may exist where the ADA is faster than the SOI. For example, at higher microwave frequencies where scattering can be significant, iterative methods (such as the SOI) are less advantageous and may require the adding method (as used by the ADA). Future work will provide accurate ways to determine when to switch between ADA and SOI.

We are evaluating available scattering property databases (including those in the CRTM) for non-spherical ice particles between 10 and 200 GHz (Kulie et al. 2009). This work is in collaboration with Yong Chen and Fuzhong Weng at JCSDA. It will lead to a better characterization of scattering optical properties as well their forward modeling errors and potentially error covariances.

In collaboration with the Swedish Meteorological and Hydrological Institute we have studied the impact of cloudy infrared radiance assimilation in 4D-VAR mesoscale model framework (Stengel et al. 2009). This work was done in the framework of the HIRLAM mesoscale model. However, results can be easily transferred to other models, since only an appropriate screening of cloudy radiances needs to be performed.

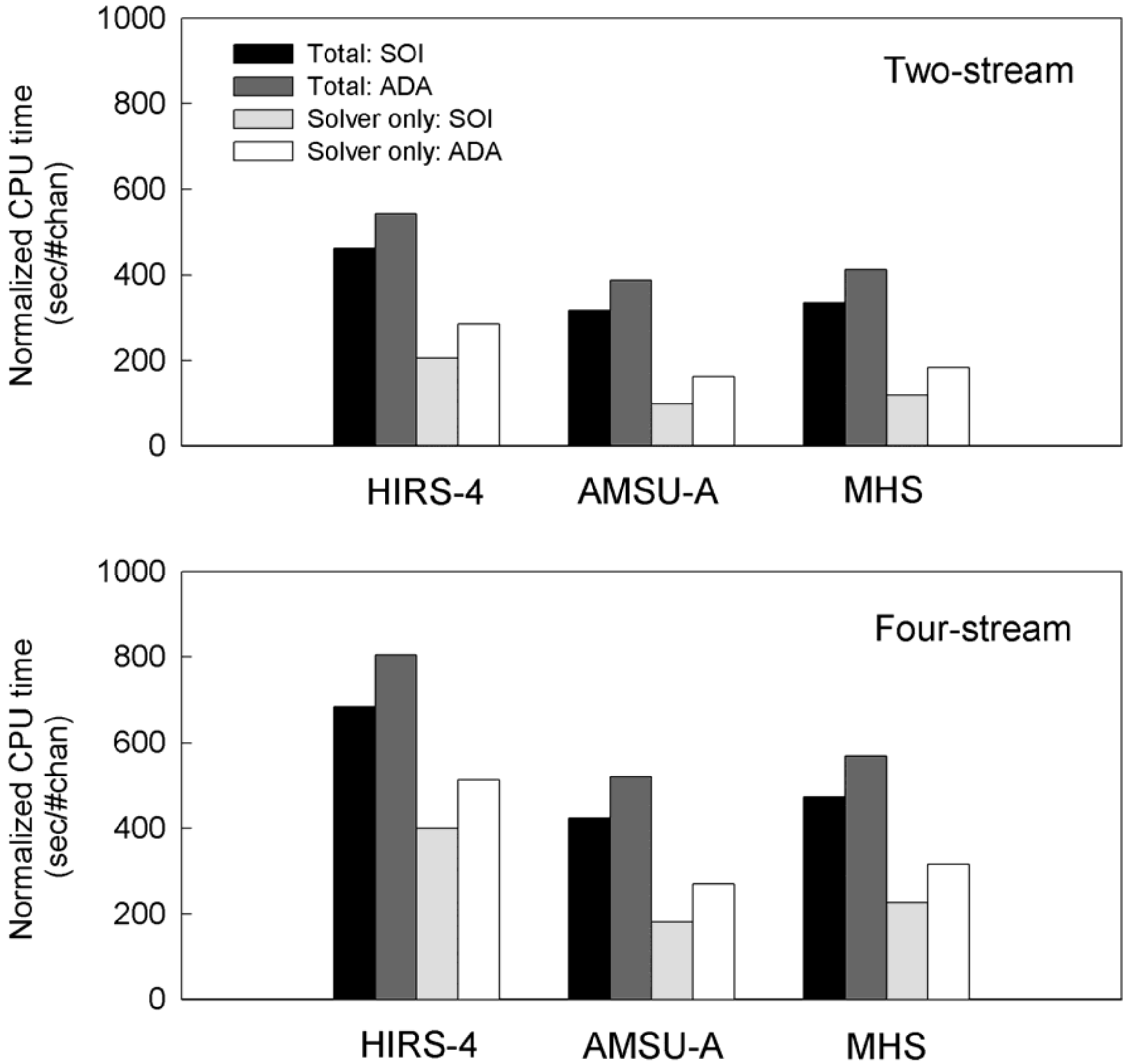


Figure 11.3.1. CRTM timing results for the SOI and ADA at 2 and 4 streams for 3 instruments based on 95,703 model profiles.

Publications and Conference Reports

Kulie, M. S., R. Bennartz, T. Greenwald, Y. Chen, and F. Weng, 2009: Characterizing uncertainties associated with ice particle models in simulating high frequency passive microwave observations of clouds and precipitation. *J. Atmos. Sci.*, in preparation.

Stengel, M., P. Unden, M. Lindskog, P. Dahlgren, N. Gustafsson, and R. Bennartz: 4D-Var assimilation of SEVIRI infrared radiances into the limited-area numerical weather prediction model HIRLAM. *Quarterly Journal of the Royal Meteorological Society*, in press.

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

CIMSS Project Lead(s): Scott Bachmeier, Steve Ackerman
CIMSS Support Scientist(s): Scott Lindstrom, Tom Whittaker, Jordan Gerth
NOAA Collaborator(s): Tim Schmit, Robert Aune, CIRA, WDTB
NOAA Strategic Goals Addressed:

- 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 creating VISITview distance learning modules for the community, in an effort to provide satellite imagery interpretation materials that can be used in education, and also on maintenance and updates to existing satellite lesson material.

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

The presence of fully-functioning AWIPS workstations at CIMSS allows faster development of educational materials on these types of satellite topics (or a freshening of past modules) as new case study datasets are uncovered. This AWIPS capability gives CIMSS the unique ability to present these satellite topics in a context that the NWS forecaster or intern can easily relate to. We also proposed to begin creating lessons in the self-contained Warning Event Simulator (WES) format, which is an AWIPS training format that is widely used by NWS forecast offices. A WES case using simulated ABI data has been developed at CIMSS in an effort headed by Tim Schmit.

We planned to continue to leverage the real-time Advanced Weather Information Processing System (AWIPS) capability at CIMSS to collect a variety of satellite and other remote sensing data during interesting case studies that cover a diverse set of regions and seasons. It was also proposed that CIMSS continue to act as a "beta test site" for 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 we have done with the "MODIS in AWIPS" project since 2006).

Summary of Accomplishments and Findings

Fifty-four online, live tele-training sessions were given to NWS offices during this period, on the following eight topics: CRAS Cloud Products in AWIPS, Mesoscale Convective Vortices, TROWAL Identification, Basic Satellite Principles, Interpreting Satellite Signatures, Water Vapor Imagery and PV Analysis, MODIS Products in AWIPS, and Enhanced-V.

In addition, work began on 3 new modules: 1) Water Quality detection from Satellite, collaborating with Steve Brueske, MIC at MKX, Colleen Mouw at CIMSS and Galen McKenzie, AOS; 2) Satellite products in AWIPS; 3) PREs (Predecessor Rain Events) with tropical cyclones; and 4) Nearcasting Convection in collaboration with Bob Aune and Ralph Petersen.

As an adjunct to the teletraining, the VISIT project now maintains an on-line blog that provides not only a basis for new modules, but also supplemental information and examples for existing VISIT teletraining modules. Presently, there are nearly five hundred posts, covering 33 categories, ranging from Air Quality to Winter Weather. The URL of this blog is http://cimss.ssec.wisc.edu/goes/blog

In order to ensure VISIT is meeting the needs of the forecasters, site visits were made to 3 NWS offices.

We have also begun to test the process of providing AVHRR data in AWIPS (using the same method as the "MODIS in AWIPS" effort that began in 2006). Currently we have a suite of 6 AVHRR products available in AWIPS format: Sea Surface Temperature, Cloud Type, Cloud Top Temperature, Cloud Top Height, Cloud Optical Depth, and Cloud Particle Effective Radius. We will be adding individual AVHRR channels (visible, shortwave IR, longwave IR) to this list of AWIPS products. All products are made available to NWS offices who wish to add the AVHRR products to their local AWIPS via LDM subscription. Figure 12.1 illustrates an example of a MODIS water vapor image as displayed in AWIPS.

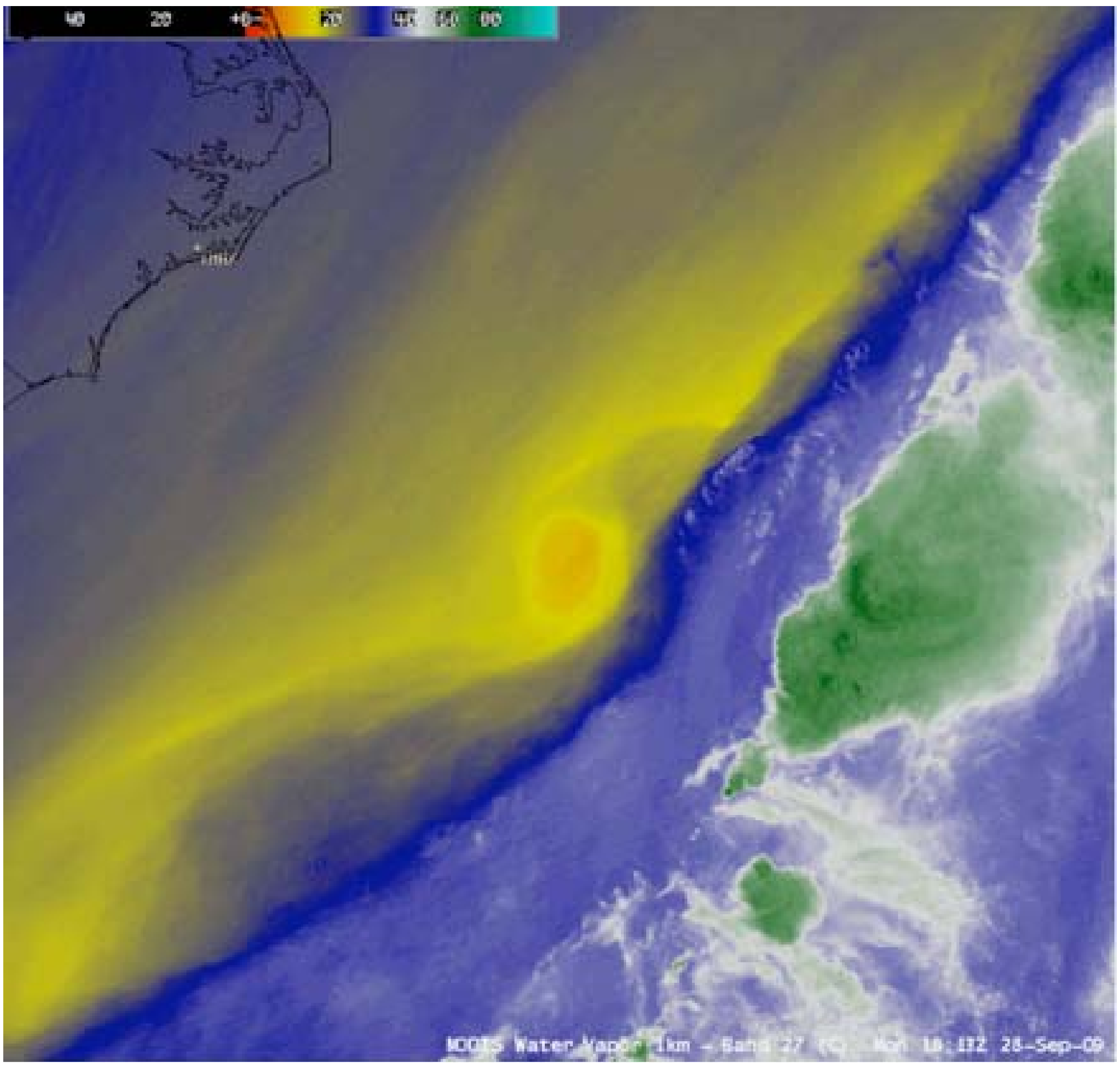


Figure 12.1. MODIS data displayed on AWIPS showing a vortex along the axis of a jet stream.

We have been participating in the evaluation of AWIPS-2 Task Order releases in corroboration with the National Weather Service 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 translation of local enhancements created under the original AWIPS operational build deployments.

13. SHyMet Activities

CIMSS Project Lead: Steve Ackerman, Scott Bachmeier
CIMSS Support Scientist: Bill Bellon, Scott Lindstrom
NOAA Collaborator: Gary Wade, Tim Schmit
NOAA Strategic Goals Addressed:

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

Proposed Work

CIMSS continues to participate in the Satellite Hydro-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 education activities, 4) develop and test appropriate satellite education materials, and 5) assist in the teaching of the courses as appropriate.

Summary of Accomplishments and Findings

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 lessons for the training topics "GOES Sounder Data and Products" and "GOES High Density Winds." The "GOES Sounder Data and Products" lesson provides 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 reviews techniques for measuring satellite winds (atmospheric motion vectors), and provides details on the display of GOES high density winds on AWIPS. These distance learning courses were again delivered in 2009 using the VISITview software. The VISIT teletraining lesson on the Water Vapor Channel Satellite Imagery is being transferred to SHyMet, the recording of this is nearly completed. was completed and added to the SHyMet curriculum. The VISITview teletraining "Interpreting Satellite Signatures for SHyMet" has been converted for the SHyMet course for Satellite Imagery and Products in the Forecast Process.

CIMSS staff are tasked with maintaining the lessons, evaluating feedback from the course, and making appropriate modifications based upon input from the students.

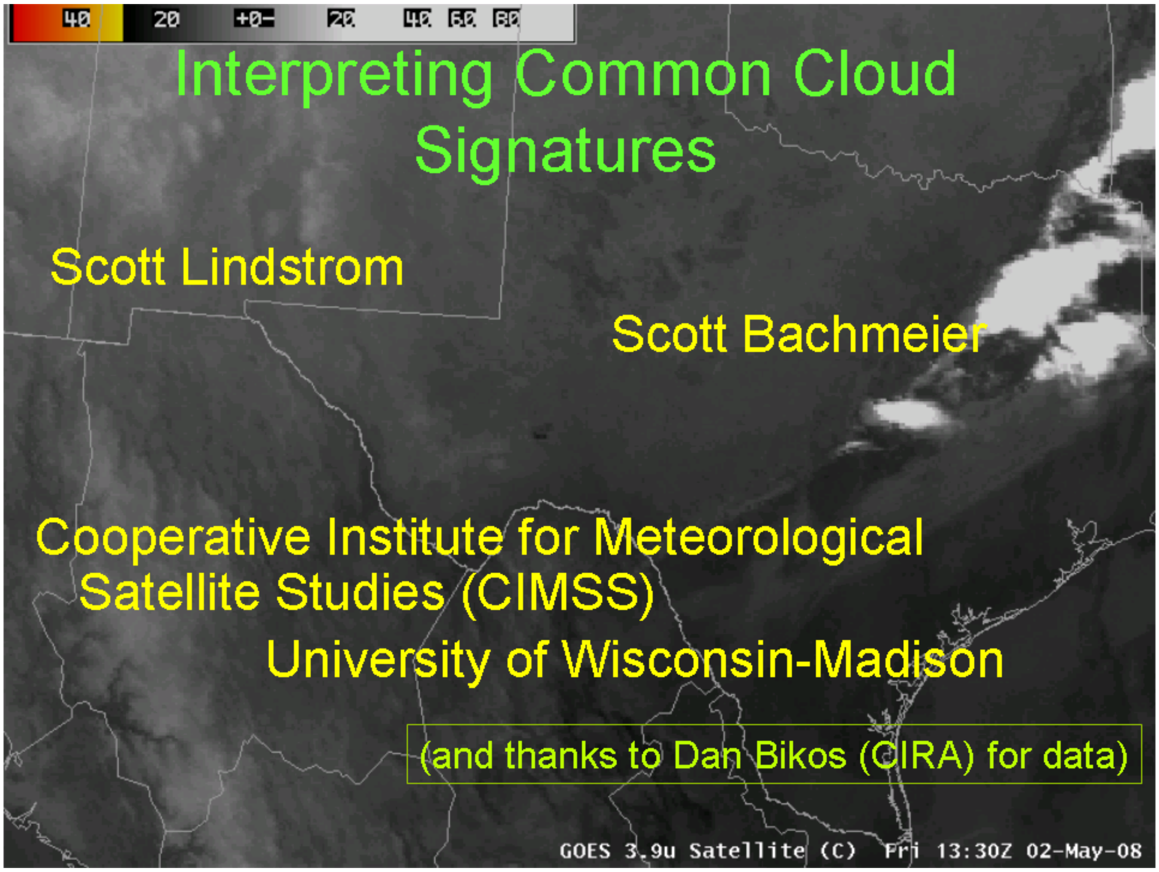


Figure 13.1. Title slide from the new SHyMet lesson on interpreting satellite signatures for SHyMet.

14. Estimation of Cloud Microphysics from MODIS Infrared Observations

Task Leaders. Sebastien Berthier
NOAA Collaborators: Andrew Heidinger
NOAA Strategic Goals addressed:

- Weather and water
- Climate

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.
- 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 NPOESS. 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

Assessment of the cloud microphysics parameters

We have to deal in this project with the estimation of cloud optical depth and particle size.

With knowledge of the effective cloud temperature as well as the clear-sky radiance and transmittance profiles generated from a radiative transfer model (RTM), one can derive ε_{11} and ε_{12}.

The first step is thus to retrieve the emissivity from the MODIS radiances. The corresponding emissivity ε_i is processed from the Radiance R_i using the following relation:

$$\varepsilon_i = \frac{(R_i - R_i^{clear})}{(R_i^{blc}(T_{cloud}) - R_i^{clear})}$$

Where R_i is the radiance at the channel i, R_i^{clear} is the clear radiance and R_i^{blc} is the radiance that would result from a black cloud with effective cloud top temperature T_{cloud} for the same atmosphere.

Given this process of the emissivity, we have investigated a way to retrieve the value of the cloud optical thickness. This last value could be easily obtained from the integration of the extinction given inside the CALIOP level 2 datasets.

Using a two days datasets (10th and 28th of August 2006), we perform our own collocation to establish a basis of comparison.

Using flags given inside both MODIS datasets, we are able to separate daytime and nighttime measurements. Thanks to the CALIOP flags, we are able to avoid multilayered cloud scenes. Using the cloud phase function given by the Baum et al. method, we are also able to select only ice cloud.

Figure 14.1 gives the 2D-distribution of the emissivity at 11um (channel 31) in function of the CALIOP optical thickness.

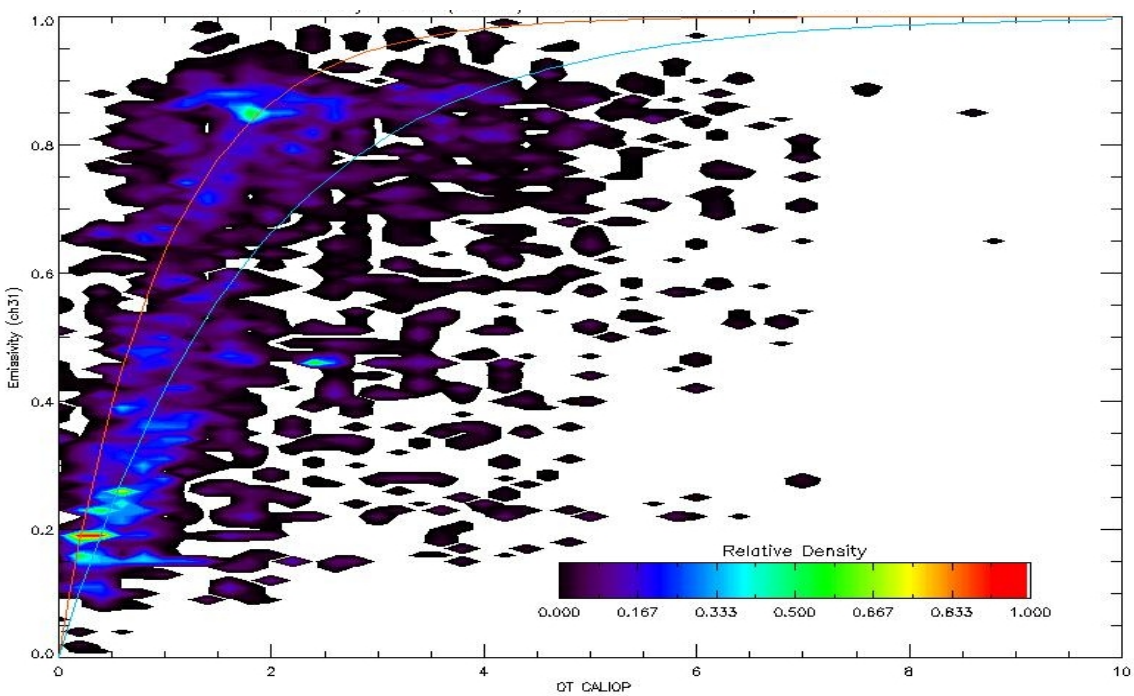


Figure 14.1. Emissivity in channel 31, as determined from MODIS data, in function of the Optical Thickness as determined from the CALIOP data. The red line gives the best fit of this distribution (k equal to 0.96)

The dependence between the emissivity and the Optical thickness is known to be described by the general equation:

$$\varepsilon_{11} = 1 - \exp\left(\frac{-k.\tau}{\mu}\right)$$

Given the value of emissivity at 11um and the CALIOP OT, we have been able to determine the value of k. We find a histogram showing a maximum value at k equal to 0.96. The red line in the figure 14.1, seem to fit the distribution. We notice that the performance is better for optical thicknesses greater than 1.5.

For OT less than 1.5, we need to lower the value of k to fit this distribution to value around 0.5 (blue line in the figure 14.1).

Knowing the behavior of this k parameter will help us to fix the relation between this two parameter, an therefore to invert MODIS datasets to obtain OT at the global scale.

Assessment of a robust metrics of cloud microphysics

In the same time, we search also in this project to investigate robust metrics of cloud microphysics that can be easily estimated with a minimum of *a priori* assumptions.

We use in this study the parameter, β, which is a very robust metric of the cloud microphysics (ice, water, even dust aerosols), and is defined as:

$$\beta_{11,12}(p) = \ln(1-\varepsilon_{11}) \big/ \ln(1-\varepsilon_{12})$$

where ε is the emissivity in the 11 and 12 um windows.

The assess β, a measure of the effective cloud temperature is needed. Because the CO_2 slicing results are largely insensitive to cloud microphysical and optical properties, one can argue that the resulting β estimate provides a robust indicator of cloud microphysics.

To determine the value of De, we rely on the Yang model (see Yang et al. 2005), which describes the dependence of β to the effective diameter De. The Yang et al. models describe this dependence for all type of particle shape. In this part of the study, we select the agglomerate shape.

We process the value of De with this method, considering two day of the MODIS datasets (the 10 and 29th of august 2006) (see Figure 14.2). Processing the histogram of the De parameter, we find a maximum occurring around 20 μm.

By using this methodology, we can separate the process of the histogram following daytime (red line) and nighttime (blue line) measurements. Very similar distributions are retrieved, which seem to show the consistence of our method between nighttime and daytime measurements.

Some variability are retrieved in this curves, but this lasts could be explained by the few datasets (only two days) used actually in the study.

We are actually pursuing our effort to characterize the De parameter, and proving the validity of our method, by extending the used datasets to one complete month of data. By this way, we will soon also be able to extend the analysis to the global scale, and describe the geographic distribution of this parameter.

Publications and Conference Reports

Berthier, Sébastien and Andrew K. Heidinger, 2009: Estimation of Cloud Microphysics from Nighttime MODIS Infrared Observations. In preparation.

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.

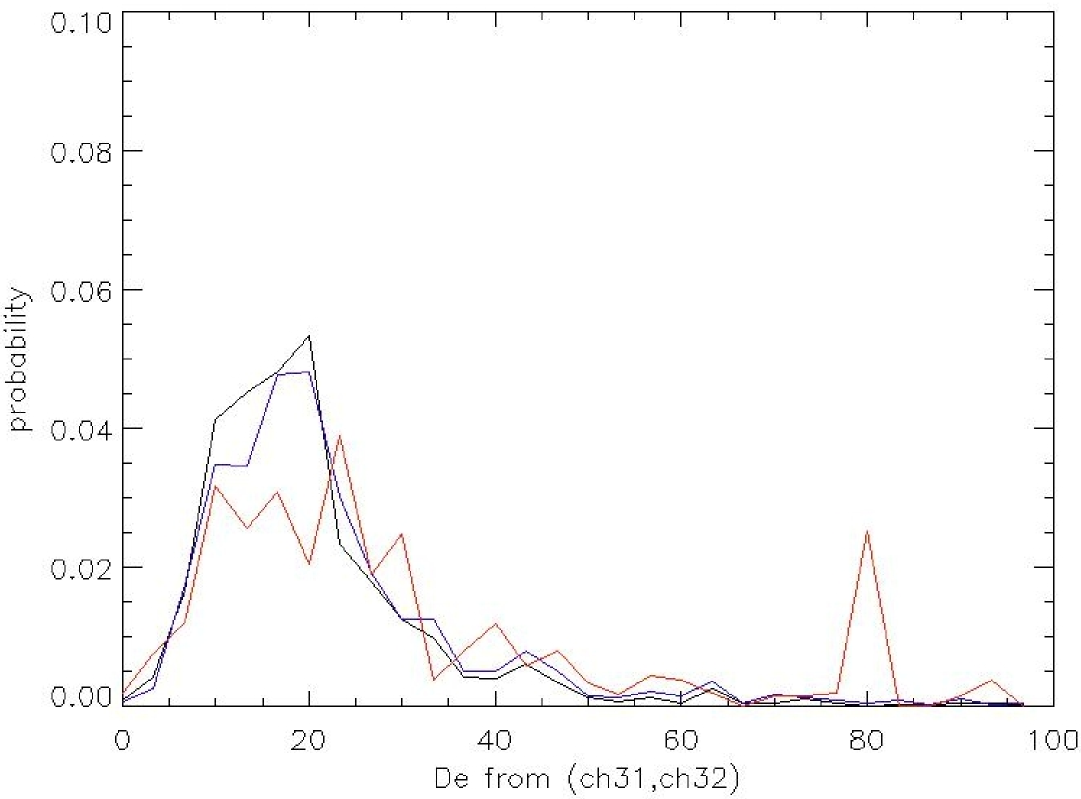


Figure 14.2. Particle effective diameters distribution as determined from our algorithm applied to the MODIS data. Red (Blue) curves correspond to Daytime (Nighttime) measurements, and the black line corresponds to both conditions.

15. Support for the WVSS-II Field Program

CIMSS Project Leads: Ralph Petersen, Wayne Feltz

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

CIMSS Research Themes

- Weather nowcasting and forecasting

Proposed Work

CIMSS will conduct a third ground-truth assessment of the WVSS-II systems being flown on UPS aircraft at either Louisville, KY and/or Rockford, IL. Proposed objectives included: 1) assessing the accuracy of WVSS-II observations from the re-engineered WVSS-II units by comparing them to rawinsonde observations and 2) continue to provide guidance about optimal water vapor observing strategies through the ongoing evaluation of temporal moisture variability intended to help define the temporal and spatial requirements for aircraft observations.

Summary of Accomplishments and Findings

At the request of the National Weather Service, work on this project has been reduced to a minimal level for the past year, pending installation of re-engineered WVSS-II on UPS aircraft. Although these installations were expected at the beginning of the calendar year, a variety of engineering, pre-testing and certification issues have delayed the installations until late-summer and fall. As a result, the proposed Rawinsonde/WVSS-II co-location tests are now planned for a short period in the fall of 2009 and a longer period in the spring of 2010.

Observing Systems Available for WVSS-II Validation and Status of Intercomparisons

Although no rawinsonde comparisons have yet been made using the re-engineered WVSS-II units, a limited data set has been provided by Randy Baker of UPS which allows comparison the WVSS-II data with measurements from surface METAR stations. (It should be noted that the METAR moisture sensor has less error that rawinsonde sensors, so in some senses these data provide a better measure of absolute accuracy of the WVSS-II instrument than airborne tests.) The results, shown in Figure 15.1, indicate that, for observations taken at the surface with little or no airplane motion, the WVSS-II data have almost no systematic error (Bias) and extremely small random error (Standard Deviation - StDev). In addition, the StDev in Dewpoint Temperatures derived from the fundamental mixing ratio reports is ~50% that of the aircraft Temperature reports, and again without bias. As such, any biases noted in derived Relative Humidity (RH) are almost completely the result of errors in temperature observations, while ~60-70% of the random RH error is the result of aircraft temperature errors. When the temperature error components are removed, the moisture errors account for and RH error of <4%, a value with exceeds the accuracy of most rawinsonde sensors and all WMO requirements.

