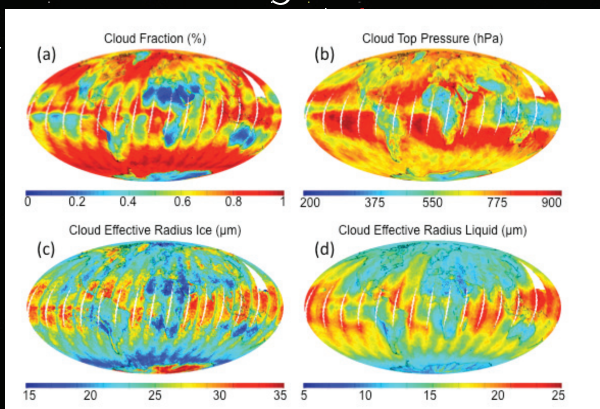
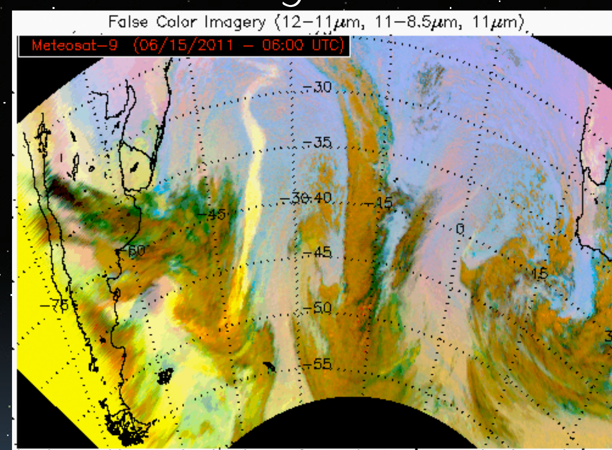
Cooperative Institute for Meteorological Satellite Studies

Board of Directors Report
2011

Collaborating with NASA...



Collaborating with NOAA...



Collaborating out in the field...

Reaching out to the public...

CIMSS Board
Friday, June 24, 2011
Room 351, Atmospheric, Oceanic and Space Sciences Building
Draft Agenda

9:00 – 9:10	Welcome – Ackerman
9:10 – 9:30	Graduate School Overview – Dean Cadwallader
9:30 – 10:15	Administrative and Financial Overview: Tom Achtor Presentation and Discussion Meeting CIMSS mission: Example projects
10:15 – 10:30	Break/Discussion
10:30 – 11:30	Mission 1 – 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 Overview of current activities: Ackerman (15 min) One example: CIMSS GOES-R Activities: Wayne Feltz (15 min) Future Directions (15 min) Discussion throughout
11:30 – 12:30	Working lunch (food provided) Tour of STAR High Performance Computing System: Scott Nolin
12:30 – 1:30	Mission 2 – Serve as a center at which scientists and engineers working on problems of mutual interests can focus on satellite-related research in atmospheric and earth system science Overview of current activities: Ackerman (15 min) One example: Cal/Val Activities: Dave Tobin (15 min) Future Directions (15 min) Discussion throughout
1:30 – 2:30	Stimulate the training of scientists and engineers in the disciplines involved in atmospherics and earth sciences Overview of current activities: Ackerman (15 min) One example: International Training: Kathy Strabala (15 min) Future Directions (15 min) Discussion throughout
2:30 – 2:45	Discussion of pending MOUs
2:45 – 3:00	Discussion and wrap up

After the meeting, the SSEC monthly Hail/Farewell will start at 3:30. Sponsored this month by 2nd floor, it will include ice cream and floats.

CIMSS BOARD OF DIRECTORS
June 2011

Martin Cadwallader, Chair
Dean, UW-Madison Graduate School

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Director, CIMSS

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Peter Hildebrand
Director, Earth-Sun Exploration Division of the Sciences and Exploration Directorate, NASA Goddard Space Flight Center

Lelia Vann
Director, Science Directorate, NASA Langley Research Center

<u>Invited Representatives</u>

Wendy Crone
Associate Dean for Physical Sciences, Graduate School, University of Wisconsin—Madison

Ramesh Kakar
NASA Headquarters, Earth Science Division: Atmospheric Dynamics
Representing Jack Kaye