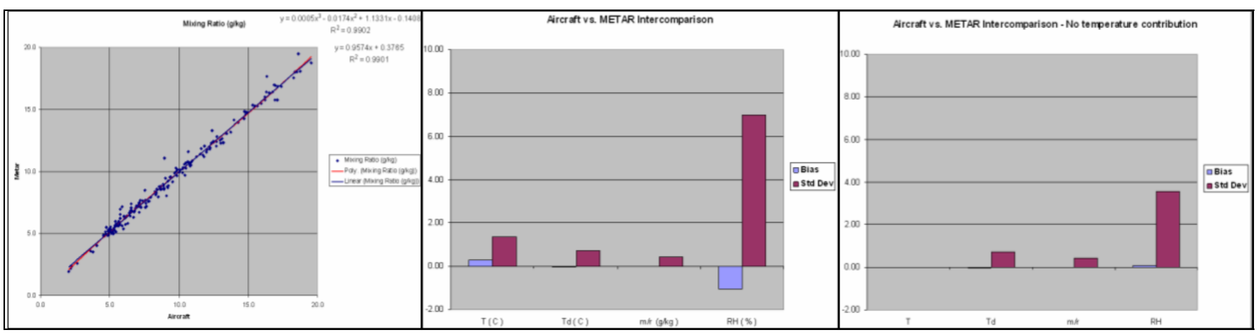


Figure 15.1. Comparisons of WVSS-II equipped aircraft observations with co-located surface METAR reports. Left Panel - Scatter plot of WVSS-II and METAR Mixing Ratio observations including linear and quadratic fits; Center Panel - Bias and Standard Deviation of aircraft Temperature (T), Mixing Ratio (m/r) with derived Dewpoint Temperature (Td) and relative Humidity (RH) using METAR observations as 'truth'; Right Panel - Same as Center Panel, but for (idealized) case with aircraft Temperature errors removed (considering only m/r errors).

Temporal Moisture Variability Evaluation

Effort in this area was also minimized during 2009 both due to the delays described above and to assure that assets would be available to complete the required field testing. Previous analyses of existing high time resolution boundary layer moisture profiles were also begun to help determine the optimal moisture observing frequency. Using-term time series of 7.2 minutes frequency AERI moisture profiles from surface-700 hPa made at the DOE ARM/CART site at Lamont OK were used to assess the observed temporal (and spatial in future) moisture variability. A two-sided quality control procedure similar to that used in the Wind Profiler evaluation discussed in the report form last year was applied to the AERI moisture profiles as an additional check for possible cloud contamination or other intermittent errors. It should be noted that these data were only available in clear sky conditions. After substantial investigation, the sources of a number of errors in the ARM/CART data sets have been identified are in the process of being corrected at CIMSS, at which time the analyses can be completed.

Results from multiple seasons for the period from 2002-2004 continue to indicate that observations of moisture changes taken no more frequently than 1 per hour may not be sufficient to detect many significant moisture changes which occur in the atmosphere, especially those related to hazardous weather events. This applied both to increases in moisture in the lowest levels and the simultaneous decrease of moisture in the upper part of the boundary layer, a necessary condition for the development of convective instability. Collaborations have been established with NOAA/ESRL personnel whose evaluations using surface GPS-based Total Precipitable Water data have shown similar results.

Publications and Conference Reports

Petersen, R, S Bedka, W. Feltz, E. Olson and D. Helms, 2009: WVSS-II moisture observations – A low-cost tool for validating and monitoring the quality of a-synoptic satellite moisture measurements. EUMETSAT Satellite Conference, September 2009, Bath, UK.

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

CIMSS Project Lead: Xuanji Wang
CIMSS Support Scientist: Yinghui Liu
NOAA collaborator: Jeffrey R. Key
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

CIMSS Research Themes:

- Climate

Proposed Work

The availability, consistency and accuracy of cryospheric products, namely snow and ice, are critical for a wide range of applications ranging from climate change detection, climate modeling, and operational uses such as 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 will 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 is a new project that started in July 2009. This report covers three months of effort from 1 July 2009 to 30 September 2009. During this period, the primary accomplishment was to inventory existing algorithms and models, begin data collection, and revise our retrieval tool, i.e., CASPR algorithms, especially for consistent cloud detection and inter-satellite data calibration. Based on our experience in producing long-term geophysical fields from satellite data, as demonstrated in Figure 16.1 and 16.2 for ice thickness, extent, and volume, we will upgrade the eXtended AVHRR Polar Pathfinder (APP-x) products. This involves the production of both FCDRs and TCDRs. The APP-x products currently include also climate information about clouds, surface temperature and albedo, and radiation. Our APP-x products have been used to detect changes and trends that in some cases were counter-intuitive, e.g., an increase in cloud amount over the central Arctic during the spring, but a decrease in the winter (Wang and Key, 2003, 2005a, 2005b). They have also been instrumental in assessing the relationship between surface albedo and vegetation changes in Alaska, the "damping" effect of clouds on Arctic warming, and the relative roles of surface temperature, radiation, moisture advection and surface evaporation on sea ice cover trends (Chapin et al. 2005; Liu et al. 2007, 2008; Francis et al. 2005). More recent studies with APP-x include Fernandes et al. (2009) and Liu et al. (2009).

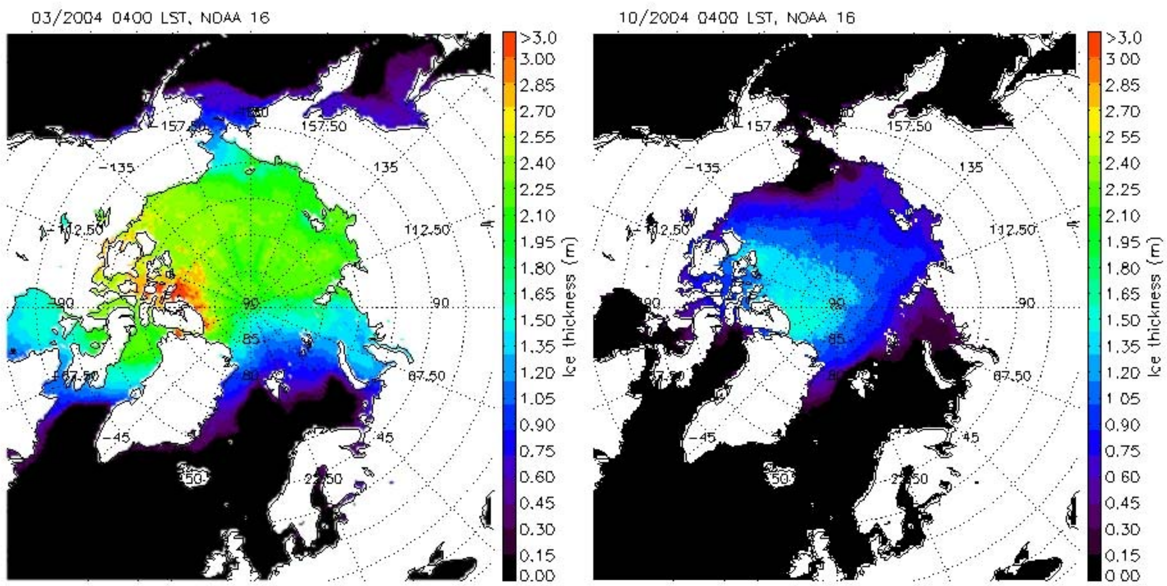


Figure 16.1. Arctic sea ice thickness distribution in March (left) and October (right) in 2004 retrieved by OTM with AVHRR Data at 04:00 local solar time on monthly average.

Publications and Conference Reports

Wang, X., J. R. Key, and Y. Liu, 2009: A thermodynamic model for estimating sea and lake ice thickness with optical satellite data. *J. Geophys. Res.*, submitted, September 2009.

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.*, in press, October 2009.

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. *Geophysical Research Letters*, in press, October 2009.

References

Chapin, F.S., M. Sturm, M.C. Serreze, J.P. McFadden, J.R. Key, A.H. Lloyd, A.D. McGuire, T.S. Rupp, A.H. Lynch, J.P. Schimel, J. Beringer, H.E. Epstein, L.D. Hinzman, G. Jia, C.-L. Ping, K. Tape, W.L. Chapman, E. Euskirchen, C.D.C. Thompson, J.M. Welker, and D.A. Walker, 2005: Role of land surface changes in Arctic summer warming. *Science*, **310**, doi: 10.1126/science.1117368, October 28.

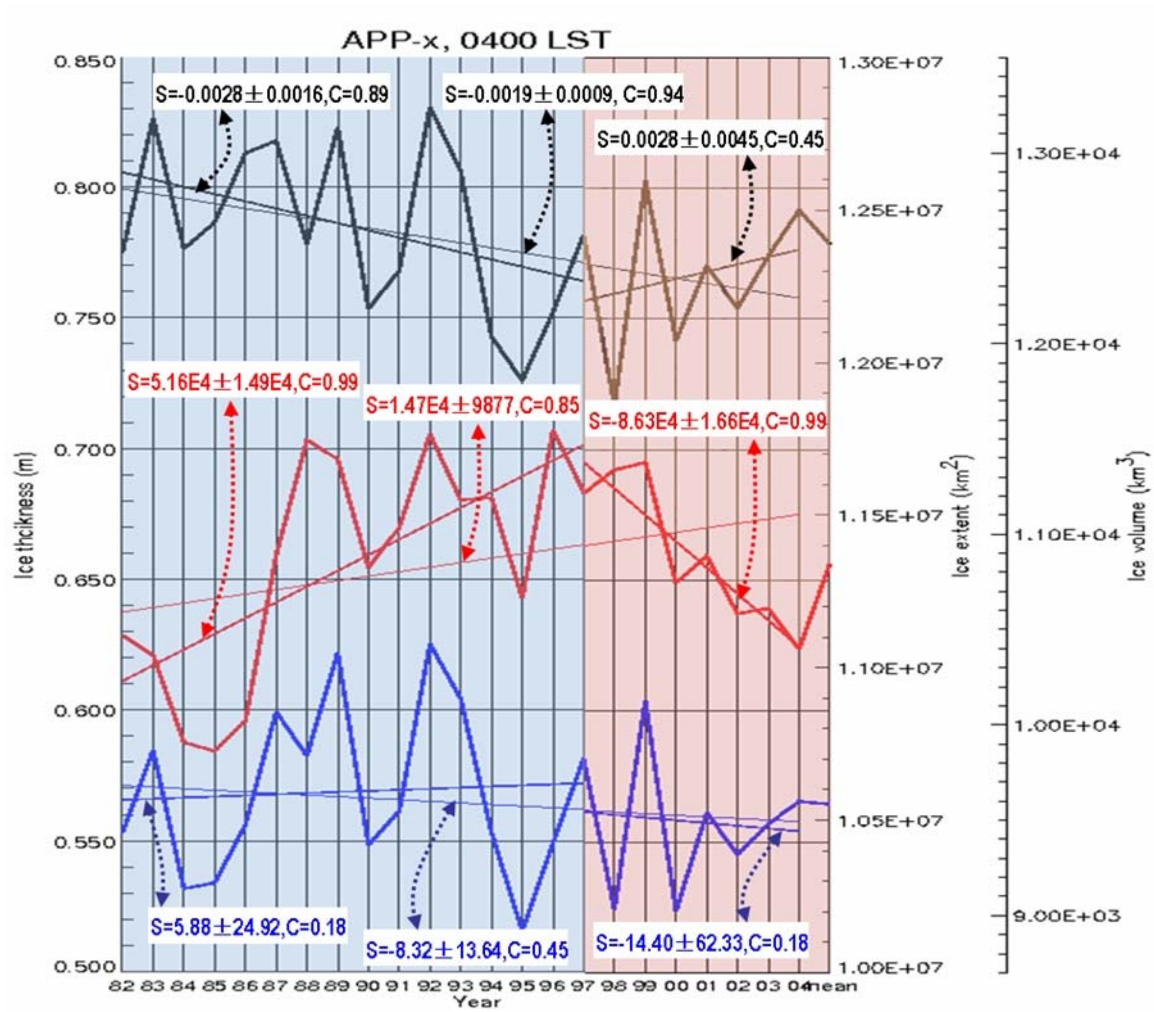


Figure 16.2. Trends in sea ice thickness (black), sea ice extent (red), and sea ice volume (blue) on annual average for the Arctic ocean north of 60^{o}N for three periods: 1982~1997, 1982~2004, and 1997~2004. The pair of S and C denotes the corresponding period trend slope per year with its standard deviation and F test confidence level, respectively.

Francis, J.A., E. Hunter, J. Key, and X. Wang, 2005: Clues to variability in Arctic minimum sea ice extent. *Geophys. Res. Letters,* **32**, L21501, doi: 10.1029/2005GL024376, November 15.

Liu, Y., J. R. Key, and X. Wang, 2008: The influence of changes in cloud cover on recent surface temperature trends in the Arctic. *J. Climate*, **21**, 705-715.

Liu, Y., J. Key, J. Francis, and X. Wang, 2007: Possible causes of decreasing cloud cover in the Arctic winter, 1982-2000. *Geophys. Res. Letters*, **34**, L14705, doi:10.1029/2007GL030042.

Wang, X. and J. R. Key, 2005a: Arctic surface, cloud, and radiation properties based on the AVHRR polar pathfinder data set. Part I: Spatial and temporal characteristics. *J. Climate*, **18**, No.14, 2558-2574.

Wang, X. and J. R. Key, 2005b: Arctic surface, cloud, and radiation properties based on the AVHRR polar pathfinder data set. Part II: Recent trends. *J. Climate*, **18**, No.14, 2575-2593.

Wang, X. and J. R. Key, 2003: Recent trends in Arctic surface, cloud, and radiation properties from space. *Science*, **299**, 1725-1728.

17. NPOESS Projects

17.1. VIIRS Cloud Studies for NPOESS

CIMSS Project Lead: Richard Frey
CIMSS Support Scientists: Sebastien Berthier, Mike Foster
NOAA Collaborators: Andrew Heidinger
NOAA Strategic Goals Addressed:

- 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 VIIRS cloud mask has been produced using several months of Aqua data, including twelve contiguous months from July 2007 through June 2008. This has been accomplished using the Atmospheric Product Evaluation And Test Element (PEATE) processing system at CIMSS. A comparison example is shown in Figure 17.1.1. Plotted is the percentage of collocated CALIOP and VIIRS cloud mask (version 1.5) results that were in agreement ("hit rate") during the twelve months above, given that the locations were over non-polar land surfaces. Also shown is the agreement between CALIOP and the Collection 5 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. The hit rate varies from about 82-86 percent, generally about 2 percent lower agreement than for MOD35. The VCM for nighttime land conditions agrees less often with CALIOP (77-85 percent), and is as much as 7 percent lower than MOD35 during the Northern Hemisphere winter months. Similar studies were performed for nighttime land, day and night oceans, and polar regions. Global, day and night statistics for the month of August 2006 show the overall agreement between the VCM version 1.5 and CALIOP to be 79.2 percent. The agreement between Collection 5 MOD35 and CALIOP for this month was 86.8 percent.

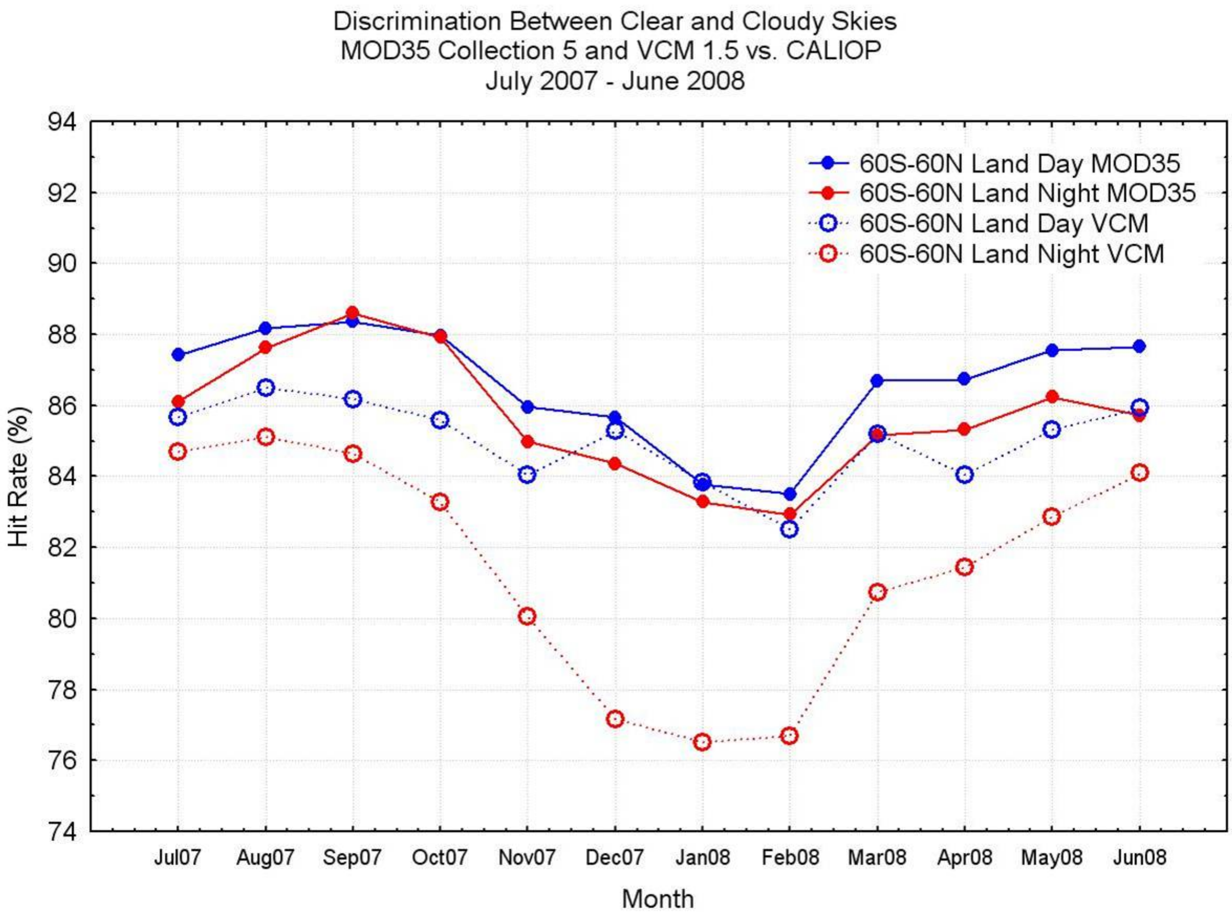


Fig 17.1.1. Agreement between VCM and CALIOP cloud detection algorithm (dotted lines) MOD35 agreement is also shown for comparison (solid lines). Blue lines indicate non-polar daytime land scenes, while red is for nighttime land.

Individual cloud test thresholds have also been evaluated by using collocated CALIOP to define clear-sky locations. Thresholds were evaluated using proxy MODIS radiances collected on August 28, 2006. Figure 17.1.2 shows an example of this evaluation for the 11-3.9 μm brightness temperature difference (BTD) cloud test over ice-free, daytime ocean surfaces. The plot shows a cumulative histogram of 11-3.9 μm BTDs for clear-sky conditions as defined by CALIOP. The high-confident clear threshold is marked in the figure by the solid red line. One can see that approximately 95 percent of clear observations have values of BTD greater than the threshold of -8K. Similar work was done for other VCM threshold cloud tests where appropriate proxy data were available.

In addition to the VCM work, we have also made progress on the VIIRS Nighttime Cloud Properties Algorithm. The VIIRS approach is based on a relatively new 4-channel approach developed by Northrup Grumman, the VIIRS contractor. Our goal has been to explore the validity of the assumptions made by the approach and to assess the overall accuracy.

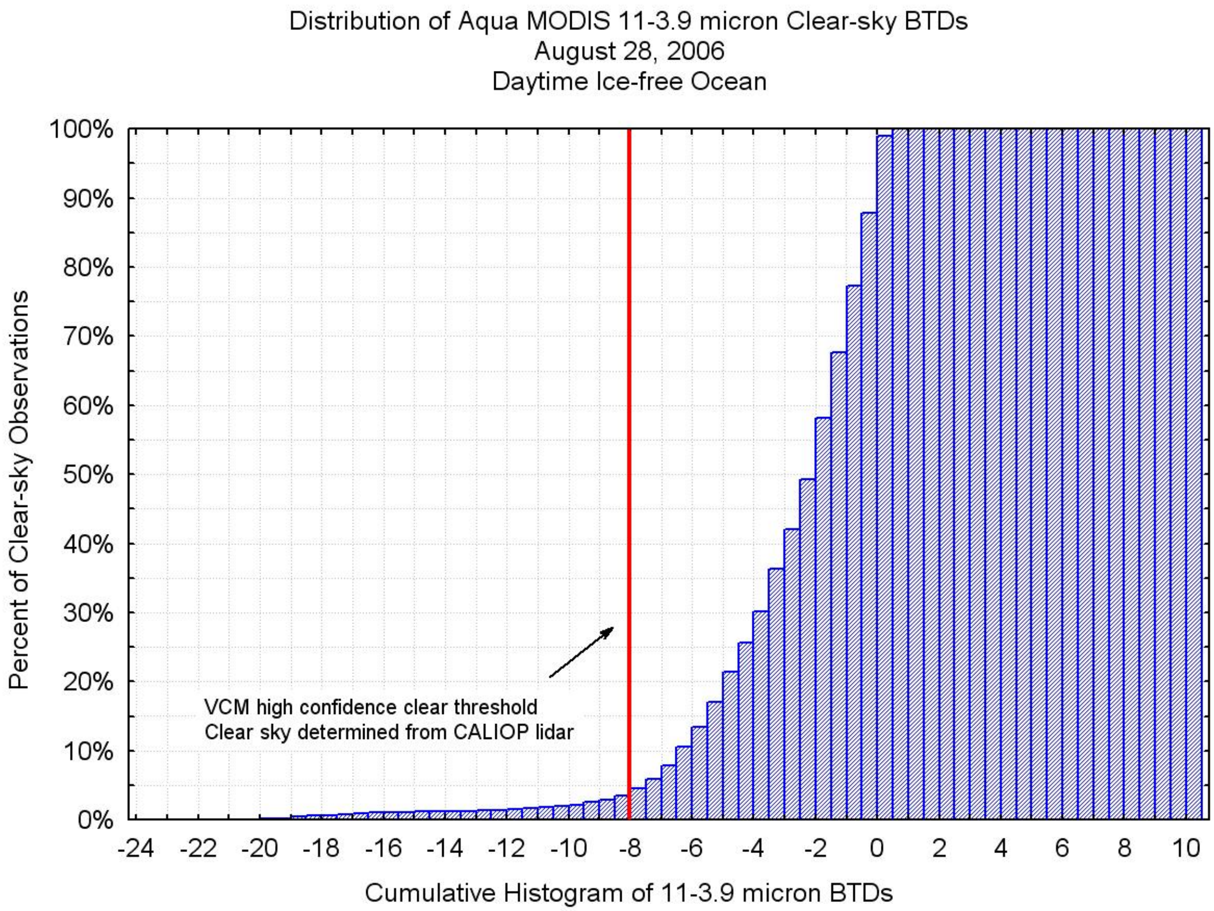


Figure 17.1.2. Cumulative histogram of daytime, ice-free ocean, clear-sky observations of MODIS 11-3.9um BTDS. The VCM confident clear threshold is indicated by the red line. Reflectances >-8K are labeled clear by this test in the VCM.

In a poster presented at the AMS, we demonstrated that the assumed microphysical models employed by the baseline VIIRS approach did not match those inferred from observations. We have demonstrated the benefits of modifying the operational VIIRS algorithm using new IR scattering models provided by Ping Yang (Yang, 2000) of Texas A&M University.

In the following example scene, we retrieve a mean value of 12.98±2.53 km for the cloud top altitude, a mean value of 58 ±14 μm for the Particle Effective Diameter, and a mean value of 217 ±17 K for the cloud top temperature. The following comparisons demonstrate the performance of the modified VIIRS results applied to MODIS data to those from standard MODIS products (MYD06). Figure 17.1.3 shows an image of the Cloud Top Temperature Comparison (CTT). A strong correlation of about ~0.96 was observed between cloud top temperature from the modified VIIRS and the MYD06 cloud product on the cirrus areas. The results of the standard VIIRS approach are not shown because for this scene, the baseline approach did not converge for many of the cloudy pixels. This cause of this behavior is the incorrect microphysical assumption employed in the baseline approach. We refer to the baseline VIIRS approach modified with microphysical parameters from Ping Yang's data as the modified VIIRS approach. We have communicated these issues to NGST and the IPO.

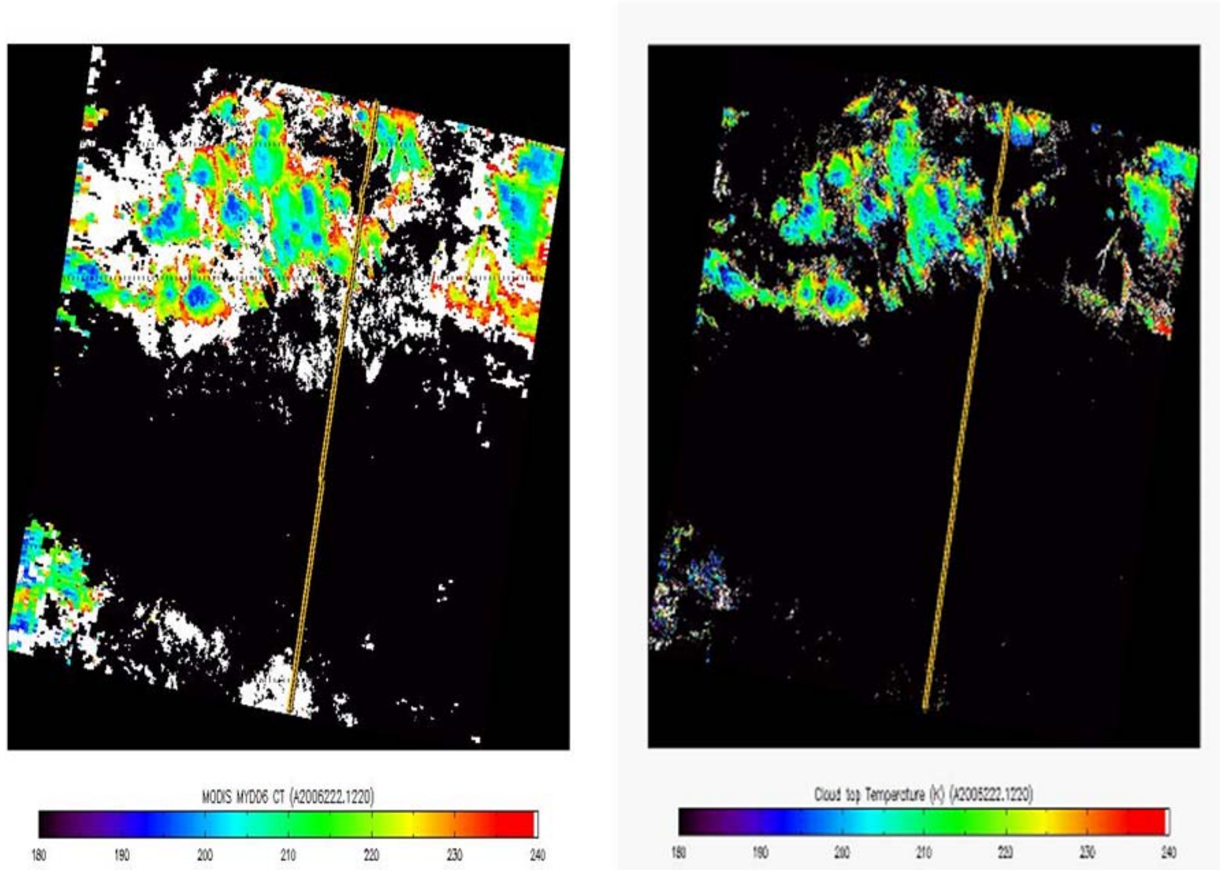


Figure 17.1.3. MODIS MYD06 (left panel) and Modified VIIRS Cloud Top Temperature (right panel). The yellow line gives the path of CALIOP.

With the launch of CALIPSO and CloudSat in EOS A-Train, NASA has provided us a new opportunity to evaluate the characteristics of cloud remote sensing from passive instruments. This data has been a critical component of our project. During this year, we have used the CALIPSO data to characterize the performance of the VIIRS approach. Comparisons are made between the cloud layers detected by CALIPSO and the heights from our modified VIIRS product. The results show a strong correlation of ~0.92 for cloud top altitude in the case of single layer clouds. As expected (see Berthier et al. 2008), we retrieve an underestimation of the cloud top height in the case of multilayered structure. Results of this study have been presented in an oral presentation at AMS conference in January 2009.

We also performed a comparison between the MODIS and CALIOP retrieval, by focusing more on microphysical parameters. We reprocessed the emissivity in bands 29, 31 and 32, starting from the MYD06 cloud top temperature. The same operation was done from the CALIOP Cloud top pressure. In each of the bands, strong correlations of about 0.99 between MODIS and CALIOP emissivities are obtained.

Another of our interests is to characterize the relationship between emissivity and optical thickness. We retrieved the optical thickness from the integration of the extinction given by the CALIOP Level 2 product. This dependence could be described by the general equation:

$$\varepsilon_{11} = 1 - \exp(\frac{-k.\tau_{CALIPSO}}{\mu}).$$

Then, we compared this value with the collocated MODIS emissivity in band 31 (Figure 17.1.4), and found the value of the parameter k equal to 0.96.

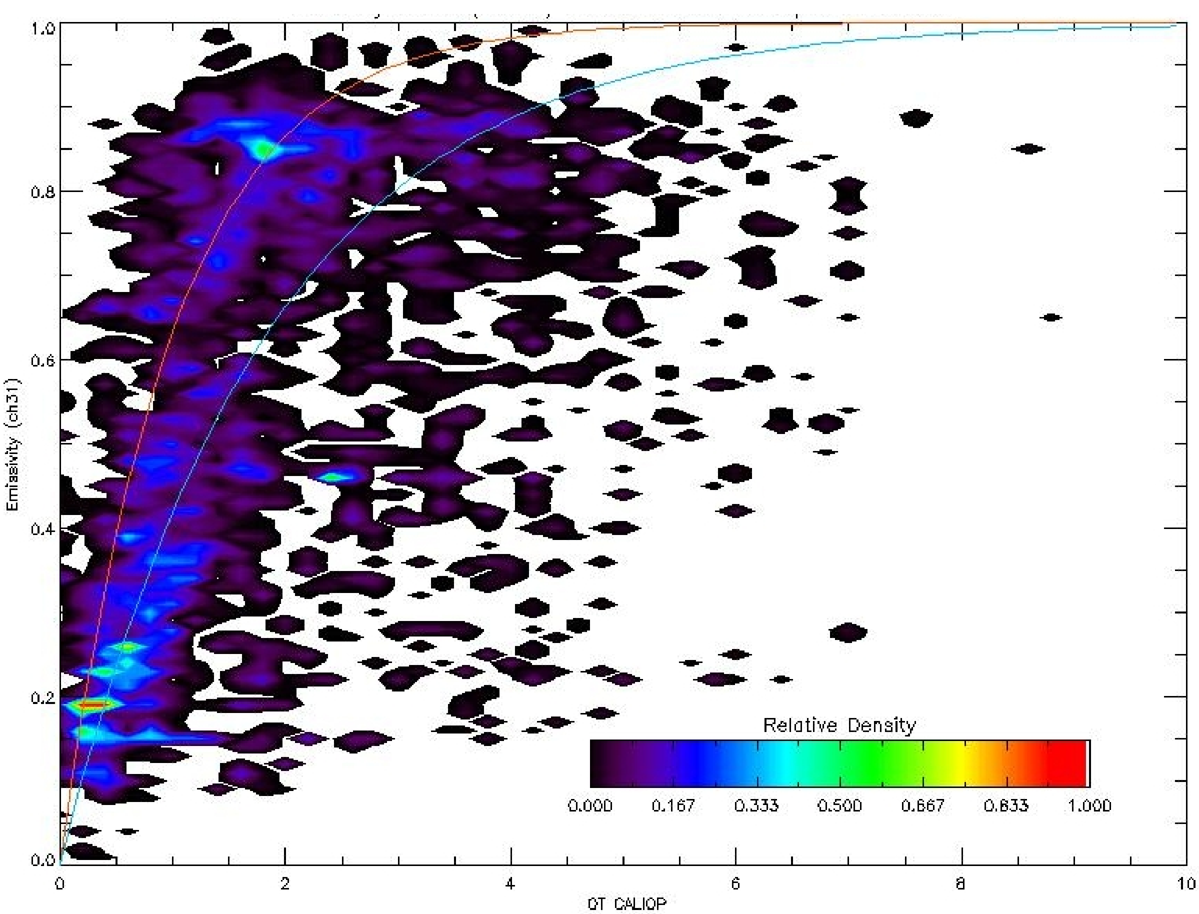


Figure 17.1.4. Emissivity in MODIS band 31, as determined from MODIS data in conjunction with optical thickness from CALIOP data. The red line shows the best fit of this distribution (k equal to 0.96).

Another study has been an attempt to retrieve the value of the effective diameter. From the MODIS emissivities discussed above generated from MODIS bands 31 and 32, we are able to calculate the value of the beta factor, whose definition is:

Coupling this factor and the Pin-Yang model describing the dependence of the beta factor to the effective diameter De, we can find the value of the latter. Figure 17.1.5 gives the result of such processing for daytime and nighttime measurements. This result is from two days of data. The variability in the curves is explained by this limited amount of data. We plan to extend this study to include a complete month of data.

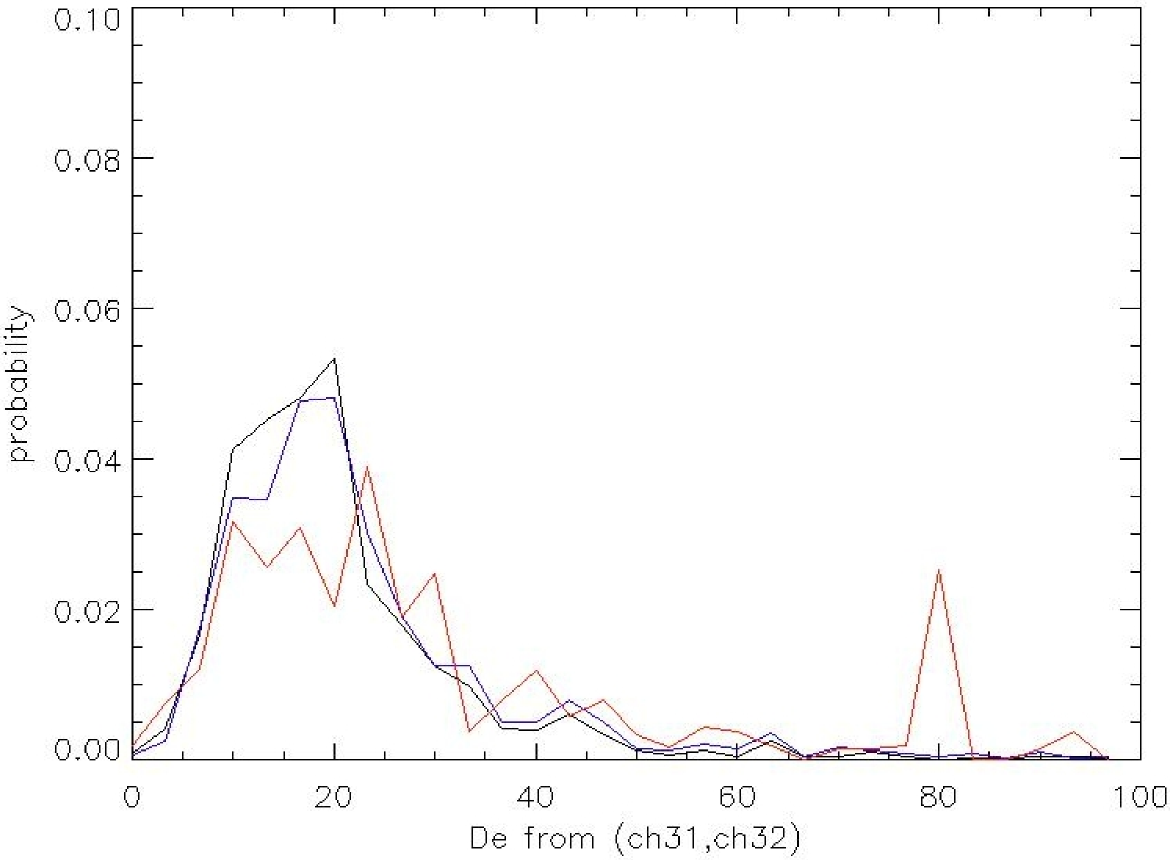


Figure 17.1.5. Distribution of particle effective diameter as determined from our algorithm applied to MODIS data.

Publications and Conference Reports

Berthier, Sebastien, 2009: Comparisons of the cirrus cloud statistics derived from CALIOP Spaceborne lidar and MODIS Measurements, AMS Meeting, Phoenix, AZ; January 2009 (Oral Presentation).

Heidinger, Andrew K., Robert Holz, Bryan Baum and Pavolonis, Michael J., 2009: Using CALIPSO to Explore the Sensitivity to Cirrus Height in the Infrared Observations from NPOESS/VIIRS and GOES-R/ABI. Submitted to *JGR*.

Heidinger, Andrew, 2008: Cloud-top Pressure Solution Space Offered by NPOESS/VIIRS and GOES-R/ABI. MODIS Science Team Meeting, Baltimore, MD, May 2008 (Oral Presentation).

References

Yang, P., Liou, K., Wyser, K., and Mitchell, D., 2000: Parameterization of the scattering and absorption properties of individual ice crystals. *J. Geophys. Res.*, **105**, 4699–4718. 1326, 1342.

17.2 NPP/NPOESS Cryospheric Products Calibration & Validation Activities

CIMSS Project Lead: Yinghui Liu
CIMSS Support Scientist: Xuanji Wang
NOAA collaborator: Jeffrey R. Key
NOAA Strategic Goals addressed:

- 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 NPOESS 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 new project started in June 2009. This report therefore covers the four months of June through September. During this short period, the development of retrieval methods for multiple products was begun, and retrieval products using AVHRR, MODIS (Aqua an Terra) data as VIIRS proxies were validated with other satellite products and in-situ observations. Ice surface temperature retrieval was accomplished with the split-window algorithm developed by Key and Haefliger (1992), and applied to AVHRR and MODIS data. A sea ice concentration/extent algorithm combines two existing ice concentration/extent retrieval algorithms and was also applied to MODIS and AVHRR data. The two algorithms are (1) a group threshold technique from MODIS snow and sea ice mapping algorithms based on the normalized difference snow index and visible reflectance observations (Hall et al. 2001), and (2) tie point analysis from the VIIRS fresh water ice algorithm (Appel and Kenneth, 2002).

A One-dimensional Thermodynamic Ice Model (OTIM) has been implemented based on the theoretical basis of surface energy balance at thermo-equilibrium, and has been applied to MODIS and AVHRR data as VIIRS proxy data to retrieve ice thickness/age. The retrieval algorithm for the surface albedo over snow/ice has been developed and implemented using AVHRR data. Data inventory, sampling strategy, data acquisition, ingest, collocation for case studies have begun. Validation of sea ice concentration with the Advanced Microwave Scanning Radiometer - EOS (AMSR-E) sea ice concentration product shows good agreement. Ice thickness/age retrieval shows good agreement with numerical model simulations from the Pan-Arctic Ice-Ocean Modeling and Assimilation System (PIOMAS), submarine upward looking sonar ice draft data from Scientific Ice Expeditions (SCICEX) in 1999, and Canadian station measurements from the Canadian Ice Service (CIS). Examples of these retrieval products and validation work are demonstrated in Figure 17.2.1 and Figure 17.2.2.

Publications and Conference Reports

Wang, X., J. R. Key, and Y. Liu, 2009: A thermodynamic model for estimating sea and lake ice thickness with optical satellite data. *J. Geophys. Res.*, submitted, September 2009.

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.*, in press, October 2009.

References

Appel I., and J. A. Kenneth, 2002: Fresh water ice Visible/Infrared Imager/Radiometer Suite algorithm theoretical basis document, Version 5. SBRS document #: Y2404

Hall D.K., G.A. Riggs, and V.V. Salomonson, 2001: Algorithm theoretical basis document for the MODIS snow and sea ice mapping algorithms.

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

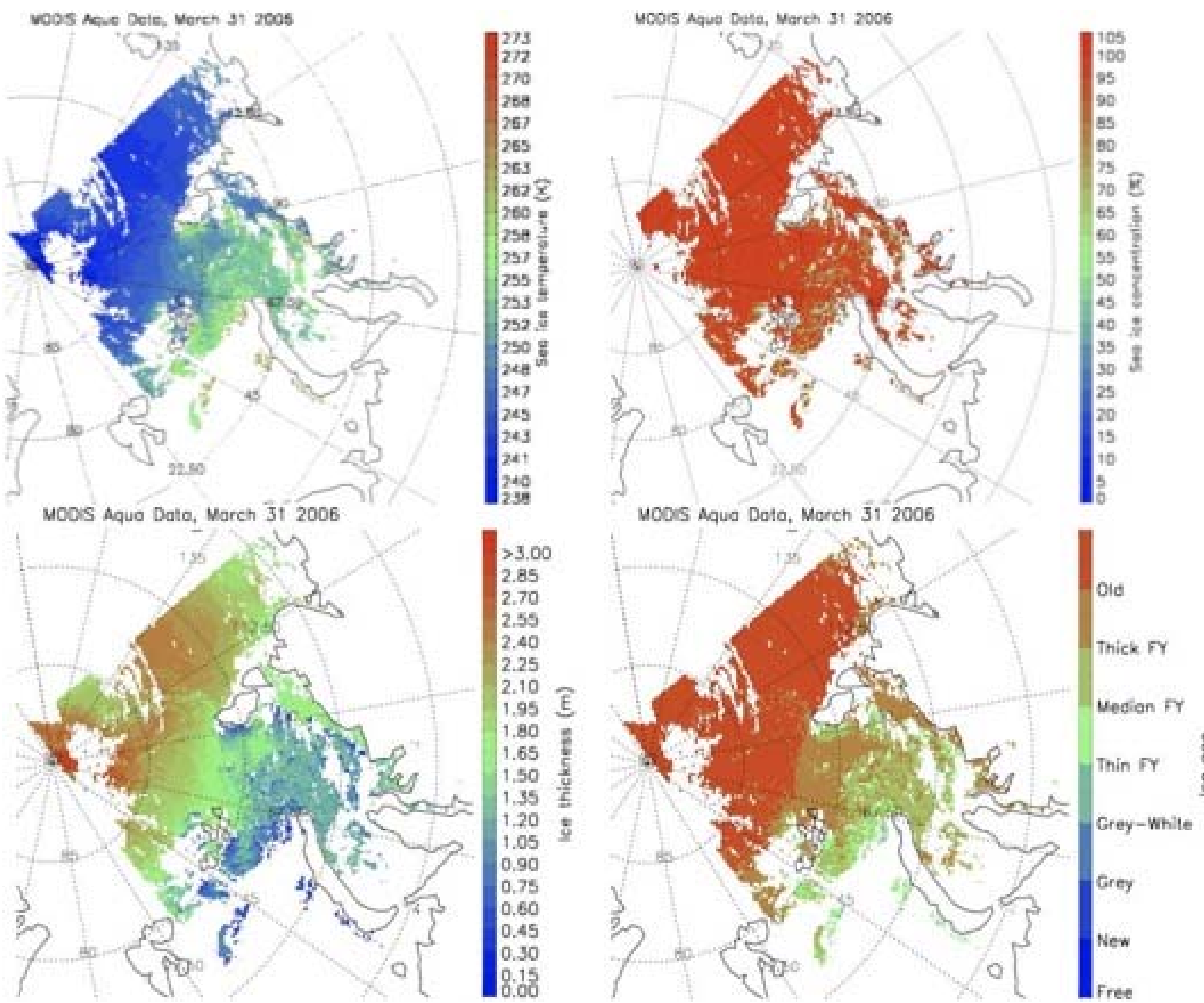


Figure 17.2.1. Retrieved (a) ice surface temperature (b) ice concentration, (c) ice thickness, (d) ice age, and from MODIS Aqua on March 31, 2006.

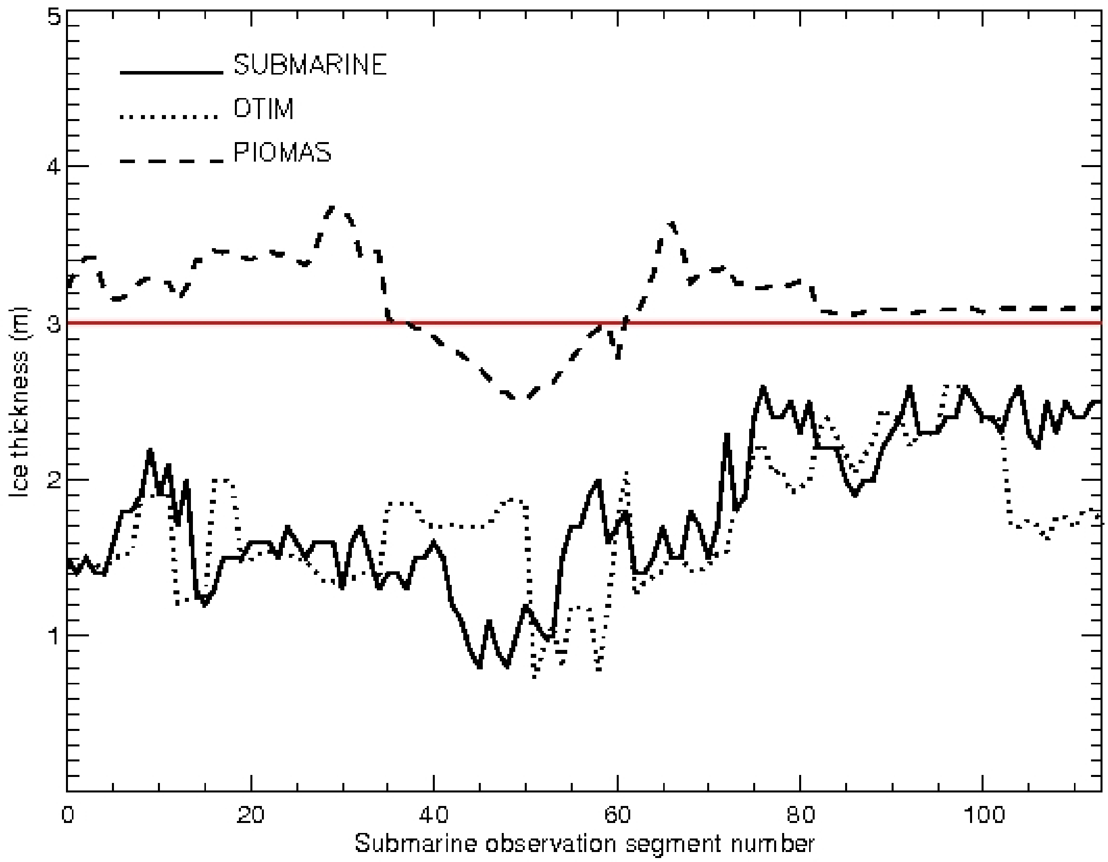


Figure 17.2.2. Comparison of ice thickness values retrieved by OTIM with AVHRR data, submarine sonar data, and simulated thickness from the PIOMAS model along the submarine tracks segments.

17.3. A Broad Scope of Cal/Val and Independent Verification and Validation Activities in support of IPO, with an Emphasis on CrIS

CIMSS Project Lead(s): Hank Revercomb
CIMSS Support Scientist(s): Fred Best, Bob Knuteson, Joe Taylor, Lori Borg, Dave Tobin
NOAA Collaborator(s):
NOAA Strategic Goals Addressed:

- 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. Descriptions of the tasks for this year are presented below.

Task 1.1: Support CrIS Planning and Review Meetings

We will support the appropriate NPP, NPOESS, and CrIS test related meeting and conferences under this task. Examples include CrIS test review and analyses meetings at ITT, SOAT meetings, NPOESS cal/val meetings, and conferences where CrIS and NPOESS relevant topics are discussed.

Task 1.2: CrIS Pre-launch Test Support and Performance Analyses

This involves participation in the design and review of the CrIS pre-launch testing and analyses of the resulting data to assess the performance of the sensor. This includes a wide range of participation. Our efforts are focusing on the CO_2 laser and gas cell data for ILS determination, CO_2 laser and diagnostic mode blackbody data for nonlinearity assessment, the absolute accuracy of the calibration targets, stepped ECT views for absolute calibration and linearity assessment, and blackbody view data for noise assessments. This includes FM1 and FM2 related efforts.

Task 1.3: CrIS Sensor Data Record (SDR) Algorithm Support and Development

This task includes analyses and code development to further improve the CrIS SDR algorithm. Specific tasks include: (1) further development and assessment of a radiometric non-linearity correction, (2) the development and assessment of a correction algorithm for ILS variations in the presence of spatially non-uniform scenes, (3) the assessment of the fringe count error identification and correction algorithm, and (4) participation in determining and fixing an error in the current ILS portion of the SDR algorithm that is introducing small radiometric errors.

Task 1.4: Validation Analyses and Technique Demonstration

Through previous experience with other satellite programs, we have developed and utilized several key post-launch validation activities. Under this task, we will continue to develop and demonstrate these activities and work to incorporate them into the CrIMSS calibration/validation plan. Specific activities include: EDR validation planning using ARM site ground truth observations, METOP IASI spectral radiance validation using JAIVEx aircraft data, radiance validation using Simultaneous Nadir Overpass (SNOs) method, and validation of operational retrieval using reference retrieval method. We will also continue to work to develop the post-launch calibration/validation plan to include key activities related to the optimization of on-orbit activities, such as the frequency and optimal use of the Neon calibration views for spectral calibration and the frequency and optimal use of diagnostic blackbody and space view data collects for linearity assessments.

Task 1.5: Aircraft Instrument Support and Calibration

Maintain and refine S-HIS NIST traceability

A comprehensive plan will be developed with Joe Rice of NIST to expand and refine the traceability of the Scanning-HIS measurements to NIST. Activities expected to be in the plan include: (1) refinement of the analysis of the radiometric and reflectivity tests conducted at UW-Madison with the NIST TXR in January of 2007; (2) measurement of the Scanning-HIS instrument line shape using an integrating sphere illuminated with a laser; (3) repeat the TXR/Scanning-HIS radiometric and reflectivity tests at UW-Madison; (4) conduct radiometric and reflectivity tests using the NIST FTXR or SIRCUS facility; and (5) conduct characterization of the Scanning-HIS reference sources used for (in-flight) instrument calibration. This task is an ongoing multi-year effort. This year we will develop the traceability plan, and complete items (1) and (5).

NAST aircraft instrument support

Under this task we will provide support to the LaRC NAST team to help analyze data collected during an end-to-end radiometric test that was conducted last year at LaRC using an AERI blackbody. We will also help refine future test plans and procedures with the goal to advance the level of NAST radiometric calibration.

Task 1.6: Cal/Val Aircraft Campaign Planning Support

The objective of this task is to create a plan for aircraft related cal/val efforts, including CrIS, ATMS, and VIIRS SDRs, and EDRs.

Task 1.7: Mock Post-launch Evaluation Campaign

The thrust of this task is to exercise our calibration/validation plans using real satellite and field campaign data. The effort is valuable in its own right and serves as preparation for a more general Mock Post-launch Evaluation Campaign (MPEC) that would involve all of the key NPOESS players, including international partners. Complete MPEC activities would include all candidate validation efforts such as the use of global radiosondes, ARM site observations, and model analyses fields for the assessment of products, in addition to a focused aircraft field campaign. Such an active trial of the process planned for NPP in 2010 will allow us to simultaneously (1) test our readiness through a very realistic “dress rehearsal,” (2) provide a strong basis for refining our plans as needed, and (3) improve the characterization of the joint polar system (NOAA and MetOp now, transitioning to NPP/NPOESS and MetOp).

Summary of Accomplishments and Findings

The majority of our efforts in this reporting period again focused on the CrIS Flight Model 1 thermal vacuum test participation and analyses (Tasks 1.1, 1.2, and 1.3). Other efforts have contributed to tasks Cal/Val planning (1.6) and Aircraft validation analyses (1.5).

Task 1.1: Support CrIS Planning and Review Meetings

We reported on our CrIS TVAC efforts at numerous conferences and NPOESS meetings in 2009 (see reference list). In particular, a comprehensive presentation of our results was given at the May 2009 SOAT meeting. Also, we participated in numerous weekly telecons, such as the Thursday and Friday technical telecons.

Task 1.2: CrIS Pre-launch Test Support and Performance Analyses

The majority of our efforts fall under this task for this reporting period. 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 May 2009 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 percent of 287K blackbody radiance (top panels, units compatible with the specification) and 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. 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.

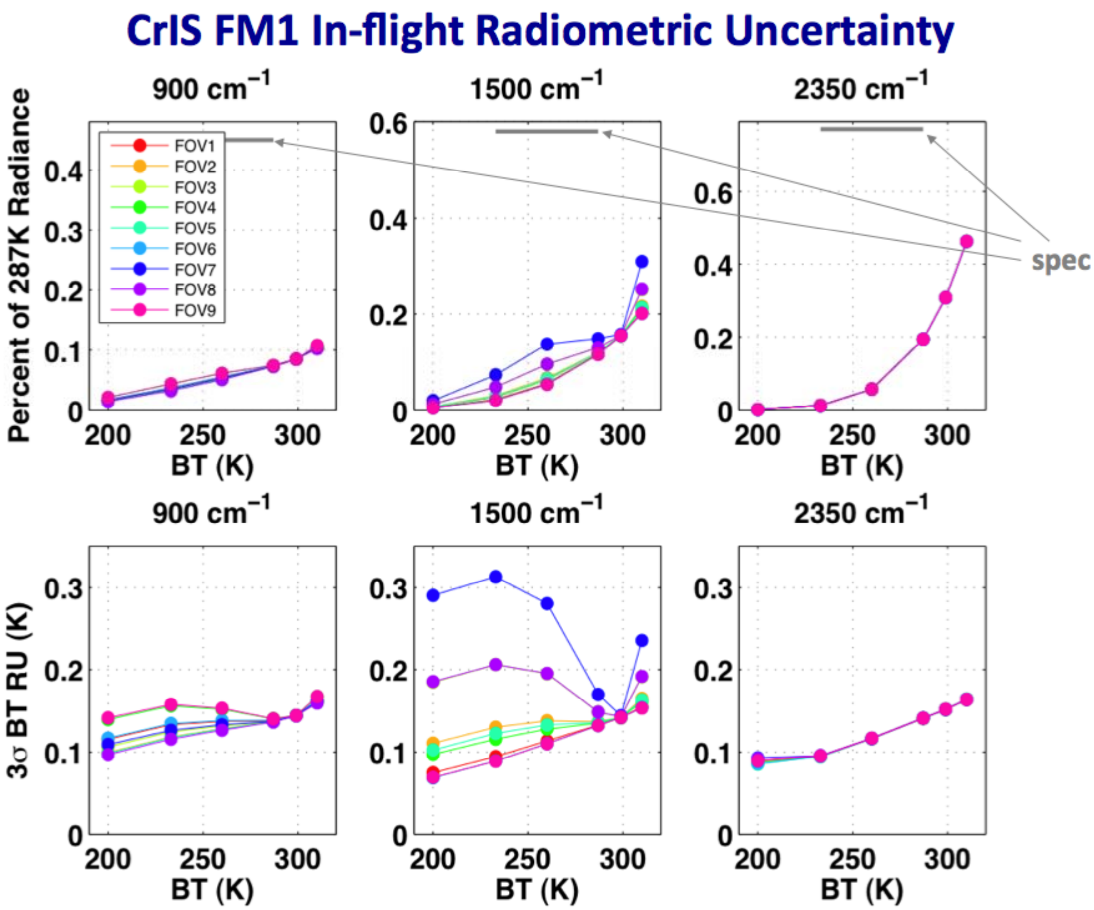


Figure 17.3.1. CrIS Flight Model 1 In-flight Radiometric Uncertainty Estimates. See the text for the description.

Task 1.3: CrIS Sensor Data Record (SDR) Algorithm Support and Development

Our efforts under this task have focused on further development and validation of the CrIS detector nonlinearity correction algorithm, as well as improvement and subsequent validation of the CrIS Internal Calibration Target (ICT) emissivity retrieval algorithm and results, and of the ICT environmental model. Details of detector nonlinearity correction model are found in several of our presentations from 2009. Following the replacement of the original ICT with the EDU3 ICT in 2008 and subsequent derivation of the ICT emissivity by ITT using a special TVAC test, we were not able to replicate the ITT results, and discovered several important issues with the methodology. These issues were eventually resolved, and a refined ICT emissivity estimate produced and distributed. Details of this effort are found in several internal memos and presentations.

Task 1.5: Aircraft Instrument Support and Calibration

This year, considerable progress to further characterize the uncertainties of the UW/SSEC in-flight calibration sources (blackbodies) has been made. Particular emphasis has been placed on extended our previous results using the NIST TXR and a "heated halo" experiment to measure the effective emissivity of the blackbodies. Opposed to previous results obtained for only the two TXR channels at 5 and 10 um, the current results are obtained using the Scanning HIS and are therefore at high spectral resolution and with broadband coverage. Preliminary results to date are very encouraging, with very good agreement between the modeled emissivity and several different, independent ways of measuring the emissivity (Best, CALCON 2009).

Task 1.6: Cal/Val Aircraft Campaign Planning Support

Over the past year, we have made significant contributions to the NPP Cal/Val plan, with particular emphasis on providing material and perspective on the relative merits of various radiance validation techniques, and ARM site radiosonde cal/val planning efforts.

Publications and Conference Reports

Best, Fred A., Bob Knuteson, Henry E. Revercomb, David C. Tobin, Jonathan Gero, Joseph K. Taylor, Joseph P. Rice, Leonard M. Hanssen, Sergey N. Mekhontsev, 2009: Measurements of the Atmospheric Emitted Radiance Interferometer (AERI) Blackbody Emissivity and Radiance Using Multiple Techniques. CALCON 2009.

Revercomb et al., 2009: Expected Calibration Performance of the NPP Cross-track Infrared Sounder (CrIS). NASA Sounder Science Team (aka AIRS) Meeting, Pasadena, 4-7 May 2009.

Strow, L., Howard Motteler, Scott Hannon, David Tobin, Joe Taylor, Lori Borg, Graeme Martin, Hank Revercomb, 2008: Pre–Launch Spectral Calibration of the CrIS Sensor on NPOESS/NPP. CALCON 2008. Utah State University, Logan UT, USA, Space Dynamics Laboratory, Utah State University.

Taylor, J. K., David Tobin, Hank Revercomb, Fred Best, Lori Borg, Robert Knuteson, 2008: Analysis of CrIS Flight Model 1 Radiometric Linearity and Radiometric Noise. CALCON 2008. Utah State University, Logan UT, USA, Space Dynamics Laboratory, Utah State University.

Taylor, J. K., Hank Revercomb, Dave Tobin, Fred Best, Lori Borg, Robert Knuteson, Graeme Martin, 2008: Analysis of CrIS Flight Model 1 Radiometric Linearity and Noise. 2008 Telops FTS Workshop. Washington DC, USA.

Taylor, J. K., Hank Revercomb, Dave Tobin, Fred Best, Lori Borg, Robert Knuteson, Graeme Martin, 2008: Analysis of CrIS Flight Model 1 Radiometric Linearity and Noise. Workshop on Infrared Remote Sensing Applications (WIRSA) 2008. Quebec City PQ, Canada, ABB Analytics.