Invited Visitors

Wendy Crone
Associate Dean for Physical Sciences, Graduate School, University of Wisconsin—Madison

Allen Huang
CIMSS Science Council

Chris Velden
CIMSS Science Council

Jun Li
CIMSS Scientist

Wayne Feltz
CIMSS Scientist

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An Overview of the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison

CIMSS was established in 1980 to formalize and support cooperative research between the National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) and the University of Wisconsin-Madison's Space Science and Engineering Center. Sponsorship and membership of the Institute was expanded to include the National Aeronautics and Space Administration (NASA) in 1989. NOAA re-competed their sponsorship of CIMSS in 2010. After a thorough review, NOAA awarded the sponsorship to UW-Madison, allowing the university to continue the hosting of this cooperative institute to support NOAA's mission goals of “Serve Society's Needs for Weather and Water Information” and “Mission Support.”

Under this new agreement with NOAA, CIMSS will conduct work in four theme areas:

(1) Satellite Meteorology Research and Applications: to support weather analysis and forecasting through participation in NESDIS product assurance and risk reduction programs and the associated transitioning of research progress into NOAA operations;
(2) Satellite Sensors and Techniques: to conduct instrument trade studies and sensor performance analysis supporting NOAA's future satellite needs as well as assisting in the long term calibration and validation of remote sensing data and derived products;
(3) Environmental Models and Data Assimilation: to work with the Joint Center for Satellite Data Assimilation (JCSDA) on improving satellite data assimilation techniques in operational weather forecast models; and
(4) Outreach and Education: to engage the workforce of the future in understanding and using environmental satellite observations for the benefit of an informed society.

CIMSS maintains its strong relationship with NASA through partnerships with scientists in NASA centers and the NASA' Research Opportunities in Space and Earth Sciences (ROSES). CIMSS's relationship with the UW-Madison Department of Atmospheric and Oceanic Sciences provides graduate student research support to more than ten students per year. The education/research center link provides an excellent path for young scientists entering geophysical fields.

As demonstrated throughout this report, CIMSS has made numerous innovations and outstanding contributions to the field of remote sensing. As an internationally recognized center in remote sensing science and education, CIMSS has been providing fundamental contributions to NOAA and NASA's environmental satellite programs.

Research. CIMSS has fostered numerous advances to the science of satellite remote sensing. Our research ranges from developing methods to measure surface and atmospheric properties from space, to calibrating and validating sensor data, to testing applications in numerical models. CIMSS develops and successfully implements techniques and products for using geostationary and polar orbiting weather satellite visible, thermal and microwave radiation observations to improve forecasts of severe storms, including tornadoes and hurricanes. CIMSS plays a major role in the transfer of new technology into operational practice.

CIMSS has worked with U.S. and international geostationary and polar-orbiting satellite systems as well as experimental instruments flown on research aircraft. Our scientists have designed and tested spacecraft instrumentation for monitoring the earth-atmosphere system and are active members on NOAA and NASA science and mission teams. Current research also focuses on the development and testing of computer-based analysis and forecast techniques that use observations from existing and planned spacecraft and ground-based weather observing systems as part of a national program to greatly improve weather forecast capabilities for the next decade. The optimal use of satellite data in climate and global change studies has become another essential part of the CIMSS mission.

Collaborative Activities. CIMSS serves as an international center for research on the interpretation and uses of operational and experimental satellite observations and remote sensing data acquired from aircraft and the ground. These data are applied to a wide variety of atmospheric and oceanographic studies and evaluated for their potential operational utility. CIMSS international role is further strengthened through its visiting scientist program that hosts sabbaticals for several foreign scholars each year.

One measure of our strong relationship with NESDIS is the more than two dozen UW-CIMSS research projects that have become operational in NOAA. Working with the Advanced Satellite Products Branch (ASPB) co-located at UW-Madison, our scientists have been participating in the checkout of the new GOES and Polar-orbiting Operational Environmental Satellite (POES) instruments, defining the future GOES instrument requirements, working closely to deliver software for the GOES-R Algorithm Working Group, and assessing changes in Arctic climate and global cloud cover over the past two decades using satellite observations. CIMSS has scientists working on current NASA satellite missions as well, including MODIS, AIRS, and CALIPSO.

CIMSS is very active in national and international field programs, testing new instrumentation, data processing systems and assessing the geophysical utility of measurements.