Taylor, J. K., David C Tobin, Lori Borg, Henry E Revercomb, Robert O Knuteson, Fred A Best, 2009: Analysis of the CrIS Flight Model 1 Radiometric Linearity and Radiometric Uncertainty. Telops Scientific Workshop: Working with IR Remote Hyperspectral Imaging Sensors. Madrid, Spain.

Taylor, J. K., David C. Tobin, Henry E. Revercomb, Robert O. Knuteson, Lori Borg, Fred A. Best, 2009: Analysis Of The CrIS Flight Model 1 Radiometric Linearity And Radiometric Uncertainty. CALCON 2009.

Taylor, J. K., David C Tobin, Lori Borg, Henry E Revercomb, Robert O Knuteson, Fred A Best, 2009: Analysis of the CrIS Flight Model 1 Radiometric Linearity and Radiometric Uncertainty. ASSFTS 14. Florence, Italy, 6-8 May 2009.

Taylor, J. K., D. C. Tobin, H. E. Revercomb, R. O. Knuteson, L. Borg, and F. A. Best, 2009: Analysis of the CrIS Flight Model 1 Radiometric Linearity. *Fourier Transform Spectroscopy*, OSA Technical Digest (CD) (Optical Society of America, 2009), paper FMA4.

Tobin, D. C., F.A. Best, L.A. Borg, R.O. Knuteson, J.K. Taylor, H. E. Revercomb (2008). CrIS Radiometric Non-Linearity Characterization and Correction Algorithm. AGU Fall Meeting 2008. San Francisco CA, USA, American Geophysical Union (AGU).

Tobin, D. C. et al., 2009: Infrared Spectral Radiance Validation and Plans for the Cross-track Infrared Sounder. *Hyperspectral Imaging and Sensing of the Environment*, OSA Technical Digest (CD) (Optical Society of America, 2009), paper HMC1.

Tobin et al., 2009: Progress on a novel correction technique for non-uniform Instrument Line Shape effects. ASSFTS-14, Florence, Italy, 6-8 May 2009.

Tobin, David, Lori Borg, Joe Taylor, Robert Knuteson, Fred Best, Hank Revercomb, 2009: UW Analysis of CrIS FM1 TVAC Data. Sounder Operational Algorithm Team Meeting, IPO, Silver Spring, MD, USA, 20•21 May 2009.

17.4. Radiance Cal/Val, Cloud Property Determination and Combined Geometric plus Radiometric Soundings with Emphasis on VIIRS

CIMSS Project Leads: Eva Borbas, Chris Moeller, Tom Achtor
CIMSS Support Scientists: Youri Plokhenko, Tom Rink
NOAA Collaborators: Bruce Guenther
NOAA Strategic Goals Addressed:

- Serve society's need for weather and water

CIMSS Research Themes:

- Weather
- Clouds
- Hydrological cycle
- Trends
- Climate
- Outreach

Assessing VIIRS Prelaunch Performance

Chris Moeller and Dan LaPorte continued participation in the VIIRS pre-launch test and assessment program. FU-1 Pre-TVAC have been completed and TVAC is underway at the Raytheon El Segundo facility. The test program has begun to reveal the performance and characterization necessary to bring VIIRS to launch readiness. Moeller and LaPorte have spent time on-site at Raytheon in the role of GOST team members and as Govt POC for the spectral characterization testing. Cold operational and performance plateaus have been completed and the test program is now in the nominal plateau portion of testing with spectral characterization testing imminent. This work is partially supported by Integrated Project Office funding.

TVAC radiometric testing was completed for all bands during cold performance. Concern about vignetting of detector 1 observed during cold operational testing was assessed and found to be largely mitigated by the warmer temperature of the instrument. Radiometric testing for thermal bands is underway in Nominal Plateau and is yet to come for RSB.

Spectral characterization (FP-15 and FP-16) of VisNIR bands shifted from Pre-TVAC to TVAC in order to allow work on the SpMA GSE. Problems with the Tungsten source (old bulb was replaced) and its optical alignment were addressed, improving the signal level on each detector (non-uniformity in the along track direction was leading to not useful illumination for edge detectors). Further, issues associated with GINS software have been largely worked out, allowing the test program to take advantage of automation of test scripts. The delay of spectral testing into TVAC has also allowed for additional work to assess “tall pole” spectral leaks due to angle resolved scatter (ARS) in the VisNIR filters. This optical cross talk is an issue for ocean color products. A list of recommended spectral wavelengths for special measurement using polarized light (ETP-655) has been forwarded to Raytheon by the Govt team. The Govt team has also recommended that the out-of-band (OOB) spectral sampling of VisNIR be improved for contiguous spectral coverage. This will assure spectral coverage of all ARS features during FP-16. Additionally, the Govt team is recommending re-measure of the SpMA RSO (relative spectral output) to address concerns about changes in the SpMA output due to configuration changes of the SpMA. On a related note, FU-1 spectral measurements will be split between Primary and Redundant electronics in order to exercise electronics on both sides. No impact on spectral characterization is anticipated. Further, the choice of which bands to measure on which E-side is being matched to the selection that was used during FP-13 testing (cross talk) in order that the cross talk and spectral characterization measurements can be correlated for further insight on cross talk.

Visualization Tools

HYDRA added the capability to interrogate AMSU data. HYDRA was used in remote sensing schools in Sardenia (Sep 08), Turkey (Oct 08), Australia (Feb 09), and Italy (Jul 09). Testing of multi-spectral visualization capabilities in McIDAS-V continued. The goal is to combine the ability to quantitatively inspect satellite data and to compare with non-satellite measurements (e.g., raobs, surface reports) and NWP models output; this will be important for cal/val of NPP and beyond. Beta testing with students is beginning.

Estimating Cloud Top Pressures with VIIRS

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. Two different approaches have been tested with MODIS being used as a proxy for VIIRS and AIRS for CrIS:

(1) MODIS window channel brightness temperatures and lapse rates are used to make adjustments to AIRS cloud top pressures (CTPs); so that

$$CTP_{MODIS} = CTP_{AIRS,i} + \frac{BT_{MODIS} - \overline{BT_{MODIS}}}{\gamma}$$

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 lapse rate within clouds. γ has been chosen empirically; $\gamma = 0.3$ is for high clouds ($CTP_{AIRS,i}$ < 500 hPa pressure level) and $\gamma = 0.04$ is for low clouds ($CTP_{AIRS,i}$ >= 500 hPa pressure level).

(2) pseudo MODIS radiances (AMODIS) calculated from AIRS measurements are used to establish a regression relationship for CTPs and measured MODIS IRW brightness, so at 15 km resolution, we derive the regression coefficients ai for high, mid, and low AIRS CTPs where

$$CTP(AIRS) - CTPmean(AIRS) = \sum ai\ [R(AMODIS)i - Rmean(AMODIS)i]$$

And at 1 km resolution within the 15 km AIRS pixel we apply the ai to get

$$CTP(AIRS+MODIS) - CTP(AIRS) = \sum ai\ [R(MODIS)i - Rmean(MODIS)i]$$

In all approaches, cloudy pixels are indicated by the MODIS cloud mask (CM) (MYD35). Figure 17.4.1 shows the results for one of the granules.

Comparing the granule CTPs (using the 1km MODIS CTPs as truth), we find the regression approach has a bias of -78.37 hPa with a scatter of 189.16 hPa while the two layer lapse rate approach has a bias of -50.75 hPa with a scatter of 164.56 hPa. Visual inspection also favors the lapse rate approach. Similar results were found for other granules. We are experimenting with a three layer lapse rate approach.

Estimating Cloud profiles from AIRS measurements

AIRS cloud vertical profile estimates continue to be studied. Recent comparisons with CALIPSO determinations of cloud vertical extent have given encouragement that CrIS derived cloud vertical profiles can be used for validation of VIIRS cloud top and cloud base estimates. For the granule studied (20060615 AIRS granule 064) the cloud height difference (CALIPSO minus AIRS) at top shows a mean difference of 0.17 km with a standard deviation of 1.33 km, (and an uncertainty of mean of 0.12 km); at bottom a difference of -0.33 km is found with a standard deviation of 1.48 km (and an uncertainty of mean of 0.16 km). See Figure 17.4.2.

Further analysis of the cloud profile solutions has revealed areas of significant maxima in the spatial distribution of the residual function (the spectral average of the absolute ratio of the radiative temperature residual [K] to the noise variance [K]). These areas are associated with cloud estimates indicating high altitude clouds over mid altitude clouds. These complicated cases were not properly described in the algorithm; the algorithm was refined to handle such cloud cases.

Estimating CO2 profiles from AIRS measurements

Studies continued on the estimating CO2 concentrations in cloud free pixels by minimizing residuals between AIRS measured radiances versus radiative calculations. To date conclusions from this work include:

- Geophysical interpretation of AIRS hyperspectral measurements from 18 granules for 18 days from Oct 2002 to Jan 2004 show that there is physically meaningful information about the vertical CO2 profile in the atmospheric layer 150 to 350 hPa.
- The derived CO2 fields demonstrate spatial consistency with noticeable horizontal and vertical variations. Temporal variations in the derived average CO2 concentration at 150-350 hPa demonstrate excellent correlation with temporal variations of direct CO2 measurements over Hawaii.
- The information extraction techniques used on AIRS spectral measurements enable derivation of reliable instantaneous estimates of atmospheric CO2 concentration.

Publications

Y. Plokhenko attended the AGU conference held in San Francisco 15-19 December 2008 where he presented a poster summarizing his AIRS investigation of CO_2 concentrations entitled "Study of spatial-temporal distribution of non-linear estimate of carbon dioxide derived from AIRS hyperspectral measurements." Co-authors include Y. Plokhenko, W. P. Menzel, R. Knuteson, H. Revercomb and Sz. Moeller.

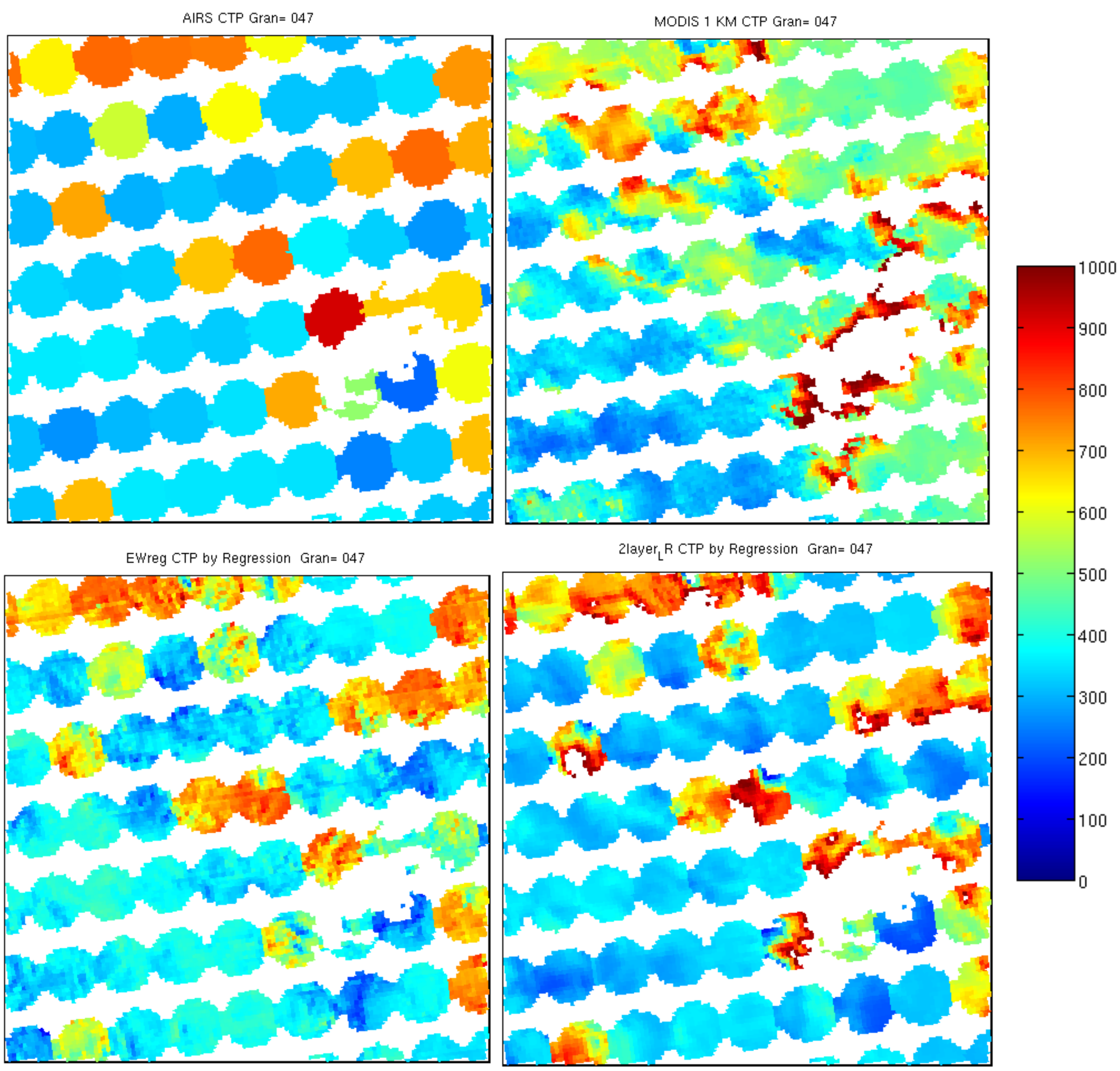


Figure 17.4.1. An example of AIRS FOV area on 28 Aug 2006, 04:45 GMT. (top left) AIRS CTPs. (top right) MODIS CO_2 slicing CTPs. (bottom left) CTPs determined from AIRS CTPs and MODIS IRWs (bands 29, 31, 32 at 8.6, 11, and 12 microns respectively) using the regression relationship between AMODIS radiances and AIRS CTPs. (bottom right) CTPs determined from AIRS CTPs and MODIS IRW and CM by the empirical lapse rate method using $\gamma = 0.3$ for high clouds and $\gamma = 0.04$ for low clouds.

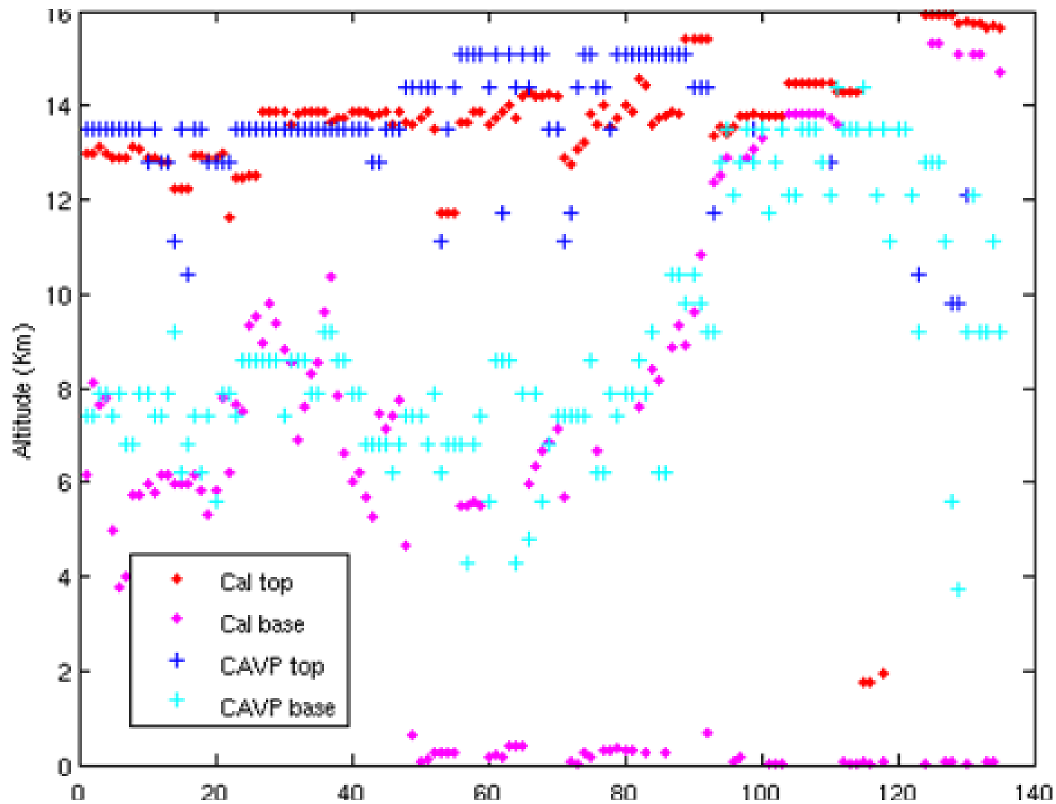


Figure 17.4.2. Cloud top and base determined from CALIPSO backscatter (Cal) compared with AIRS retrievals (CAVP) for granule 64 on 15 June 2006.

17.5 International Polar Orbiting Processing Package (IPOPP) for Direct Broadcast Users

CIMSS Project Lead(s): Allen Huang, Liam Gumley
CIMSS Support Scientist(s): Geoff Cureton, Ray Garcia, Graeme Martin, Nadia Smith, Elisabeth Weisz, Kathy Strabala
NOAA Collaborator(s): Richard Ullman, NOAA Integrated Program Office
NOAA Strategic Goals Addressed:

- Serve society's needs for weather and water

CIMSS Research Themes

- Weather nowcasting and forecasting

Proposed Work

The baseline IPOPP package will adopt IPO provided IDPS operational 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 OS X. CIMSS/SSEC and partners will ensure that any new IPOPP software components are well documented, easy to install, and portable to common UNIX platforms. The development philosophy and software features will include:

- Open source (GPL)
- Freely available (no COTS licenses required)
- Easy to install & run
- Multi-platform (e.g., Linux Intel, OS X)

- HDF5 standard data format
- Uses consistent & up to date calibration LUTs

CIMSS/SSEC will follow the IPOPP Master Schedule to conduct the build efforts to complete ports of the following IDPS software components:

1. CrIS SDR calibration/navigation
2. ATMS SDR calibration/navigation
3. CrIMSS EDR atmospheric profile retrievals
4. VIIRS Cloud Mask/Phase/Type (IP)
5. VIIRS Cloud Optical Thickness
6. VIIRS Cloud Effective Particle Size
7. VIIRS Cloud Top Height
8. VIIRS Cloud Top Pressure
9. VIIRS Cloud Top Temperature
10. VIIRS Cloud Cover/Layers
11. VIIRS Cloud Base Height
12. VIIRS Aerosol Optical Thickness
13. VIIRS Aerosol Particle Size
14. VIIRS Suspended Matter

CIMSS is also tasked to develop visualization applications and training courses to support the international DB community.

Summary of Accomplishments and Findings

Overall progress

All local source code under active development is now in revision control on the SSEC Subversion server. A 64-bit Red Hat Enterprise Linux development and test server (galactica) was procured, installed, and is now used by all the IPOPP development team.

CrIS and ATMS SDR (using IDPS PRO v1.5.0.18 code)

- All source code modules compile without errors
- CrIS RDR ingest runs to completion
- CrIS SDR algorithm runs to completion
- HDF5 output is created (data only; not metadata)
- CrIS output spectra have been verified; one issue remains with wavenumber calibration
- ATMS SDR code is in development
- Developed “Backflip” tool for converting complex big-endian data structures to little-endian; now used by all of SSEC IPOPP Team
- Adapted “Glance” tool from GOES-R to allow comparisons between SSEC and IDPS CrIS spectra
- Downloaded and archived IDPS PRO code versions 1.5.0.25, 1.5.0.37, and 1.5.0.48 from NASA GSFC DRL server
- Have compiled a list of all UW HDF5 output file specifications (data and metadata)
- Have initiated a cooperative dialog with Univ. of Utah SDL on CrIS/ATMS SDR porting
- Source code synchronized to NASA GSFC DRL server “draca”

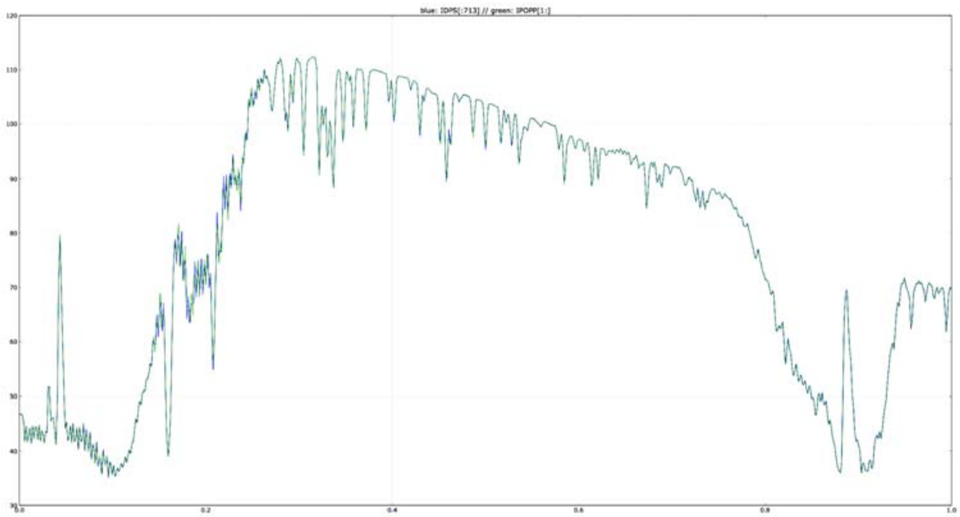


Figure 17.5.1. Comparison of CrIS spectra from IDPS (Blue) vs. SSEC IPOPP (green)

CrIMSS EDR (using IDPS PRO v1.5.0.18 code)

- The C++ I/O routine has been replaced with our own Fortran 90 driver.
- Created a Makefile and main module which calls the executable.
- Added HDF5 reading and writing capabilities.
- Wrapped the C++ apodization routine which is called by the F90 I/O driver.
- Added the post-processing C++ module which is called by the main module. This interpolates the 101 OSS levels to the EDR levels for Temperature (T) and Humidity (Q).
- Tested retrieval algorithm with a test set made up of mini-IDPS CrIS and ATMS SDR granules, NCEP-GDAS forecast fields for T, Q and Elevation. Geopotential height is calculated from the elevation and land fraction is set to "1" for 100% land.
- Compared retrievals with mini-IDPS EDR products. Exact comparison with ATMS (MW) retrieval, but most IR retrievals fail the quality test after 4 iterations.
- Held a series of telecons with scientists from JPL (Sung-Yung Lee) and NASA Langley (Xu Liu and Susan Kizer) to investigate reasons for the IR retrieval failure. Problem lies with science code and not with our implementation or the test data used.
- Exchanged our HDF reading routine for Hamming Apodization coefficients with Susan Kizer at NASA LaRC.
- Source code synchronized to NASA GSFC DRL server "draca"

VIIRS Atmosphere EDRs (using IDPS PRO v1.5.0.18 code)

- The following VIIRS Atmosphere EDRs are ported to Linux in LEOCAT and verified to produce acceptable output (although not necessarily identical to IDPS):
    - Cloud Mask/Phase/Type
    - Cloud Optical Thickness
    - Cloud Effective Particle Size
    - Cloud Top Height
    - Cloud Top Pressure
    - Cloud Top Temperature
- LEOCAT version for arbitrary MODIS input granules delivered to DRL (May 19)
- LEOCAT source code synchronized to draca (May 28)
- Makefile build environment created

- New code developed to ingest VIIRS SDR HDF5 radiance and geolocation data (v1.5.0.48 from mini-IDPS)
- VIIRS Cloud Mask run using mini-IDPS SDR data for the first time
- Developed workarounds for VIIRS Land/Sea mask and Quarterly Surface Type

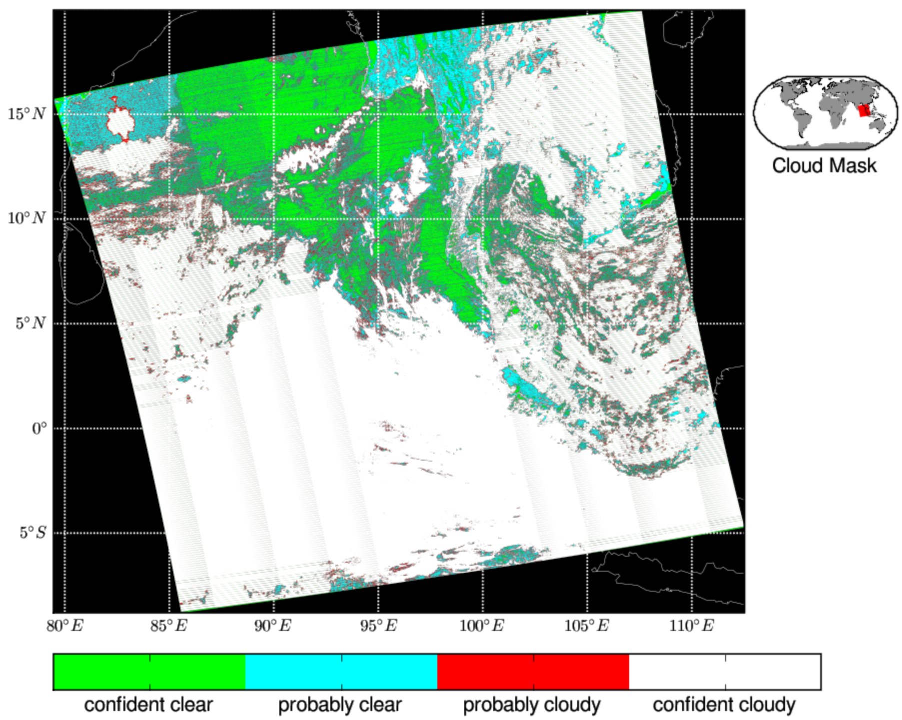


Figure 17.5.2. VIIRS Cloud Mask generated in LEOCAT from IDPS SDR granules

Visualization

- Direct Broadcast Google Earth (DBGE) beta testing started Nov 11, 2008. This is an application that enables users who create MODIS Level 1B products from direct broadcast to generate MODIS true color imagery in optimized KML format in near real-time. The image products can then be displayed in Google Earth, when served by a standard web server (e.g., Apache)
- DBGE version 1.1 released to the DB community on Jan 22, 2009
- Have tested in-house a version of DBGE which does not require an IDL license

Training and Education

- Kathy Strabala, Liam Gumley, Allen Huang, Nadia Smith, Jordan Gerth (SSEC) along with Philip Frost, Willem Marais, Karen Steenkamp (CSIR) presented IGARSS SC-4 in Stellenbosch, South Africa
- “MODIS direct broadcast data for enhanced forecasting and real-time environmental decision making”

Publications and Conference Reports

- CIMSS/SSEC attended IPOPP Face-to-Face meetings in Jul 08, Oct 08, Mar 09, Jun 09 and presented status of UW activities to support the project.

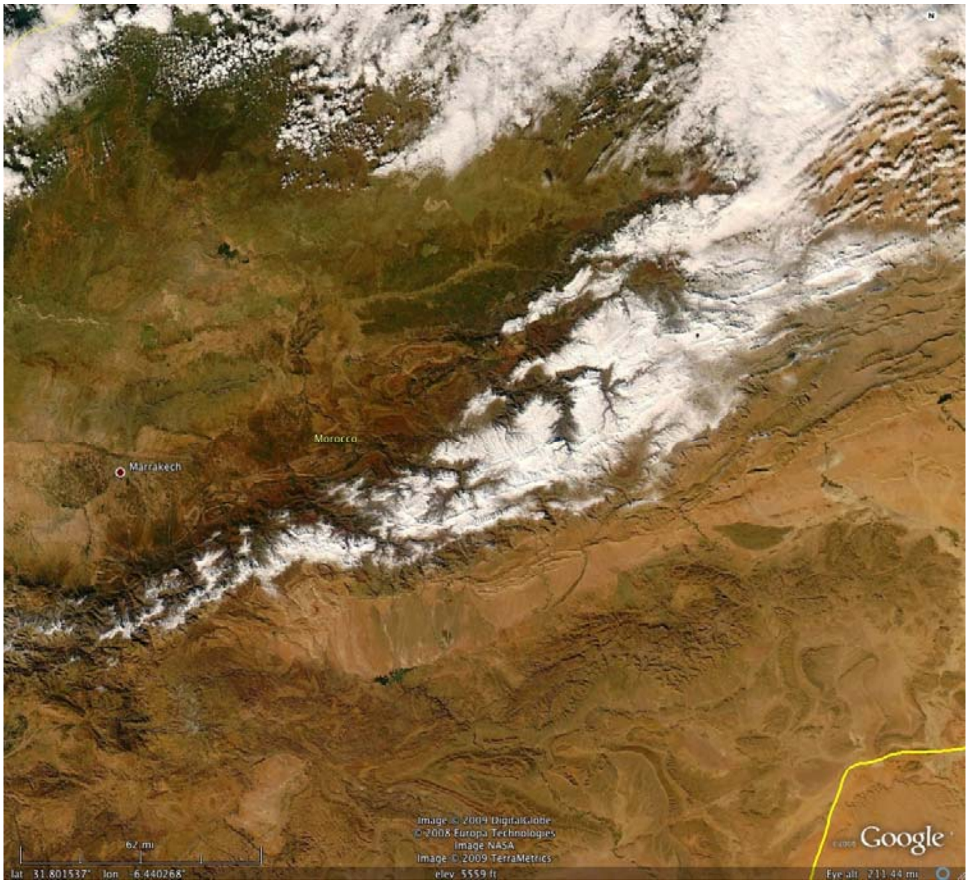


Figure 17.5.3. DBGE example image of Morocco from G. Meoli, MARSEC

17.6. NPP-VIIRS-CrIS Calibration and Validation Activities

CIMSS Project Lead(s): Dave Tobin, Bryan Baum, Robert Holz
CIMSS Support Scientist(s): Chris Moeller, Rich Fry
NOAA Collaborator(s):
NOAA Strategic Goals Addressed:

- 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

NPP-VIIRS-CrIS Radiance Intercomparison and Validation (Tobin)

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 been published (Tobin et al., JGR 2006); these 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 for Tobin

FY09:

- 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.

FY10:

- Intercompare IASI and HIRS measurements from METOP and study the effects of suggested spectral shifts on HIRS 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.

NPP-VIIRS Ice Cloud Property EDR Validation Activities (Baum)

We propose to focus on ice cloud properties. Our experience to date with the Northrop Grumman algorithm theoretical basis documents (ATBDs) and resulting software indicates that the inference of ice cloud properties will stand out as a major deficiency in the NGST products. The validation effort we propose will focus on this aspect with specific tasks listed below. This validation effort involves working closely with the Atmosphere PEATE. As part of the Atmosphere PEATE activities, the NGST Build 1.5 cloud and aerosol algorithms are being ported into the PEATE system for testing and evaluation in support of the NASA Science Team. The PEATE is responsible for applying the NGST operational software to global data. For the purposes of evaluating the NGST cloud and aerosol products, MODIS data will be used as a proxy. Additionally, the PEATE will be generating match-up files of MODIS products with pertinent products from active sensors on the A-Train platform, specifically CALIPSO and CloudSat. Given the current availability of both MODIS Collection 5 and pre-Collection 6 cloud products, products generated from other sensors such as AVHRR and HIRS, and the imminent availability of cloud products derived using NGST algorithms, a significant validation effort is required to evaluate and understand the performance of the products, both from heritage sensors and NGST operational code. Since NGST has implemented cloud mask and cloud typing algorithms based on interaction with NOAA and SSEC scientists, we do not expect significant issues to be encountered with these global products. However, we note that the other NGST cloud-top properties, including water and ice cloud height/pressure/temperature, particle size, and optical thickness, have never been tested globally. The focus of this validation effort will be initially on these untested properties, and more specifically on the performance of the NGST algorithms for daytime cirrus initially, and subsequently nighttime cirrus. The validation of the NGST ice cloud properties will be made in light of ongoing work being performed as part of MODIS pre-Collection 6 studies, specifically with regards to the use of new ice bulk scattering models currently being developed by Ping Yang, Bryan Baum, and Andy Heymsfield – these new models will incorporate advances in light scattering models as well as include surface roughening, new habits such as hollow bullet rosettes, and a wealth of recent (over last five years) in situ microphysical data obtained in various field campaigns. Additionally, our new scattering database will include an updated database of the ice refractive index by Steve Warren (with a journal article in press in JGR) that necessitates updating the scattering calculations. The NGST look-up tables of ice cloud radiance and transmission properties, which are used in the ice cloud retrievals, do not include these recent advances, and in fact were developed based primarily on data from a single FIRE campaign.

Our effort will not only assess the NGST/NPP ice cloud retrievals globally in comparison with CALIPSO, but also with MODIS ice cloud retrievals.

Specific tasks for Baum:

FY09:

- once NGST Build 1.5 algorithms have been applied to at least 1 month of global MODIS data, work with PEATE to obtain matchup files.
- begin evaluation of NGST and MODIS daytime ice cloud properties, including cloud top height/pressure/temperature, cloud thermodynamic phase, and microphysical/optical properties.
- Work with members of the CALIPSO team to provide feedback on their cloud products, including thermodynamic phase and extinction profile/optical thickness.
- Work with other Cal/Val team members to improve interpretation of comparison between active and passive cloud products
- Evaluate where NGST algorithms and CALIPSO products agree, as well as where they do not

FY10:

- Assume that CALIPSO/CloudSat, NGST algorithms, MODIS algorithms, and other heritage algorithms will improve over time as more experience is gained with assessment using active measurements
- repeat evaluation of cloud properties globally, but over lengthier periods of data (at least one year of CALIPSO/CloudSat/MODIS), focusing on problem areas such as clouds over snow/mountains, data from low-sun conditions (terminator).
- Begin similar evaluation of ice cloud properties based on nighttime (IR) retrievals, working with Andy Heidinger.
- Prepare summary of problem areas that need additional focus for validation activities
- By this time, there will be more clarity as to whether the NGST algorithms will be of sufficient quality to meet required specifications pre-launch

FY11:

- Provide final assessment of each cloud product, in terms of demonstrated of the global matchup files generated over at least one year of MODIS/CALIPSO/CloudSat data

NPP-VIIRS Cloud and Aerosol EDR Radiative Closure Evaluation (Holz)

We propose to calculate cloudy Top Of Atmosphere (TOA) high spectral resolution radiances derived using both the NGST cloud property retrievals and existing measurements including MODIS, CALIOP, and CloudSat cloud retrievals. The cloud radiative properties provided by the retrievals, combined with model thermodynamic atmosphere and surface properties will be used as input to a line by line clear and cloudy radiative transfer code (LBLDIS). These calculated radiances will be compared directly to collocated sounder measurements provided by CrIS/AIRS. Comparing the calculated radiance derived form the NGST cloud retrievals to the directly measured radiances provided by AIRS/CrIS will provide a unique capability to evaluate the NGST products. Leveraging the computing resources at SSEC, the software will be run globally providing assessments of the regional and seasonal dependencies with uncertainties characterized interims of radiative consistency with CrIS/AIRS. This effort will be coordinated with the direct comparison of cloud properties derived from both active and passive sensors including the MODIS, CloudSat, and CALIOP.

Specific tasks for Holz:

FY09 :

- Integrate CloudSat into Collocation/Matchup UW processing system in collaboration with Jay Mace
- Begin developing a system to integrate the cloud retrievals from both active and passive observations into cloudy forward radiative transfer software (LBLDIS)

FY10:

- Continue development of the forward radiative transfer capability and integrate into the processing system. The system will be flexible, allowing for different combinations of satellite retrieval methods to be used in the forward radiative transfer calculations including combined active and passive methods.
- Using collocated AIRS measurements as proxy for CrIS, global radiance comparisons of calculated (LBLDIS) and measured (AIRS) top of atmosphere radiance calculated using the VIIRS cloud properties retrievals will be compared to collocated AIRS radiances.

FY11:

- Investigate TOA radiances calculations using different combinations of passive and active remote sensed observations (CALIOP, CloudSat ,MODIS) to assess the quality of the VIIRS algorithms using radiative closure with AIRS. This analysis will be global and extend for at least one year of measurements to investigate seasonal and regional dependencies.
- Apply system to VIIRS observations at launch with CrIS.
- Access the uncertainties of the VIIRS algorithms in the context of TOA radiative closure.

Summary of Accomplishments and Findings

Work on these new projects started in July/August and so the efforts are just underway. Brief statements of progress, accomplishments for the three areas are given below.

NPP-VIIRS-CrIS Radiance Intercomparison and Validation (Tobin)

We have recently begun a study to assess the differences between AIRS and IASI using simultaneous nadir overpasses. These differences will be used to assess the IARS spectral gap-filling technique, and previous conclusions drawn from AIRS/MODIS differences, and assist in the development of IASI/MODIS and IASI/VIIRS comparison techniques and efforts.

NPP-VIIRS Ice Cloud Property EDR Validation Activities (Baum)
Tow orbits of simulated VIIRS products have been obtained just recently, and they are being assessed.

NPP-VIIRS Cloud and Aerosol EDR Radiative Closure Evaluation (Holz)
1. We have begun evaluating the simulated VIIRS cloud products generated on the NASA mini IDPS. This includes direct comparisons with the MODIS collection 5 products.
2. Working the IPO, we have delivered sample evaluation match files to the contractors. These files are proto-types of the evaluation products we will produce post launch.

18. Developing Training Materials for McIDAS Users and Programmers
CIMSS Project Leads: Thomas Achtor, Becky Schaffer
CIMSS Support Scientists: Jay Heinzelman, Kristin Klingelhutz, Scott Lindstrom, Jessica Staude
NOAA Strategic Goals Addressed:
- Provide critical support for the NOAA mission

CIMSS Research Themes:
- Education, training and outreach

Proposed Work
The University of Wisconsin-Madison SSEC and IPD/SSD will develop and evaluate training course material for McIDAS users, as well as those wishing to do their own programming within McIDAS-X. SSEC will send four McIDAS instructors to the NOAA Satellite Operations Facility (NSOF) building in Suitland, Maryland, to conduct a two week McIDAS training session. The course design will include both lectures and hands-on training.

Lectures will be aided by the use of Microsoft PowerPoint presentations, the McIDAS Learning Guide and the McIDAS Programmer's Manual. Additional handouts will be available to all participants.

The hands-on portion of the user training will include acquiring, displaying (static and time-lapse), analyzing, interpreting and managing the data. During the hands-on sessions the users will learn to use many of the hundreds of commands available in McIDAS-X and to utilize the functionality available in McIDAS-V.

The hands-on portion of the programmer training will cover writing application programs and ADDE servers. The users will write a program in the McIDAS-X environment, compile and debug it. Additional sample programs will be made available.

Summary of Accomplishments and Findings
SSEC and IPD/SSD worked together to develop training materials for the McIDAS training sessions. IPD/SSD employees Thomas Renkevens and Brian Hughes created an outline of desired training topics, and SSEC employees developed training materials to match the topics needed by the IPD/SSD.

SSEC sent four McIDAS instructors to the NSOF building in Suitland, Maryland, to conduct a two week McIDAS training session from August 24, 2009 until September 4, 2009.

Three of the instructors (Jay Heinzelman, Kristin Klingelhutz, and Jessica Staude) conducted the first week of training with McIDAS-X and McIDAS-V user training. The McIDAS-X session was two days long and attended by 16 people. The two McIDAS-V sessions were 1.5 days each and attended by 18 and 16 people, respectively.

One instructor, Scott Lindstrom, conducted the second week of McIDAS-X programmer training. The two McIDAS-X programming sessions were 2 days each and attended by 15 and 12 people, respectively.

At the conclusion of each training session, participants filled out training evaluation forms, which SSEC used to modify and improve the training materials for future McIDAS training sessions.

The numbers of attendees participating in the training sessions were:
McIDAS-X - 15
McIDAS-V session 1 - 16
McIDAS-V session 2 - 17
McIDAS-X Programming session 1 - 17
McIDAS-X Programming session 2 -*16

19. Holding Teacher Workshops in Conjunction with ESIP Meetings

CIMSS Project Lead: Margaret Mooney
CIMSS Support Scientist: Tommy Jasmin
NOAA Collaborator: Nina Jackson
NOAA Strategic Goals Addressed:

- 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 2009 Federation of Earth System Information Partners (ESIP) summer conference at the University of California - Santa Barbara (UCSB) on July 8th and 9th. As a unique consortium of over 100 organizations that collect, interpret and develop applications for remotely sensed Earth science data, ESIP meetings are a perfect venue to connect K-12 educators with remote sensing scientists. ESIP members from around the country have been meeting annually for over a decade. This summer, for the first time, the ESIP education committee invited California educators to attend the summer meeting to learn about ESIP Federation efforts to study and steward our planet. With support from NOAA, participating G6-12 teachers were invited to attend the ESIP introductory plenary sessions followed by an afternoon and second full day 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, TERC and other ESIP organizations.

Summary of Accomplishments and Findings

A total of twenty-nine attendees registered for the conference teacher track sessions. The first twenty G6-12 educators 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 sixteen different events for educators and eleven full-length sessions showcasing hands-on data activities. Two sessions were led by NOAA presenters and two others were led by CIMSS presenters. Surveys were distributed and collected to assess all the full-length sessions. There was also an overall workshop evaluation distributed at the end of the meeting. By all accounts the debut workshop was a resounding success. Seventeen teachers rated the ESIP workshop experience as “excellent”, the rest checked the next best box of “very good”. Participants also provided numerous constructive feedback comments for future endeavors. The agenda and complied workshop evaluations are available on-line at http://cimss.ssec.wisc.edu/teacherworkshop/esip/2009agenda.htm.

Fig. 19.1. ESIP Teacher Workshop Group Photo 7/8/09

20. A Museum Exhibit to Describe NOAA/ASPB Success in Support of the NOAA Environmental Satellite Program

CIMSS Project Lead(s): Thomas H. Achtor
CIMSS Supporting Staff: Leanne Avila, Maria Vasys, Schwerdtfeger Library staff
NOAA Collaborator(s): Gary S. Wade
NOAA Strategic Goals Addressed:

- Provide critical support for the NOAA mission

NOAA Cross-Cutting Priorities Addressed:

- Promoting environmental literacy

CIMSS Research Themes:

- Education, training, and outreach

Proposed Work

The goal of the project is creation of an exhibit describing the historical and current contributions of the NOAA/NESDIS/StAR/CoRP/Advanced Satellite Products Branch (ASPB) to the successes of satellite-borne remote sensing of the earth-atmosphere system. The ASPB works in collaboration the Cooperative Institute for Meteorological Satellite Studies (CIMSS), housed within the University of Wisconsin-Madison (UW-Madison) Space Science and Engineering Center (SSEC).

This exhibit will focus on and highlight the work of the NOAA/NESDIS contingent in Madison, since the mid 1970s through today, emphasizing the benefit provided to NOAA as well as to the atmospheric science community at large. The Development Lab was relocated to Madison from the Washington-D.C. area under the leadership of Dr. William L. Smith. The local NOAA branch continued under the successive leadership of Dr. Christopher "Kit" Hayden, Dr. Paul Menzel, Ms. Elaine Prins, and today, Dr. Jeff Key. Collaboration with CIMSS scientists has led to advances in remotely sensed vertical profiles of temperature and moisture, hyperspectral sounding capabilities, satellite cloud tracked winds, cloud characteristics, and, satellite determination of fires as well as smoke, aerosols, and volcanic emissions in the atmosphere.

Summary of Accomplishments and Findings

A timeline of the NOAA/NESDIS group at Wisconsin has been compiled and is being embellished with description of their work, interconnections, and achievements. The poster displaying this information content remains work in progress (at the time of this writing), but is being done with the objective to display this poster at the 50th Anniversary Commemoration of Explorer-7, which is to be held in November 2009. (See Figure 20.1 for an example of the type of material to be included in the poster.)

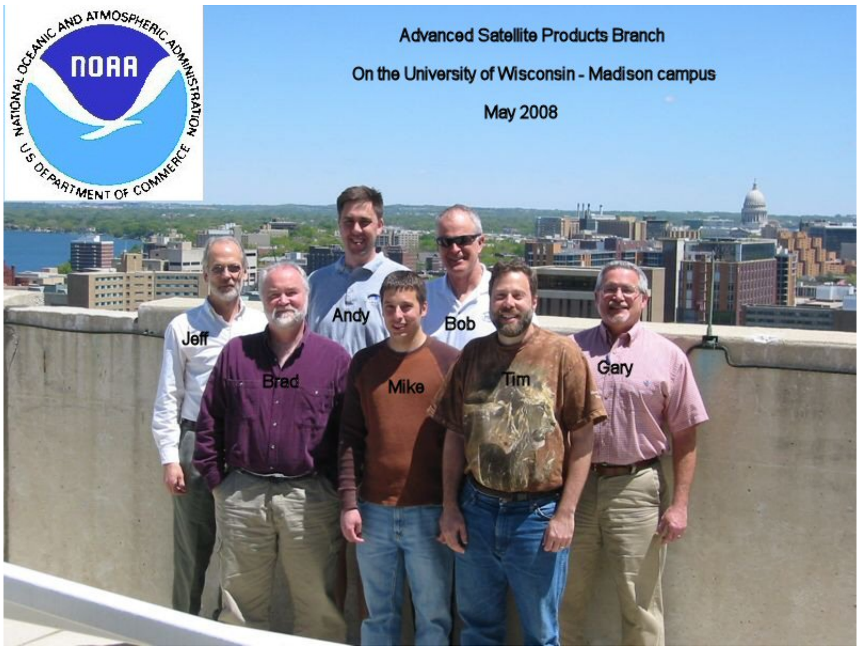


Figure 20.1. All members of the NOAA/NESDIS ASPB pose on the roof of the University of Wisconsin-Madison AOSS (Atmospheric, Oceanic, and Space Sciences) Building, in May 2008. The dome of the Wisconsin State Capitol is seen in front of the horizon on the right side.

Appendices

Appendix 1: List of Awards to Staff Members

Steve Ackerman	AMS Teaching Excellence Award
Amato Evan	2009 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.
Jordan Gerth	2009 Wisconsin Space Grant Consortium Graduate Fellowship Award
Mathew Gunshor	2009 University of Wisconsin-Madison's NOAA-CIMSS Collaboration Award for developing NOAA's Strategic Satellite Plan to balance requirements, observation capabilities, and resources.
Annelise Lenz	AMS Father James B. Macelwane Award
Jun Li	2009 University of Wisconsin-Madison's NOAA-CIMSS Collaborative Award for developing NOAA’s Strategic Satellite Plan to balance requirements, observation capabilities, and resources.
Chian-Yi Liu	Second Prize for Oral Presentation titled "The Upper Tropospheric Storm-scale Signatures from Hyperspectral Infrared Soundings" at the Sixth Annual NOAA/NESDIS/CoRP Symposium held at the City College of City University of New York, August 18-19, 2009.
Yinghui Liu	2009 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.
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 and also learn about the research conducted at either JPL or Goddard.
Dave Tobin	International Radiation Commission, 2008 Young Scientist Award
Chris Velden	Elected to Fellow of the American Meteorological Society
Xuanji Wang	2009 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.

Appendix 2: Publications

The tables below show the number of papers where CIMSS and ASPB scientists were first author (Table A2.1) or contributors (Table A2.2) to referred journal articles and non-peer reviewed articles. Note that data for 2009 is incomplete.

Table A2.1: Peer Reviewed and Non Peer Reviewed journal articles having CIMSS and/or NOAA lead authors, 2007-2009*. Publications categorized by Institute, NOAA and Other Lead Author.

	CIMSS Lead Author			NOAA Lead Author			Other Lead Author		
	2007	2008	2009*	2007	2008	2009*	2007	2008	2009*
Peer Reviewed	31	24	13	1	1	3	39	43	28
Non Peer Reviewed	2	4	0	1	0	0	1	1	0

*incomplete

Table A2.2: Peer Reviewed and Non Peer Reviewed Journal Articles having one or more CIMSS and/or NOAA Co-Authors, 2007-2009

	Institute Co-Author			NOAA Co-Author		
	2007	2008	2009*	2007	2008	2009*
Peer Reviewed	57	67	37	15	11	12
Non Peer Reviewed	0	0	0	1	0	0

*incomplete

Figure A2.1 shows a 15 year summary of CIMSS publications, updated from a recent article in the AMS Bulletin (Ackerman, et. al, 2009). Note that data for 2009 is incomplete.

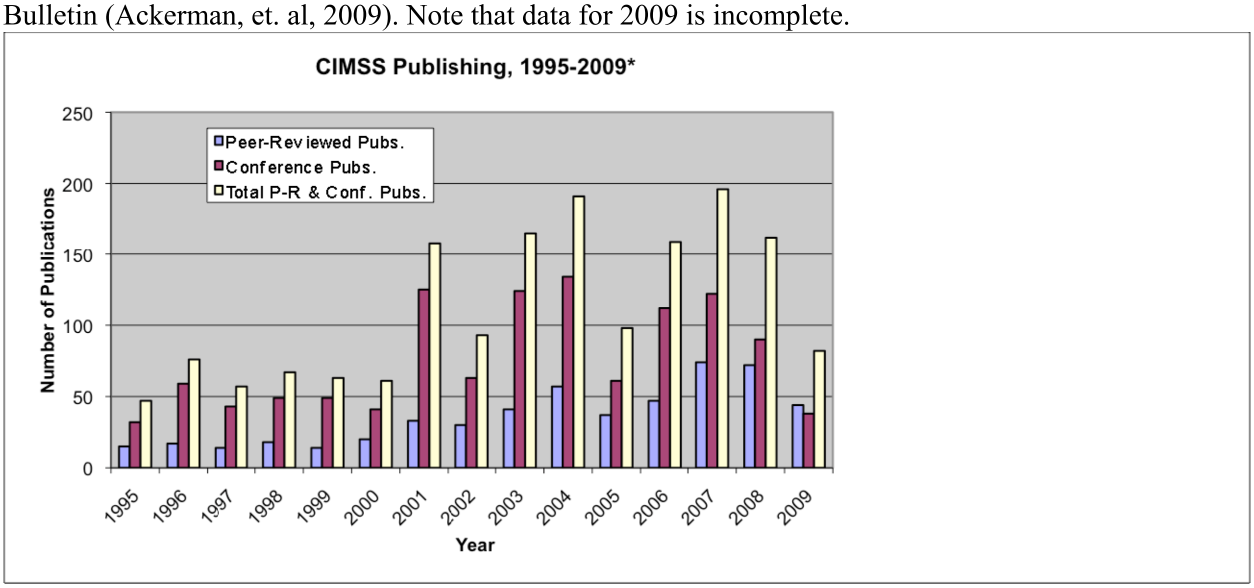


Figure A2.1. Summary of CIMSS peer reviewed and non-peer reviewed publications from 1995 to 2009.

A list of all CIMSS and ASPB publications for 2008-2009 is provided in Appendix 6.

Appendix 3: Employee Information

Number of employees/students receiving 100% of their support from NOAA: An SSEC/CIMSS full time equivalent (FTE) employee delivers at least 1,757 direct support hours per year. During the 12 months from October 1, 2008 to September 30, 2009, 17 SSEC personnel were fully funded by NOAA. These people are shown in bold italics in Table 3.1 below.

Number of employees by title with 50% support from NOAA: The SSEC/CIMSS delivered over 99,000 (56.6 FTE) direct support hours to NOAA during this reporting period. 50 personnel (including five students) received over half of their funding from NOAA. These people are shown in Table 3.1, sorted by SSEC labor category.

Number of GS and UG receiving any level of support from NOAA: Eight graduate students and six undergraduate students receive support from NOAA. These students are shown by name in Table 3.2.

Table A3.1: SSEC/CIMSS employees supported at least 50% by NOAA (100% in bold)

CIMSS Staff Member	Labor Category	Total Hours	FTE %	# in series
Jung, James	**Scientist**	**1,757**	**100**	**1**
Li, Jun	Scientist	1,622	90	
Schmidt, Christopher	Scientist	1,495	83	
Greenwald, Thomas	Scientist	1,437	80	
Wimmers, Anthony	Scientist	1,202	67	
Evan, Amato	Scientist	1,064	59	
Velden, Christopher	Scientist	1,024	57	
Huang, Hung-Lung	Scientist	955	53	
Borbas, Eva	Scientist	909	51	
Feltz, Wayne	Scientist	872	48	
Bachmeier, Anthony	**Researcher**	**1,757**	**100**	**12**
Bah, Momodou	**Researcher**	**1,757**	**100**	
Calvert, Corey	**Researcher**	**1,757**	**100**	
Jin, Xin	**Researcher**	**1,757**	**100**	
Li, Jinlong	**Researcher**	**1,757**	**100**	
Liu, Yinghui	**Researcher**	**1,757**	**100**	
Nelson, James III	**Researcher**	**1,757**	**100**	
Stettner, David	**Researcher**	**1,757**	**100**	
Wang, Xuanji	**Researcher**	**1,757**	**100**	
Wanzong, Steven	**Researcher**	**1,757**	**100**	
Schreiner, Anthony	**Researcher**	**1,757**	**100**	
Otkin, Jason	**Researcher**	**1,757**	**100**	
Hoffman, Jay	Researcher	1,744	97	
Sieglaff, Justin	Researcher	1,719	96	
Gunshor, Mathew	Researcher	1,711	95	
Olander, Timothy	Researcher	1,708	95	
Parker, Andrew	Researcher	1,577	88	
Smith, Nadia	Researcher	1,504	84	
Li, Zhenglong	Researcher	1,443	80	
Foster, Mike	Researcher	1,370	76	
Straka, William	Researcher	1,336	74	
Bedka, Kristopher	Researcher	1,270	71	
Brunner, Jason	Researcher	1,251	70	

Dworak, Richard	Researcher	999	56	
Cronce, Lee	Researcher	960	53	
Schaack, Todd	Researcher	919	51	
Berthier, Sebastien	**Post Doctor**	**1,757**	**100**	**3**
Lee, Yong-Keun	**Post Doctor**	**1,757**	**100**	
Walther, Andi	**Post Doctor**	**1,757**	**100**	
Bi, Li	Post Doctor	1,402	78	
Lenzen, Allen	Computer Scientist	1,683	94	
Martin, Graeme	Computer Scientist	1,539	85	
Rink, Thomas	Computer Scientist	1,304	72	
Garcia, Raymond	Computer Scientist	1,267	70	
Flynn, Bruce	Computer Scientist	1,110	62	
Dengel, Russell	Computer Scientist	944	52	
Vasys, Egle	Administrative Asst.	946	53	

Table A3.2: Students receiving support from NOAA

CIMSS Staff Member	Labor Category	Total Hours	FTE %
Bi, Li	Graduate Student	1,402	78
Lim, Agnes	Graduate Student	450	25
Liu, Chian-Yi	Graduate Student	1,350	75
Mozer, Katherine	Graduate Student	765	43
Park, Chang Hwan	Graduate Student	315	18
Rausch, John	Graduate Student	75	4
Sitkowski, Matthew	Graduate Student	450	25
Smith, Nadia	Graduate Student	1,504	84
Gerth, Jordan	Undergraduate Student	1,565	87
Monette, Sarah	Undergraduate Student	75	4
Pasowicz, Daniel	Undergraduate Student	183	10
Rauber, Carolyn	Undergraduate Student	13	1
Rowe, Shellie	Undergraduate Student	34	2
Schiferl, Luke	Undergraduate Student	695	39

Research Topics of Current CIMSS Graduate Students and Post-Docs

NOAA Funded Graduate Students

Jordan Gerth

Research interests involve determining the impact of satellite-derived sea surface temperatures on high spatial resolution numerical weather prediction simulations, particularly centered on the Great Lakes. This work has investigated the genesis of the "pneumonia front", a poorly understood phenomena similar to a sharp mesoscale back door cold front, which occasionally accelerates down the western shore of Lake Michigan during the spring and summer months.

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 these 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, a possible relationship between the number of overshooting tops to the intensification of a hurricane is under investigation. 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 topic uses the new PATMOSx data set constructed by Andrew Heidinger to observe a climatology of microphysical cloud properties. Specifically, the research will focus on those properties as they pertain to marine stratocumulus clouds, hopefully providing more insight to the area of cloud feedback processes.

Chang-Hwan Park
Master's Thesis title: "Assimilation of non-linear observations using approximate background error covariances." Major obstacles for the assimilation of radar data lie in the strong non-linearity of the observation operators and the intermittent nature of the precipitation processes which causes the unrealistic background error covariance matrices in the data assimilation. In this study, a new method is proposed to address this problem and to assimilate radar observations into mesoscale models.

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.

NOAA Funded Post Docs
Sebestien Berthier
Currently focusing on two projects: 1) VIIRS Cloud Studies for NPOESS. The goal of this project is to support the Calibration and Validation Teams created by the Integrated Program Office. By processing MODIS data through VIIRS algorithms globally, traditional validation approaches are used to expose weaknesses in VIIRS algorithms that might go unnoticed until after launch. In addition, modified algorithms are planned in parallel with the VIIRS baseline algorithms and demonstrate improvements for future algorithm updates. 2) Estimation of Cloud Microphysics from MODIS Infrared Observations. MODIS data is used to develop an IR retrieval algorithm for cloud optical thickness and particle size (and hence water content). This approach is applied to global data, and then compared to independent measurements sources, such as CALIOP or Cloudsat data.

Michael Foster
Involved with the development of a method of estimating liquid cloud properties that conserves total-scene reflectance using near-infrared satellite measurements. Also exploring long-term trends in cloud field morphology and feedback processes using the PATMOS-x cloud climatology.

Zhenglong Li (hired into Researcher 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." A unique, standardized database of microwave optical properties for both non-spherical and spherical ice particle models has been developed and is employed to study active and passive microwave remote sensing of clouds and precipitation at higher latitudes. The feasibility of global snowfall retrievals using CloudSat data, and the attendant uncertainties of these snowfall retrievals due to ice particle model assumptions, has been demonstrated as the first component of this research. Additionally, a modeling testbed that seamlessly converts active CloudSat radar reflectivity observations to multi-frequency passive microwave brightness temperatures has been developed and thoroughly tested. This modeling system will enable an objective assessment of various ice particle scattering models over the entire microwave spectral range when compared to actual observations. Furthermore, realistic uncertainties associated with forward modeling can also be established.

Aronne Merrelli

Ph.D. research focuses on far infrared radiative transfer. Current research involves "line by line" radiative transfer codes to create models of atmospheric transmission, and uses these models to develop physically based retrieval algorithms for clear sky atmospheric parameters. Future work will use discrete ordinates codes to model radiation scattering, in order to include cloud properties in the modeling and retrieval framework.

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 on how hyper-spectral channel selection using AIRS can improve cloud top height retrievals and looks to quantify the main uncertainties in the CO2 slicing algorithm.

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 Docs funded on other projects than NOAA
Giuseppe Baldassarre)
Master`s Thesis title: "Robust satellite techniques for fire monitoring: analysis of expected performances using geostationary satellites (MSG-SEVIRI)." Ph.D. research activities aimed at demonstrating the extension of RST (Robust Satellite Techniques, developed at the University of Basilicata) to different geographical areas and different satellite instrumental packages. Analysis of RST and WF-ABBA (Wildfires Automated Biomass Burned Algorithm) approach to detect forest fires by using GOES-Imager and MSG-SEVIRI data. Description of different remapping programs for GOES-Imager data (included the remapping used on MSG program) to detect forest fires.

Colleen Mouw (post-doc)
M.S. thesis title (2003): "Primary production calculations of the Mid-Atlantic Bight, including effects of phytoplankton community size structure." Ph.D. dissertation title (2009): "Bio-optical and remote sensing investigation of phytoplankton community size structure." Current research interests: Optical properties of ocean, Great Lakes and inland water bodies. Algorithm development for remote sensing applications. Phytoplankton ecology, physiology, and primary production. Temporal and spatial variability of phytoplankton in response to climate and anthropogenic change.

Appendix 4. 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 and $50,000 in 2009.

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).

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.

Appendix 5. List of CIMSS Students and/or Staff hired by NOAA during this period

None

Appendix 6. CIMSS publications for 2008-2009

2008-2009 CIMSS Publications

2009 Journal Literature

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*, Volume 90, Issue 9, 2009, pp.1313-1320. Call Number: Reprint # 6131.
http://ams.allenpress.com.ezproxy.library.wisc.edu/archive/1520-0477/90/9/pdf/i1520-0477-90-9-1313.pdf
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*, Volume 114, 2009, doi:10.1029/JD010543, 2009. Call Number: Reprint # 5931.

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*, Volume 48, Issue 8, 2009, pp.1542–1561. Call Number: Reprint # 6108.
http://ams.allenpress.com.ezproxy.library.wisc.edu/archive/1558-8432/48/8/pdf/i1558-8432-48-8-1542.pdf
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*, Volume 47, Issue 7, 2009, pp.1887-1900. Call Number: Reprint # 6081.

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*, Volume 135, 2009, pp.645-662. Call Number: Reprint # 6076.

Cimini, Domenico; Nasir, Francesco; Westwater, Ed. R.; Payne, Vivienne H.; Turner, David D.; Mlawer, Eli J.; Exner, Michael L. and Cadeddu, Maria P. **Comparison of ground-based millimeter-wave**

observations and simulations in the Arctic winter. *IEEE Transactions on Geoscience and Remote Sensing*, Volume 47, Issue 9, 2009, pp.3098-3106. Call Number: Reprint # 6115.

Crewell, Suzanne; Ebell, Kerstin; Lohnert, Ulrich and Turner, D. D. **Can liquid water profiles be retrieved from passivel microwave zenith observations**. *Geophysical Research Letters*, Volume 36, 2009, doi:1029/2008GL036934, 2009. Call Number: Reprint # 6112.

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*, Volume 110, 2009, pp.1190-1198. Call Number: Reprint # 6060.

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*, Volume 48, Issue 1, 2009, pp.24-40. Call Number: Reprint # 5979.
http://ams.allenpress.com/archive/1558-8432/48/1/pdf/i1558-8432-48-1-24.pdf

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*, Volume 324, Issue 5928, 2009, pp.778-781, supplement. Call Number: Reprint # 6054.

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*, Volume 24, Issue 1, 2009, pp.76-86. Call Number: Reprint # 6016.
http://ams.allenpress.com/archive/1520-0434/24/1/pdf/i1520-0434-24-1-76.pdf

Garrett, Kevin, J.; Yang, Ping; Nasiri, Shaima L.; Yost, Christopher R. and Baum, Bryan A. **Influence of cloud-top height and geometric thickness on a MODIS infrared-based ice cloud retrieval**. *Journal of Applied Meteorology and Climatology*, Volume 48, Issue 4, 2009, pp.818-832. Call Number: Reprint # 6050.
http://ams.allenpress.com/archive/1558-8432/48/4/pdf/i1558-8432-48-4-818.pdf

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*, Volume 26, Issue 4, 2009, pp.746-758. Call Number: Reprint # 6053.
http://ams.allenpress.com/archive/1520-0426/26/4/pdf/i1520-0426-26-4-746.pdf

Ham, Seung-Hee; Sohn, Byung-Ju; Yang, Ping and Baum, Bryan A. **Assessment of the Quality of MODIS Cloud Products from Radiance Simulations**. *Journal of Applied Meteorology and Climatology*, Volume 48, Issue 8, 2009, pp.1591-1612. Call Number: Reprint # 6109.
http://ams.allenpress.com.ezproxy.library.wisc.edu/archive/1558-8432/48/8/pdf/i1558-8432-48-8-1591.pdf

Heidinger, Andrew K. and Pavolonis, Michael J. **Gazing at cirrus clouds for 25 years through a split window, part 1: Methodology**. *Journal of Applied Meteorology and Climatology*, Volume 48, Issue 6, 2009, pp.110-1116. Call Number: Reprint # 6079.
http://ams.allenpress.com.ezproxy.library.wisc.edu/archive/1558-8432/48/6/pdf/i1558-8432-48-6-1100.pdf

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*, Volume 66, Issue 3, 2009, pp.705-722. Call Number: Reprint # 6036.
http://ams.allenpress.com/archive/1520-0469/66/3/pdf/i1520-0469-66-3-705.pdf

Hillger, Donald W. and Schmit, Timothy J. **The GOES-13 science test: A synopsis**. *Bulletin of the American Meteorological Society*, Volume 90, Issue 5, 2009, pp.592-597. Call Number: Reprint # 6066.
http://ams.allenpress.com/archive/1520-0477/90/5/pdf/i1520-0477-90-5-592.pdf

Hong, Gang; Yang, Ping; Baum, Bryan A.; Heymsfield, Andrew J.; Weng, Fuzhong; Liu, Quanhua; Heygster, Georg and Buehler, Stefan A. **Scattering database in the millimeter and submillimeter wave range of 100-1000 GHz for nonspherical ice particles**. *Journal of Geophysical Research*, Volume 114, 2009, doi:10.1029/2008JD010451, 2009. Call Number: Reprint # 5986.

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*, Volume 135, 2009, pp.979-1002. Call Number: Reprint # 6082.

Kossin, James P. and Sitkowski, Matthew **An objective model for identifying secondary eyewall formation in hurricanes**. *Monthly Weather Review*, Volume 137, Issue 3, 2009, pp.876-892. Call Number: Reprint # 6048.
http://ams.allenpress.com/archive/1520-0493/137/3/pdf/i1520-0493-137-3-876.pdf

Lakshmanan, Valliappa; Hondl, Kurt and Rabin, Robert **An efficient, general-purpose technique for identifying storm cells in geospatial images**. *Journal of Atmospheric and Oceanic Technology*, Volume 26, Issue 3, 2009, pp.523-537. Call Number: Reprint # 5998.
http://ams.allenpress.com/archive/1520-0426/26/3/pdf/i1520-0426-26-3-523.pdf

Langland, Rolf H.; Velden, Christopher; Pauley, Patricia M. and Berger, Howard **Impact of satellite-derived rapid-scan wind observations on numerical model forecasts of Hurricane Katrina**. *Monthly Weather Review*, Volume 137, Issue 5, 2009, pp.1615-1622. Call Number: Reprint # 6059.
http://ams.allenpress.com/archive/1520-0493/137/5/pdf/i1520-0493-137-5-1615.pdf

Larar, A. M.; Smith, W. L.; Zhou, D. K.; Liu, X.; Revercomb, H.; Taylor, J. P.; Newman, S. M. and Schlussel, P. **IASI spectral radiance performance validation: Case study assessment from the JAIVEx field campaign**. *Atmospheric Chemistry and Physics Discussions*, Volume 9, 2009, pp.10193-10234. Call Number: Reprint # 6085.
http://www.atmos-chem-phys-discuss.net/9/10193/2009/acpd-9-10193-2009-print.pdf

Lepore, Brian J.; Morgan, Cristine L. S.; Norman, John M. and Molling, Christine C. **A mesopore and matrix infiltration model based on soil structure**. *Geoderma*, Volume 152, 2009, pp.301-313. Call Number: Reprint # 6099.

Li, Jun and Liu, Hui **Improved hurricane track and intensity forecast using single field-of-view advanced IR sounding measurements**. *Geophysical Research Letters*, Volume 36, 2009, doi:10.1029/2009GL038285, 2009. Call Number: Reprint # 6074.

Li, Zhenglong; Li, Jun; Menzel, W. Paul; Nelson, James P. III; Schmit, Timothy J.; Weisz, Elisabeth and Ackerman, Steven A. **Forecasting and nowcasting improvement in cloudy regions with high temporal GOES sounder infrared radiance measurements**. *Journal of Geophysical Research*, Volume 114, 2009, doi:10.1029/2008JD10596, 2009. Call Number: Reprint # 6056.

Limaye, Sanjay S.; Kossin, James P.; Rozoff, Christopher; Piccioni, Giuseppe; Titov, Dmitry V. and Markiewicz, Mojciech J. **Vortex circulation on Venus: Dynamical similarities with terrestrial**

hurricanes. *Geophysical Research Letters*, Volume 36, 2009, doi:10.1029/2008GL036093. Call Number: Reprint # 5981.

McComiskey, Allison; Feingold, Graham; Frisch, A. Shelby; Turner, David D.; Miller, Mark A.; Chiu, J. Christine; Min, Qilong and Ogren, John A. **An assessment of aerosol-cloud interactions in marine stratus clouds based on surface remote sensing**. *Journal of Geophysical Research*, Volume 114, 2009, doi:1029/2008JD011006, 2009. Call Number: Reprint # 6075.

Morrison, Hugh; McCoy, Renata B.; Klein, Stephen A.; Xie, Shaocheng; Lao, Yali; Avramov, Alexander; Chen, Mingxuan; Cole, Jason N. S.; Falk, Michael; Foster, Michael J.; Del Genio, Anthony D.; Harrington, Jerry Y.; Hoose, Corinna; Khairoutdinov, Marat F.; Larson, Vincent E.; Liu, Xiaohong; McFarquhar, Greg M.; Poellot, Michael R.; von Salzen, Knut; Shipway, Ben J.; Shupe, Matthew D.; Sud, Yogesh C.; Turner, David D.; Veron, Dana E.; Walker, Gregory K.; Wang, Zhien; Wolf, Audrey B.; 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, II: Multilayer cloud**. *Quarterly Journal of the Royal Meteorological Society*, Volume 135, 2009, pp.1003-1019. Call Number: Reprint # 6083.

Nagle, Frederick W. and Holz, Robert E. **Computationally efficient methods of collocating satellite, aircraft, and ground observations**. *Journal of Atmospheric and Oceanic Technology*, Volume 26, Issue 8, 2009, pp.1585-1595. Call Number: Reprint # 6097.
http://ams.allenpress.com.ezproxy.library.wisc.edu/archive/1520-0426/26/8/pdf/i1520-0426-26-8-1585.pdf
Newman, Stuart M.; Knuteson, Robert O.; Zhou, Daniel K.; Larar, Allen M.; Smith, William L. and Taylor, Jonathan P. **Radiative transfer validation study from the European Aqua Thermodynamic Experiment**. *Quarterly Journal of the Royal Meteorological Society*, Volume 135, 2009, pp.277-290. Call Number: Reprint # 5987.

Otkin, Jason A.; Greenwald, Thomas J.; Sieglaff, Justin and Huang, Hung-Lung **Validation of a Large-Scale Simulated Brightness Temperature Dataset Using SEVIRI Satellite Observations**. *Journal of Applied Meteorology and Climatology*, Volume 48, Issue 8, 2009, pp.1613-1626. Call Number: Reprint # 6110.
http://ams.allenpress.com.ezproxy.library.wisc.edu/archive/1558-8432/48/8/pdf/i1558-8432-48-8-1613.pdf
Pierce, R. Bradley; Al-Saadi, Jassim; Kittaka, Chieko; Schaack, Todd; Lenzen, Allen; Bowman, Kevin; Szykman, Jim; Soja, Amber; Ryerson, Tom; Thompson, Anne M.; Bhartia, Pawan and Morris, Gary A. **Impacts of background ozone production on Houston and Dallas, Texas air quality during the Second Texas Air Quality Study field Mission**. *Journal of Geophysical Research*, Volume 114, 2009, doi:10.1029/2008JD011337, 2009. Call Number: Reprint # 6064.

Qian, Yun; Gong, Daoyi; Fan, Jiwen; Leung, L. Ruby; Bennartz, Ralf; Chen, Deliang and Wang, Weiguo **Heavy pollution suppresses light rain in China: Observations and modeling**. *Journal of Geophysical Research*, Volume 114, 2009, doi:1029/2008JD011575, 2009. Call Number: Reprint # 6102.

Rozoff, Christopher M.; Kossin, James P.; Schubert, Wayne H. and Mulero, Pedro J. **Internal control of hurricane intensity variability: The dual nature of potential vorticity mixing**. *Journal of the Atmospheric Sciences*, Volume 66, Issue 1, 2009, pp.133-147. Call Number: Reprint # 5947.
http://ams.allenpress.com/archive/1520-0469/66/1/pdf/i1520-0469-66-1-133.pdf

Schmit, Timothy J.; Rabin, Robert M.; Bachmeier, A. Scott; Li, Jun; Gunshor, Mathew M.; Steigerwaldt, Henry; Schreiner, Anthony J.; Aune, Robert M. and Wade, Gary S. **Many uses of the geostationary operational environmental satellite-10 sounder and imager during a high inclination state**. *Journal of Applied Remote Sensing*, Volume 3, 2009, doi:10.1117/1.2099709. Call Number: Reprint # 5982.

Shephard, M. W.; Clough, S. A.; Smith, W. L.; Kireev, S. and Cady-Pereira, K. E. **Performance of the line-by-line radiative transfer model (LBLRTM) for temperature and species retrievals: IASI case studies from JAIVEx**. *Atmospheric Chemistry and Physics Discussions*, Volume 9, 2009, pp.9313-9366. Call Number: Reprint # 6084.
http://www.atmos-chem-phys-discuss.net/9/9313/2009/acpd-9-9313-2009-print.pdf

Sieglaff, Justin M.; Schmit, Timothy J.; Menzel, W. Paul and Ackerman, Steven A. **Inferring convective weather characteristics with geostationary high spectral resolution IR**. *Journal of Atmospheric and Oceanic Technology*, Volume 26, Issue 8, 2009, pp.1527-1541. Call Number: Reprint # 6096.
http://ams.allenpress.com.ezproxy.library.wisc.edu/archive/1520-0426/26/8/pdf/i1520-0426-26-8-1527.pdf

Smith, W. L. Sr.; Revercomb, H.; Bingham, G.; Larar, A.; Huang, H.; Zhou, D.; Li, J.; Liu, X. and Kireev, S. **Evolution, current capabilities, and future advances in satellite ultra-spectral IR sounding**. *Atmospheric Chemistry and Physics Discussions*, Volume 9, 2009, pp.6541-6569. Call Number: Reprint # 6080.
http://www.atmos-chem-phys-discuss.net/9/6541/2009/acpd-9-6541-2009-print.pdf

Velden, Christopher S. and Bedka, Kristopher M. **Identifying the uncertainty in determining satellite-derived atmospheric motion vector height attribution**. *Journal of Applied Meteorology and Climatology*, Volume 48, Issue 3, 2009, pp.450-463. Call Number: Reprint # 6017.
http://ams.allenpress.com/archive/1558-8432/48/3/pdf/i1558-8432-48-3-450.pdf

Verma, Sunita; Worden, John; Pierce, Brad; Jones, Dylan B. A.; Al-Saadi, Jassim; Boersma, Folkert; Bowman, Kevin; Eldering, Annmarie; Fisher, Brendan; Jourdain, Line; Kulawik, Susan and Worden, Helen **Ozone production in boreal fire smoke plumes using observations from the Tropospheric Emission Spectrometer and the Ozone Monitoring Instrument**. *Journal of Geophysical Research*, Volume 114, 2009, doi:1029/2008DJ010108, 2009. Call Number: Reprint # 6063.

Vidot, Jerome; Bennartz, Ralf; O'Dell, Christopher W.; Preusker, Rene; Lindstrot, Rasmus and Heidinger, Andrew K. **CO2 retrieval over clouds from the OCO Mission: Model simulations and error analysis**. *Journal of Atmospheric and Oceanic Technology*, Volume 26, Issue 6, 2009, pp.1090-1104. Call Number: Reprint # 6067.
http://ams.allenpress.com/archive/1520-0426/26/6/pdf/i1520-0426-26-6-1090.pdf

Wu, D. L.; Ackerman, S. A.; Davies, R.; Diner, D. J.; Garay, M. J.; Kahn, B. H.; Maddux, B. C.; Moroney, C. M.; Stephens, G. L.; Veefkind, J. P. and Vaughn, M. A. **Vertical distributions and relationships of cloud occurrence frequency as observed by MISR, AIRS, MODIS, OML, CALIPSO, and CloudSat**. *Geophysical Research Letters*, Volume 36, 2009, doi:10.1029/2009GL037464, 2009. Call Number: Reprint # 6055.

Zhang, Z.; Yang, P.; Kattawar, G.; Riedi, J.; Labonnete, L. C.; Baum, B.; Platnick, S. and Huang, H.-L. **Influence of ice particle model on satellite ice cloud retrieval: Lessons learned from MODIS and POLDER cloud product comparison**. *Atmospheric Chemistry and Physics*, Volume 9, Issue 7115, 2009. Call Number: Reprint # 6128.
http://www.atmos-chem-phys.net/9/7115/2009/acp-9-7115-2009.pdf

Zhang, Z.; Yang, P.; Kattawar, G.; Riedi, J.; Labonnete, L. C.; Baum, B.; Platnick, S. and Huang, H.-L. **Influence of ice particle model on retrieving cloud optical thickness from satellite measurements: Model comparison and implication for climate study**. *Atmospheric Chemistry and Physics*

Discussions, Volume 9, Issue 1757, 2009. Call Number: Reprint # 6087.
http://www.atmos-chem-phys-discuss.net/9/1757/2009/acpd-9-1757-2009-print.pdf
Zhou, D. K.; Smith, W. L.; Larar, A. M.; Liu, X.; Taylor, J. P.; Schlussel, P.; Strow, L. L. and Mango, S. A. **All weather IASI single field-of-view retrievals: Case study - validation with JAIVEx data**. *Atmospheric Chemistry and Physics*, Volume 9, 2009, pp.2241-2255. Call Number: Reprint # 6045.
http://www.atmos-chem-phys.net/9/2241/2009/acp-9-2241-2009.pdf

2009 Gray Literature

Achtor, Thomas H.; Rink, T.; Whittaker, T. and Santek, D. **McIDAS-V: A powerful data analysis and visualization tool for multi and hyperspectral environmental satellite data**. In: Conference on International Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, 25th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Bedka, Sarah; Antonelli, P.; Knuteson, R.; Revercomb, H. E.; Smith, W.; Tobin, D. and Woolf, H. **Retrievals of upper tropospheric temperature and water vapor using UW/SSEC S-HIS data collected during the Joint Airborne IASI Validation Experiment (JAIVEx)**. In: Conference on Satellite Meteorology and Oceanography, 16th; and Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Bedka, Sarah; Cychosz, Jacob; Evansen, Megan; Knuteson, Robert; Revercomb, Henry; Tobin, David and Turner, David **An analysis of the seasonal and diurnal variation of total precipitable water from satellite and ground-based instruments over the ARM SGP and TWP sites**. In: Conference on Satellite Meteorology and Oceanography, 16th; and Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, Paper JP2.13. Call Number: Reprint # 5923.

Brunner, Jason; Schmidt, C. C.; Prins, E. M.; Feltz, J. M.; Hoffman, J. P. and Lindstrom, S. S. **WF_ABBA Version 6.5: An overview of the improvements and trend analyses of fires from 1995 to present over the western Hemisphere**. In: Conference on Satellite Meteorology and Oceanography, 16th; and Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Dutcher, Steve; Tobin, David; Holz, Bob; Moeller, Chris and Revercomb, Hank **Five years of global comparisons of AIRS and MODIS infrared radiances**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.239-242. Call Number: Reprint # 6025.

Greenwald, Tom; Lee, Yong-Keun; Otkin, Jason and Sieglaff, Justin **Verification of a cloud resolving NWP model simulation using satellite measurements**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.619-622. Call Number: Reprint # 6026.

Guch, Ingred C.; Ackerman, S. A.; DeMaria, M.; Ferraro, R.; Gallo, K.; Hudson, R. D.; Khanbivardi, D. R.; Kidder, S. Q.; Menzel, W. P.; Strub, T. and Vant Hull, B. **Collaborative training efforts at the NESDIS cooperative institutes**. In: Conference on Satellite Meteorology and Oceanography, 16th;

Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th; and Symposium on Education, 18th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, Paper 11.5. Call Number: Reprint # 5913.

Han, Hyo-Jin; Sohn, Byung-Ju; Huang, Aellen [Huang, Allen] and Weisz, Elizabeth [Weisz, Elisabeth] **Simulation of the monchromatic radiative signature of Asian dust over the infrared region**. In: Conference on Satellite Meteorology and Oceanography, 16th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, Paper P1.4. Call Number: Reprint # 5924.

Hartung, Daniel C.; Otkin, J. A.; Martin, J. E. and Turner, D. D. **The life cycle of an undular bore and its interaction with a shallow, intense cold front**. In: Conference on Mesoscale Processes, 13th, Salt Lake City, UT, 17-20 August 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication; recorded presentation only.

Heck, Patrick W.; Minnis, Patrick; Yang, Ping; Chang, Fu-Lung; Palikonda, Rabindra; Arduini, Robert F. and Sun-Mack, Sunny **Retrieval of ice cloud properties using variable phase functions**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.384-387. Call Number: Reprint # 6035.

Kassianov, Evgueni; Berg, Larry K.; McFarlane, Sally A.; Flynn, Connor and Turner, David **Long-term statistics of continental cumuli: Does aerosol trigger cumulus variability?**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.470-473. Call Number: Reprint # 6029.

Kassianov, Evgueni; McFarlane, Sally A.; Barnard, James; Flynn, Connor; Slingo, Anthony; Bharmal, Nazim; Robinson, Gary; Turner, David; Miller, Mark; Ackerman, Thomas and Miller, Ron **International RADAGAST experiment in Niamey, Niger: Changes and drivers of atmospheric radiation balance**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.537-540. Call Number: Reprint # 6027.

Kruk, Michael C.; Knapp, Kenneth R.; Levinson, David H.; Diamond, Howard J. and Kossin, James P. **An overview of the International Best Track Archive for Climate Stewardship (IBTrACS)**. In: Conference on Climate Variability and Change, 21st, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, Paper 7B.1. Call Number: Reprint # 5914.

Kuji, Makoto; Platnick, Steven; King, Michael D.; Arnold, George T.; Wind, Gala; McGill, Matthew; Hart, William D.; Hlavka, Dennis L. and Holz, Robert E. **Comparison of cloud top altitudes from passive and active remote sensors onboard ER-2 during TC**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.474-477. Call Number: Reprint # 6028.

Larar, Allen M.; Zhou, Daniel K.; Liu, Xu and Smith, William L. **Select methodology for validating advanced satellite measurement systems**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.275-278. Call Number: Reprint # 6032.

Lazzara, Matthew A.; Dworak, Richard; Santek, David A.; Velden, Chris S. and Key, Jeffrey R. **Antarctic atmospheric motion vectors: Application of Antarctic composite satellite meteorology**. In: Antarctic Meteorological Observation, Modeling, and Forecasting Workshop, 4th, Charleston, SC, 14-16 July 2009 (preprints). [Madison, WI], [University of Wisconsin-Madison, Space Science and Engineering Center, Antarctic Meteorological Research Center (AMRC)], 2009. 2p. Call Number: Reprint # 6094.

Le Marshall, J. and Jung, J. **The benefits of increased use of the information content of hyperspectral observations in numerical weather prediction**. In: Conference on Satellite Meteorology and Oceanography, 16th; Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 13th; and Annual Symposium on Future Operational Environmental Satellite Systems . Boston, MA, American Meteorological Society, 2009, Paper J14.4. Call Number: Reprint # 5915.

Lewis, Paul E.; Anderson, Gail P.; Shen, Sylvia S.; Chetwynd, James; Roman, Miguel III; Turner, David D.; Rutan, David A.; Berk, Alexander; Miller, David P. and Kroutil, Robert **MODTRAN 5 analysis of clear-sky, co-located space- and ground-based infrared atmospheric measurements: AERI, AIRS, CERES, and MODIS**. In: Algorithms and Technologies for Multispectral, Hyperspectral, and Ultraspectral Imagery XV, Orlando, FL, 13-16 April 2009. Proceedings. Bellingham, WA, SPIE-International Society for Optical Engineering, 2009, Paper 733410. Call Number: Reprint # 6116.

Li, Zhenglong; Li, J.; Menzel, P.; Schmit, T. J. and Nelson, J. **High temporal GOES sounding retrievals in cloudy regions and applications**. In: Conference on Satellite Meteorology and Oceanography, 16th; and Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Liu, Xu; Zhou, D.; Larar, A.; Smith, W. L.; Schluessel, P.; Mango, S. A. and St. Germain. K. **Atmospheric sounding under cloudy atmospheric conditions**. In: Conference on Satellite Meteorology and Oceanography, 16th; and Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Liu, Xu; Zhou, Daniel K.; Larar, Allen; Smith, William L. and Schluessel, Peter **Radiative transfer and retrieval in EOF domain**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.283-286. Call Number: Reprint # 6033.

Mehta, Payal; Harries, John E. and Turner, David D. **Effect of size distribution and particle shape on simulations of downwelling infrared spectra during Saharan dust storms**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.177-180. Call Number: Reprint # 6031.

Menzel, Paul; Antonelli, P.; Rink, T. D.; Strabala, K. I.; Gumley, L. E.; Huang, A.; Ackerman, S.; Revercomb, H. and Smith, B. **International training events and educational seminars on satellite remote sensing**. In: Conference on Satellite Meteorology and Oceanography, 16th; Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th; and Symposium on Education, 18th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Minnis, Patrick; Nguyen, L.; Palikonda, R.; Heck, P. W.; Spangenberg, D. A.; Khaiyer, M.; Ayers, J. K.; Smith, W. L. Jr.; Chang, F. L.; Trepte, Q. Z.; Doelling, D. R.; Yost, C. R.; Avey, L. A. and Chee, T. L. **Retrieving cloud and radiation parameters in near-real-time from global geostationary satellite data**. In: Conference on Satellite Meteorology and Oceanography, 16th; and Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Mishra, Subhashree; Mitchell, David L. and DeSlover, Daniel **Ground based retrievals of small ice crystals and water phase in Arctic cirrus**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.482-485. Call Number: Reprint # 6022.

Moy, Leslie; Knuteson, Robert; Tobin, David; Revercomb, Henry and Borg, Lori **Clear and all sky radiative closure studies for OLR assessment with CERES and AIRS**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.561-564. Call Number: Reprint # 6023.

Murray, Don; McWhirter, Jeff; Ho, Yuan and Whittaker, Tom **The IDV at 5: new features and future plans**. In: Conference on International Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, 25th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, Paper 7B.5. Call Number: Reprint # 5922.

Petersen, Ralph A. and Aune, R. M. **Optimizing the impact of GOES sounder products to very-short-range forecasts: Recent results and future plans**. In: Conference on Satellite Meteorology and Oceanography, 16th; and Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Petrenko, Boris; Ignatov, A.; Shabanov, N.; Liang, X.; Kihan, Y. and Heidinger, A. **Cloud mask and quality control for SST within the Advanced Clear Sky Processor for Oceans (ACSPO)**. In: Conference on Satellite Meteorology and Oceanography, 16th; and Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, Paper JP1.12. Call Number: Reprint # 5921.

Platnick, Steven; Wind, Gala; King, Michael D.; Holz, Robert E.; Ackerman, Steven A. and Nagle, Fred W. **Comparison of the MODIS collection 5 multilayer cloud detection product with CALIPSO**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.416-419. Call Number: Reprint # 6030.

Revercomb, Hank; Smith, B.; Bingham, G. A. and Velden, C. **Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS): An advanced sounder offering two orders of magnitude improvement**. In: Conference on Satellite Meteorology and Oceanography, 16th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Schmidt, Christopher C.; Prins, E. M.; Brunner, J. C.; Hoffman, J. P.; Lindstrom, S. S. and Feltz, J. M. **Geostationary detection of fires and the global and long-term datasets of the WF_ABBA**. In:

Conference on Satellite Meteorology and Oceanography, 16th; and Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Schmidt, Timothy J.; Li, J.; Gurka, J.; Daniels, J.; Goldberg, M. and Menzel, P. **Soundings from current and future geostationary satellites**. In: Conference on Satellite Meteorology and Oceanography, 16th; and Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Sieglaff, Justin; Schmit, T. J.; Menzel, P. and Ackerman, S. **Inferring convective weather characteristics with geostationary high spectral resolution IR window measurements: A look into the future**. In: Conference on Satellite Meteorology and Oceanography, 16th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Smith, William L. Sr. **Evolution, current capabilities, and advances in satellite ultra-spectral IR sounding**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.335-338. Call Number: Reprint # 6034.

Smith, William Sr.; Revercomb, H. and Tian, J. **Mesoscale sounding capabilities with GOES-R and beyond**. In: Conference on Satellite Meteorology and Oceanography, 16th; and Annual Symposium on Future Operational Environmental Satellite Systems NPOESS and GOES-R, 5th, Phoenix, AZ, 11-15 January 2009. Boston, MA, American Meteorological Society, 2009, manuscript not available for publication.

Tian, Jialin; Smith, William L. and Gazarik, Michael J. **Radiometric and spectral calibration of the Geostationary Imaging Fourier Transform Spectrometer (GIFTS) using priciple component analysis**. In: Sensors, Systems, and Next-Generation Satellites, XIII, Cardiff, Wales, UK, 15-18 September 2008. Bellingham, WA, SPIE-International Society for Optical Engineering, 2009, Paper 710613. Call Number: Reprint # 6129.

Tobin, David; Revercomb, Hank and Antonelli, Paolo **Principal component analysis of IASI spectra with a focus on non-uniform scene effects on the ILS**. In: IRS 2008: Current problems in atmospheric radiation. Proceedings of the International Radiation Symposium, Foz do Iguacu, Brazil, 3-8 August 2008. American Institute of Physics, 2009, pp.16-19. Call Number: Reprint # 6024.

2008 Journal Literature

Ackerman, S. A.; Holz, R. E.; Frey, R.; Eloranta, E. W.; Maddux, B. C. and McGill, M. **Cloud detection with MODIS, part II: Validation**. *Journal of Atmospheric and Oceanic Technology*, Volume 25, Issue 7, 2008, pp.1073-. Call Number: Reprint # 5779.
http://ams.allenpress.com/archive/1520-0426/25/7/pdf/i1520-0426-25-7-1073.pdf
Ackerman, Steven A.; Schreiner, Anthony J.; Schmit, Timothy J.; Woolf, Harold M.; Li, Jun and Pavolonis, Michael **Using the GOES sounder to monitor upper level SO2 from volcanic eruptions**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2007JD009622, 2008. Call Number: Reprint # 5730.

Al-Saadi, Jassim; Soja, Amber; Pierce, R. Bradley; Szykman, James; Wiedinmyer, Christin; Emmons, Louisa; Kondragunta, Shobha; Zhang, Xiaoyang; Kittaka, Chieko; Schaack, Todd and Bowman, Kevin **Intercomparison of near-real-time biomass burning emissions estimates constrained by satellite fire data**. *Journal of Applied Remote Sensing*, Volume 2, 2008, doi:10.1117/1.2948785. Call Number: Reprint # 5900.

Berendes, Todd A.; Mecikalski, John R.; MacKenzie, Wayne M. Jr.; Bedka, Kristopher M. and Nair, U. S. **Convective cloud identification and classification in daytime satellite imagery using deviation limited adaptive clustering**. *Journal of Geophysical Research*, Volume 113, 2008, doi.10:1029/2008JD010287, 2008. Call Number: Reprint # 5867.

Berthier, S.; Chazette, P.; Pelon, J. and Baum, B. **Comparison of cloud statistics from spaceborne lidar systems**. *Atmospheric Chemistry and Physics Discussions*, Volume 8, Issue 2, 2008, pp.5269-5304. Call Number: Reprint # 5748.
http://www.atmos-chem-phys-discuss.net/8/5269/2008/acpd-8-5269-2008.pdf
Berthier, S.; Chazette, P.; Pelon, J. and Baum, B. **Comparison of cloud statistics from spaceborne lidar systems**. *Atmospheric Chemistry and Physics*, Volume 8, 2008, pp.6965-6977. Call Number: Reprint # 6041.
http://www.atmos-chem-phys.net/8/6965/2008/acp-8-6965-2008.pdf
Boesche, Eyk; Stammes, Piet; Preusker, Rene; Bennartz, Ralf; Knap, Wouter and Fischer, Juergen **Polarization of skylight in the O2A band: Effects of aerosol properties**. *Applied Optics*, Volume 47, Issue 19, 2008, pp.3467-3480. Call Number: Reprint # 5793.

Bonilla, Carlos A.; Norman, John M.; Molling, Christine C.; Karthikeyan, K. G. and Miller, Paul S. **Testing a grid-based soil erosion model across topographically complex landscapes**. *SSSAJ: Soil Science Society of America Journal*, Volume 72, Issue 6, 2008, pp.1745-1755. Call Number: Reprint # 5901.

Borbas, Eva E.; Menzel, W. Paul; Weisz, Elisabeth and Devenyi, Dezso **Deriving atmospheric temperature of the tropopause region-upper troposphere by combining information from GPS radio occultation refractivity and high-spectral-resolution infrared radiance measurements**. *Journal of Applied Meteorology and Climatology*, Volume 47, Issue 9, 2008, pp.2300-2310. Call Number: Reprint # 5834.
http://ams.allenpress.com/archive/1558-8432/47/9/pdf/i1558-8432-47-9-2300.pdf
Bromirski, Peter D. and Kossin, James P. **Increasing hurricane wave power along the US Atlantic and Gulf coasts**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2007JC004706, 2008. Call Number: Reprint # 5752.

Buker, M. L.; Hitchman, Matthew H.; Tripoli, Gregory J.; Pierce, R. B.; Browell, E. V. and Al-Saadi, J. A. **Long-range convective ozone transport during INTEX**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2007JD009345, 2008. Call Number: Reprint # 5781.

Cady-Pereira, K. E.; Shephard, M. W./Turner, D. D.; Mlawer, E. J./Clough, S. A. and Wagner, T. J. **Improved daytime column-integrated precipitable water vapor from Vaisala radiosonde humidity sensors**. *Journal of Atmospheric and Oceanic Technology*, Volume 25, Issue 6, 2008, pp.873-883. Call Number: Reprint # 5733.
http://ams.allenpress.com/archive/1520-0426/25/6/pdf/i1520-0426-25-6-873.pdf
Elsner, James B.; Kossin, James P. and Jagger, Thomas H. **The increasing intensity of the strongest tropical cyclones**. *Nature*, Issue 7209, 2008, pp.92-95. Call Number: Reprint # 5831.

Evan, A. T. **State of the climate in 2007: Global aerosols**. *Bulletin of the American Meteorological Society*, Volume 89, Issue 7, 2008, S31-S32. Call Number: Reprint # 5790.
http://ams.allenpress.com/archive/1520-0477/89/7/pdf/i1520-0477-89-7-s1.pdf
Evan, A. T.; Liu, Y. and Maddux, B. **State of the climate in 2007: Global cloudiness**. *Bulletin of the American Meteorological Society*, Volume 89, Issue 7, 2008, S23-S26. Call Number: Reprint # 5789.
http://ams.allenpress.com/archive/1520-0477/89/7/pdf/i1520-0477-89-7-s1.pdf
Evan, Amato T.; Heidinger, Andrew K.; Bennartz, Ralf; Bennington, Val; Mahowald, Natalie M.; Corrada-Bravo, Hector; Velden, Christopher S.; Myhre, Gunnar and Kossin, James P. **Ocean temperature forcing by aerosols across the Atlantic tropical cyclone development region**. *Geochemistry, Geophysics, Geosystems*, Volume 9, 2008, doi:10.1029/2007GC001774. Call Number: Reprint # 5750.

Fishman, Jack; Bowman, Kevin W.; Burrows, John P.; Richter, Andreas; Chance, Kelly V.; Dewards, David P.; Martin, Randall V.; Morris, Gary A.; Pierce, R. Bradley; Ziemke, Jerald R.; Al-Saadi, Jassim A.; Creilson, John K.; Schaack. Todd K. and Thompson, Anne M. **Remote sensing of tropospheric pollution from space**. *Bulletin of the American Meteorological Society*, Volume 89, Issue 6, 2008, pp.805-821. Call Number: Reprint # 5727.
http://ams.allenpress.com/archive/1520-0477/89/6/pdf/i1520-0477-89-6-805.pdf
Frey, Richard A.; Ackerman, Steven A.; Liu, Yinghui; Strabala, Kathleen I.; Zhang, Hong; Key, Jeffrey R. and Wang, Xuangi **Cloud detection with MODIS, part I: Improvements in the MODIS cloud mask for collection 5**. *Journal of Atmospheric and Oceanic Technology*, Volume 25, Issue 7, 2008, pp.1057-1072. Call Number: Reprint # 5778.
http://ams.allenpress.com/archive/1520-0426/25/7/pdf/i1520-0426-25-7-1057.pdf
Holz, R. E.; Ackerman, S. A.; Nagle, F. W.; Frey, R.; Dutcher, S.; Kuehn, R. E.; Vaughan, M. A. and Baum, B. **Global Moderate Resolution Imaging Spectroradiometer (MODIS) cloud detection and height evaluation using CALIOP**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2008JD009837, 2008. Call Number: Reprint # 5918.

Hong, Gang; Yang, Ping; Baum, Bryan A. and Heymsfield, Andrew J. **Relationship between ice water content and equivalent radar reflectivity for clouds consisting of nonspherical ice particles**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2008JD009890, 2008. Call Number: Reprint # 5864.

Hoose, C.; Lohmann, U.; Bennartz, R.; Croft, B. and Lesins, G. **Global simulations of aerosol processing in clouds**. *Atmospheric Chemistry and Physics Discussions*, Volume 8, 2008, pp.13555-13618. Call Number: Reprint # 6042.
http://www.atmos-chem-phys-discuss.net/8/13555/2008/acpd-8-13555-2008-print.pdf
Huang, Bormin; Ahoja, Alok and Huang, Hung-Lung **Optimal compression of high spectral resolution satellite data via adaptive vector quantization with linear prediction**. *Journal of Atmospheric and Oceanic Technology*, Volume 25, Issue 6, 2008, pp.1041-1047. Call Number: Reprint # 5732.
http://ams.allenpress.com/archive/1520-0426/25/6/pdf/i1520-0426-25-6-1041.pdf
Jasmin, Tommy **Satellite observations in science education: A free toolkit for developing scientific e-learning activities**. *The Earth Scientist*, Volume 24, Issue 4, 2008, pp.8-10. Call Number: Reprint # 5925.

Jin, Xin; Li, Jun; Schmidt, Christopher C.; Schmit, Timothy J. and Li, Jinlong **Retrieval of total column ozone from imagers onboard geostationary satellites**. *IEEE Transactions on Geoscience and Remote Sensing*, Volume 46, Issue 2, 2008, pp.479-488. Call Number: Reprint # 5661.

Jin, Xin; Li, Jun; Schmit, Timothy J.; Li, Jinlong; Goldberg, Mitchell D. and Gurka, James J. **Retrieving clear-sky atmospheric parameters from SEVIRI and ABI infrared radiances**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2008JD010040, 2008. Call Number: Reprint # 5816.

Jung, James A.; Zapotocny, Tom H.; Le Marshall, John F. and Treadon, Russ E. **A two-season impact study of NOAA polar-orbiting satellites in the NCEP Global Data Assimilation System**. *Weather and Forecasting*, Volume 23, Issue 5, 2008, pp.854-877. Call Number: Reprint # 5859.
http://ams.allenpress.com/archive/1520-0434/23/5/pdf/i1520-0434-23-5-854.pdf
Kahn, B. H.; Chahine, M. T.; Stephens, G. L.; Mace, G. G.; Marchard, R. T.; Wang, Z.; Barner, C. D.; Eldering, A.; Holz, R. E.; Kuehn, R. E. and Vane, D. G. **Cloud type comparison of AIRS, CloudSat, and CALIPSO cloud height and amount**. *Atmospheric Chemistry and Physics*, Volume 8, 2008, pp.1231-1248. Call Number: Reprint # 5879.
http://www.atmos-chem-phys.net/8/1231/2008/acp-8-1231-2008.pdf
Knaff, John A.; Cram, Thomas A.; Schumacher, Andrea B.; Kossin, James P. and DeMaria, Mark **Objective identification of annular hurricanes**. *Weather and Forecasting*, Volume 23, Issue 2, 2008, pp.17-28. Call Number: Reprint # 5672.
http://ams.allenpress.com/archive/1520-0434/23/1/pdf/i1520-0434-23-1-17.pdf
Koch, Steven E.; Feltz, Wayne; Fabry, Frederic; Pagowski, Mariusz; Gerrts, Bart; Bedka, Kristopher M.; Miller, David O. and Wilson, James W. **Turbulent mixing processes in atmospheric bores and solitary waves deduced from profiling systems and numerical simulation**. *Monthly Weather Review*, Volume 136, Issue 4, 2008, pp.1373-1400. Call Number: Reprint # 5713.
http://ams.allenpress.com/archive/1520-0493/136/4/pdf/i1520-0493-136-4-1373.pdf
Kossin, James P. **A scientific tempest**. *American Scientist*, Volume 96, Issue 1, 2008, pp.78-80. Call Number: Reprint # 5621.

Kossin, James P. **Is the North Atlantic hurricane season getting longer?**. *Geophysical Research Letters*, Volume 25, 2008, doi:10.1029/2008GL036012, 2008. Call Number: Reprint # 5904.

Krijger, J. M.; van Weele, M.; Aben, I. and Frey, R. **The effect of sensor resolution on the number of cloud-free observations from space**. *Atmospheric Chemistry and Physics*, Volume 7, 2008, pp.2881-2891. Call Number: Reprint # 5734.
http://www.atmos-chem-phys.net/7/2881/2007/acp-7-2881-2007.pdf
Le Marshall, J.; Jung, J.; Goldberg, M.; Barnet, C.; Wolf, W.; Derber J.; Treadon, R. and Lord, S. **Using cloudy AIRS fields of view in numerical weather prediction**. *Australian Meteorological Magazine*, Volume 57, Issue 4, 2008, pp.249-254. Call Number: Reprint # 5953.

Le Marshall, J.; Jung, J.; Zapotocny, T.; Redder, C.; Dunn, M.; Daniels, J. and Riishojgaard, Lars Peter **Impact of MODIS atmospheric motion vectors on a global NWP system**. *Australian Meteorological Magazine*, Volume 57, Issue 1, 2008, pp.45-51. Call Number: Reprint # 5777.
http://www.bom.gov.au/amm/200801/lemarshall_hres.pdf
Le Marshall, J.; Seecamp. R.; Dunn,. M.; Velden, C.; Wanzong, S.; Puri, K.; Bowen, R. and Rea, A. **The contribution of locally generated MTSat-IR atmospheric motion vectors to operational meteorology in the Australian region**. *Australian Meteorological Magazine*, Volume 57, Issue 4, 2008, pp.359-365. Call Number: Reprint # 6057.
http://www.bom.gov.au/amm/200804/lemarshall_hres.pdf
Li, Jun and Li, Jinlong **Derivation of global hyperspectral resolution surface emissivity spectra from advanced infrared sounder radiance measurements**. *Geophysical Research Letters*, Volume 35, Issue 15, 2008, doi:10.1029/2008GL034559, 2008. Call Number: Reprint # 5856.

Li, Zhenglong; Li, Jun; Menzel, W. Paul; Schmit, Timothy J.; Nelson, James P. III; Daniels, Jaime and Ackerman, Steven A. **GOES sounding improvement and applications to severe storm nowcasting**. *Geophysical Research Letters*, Volume 35, Issue 3, 2008, doi:10.1029/2007GL032797, 2008. Call Number: Reprint # 5677.

Liu, Chian-Yi; Li, Jun; Weisz, Elisabeth; Schmit, Timothy J.; Ackerman, Steven A. and Huang, Hung-Lung **Synergistic use of AIRS and MODIS radiance measurements for atmospheric profiling**. *Geophysical Research Letters*, Volume 35, 2008, doi.10:1029/2008GL035859, 2008. Call Number: Reprint # 5865.

Liu, Yinghui; Key, Jeffrey R. and Wang, Xuanji **The influence of changes in cloud cover on recent surface temperature trends in the Arctic**. *Journal of Climate*, Volume 21, Issue 4, 2008, pp.705-715. Call Number: Reprint # 5644.
http://ams.allenpress.com/archive/1520-0442/21/4/pdf/i1520-0442-21-4-705.pdf

Long, C. N. and Turner, D. D. **A method for continuous estimation of clear-sky downwelling longwave radiative flux developed using ARM surface measurements**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2008JC009936, 2008. Call Number: Reprint # 5852.

Lyapustin, A.; Wang, Y. and Frey, R. **An automatic cloud mask algorithm based on time series of MODIS measurements**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2007/JD009641, 2008. Call Number: Reprint # 5850.

Martin, David W.; Kohrs, Richard A.; Mosher, Frederick R.; Medaglia, Carlo Maria and Adamo, Claudia **Over-Ocean Validation of the Global Convective Diagnostic**. *Journal of Applied Meteorology and Climatology*, Volume 47, Issue 2, 2008, pp.525-543. Call Number: Reprint # 5709.
http://ams.allenpress.com/archive/1558-8432/47/2/pdf/i1558-8432-47-2-525.pdf

Mecikalski, John R.; Bedka, Kristopher M.; Paech, Simon J. and Litten, Leslie A. **A statistical evaluation of GOES cloud-top properties for nowcasting convective initiation**. *Monthly Weather Review*, Volume 136, Issue 12, 2008, pp.4899-4914. Call Number: Reprint # 5926.
http://ams.allenpress.com/archive/1520-0493/136/12/pdf/i1520-0493-136-12-4899.pdf

Melnikov, V. M.; Zrnic, D. S.; Rabin, R. M. and Zhang, P. **Radar polarimetric signatures of fire plumes in Oklahoma**. *Geophysical Research Letters*, Volume 35, Issue 14, 2008, doi:1029/2008GL034311, 2008. Call Number: Reprint # 5791.

Menzel, W. Paul; Frey, Richard A.; Zhang, Hong; Wylie, Donald P.; Moeller, Chris C.; Holz, Robert E.; Maddux, Brent; Baum, Bryan A.; Strabala, Kathy I. and Gumley, Liam E. **MODIS global cloud-top pressure and amount estimation: Algorithm description and results**. *Journal of Applied Meteorology and Climatology*, Volume 47, Issue 4, 2008, pp.1175-1198. Call Number: Reprint # 5727.
http://ams.allenpress.com/archive/1558-8432/47/4/pdf/i1558-8432-47-4-1175.pdf

Nazaryan, Hovakim; McCornick, M. Patrick and Menzel, W. Paul **Global characterization of cirrus clouds using CALIPSO data**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2007JD009481, 2008. Call Number: Reprint # 5832.

Otkin, Jason A. and Greenwald, Thomas J. **Comparison of WRF model-simulated and MODIS-derived cloud data**. *Monthly Weather Review*, Volume 136, Issue 6, 2008, pp.1957-1970. Call Number: Reprint # 5726.
http://ams.allenpress.com/archive/1520-0493/136/6/pdf/i1520-0493-136-6-1957.pdf

Peppler, R. A.; Long, C. N.; Sisterson, D. L.; Turner, D. D.; Bahrmann, C. P.; Christensen, S. W.; Doty, K. J.; Eagan, R. C.; Halter, T. D.; Ivey, M. D.; Keck, N. N.; Kehoe, K. E.; Liljegren, J. C.; Macduff, M. C.; Mather, J. H.; McCord, R. A.; Monroe, J. W.; Moore, S. T.; Nitschke, K. L.; Orr, B. W.; Perez, R. C.;

Perkins, B. D.; Richardson, S. J.; Sonntag, K. L.; Voyles, J. W. and Wagener, R. **An overview of ARM Program Climate Research Facility data quality assurance**. *Open Atmospheric Science Journal*, Volume 2, 2008, pp.192-216. Call Number: Reprint # 5905.
http://www.ecd.bnl.gov/pubs/BNL-79549-2007-JA-R1.pdf
Plokhenko, Youri; Menzel, W. Paul; Revercomb, Henry E.; Borbas, Eva; Antonelli, Paolo and Weisz, Elisabeth **Analysis of multispectral fields of satellite IR measurements: Using statistics of second spatial differential of spectral fields for measurement characterization**. *International Journal of Remote Sensing*, Volume 29, Issue 7, 2008, pp.2105-2125. Call Number: Reprint # 5715.

Pu, Zhaoxia; Li, Xuanli; Velden, Christopher S.; Aberson, Sim D. and Liu, W. Timothy **The impact of aircraft dropsonde and satellite wind data on numerical simulations of two landfalling tropical storms during the Tropical Cloud Systems and Processes experiment**. *Weather and Forecasting*, Volume 23, Issue 2, 2008, pp.62-79. Call Number: Reprint # 5673.
http://ams.allenpress.com/archive/1520-0434/23/1/pdf/i1520-0434-23-1-62.pdf
Ramankutty, Navin; Evan, Amato T.; Monfreda, Chad and Foley, Jonathan A. **Farming the planet: 1. Geographic distribution of global agricultural lands in the year 2000**. *Global Biogeochemical Cycles*, Volume 22, Issue 1, 2008, doi:10.1029/2008GB002952, 2008. Call Number: Reprint # 5659.

Rowe, Penny M.; Miloshevich, Larry M.; Turner, David D. and Walden, Von P. **Dry bias in Vaisala RS90 Radiosonde humidity profiles over Antarctica**. *Journal of Atmospheric and Oceanic Technology*, Volume 25, Issue 9, 2008, pp.1529-1541. Call Number: Reprint # 5833.
http://ams.allenpress.com/archive/1520-0426/25/9/pdf/i1520-0426-25-9-1529.pdf
Rozoff, Christopher M.; Schubert, Wayne H. and Kossin, James P. **Some dynamical aspects of tropical cyclone concentric eyewalls**. *Quarterly Journal of the Royal Meteorological Society*, Volume 134, 2008, pp.583-593. Call Number: Reprint # 5151.

Schmit, Timothy J.; Li, Jun; Gurka, James J.; Goldberg, Mitchell D.; Schrab, Kevin J.; Li, Jinlong and Feltz, Wayne F. **The GOES-R Advanced Baseline Imager and the continuation of current sounder products**. *Journal of Applied Meteorology and Climatology*, Volume 47, Issue 10, 2008, pp.2696-2711. Call Number: Reprint # 5861.
http://ams.allenpress.com/archive/1558-8432/47/10/pdf/i1558-8432-47-10-2696.pdf
Schroeder, W.; Ruminski, M.; Csiszar, I.; Giglio, L.; Prins, E.; Schmidt, C. and Morisette, J. **Validation analyses of an operational fire monitoring product: The Hazard Mapping System**. *International Journal of Remote Sensing*, Volume 29, Issue 20, 2008, pp.6059-6066. Call Number: Reprint # 6019.
Schroeder, Wilfrid; Prins, Elaine; Giglio, Louis; Csiszar, Ivan; Schmidt, Christopher; Morisette, Jeffrey and Morton, Douglas **Validation of GOES and MODIS active fire detection products using ASTER and ETM+ data**. *Remote Sensing of Environment*, Volume 112, 2008, pp.2711-2726. Call Number: Reprint # 6020.

Seemann, Suzanne W.; Borbas, Eva E.; Knuteson, Robert O.; Stephenson, Gordon R. and Huang, Hung-Lung **Development of a global infrared land surface emissivity database for application to clear sky sounding retrievals from multispectral satellite radiance measurements**. *Journal of Applied Meteorology and Climatology*, Volume 47, Issue 1, 2008, pp.108-123. Call Number: Reprint # 5663.
http://ams.allenpress.com/archive/1558-8432/47/1/pdf/i1558-8432-47-1-108.pdf
Setvak, Martin; Lindsey, Daniel T.; Rabin, Robert M.; Wang, Pao K. and Demeterova, Alzbeta **Indication of water vapor transport into the lower stratosphere above midlatitude convective storms: Meteosat Second Generation satellite observations and radiative transfer model simulations**. *Atmospheric Research*, Volume 89, Issue 1, 2008, pp.170-180. Call Number: Reprint # 5780.

Shephard, Mark W.; Worden, Helen M.; Cady-Pereira, Karen E.; Lampel, Michael; Luo, Mingzhao; Bowman, Kevin W.; Sarkissian, Edwin; Beer, Reinhard; Rider, David M.; Tobin, David C.; Revercomb, Henry E.; Fisher, Brendan M.; Tremblay, Denis; Clough, Shepard A.; Osterman, Gregory B. and Gunson, Michael **Tropospheric Emission Spectrometer nadir spectral radiance comparisons**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2007JD008856, 2008. Call Number: Reprint # 5718.

Shupe, Matthew D.; Daniel, John S.; De Boer, Gijs; Eloranta, Edwin W.; Kollias, Pavlos; Long, Charles N.; Luke, Edward P.; Turner, David D. and Verlinde, Johannes **A focus on mixed-phase clouds: The status of ground-based observational methods**. *Bulletin of the American Meteorological Society*, Volume 89, Issue 10, 2008, pp.1549-1562. Call Number: Reprint # 5883.
http://ams.allenpress.com/archive/1520-0477/89/10/pdf/i1520-0477-89-10-1549.pdf

Slingo, A.; Bharmal, A.; Robinson, G. J.; Settle, J. J.; Allan, R. P.; White, H. E.; Lamb, P. J.; Issa Lele, M.; Turner, D. D.; McFarlane, S.; Kassianov, E.; Barnard, J.; Flynn, C. and Miller, M. **Overview of observations from the RADAGAST experiment in Niamey, Niger: Meteorology and thermodynamic variables**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2008JD009909, 2008. Call Number: Reprint # 5863.

Song, C.-K.; Brun, D. W.; Pierce, R. B.; Alsaadi, J. A.; Schaack, T. K. and Vukovich, F. **Downscale linkage of global model output for regional chemical transport modeling: Method and general performance**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2007/JD008951, 2008. Call Number: Reprint # 5726.

Tanamachi, Robin L.; Feltz, Wayne F. and Xue, Ming **Observations and numerical simulation of upper boundary layer rapid drying and moistening events during the International H2O Project (IHOP_2002)**. *Monthly Weather Review*, Volume 136, Issue 8, 2008, pp.3106-3120. Call Number: Reprint # 5800.
http://ams.allenpress.com/archive/1520-0493/136/8/pdf/i1520-0493-136-8-3106.pdf

Taylor, J. P.; Smith, W. L.; Guomo, V.; Larar, A. M.; Zhou, D. K.; Serio, C.; Maestri, T.; Rizzi, R.; Newman, S.; Antonelli, P.; Mango, S.; Di Girolamo, P.; Esposito, F.; Grieco, G.; Summa, D.; Restieri, R.; Masiello, G.; Romano, F.; Pappalardo, G.; Pavese, G.; Mona, L.; Amodeo, A. and Pisani, G. **EAQUATE: An international experiment for hyperspectral atmospheric sounding validation**. *Bulletin of the American Meteorological Society*, Volume 89, Issue 2, 2008, pp.203-218. Call Number: Reprint # 5683.
http://ams.allenpress.com/archive/1520-0477/89/2/pdf/i1520-0477-89-2-203.pdf

Turner, D. D. **Ground-based infrared retrievals of optical depth, effective radius, and composition of airborne mineral dust above the Sahel**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2008JD010054, 2008. Call Number: Reprint # 5930.

Turner, David D. and Eloranta, Edwin W. **Validating mixed-phase cloud optical depth retrieved from infrared observations with high spectral resolution lidar**. *IEEE Geoscience and Remote Sensing Letters*, Volume 5, Issue 2, 2008, pp.285-288. Call Number: Reprint # 5761.

Wagner, Timothy J.; Feltz, Wayne F. and Ackerman, Steven A. **The temporal evolution of convective indices in storm-producing environments**. *Weather and Forecasting*, Volume 23, Issue 5, 2008, pp.786-794. Call Number: Reprint # 5857.
http://ams.allenpress.com/archive/1520-0434/23/5/pdf/i1520-0434-23-5-786.pdf

Wulfmeyer, Volker; Behrendt, Andreas; Bauer, Hans-Stefan; Kottmeier, Christoph; Corsmeier, Ulrich; Blyth, Alan; Graig, George; Schumann, Ulrich; Hagen, Martin; Crewell, Susanne; Di Girolamo, Paolo; Flamant, Cyrille; Miller, Mark; Montani, Andrea; Mobbs, Stephen; Richard, Evelyne; Rotach, Mathias

W.; Arpagaus, Marco; Russchenberg, Merman; Schlussel, Peter; Konig, Marianne; Gartner, Volker; Steinacker, Reinhold; Dorninger, Manfred; Turner, David D.; Weckwerth, Tammy; Hense, Andreas and Simmer, Clemens **The convective and orographically induced precipitation study: A research and development project of the World Weather Research Program for improving quantitative precipitation forecasting in low-mountain regions**. *Bulletin of the American Meteorological Society*, Volume 89, Issue 10, 2008, pp.1477-1486. Call Number: Reprint # 5891.
http://ams.allenpress.com/archive/1520-0477/89/10/pdf/i1520-0477-89-10-1477.pdf
Yang, Ping; Zhang, Zhibo; Kattawar, George W.; Warren, Stephen G.; Baum, Bryan A.; Huang, Hung-Lung; Hu, Yong X.; Winker, David and Iaquinta, Jean **Effect of cavities on the optical properties of bullet rosettes: Implications for active and passive remote sensing of ice cloud properties**. *Journal of Applied Meteorology and Climatology*, Volume 47, Issue 9, 2008, pp.2311-2330. Call Number: Reprint # 5835.
http://ams.allenpress.com/archive/1558-8432/47/9/pdf/i1558-8432-47-9-2311.pdf
Zapotocny, Tom H.; Jung, James A.; Le Marshall, John F. and Treadon, Russ E. **A two-season impact study of four satellite data types and rawinsonde data in the NCEP Global Data Acquisition System**. *Weather and Forecasting*, Volume 23, Issue 2, 2008, pp.80-100. Call Number: Reprint # 5674.
http://ams.allenpress.com/archive/1520-0434/23/1/pdf/i1520-0434-23-1-80.pdf
Zhang, Xiaoyang; Kondragunta, Shobha; Schmidt, Christopher and Kogan, Felix **Near real time monitoring of biomass burning particulate emissions (PM2.5) across contiguous United States using multiple satellite instruments**. *Atmospheric Environment*, Volume 42, 2008, pp.6959-6972. Call Number: Reprint # 6021.

Zhao, Tom X.-P.; Laszlo, Istvan; Guo, Wei; Heidinger, Andrew; Cao, Changyong; Jelenak, Aleksander; Tarpley, Dan and Sullivan, Jerry **Study of long-term trend in aerosol optical thickness observed from operational AVHRR satellite instrument**. *Journal of Geophysical Research*, Volume 113, 2008, doi:10.1029/2007JD009061, 2008. Call Number: Reprint # 5712.

Zhou, D. K.; Smith, W. L.; Larar, A. M.; Liu, X.; Taylor, J. P.; Schlussel, P.; Strow, L. L. and Mango, S. A. **All weather IASI single field-of-view retrievals: Case study - validation with JAIVEx data**. *Atmospheric Chemistry and Physics Discussions*, Volume 8, 2008, pp.21001-21035. Call Number: Reprint # 6044.
http://www.atmos-chem-phys-discuss.net/5/9691/2005/acpd-5-9691-2005-print.pdf

2008 Gray Literature

Achtor, Thomas H.; Rink, T. D. and Whittaker, T. M. **Developing data analysis and visualization capabilities for interactive processing of multi- and hyper-spectral environmental satellite data: An update on McIDAS-V**. In: Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, 24th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Achtor, Thomas; Ackerman, Steven A.; Li, Jun; and **Quarterly report for GOES Improved Measurements and Product Assurance Plan (GIMPAP) for the period 1 October 2007 to 31 December 2007**. Madison, WI, [University of Wisconsin-Madison], Cooperative Institute for Meteorological Satellite Studies (CIMSS), 2008.
http://cimss.ssec.wisc.edu/reports/gimpap/GIMPAP_Report_2007_12.pdf
Achtor, Thomas; Ackerman, Steven A.; Li, Jun; and **Quarterly report for GOES Improved Measurements and Product Assurance Plan (GIMPAP) for the period 1 January 2008 to 31 March 2008**. Madison, WI, [University of Wisconsin-Madison], Cooperative Institute for Meteorological

Satellite Studies (CIMSS), 2008.
http://cimss.ssec.wisc.edu/reports/gimpap/GIMPAP_Report_2008_03.pdf
Achtor, Thomas; Rink, Thomas; Whittaker, Thomas; Parker, David and Santek, David **McIDAS-V - A powerful data analysis and visualization tool for multi and hyperspectral environmental satellite data**. In: Atmospheric and Environmental Remote Sensing Data Processing and Utilization IV: Readiness for GEOSS II, San Diego, CA, 12-14 August 2008 (proceedings). Bellingham, WA, SPIE-International Society for Optical Engineering, 2008, Paper 708509. Call Number: Reprint # 6144.

Ackerman, Steve; Achtor, Tom; and **CIMSS participation in the GOES-R Risk Reduction Program: Quarterly progress report for 1 October-31 December 2007**. Madison, WI, University of Wisconsin-Madison, Cooperative Institute for Meteorological Satellite Studies (CIMSS), 2008.
http://cimss.ssec.wisc.edu/reports/goes-rrr/GOES-RRR_Report_2007_12.pdf
Ackerman, Steve; Achtor, Tom; and **Quarterly progress report for CIMSS participation in the GOES-R Risk Reduction Program for 2008 for the period 1 January 2008 to 31 March 2008**. Madison, WI, University of Wisconsin-Madison, Cooperative Institute for Meteorological Satellite Studies (CIMSS), 2008.
http://cimss.ssec.wisc.edu/reports/goes-rrr/GOES-RRR_Report_2008_03.pdf
Antonelli, Paolo; Tobin, Dave; Revercomb, Hank; Turner, Dave; Dutcher, Steve; Howell, Ben; Knuteson, Bob; Vinson, Kin and Smith, William L. **Application of PCA to hyperspectral data for noise characterization, noise filtering and instrument monitoring**. In: Recent Developments in the Use of Satellite Observations in Numerical Weather Prediction, Reading, UK, 3-7 September 2007. ECMWF seminar proceedings. Shinfield Park, Reading, UK, European Centre for Medium-range Weather Forecasts (ECMWF), 2008, pp.111-126. Call Number: Reprint # 5668.

Bedka, Kristopher M.; Feltz, W. F..; Seiglaff, J. and Medikalski, J. R. **Improving Nowcasting of convective storm development using MSG SEVIRI, MODIS, and GOES-12 imagery as risk reduction for GOES-R ABI**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Bedka, Kristopher; Velden, Christopher; Feltz, Wayne and Petersen, Ralph. **Development, validation, and application of a mesoscale AMV product at UW-CIMSS**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5836.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s6_31_bedka_v.pdf
Bedka, Sarah; Antonelli, P.; DeSlover, D.; Dutcher, S.; Knuteson, R.; Revercomb, H.; Smith, W.; Taylor, J.; Tobin, D.; Woolf, H. and Zhou, D. **Retrievals of atmospheric thermodynamic structure from University of Wisconsin Scanning-High-resolution Interferometer Sounder (S-HIS) upwelling radiance observations using Bayesian Maximum A Posteriori (MAP) inverse method**. In: Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 12th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, Paper P2.7. Call Number: Reprint # 5644.

Berger, Howard; Velden, C.; Wanzong, S. and Daniels, J. **Assessing the 'expected error' as a potential new quality indicator for atmospheric motion vectors**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5841.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s4_19_berger_v.pdf

Best, Fred A.; Adler, Douglas P.; Ellington, Scott D.; Thielman, Donald J. and Revercomb, Henry E. **On-orbit absolute calibration of temperature with application to the CLARREO Mission**. In: Earth Observing Systems XIII, San Diego, CA, 11-13 August 2008 (proceedings). Bellingham, WA, SPIE-International Society for Optical Engineering, 2008, Paper 70810O. Call Number: Reprint # 6140.

Beven, John L. II; DeMaria, M. and Velden, C. **Satellite meteorology of tropical cyclones in the GOES-R era**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Beven, John L. II; Velden, C. S. and Olander, T. L. **Possible impacts of GOES-R temporal resolution on tropical cyclone intensity estimates**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Bi, Li; Jung, J. A.; Morgan, M. C. and Le Marshall, J. F. **A one-season assimilation and impact study of NESDIS and Navy's WindSat retrieved data in the NCEP global data assimilation system**. In: Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 12th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, Paper P1.8. Call Number: Reprint # 5643.

Bi, Li; Jung, James A. and Le Marshall, John F. **Assimilating the Windsat winds in the NCEP global data assimilation system and determining the forecast impact from a two-season study**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5837.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s7_36_lemarsha_v.pdf

Black, Peter G.; Mullins, S.; Velden, C.; Powell, M. D.; Uhlhorn, E. W.; Olander, T. L. and Burton, A. **Comparison of airborne SFMR, Dvorak satellite and best track maximum surface wind estimates**. In: Conference on Hurricanes and Tropical Meteorology, 28th, Orlando, FL, 28 April-2 May 2008 (preprints). Boston, MA, American Meteorological Society, 2008, manuscript not available for publication; recorded presentation only.

Blackwell, Keith O.; Wimmers, A.; Velden, C.; Fitzpatrick, P. J. and Jelley, B. **Hurricane Katrina's eyewall replacement cycle over the northern Gulf and accompanying double eyewalls at landfall: A key to the storm's huge size and devastating impact over a three-state coastal region**. In: Conference on Hurricanes and Tropical Meteorology, 28th, Orlando, FL, 28 April-2 May 2008 (preprints). Boston, MA, American Meteorological Society, 2008, manuscript not available for publication; recorded presentation only.

Borg, Lori; Tobin, David; Turner, David; Holz, Robert; DeSlover, Daniel; Eloranta, Edwin; Knuteson, Robert; Revercomb, Henry and Moy, Leslie **Assessing the vertical structure of radiative heating using radar/Lidar/AERI for cirrus cloud events at SGP**. In: Atmospheric Radiation Measurement (ARM) Science Team Meeting, 18th, Norfolk, VA, March 2007 Proceedings. Washington, DC, US Department of Energy, Office of Energy Research, Office of Health and Environmental Research, Environmental Sciences Division, 2008, abstract and poster.
http://www.arm.gov/publications/proceedings/conf18/display.php?id=NDky

Cimini, Domenico; Nasir, Francesco; Westwater, Ed R.; Payne, Vivienne H.; Turner, Dave E.; Mlawer, Eli J. and Exner, Michael L. **Comparison of ground-based millimeter-wave observations in the Arctic winter**. In: Microwave Radiometry and Remote Sensing of the Environment 2008 - MICRORAD 2008, Florence, Italy, 11-14 March 2008. Proceedings. Piscataway, NJ, Institute of Electrical and Electronic Engineers, Inc. (IEEE), 2008, pp.4p. Call Number: Reprint # 6005.

Connell, Bernadette H.; Castro, V.; Davison, M.; Mostek, A. and Whittaker, T. M. **International focus group - virtually there with VISITview**. In: Symposium on Education, 17th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, Paper P1.54. Call Number: Reprint # 5645.

Daniels, Jaime M.; Bresky, W.; Velden, C.; Genkova, I.; Wanzong, S. and Santek, D. **Algorithm and software development of atmospheric motion vector products for the GOES-R ABI**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Daniels, Jaime; Velden, Chris; Bresky, Wayne; Genkova, Illiana and Wanzong, Steve **Algorithm and software development of Atmospheric Motion Vector (AMV) products for the future GOES-R Advanced Baseline Imager (ABI)**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5838.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s8_42_irving_v.pdf

Dworak, Richard and Key, Jeff **Assessing the quality of historical AVHRR polar wind height assignment**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5846.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s2_10_dworak_v.pdf

Dykema, John A.; Gero, P. Jonathan; Leroy, Stephen S.; Revercomb, Henry E.; Kirk-Davidoff, Daniel and Anderson, James G. **On-orbit accuracy of infrared spectra for climate model testing**. In: Earth Observing Systems XIII, San Diego, CA, 11-13 August 2008 (proceedings). Bellingham, WA, SPIE-International Society for Optical Engineering, 2008, Paper 70810N. Call Number: Reprint # 6141.

Dykema, John A.; Holz, R.; Tobin, D.; Kirk-Davidoff, D. B.; Leroy, S. S.; Knuteson, R. O.; Best, F. A.; Revercomb, H. E. and Anderson, J. G. **Benchmark measurements for achieving societal objectives**. In: Symposium on Future National Operational Environmental Satellites, 4th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Evan, Amato; Heidinger, A.; Bennartz, R.; Mahowald, N. and Velden, C. S. **A climatology of ocean temperature forcing by aerosols across the tropical Atlantic**. In: Conference on Hurricanes and Tropical Meteorology, 28th, Orlando, FL, 28 April-2 May 2008 (preprints). Boston, MA, American Meteorological Society, 2008, manuscript not available for publication; recorded presentation only.

Feltz, Wayne F.; Pryor, K. L.; Pavolonis, M. J.; Mecikalski, J. R.; Smith, W. L. and Lindsey, D. T. **GOES-R Aviation Algorithm Working Group: Toward meeting aviation-related requirements**. In: Conference on Aviation, Range and Aerospace Meteorology, 13th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Garcia, Raymond K.; Flynn, Bruce M.; Knuteson, Robert O.; Whittaker, Thomas; Rink, Thomas; Achtor, Thomas; Mindock, Scott; Dutcher, Steven T.; Snuga-Otto, Maciaj J. and Martin, Graeme D. **Tools for integrating distributed computing with interactive visualization in McIDAS-V**. In: Conference on

Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, 24th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, Paper 6A.8. Call Number: Reprint # 5647.

Genkova, Iliana; Borde, Regis; Schmetz, Johannes; Daniels, Jaime; Velden, Chris and Holmlund, Ken **Global atmospheric motion vector inter-comparison study**. In: 2008 EUMETSAT Meteorological Satellite Conference, Darmstadt, Germany, 8-12 September 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5911.
http://www.eumetsat.int/groups/cps/documents/document/doc_conf_p_s12_52_genkova_p.pdf

Genkova, Iliana; Wanzong, S.; Velden, C. S.; Santek, D. A.; Li, J.; Olson, E. R. and Otkin, J. A. **GOES-R wind retrieval algorithm development**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Genkova, Illiana; Borde, Regis; Schmetz, Johannes; Daniels, Jamie; Velden, Chris and Holmlund, Ken **Global atmospheric motion vector inter-comparison study**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5842.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s4_20_genkova_v.pdf

Genkova, Illiana; Velden, Chris; Shapiro, Mel; Hsu, Hsiao-Ming; Dunion, Jason and Stettner, Dave **Saharan dust motion extraction from MSG-SEVIRI**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5840.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s6_30_genkova_v.pdf

Greenwald, Thomas; Sieglaff, J.; Lee, Y. K.; Huang, H. L.; Otkin, J.; Olson, E. and Gunshor, M. **Verifying large-scale, high-resolution simulations of clouds for GOES-R activities**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Guan, Li and Huang, Hung-Lung **Objective determination of AIRS cloud mask using co-located MODIS cloud mask information**. In: International Conference on Bioinformatics and Biomedical Engineering, 2nd, ICBBE 2008, Shanghai, China 16-18 May 2008. Piscataway, NJ, IEEE: Institute of Electrical and Electronics Engineers, Inc., 2008, pp.3819-3823. Call Number: Reprint # 6047.

Gunshor, Mathew M.; Olson, E.; Sieglaff, J.; Greenwald, T.; Huang, A. and Otkin, J. A. **GOES-R ABI proxy data set generation at CIMSS**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Hawkins, Jeffrey D. and Velden, C. S. **Satellite-based TC surveillance: Status and future needs**. In: Conference on Hurricanes and Tropical Meteorology, 28th, Orlando, FL, 28 April-2 May 2008 (preprints). Boston, MA, American Meteorological Society, 2008, manuscript not available for publication; recorded presentation only.

Heck, Patrick W.; Minnis, P.; Palikonda, R.; Yost, C. R.; Chang, F. L. and Heidinger, A. K. **Nighttime retrieval of cloud microphysical properties for GOES-R**. In: GOES Users' Conference, 5th, New

Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, Paper P1.79. Call Number: Reprint # 6018.

Heidinger, Andrew K. **Candidate approaches for the real-time generation of cloud properties from GOES-R ABI**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Huang, Allen and Goldberg, M. **Overview of GOES-R Analysis Facility for Instrument Impacts on Requirements (GRAFIIR) planned activities and recent progress**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Huang, Bormin; Wei, Shih-Chieh; Huang, Hung-Lung; Smith, William L. and Bloom, Hal J. **Vector quantization with self-resynchronizing coding for lossless compression and rebroadcast of the NASA Geostationary Imaging Fourier Transform Spectrometer (GIFTS) data**. In: Satellite Data Compression, Communication, and Processing IV, San Diego, CA, 10-11 August 2008 (proceedings). Bellingham, WA, SPIE-International Society for Optical Engineering, 2008, Paper 708408. Call Number: Reprint # 6143.

Jin, Xin; Li, J.; Schmit, T. J.; Li, J.; Weisz, E. and Li, Z. **GOES-R/ABI legacy profile algorithm evaluation with MSG/SEVIRI**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Jin, Xin; Li, Jun; Schmit, Timothy J.; Li, Jinlong; Huang, Allen and Goldberg, Mitchell D. **GOES-R/ABI legacy profile algorithm evaluation using MSG/SEVIRI and AMSR-E**. In: Atmospheric and Environmental Remote Sensing Data Processing and Utilization IV: Readiness for GEOSS II, San Diego, CA, 12-14 August 2008 (proceedings). Bellingham, WA, SPIE-International Society for Optical Engineering, 2008, Paper 70850F. Call Number: Reprint # 6145.

Key, Jeffrey; Santek, David; Velden, Christopher; Daniels, Jaime and Dworak, Richard **The polar wind product suite**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5848.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s2_06_key_v.pdf
Knapp, Kenneth R.; Kruk, M. C.; Levinson, D. H. and Kossin, J. P. **Data stewardship of global tropical cyclone best tracks**. In: Conference on Hurricanes and Tropical Meteorology, 28th, Orlando, FL, 28 April-2 May 2008 (preprints). Boston, MA, American Meteorological Society, 2008, Paper P2A.12. Call Number: Reprint # 5739.

Kossin, James P. **Hurricane variability and trends: The varying roles of sea surface temperature**. In: Tropical Meteorology Special Symposium and Conference on Climate Variability and Change, 20th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, Paper J9.2. Call Number: Reprint # 5652.

Kruk, Michael C.; Knapp, Kenneth; Levinson, David and Kossin, Jim **National Climatic Data Center global tropical cyclone stewardship**. In: Conference on Hurricanes and Tropical Meteorology, 28th, Orlando, FL, 28 April-2 May 2008 (preprints). Boston, MA, American Meteorological Society, 2008, Paper P2A.12. Call Number: Reprint # 5729.

Lakshmanan, Valliappa and Rabin, Robert **Nowcasting of thunderstorms from GOES infrared and visible imagery**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, Paper P1.73. Call Number: Reprint # 5649.

Larar, Allen M.; Smith, W. L.; Revercomb, H. E.; Zhou, D. K.; Liu, X.; Tobin, D.; Taylor, J. P.; Schlussel, P. and Mango, S. A. **The Joint Airborne IASI Validation Experiment (JAIVEx) and select contributions from NAST-I**. In: Symposium on Future National Operational Environmental Satellites, 4th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Lazzara, Matthew A.; Ackerman, Steven A. and Hillger, Donald W. **Antarctic fog depiction via satellite analysis**. In: Antarctic Meteorological Observation, Modeling, and Forecasting Workshop, 3rd, Madison, WI, 9-12 June 2008 (preprints). [Madison, WI], [University of Wisconsin-Madison, Space Science and Engineering Center, Antarctic Meteorological Research Center (AMRC)], 2008, unpaged. Call Number: Reprint # 5796.

Le Marshall, J.; Seecamp, R.; Dunn, M.; Skinner, T.; Jung, J.; Velden, C.; Wanzong, S.; Puri, K.; Bowen, R.; Rea, A.; Ziao, Yi; Steinle, P.; Sims, H. and Le, T. **Locally generated and error characterized MTSAT-IR Atmospheric Motion Vectors and their contribution to operational NWP in the Australian region**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5847.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s1_05_lemarsha_v.pdf
Li, Jun; Martinez, Miguel Angel; Manson, Marcelino; Valazquez, Mercedes and Cuevas, Gabriela **Physical retrieval algorithm development for operational SEVIRI clear sky nowcasting products**. In: 2008 EUMETSAT Meteorological Satellite Conference, Darmstadt, Germany, 8-12 September 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5909.
http://www.eumetsat.int/groups/cps/documents/document/pdf_conf_p_s5_32_martinez_v.pdf
Li, Jun; Schmit, T. J.; Gurka, J. J.; Daniels, J.; Goldberg, M. D. and Menzel, P. **Current GOES sounder applications and future needs**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Liang, XingMing; Ignatov, Alexanader; Kihai, Yury; Heidinger, Andrew; Han, Yong and Chen, Yong **Validation of the Community Radiative Transfer Model (CRTM) against AVHRR Clear-Sky Processor for Oceans (ACSPO) nighttime radiances for improved cloud detection and physical SST retrievals**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, Paper P1.13. Call Number: Reprint # 5648.

Lindstrom, Scott S.; Schmidt, C. C.; Prins, E. M.; Hoffman, J.; Brunner, J. and Schmit, T. J. **Proxy ABI datasets relevant for fire detection that are derived from MODIS data**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Liu, Chian-Yi; Li, Jun; Weisz, Elisabeth; Schmit, Timothy J. and Huang, Allen **Synergistic use of high spectral sounder and high spatial imager radiance measurements for atmospheric profiling**. In: Atmospheric and Environmental Remote Sensing Data Processing and Utilization IV: Readiness for

GEOSS II, San Diego, CA, 12-14 August 2008 (proceedings). Bellingham, WA, SPIE-International Society for Optical Engineering, 2008, Paper 70850Y. Call Number: Reprint # 6146.

Liu, Xu; Zhou, D. K.; Larar, A. M.; Smith, W. L.; Schlussel, P.; Taylor, J. P.; Revercomb, H. and Mango, S. A. **Atmospheric temperature and moisture profile retrievals using more than eight thousand channels**. In: Symposium on Future National Operational Environmental Satellites, 4th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Liu, Xu; Zhou, Daniel K.; Larar, Allen; Smith, William L. and Schluessel, Peter **Remote sensing of atmosphere and surface properties from ultra-spectral sensors**. In: Program In Electromagnetic Research Symposium, Hangzhou, China, 24-28 march 2008. PIERS 2008. Abstracts. Cambridge, MA, MIT Press, 2008, manuscript not available for publication.

Majundar, Sharan; Cione, J. J.; Uhlhorn, E.; Cascella, G.; Aberson, S. C.; Atlas, R.; Beven, J. L.; Brown, D. P.; Dunion, J. P.; Fogarty, C.; Hart, R.; Herndon, D. C.; Knaff, J. A.; Landsea, C. W.; Marks, F. D. and Velden, C. **Analysis of the inner-core characteristics of Noel (2007) during its extratropical transiti**. In: Conference on Hurricanes and Tropical Meteorology, 28th, Orlando, FL, 28 April-2 May 2008 (preprints). Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Menzel, W. Paul; Baum, Bryan; Jackson, Darren L.; Grey, Richard; Weisz, Elisabeth; Wylie, Don; Olson, Erik and Bates, John **Using CO2 slicing to infer global cloud cover (improving algorithm applications and overcoming instrument idiosyncrasies)**. In: 2008 EUMETSAT Meteorological Satellite Conference, Darmstadt, Germany, 8-12 September 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5908.
http://www.eumetsat.int/groups/cps/documents/document/pdf_conf_p_s4_19_menzel_v.pdf

Minnis, Patrick; Nyugen, Louis; Chang, Fu-Lung; Palikonda, Rabindra; Khaiyer, Mandana; Trepte, Qing; Yost, Chris; Smith, William; Sun-Mack, Szedung; Heck, Patrick and Spangenberg, Douglas **Advances in cloud satellite remote sensing for ARM**. In: Atmospheric Radiation Measurement (ARM) Science Team Meeting, 18th, Norfolk, VA, March 2007 Proceedings. Washington, DC, US Department of Energy, Office of Energy Research, Office of Health and Environmental Research, Environmental Sciences Division, 2008, abstract and poster.
http://www.arm.gov/publications/proceedings/conf18/display.php?id=NTE4

Moy, Leslie; Revercomb, Henry; Tobin, David; Borg, Lori; Knuteson, Robert; Li, Jun and Turner, David **Clear- and all-sky TOA OLR comparisons between RTM calculations and CERES observations**. In: Atmospheric Radiation Measurement (ARM) Science Team Meeting, 18th, Norfolk, VA, March 2007 Proceedings. Washington, DC, US Department of Energy, Office of Energy Research, Office of Health and Environmental Research, Environmental Sciences Division, 2008, abstract and poster.
http://www.arm.gov/publications/proceedings/conf18/display.php?id=NDg5

Mullins, Stephanie Ann; Black, P. G.; Velden, C. S.; Powell, M. D.; Uhlhorn, E. W.; Olander, T. L.; Burton, A. and Beven, J. L. **Defining uncertainty in hurricane maximum surface wind estimation**. In: Tropical Meteorology Special Symposium, and Conference on Probability and Statistics, 19th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Otkin, Jason A.; Huang, A.; Greenwald, T.; Olson, E. R. and Seiglaff, J. **Large-scale WRF model simulations used for GOES-R research activities**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Pavolonis, Michael J. **New automated methods for detecting volcanic ash and determining mass loading from infrared radiances: Looking towards the NPOESS and GOES-R era's**. In: Conference on Aviation, Range and Aerospace Meteorology, 13th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Petersen, Ralph A. and Aune, R. M. **Nearcasting convective destabilization of isolated summer-time convection using objective tools which optimize the impact of sequences of GEOS moisture products**. In: Conference on Aviation, Range and Aerospace Meteorology, 13th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Petersen, Ralph A. and Aune, R. M. **Nearcasting convective destabilization using objective tools which optimize the impact of sequences of GOES moisture products**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Petersen, Ralph A.; Bedka, S.; Feltz, W. F.; Olson, E. R. and Helms, D. **Further evaluation of the WVSS-II moisture sensor using co-located in-situ and remotely sensed observations**. In: Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS), 12th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Pryor, Kenneth L.; Feltz, W.; Mecikalski, J. R.; Pavolonis, M. and Smith, W. L. **GOES-R applications for the assessment of aviation hazards**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Revercomb, Henry E. **High spectral and temporal resolution imaging sounders for GOES**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Rink, Thomas D.; Whittaker, T.; Achtor, T. H.; Flynn, B.; Dengel, G. and Baggett, K. **Recasting HYDRA into the next generation of McIDAS**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Santek, David **The impact of MODIS-derived polar winds on global forecasts**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5845.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s2_07_santek_v.pdf
Schmidt, Christopher C.; Lindstrom, S.; Hoffman, J.; Brunner, J. and Prins, E. M. **GOES-R ABI fire detection and monitoring development activities**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Schmit, Timothy J.; Gurka, J. J.; Gunshor, M. M. and Li, J. **The ABI (Advanced Baseline Imager) on the GOES-R series**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Setvak, Martin; Lindsey, Daniel T.; Novak, Petr; Rabin, Robert M.; Wang, Pao K.; Kerkmann, Jochen; Radova, Michaela and Stastka, Jindrich **Cold-ring shaped storms in central Europe**. In: 2008 EUMETSAT Meteorological Satellite Conference, Darmstadt, Germany, 8-12 September 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5910.
http://www.eumetsat.int/groups/cps/documents/document/pdf_conf_p_s5_35_setvak_v.pdf
Smith, William L.; Kireev, Stanislav; West, Leanne L.; Gimmestad, Gary G.; Cornman, Larry; Feltz, Wayne; Perram, Glen and Daniels, Taumi **Interferometric radiometer for in-flight detection of aviation hazards**. In: Remote Sensing Applications for Aviation Weather Hazard Detection and Decision Support, San Diego, CA, 13-14 August 2008 (proceedings). Bellingham, WA, SPIE-International Society for Optical Engineering, 2008, Paper 70880A. Call Number: Reprint # 6147.

Smith, William Sr.; Kireev, S.; Zhou, D.; Larar, A. M.; Liu, X.; Goldberg, M. D. and Maturi, E. M. **High spatial and temporal resolution retrievals obtained from the combination of GOES-R multispectral ABI and joint polar satellite ultraspectral radiances**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Staude, Jessica A.; Stearns, Charles R.; Lazzara, Matthew A.; Keller, Linda M. and Ackerman, Steven A. **Poleward propagating weather systems in Antarctica**. In: Antarctic Meteorological Observation, Modeling, and Forecasting Workshop, 3rd, Madison, WI, 9-12 June 2008 (preprints). [Madison, WI], [University of Wisconsin-Madison, Space Science and Engineering Center, Antarctic Meteorological Research Center (AMRC)], 2008, unpaged. Call Number: Reprint # 5794.

Tarpley, Dan; Yu, Y.; Romanov, P.; Prins, E.; Gallo, K.; Kogan, F.; Xu, H.; Rama Varma Raja, M K.; Vinnikov, K. Y.; Goldberg, M.; Qiu, S. and Privette, J. L. **Activities of GOES-R land applications working group team**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Tripoli, Gregory J. Tripoli; Fang, H.; Haddad, Z. S.; Lewis, W. E.; Marks, F. D.; Ramat-Sammi, Y.; Smith, E. A.; Tanelli, S. and Velden, C. **The NEXRAD in SPACE: Potential Improvements to Hurricane Analysis and Prediction**. In: Conference on Hurricanes and Tropical Meteorology, 28th, Orlando, FL, 28 April-2 May 2008 (preprints). Boston, MA, American Meteorological Society, 2008, manuscript not available for publication; recorded presentation only.

Velden, Christopher S. **The new CIMSS tropical cyclone web site: A portal to advances in satellite analysis**. In: Conference on Hurricanes and Tropical Meteorology, 28th, Orlando, FL, 28 April-2 May 2008 (preprints). Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Velden, Christopher S. and Beka, Kristopher **Identifying the uncertainty in determining satellite-derived Atmospheric Motion Vector height attribution**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5844.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s3_11_velden_v.pdf

von Bremen, Lueder; Bormann, Niels; Wanzong, Steve; Hortal, Mariano; Salmond, Deborah; Thepaut, Jean-Noel and Bauer, Peter **Evaluation of AMVs derived from ECMWF model simulations**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5843.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s5_26_bauer_v.pdf

Walsh, Tim and Schmit, T. J. **Future GOES-R instrument operations - Capabilities and constraints**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Wang, Xuanji; Key, J. R.; Liu, Y. and Straka, W. **Estimation of sea and lake ice characteristics with GOES-R ABI**. In: GOES Users' Conference, 5th, New Orleans, LA, 20-24 January 2008. Boston, MA, American Meteorological Society, 2008, manuscript not available for publication.

Wanzong, Steve; Genkova, Illiana; Velden, Christopher S. and Santek, David A. **AMV research using simulated datasets**. In: International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5839.
http://www.eumetsat.int/Home/Main/Publications/Conference_and_Workshop_Proceedings/groups/cps/documents/document/pdf_conf_p51_s5_25_wanzong_v.pdf

Wei, Shih-Chieh and Huang, Bormin **Ultraspectral sounder data compression using the non-exhaustive Tunstall coding**. In: Satellite Data Compression, Communication, and Processing IV, San Diego, CA, 10-11 August 2008 (proceedings). Bellingham, WA, SPIE-International Society for Optical Engineering, 2008, Paper 708406. Call Number: Reprint # 6142.

Westwater, Ed R.; Cimini, Domenico; Mattioli, Vinia; Gasiewski, Albin J.; Klein, Marian; Leuski, Vladimir and Turner, David D. **Deployments of microwave and millimeter-wave radiometers in the Arctic**. In: Microwave Radiometry and Remote Sensing of the Environment 2008 - MICRORAD 2008, Florence, Italy, 11-14 March 2008. Proceedings. Piscataway, NJ, Institute of Electrical and Electronic Engineers, Inc. (IEEE), 2008, pp.4p. Call Number: Reprint # 6006.

Wu, X.; Schmit, T.; Galvin, R.; Gunshor, M.; Hewison, T.; Koenig, M.; Tahara, Y.; Blumstein, D.; Li, Y.; Sohn, S. and Goldberg, M. **Investigation of GOES imager 13 micron channel cold bias**. In: 2008 EUMETSAT Meteorological Satellite Conference, Darmstadt, Germany, 8-12 September 2008. Proceedings. Darmstadt, Germany, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2008, unpaged. Call Number: Reprint # 5907.
http://www.eumetsat.int/groups/cps/documents/document/pdf_conf_p_s2_06_wu_p.pdf