Education. UW-CIMSS mentors students both formally and informally. Our scientists have directly supervised 90 Master’s and 37 Ph.D. students; undergraduate students also are involved in our research. UW-CIMSS has supported the teaching of graduate-level courses in satellite remote sensing and an undergraduate course in satellite meteorology. Our efforts to extend our educational reach beyond the state of Wisconsin have benefitted countless students and colleagues worldwide.

Visit the CIMSS WWW Home Page at **http://cimss.ssec.wisc.edu**

Organizational Structure within the University of Wisconsin System

Research institutions with the University of Wisconsin system are administered through the Graduate School. The Space Science and Engineering Center (SSEC) is a research institution employing roughly 200 scientists, engineers, programmers and support staff. The SSEC program includes development of the Man-computer Interactive Data Access System (McIDAS), development and construction of spacecraft instrumentation and scientific investigations of earth and other planetary environmental systems. Within SSEC, the Cooperative Institute for Meteorological Satellite Systems (CIMSS) is a research arm conducting scientific investigation from passive remote sensing systems for meteorological and surface-based applications.

NOAA Team at CIMSS

NESDIS established the Advanced Satellite Products Branch (ASPB) as a research and development facility at CIMSS. ASPB is part of the NESDIS Center for Satellite Applications and Research (STAR). The branch is primarily responsible for the validation and calibration of measured radiances, satellite-derived products useful for short term weather forecasting, algorithms for deriving temperature and moisture soundings, atmospheric motions, cloud properties, and snow/ice characteristics, the optimal use of satellite-derived mass and motion information in data assimilation and numerical weather prediction systems, and satellite-derived fire and smoke products for real time monitoring and climate change studies. The group plays a critical role in transitioning research products to operations, training the user community in new satellite capabilities, and planning the evolution to advanced instrumentation such as improved multi-channel imagers and high spectral resolution interferometer sounders.

ASPB collaborates with the international user community to improve the use of satellite observations. This is accomplished through active participation in the International TOVS and Winds Working Groups as well as a vibrant collaboration with ECMWF and EUMETSAT. ASPB also participates in activities of the World Meteorological Organization (WMO), the Coordinating Group for Meteorological Satellites (CGMS), the Committee on Earth Observation Satellites (CEOS), the Integrated Global Observing Strategy (IGOS), and the Group on Earth Observations (GEO).

NOAA has established a new relationship with CIMSS through the NESDIS National Climatic Data Center (NCDC). A CIMSS scientist specializing in hurricane and climate research, Dr. J. Kossin was recently hired by NCDC and stationed at CIMSS. His interests and expertise will foster new collaborations in satellite climate data sets to the benefit of both NCDC and CIMSS, and we look forward to this budding relationship.

CIMSS Research Activity Summaries
(organized by the CIMSS Mission)

The following pages provide a brief summary of the research activities carried out by CIMSS. Each project is categorized, generally, as address one of the CIMSS's mission statements:

Mission 1
Foster collaborative research among NOAA, NASA, and the University in those aspects of atmospheric and earth system science which exploit the use of satellite technology.

Mission 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 system science.

Mission 3
Stimulate the training of scientists and engineers in the disciplines involved in the atmospheric and earth sciences.

Following these research sections is a summary of the administration of CIMSS.

Contents

FIGURES

Mission 1

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.

GOES-14 and -15 Checkout & Data Analysis

CIMSS Personnel: Scott Bachmeier, Mat Gunshor, Jim Nelson, Tony Schreiner, Chris Velden
Federal Collaborators: Tim Schmit, Gary Wade, Don Hillger
Funded by: NOAA/NESDIS under PSDI/GIMPAP

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

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

Quantitative comparison of the GOES-13 and GOES-15 Sounder Cloud Top Pressure (CTP) products show that overall the average difference between the two is about 3hPa (for a number of randomly chosen time periods during the Science Test). Closer comparisons showed that:

- for all observations (clear and cloudy): the average difference (bias) is 2.69 hPa (GOES-15 cloud heights are slightly higher in altitude than GOES-13 cloud heights);
- for all cloudy observations: the average difference is 5.49 hPa (same bias as above); and
- for CO_2 Absorption Height determinations only: the average difference is 5.47 hPa (same bias as above).

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

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

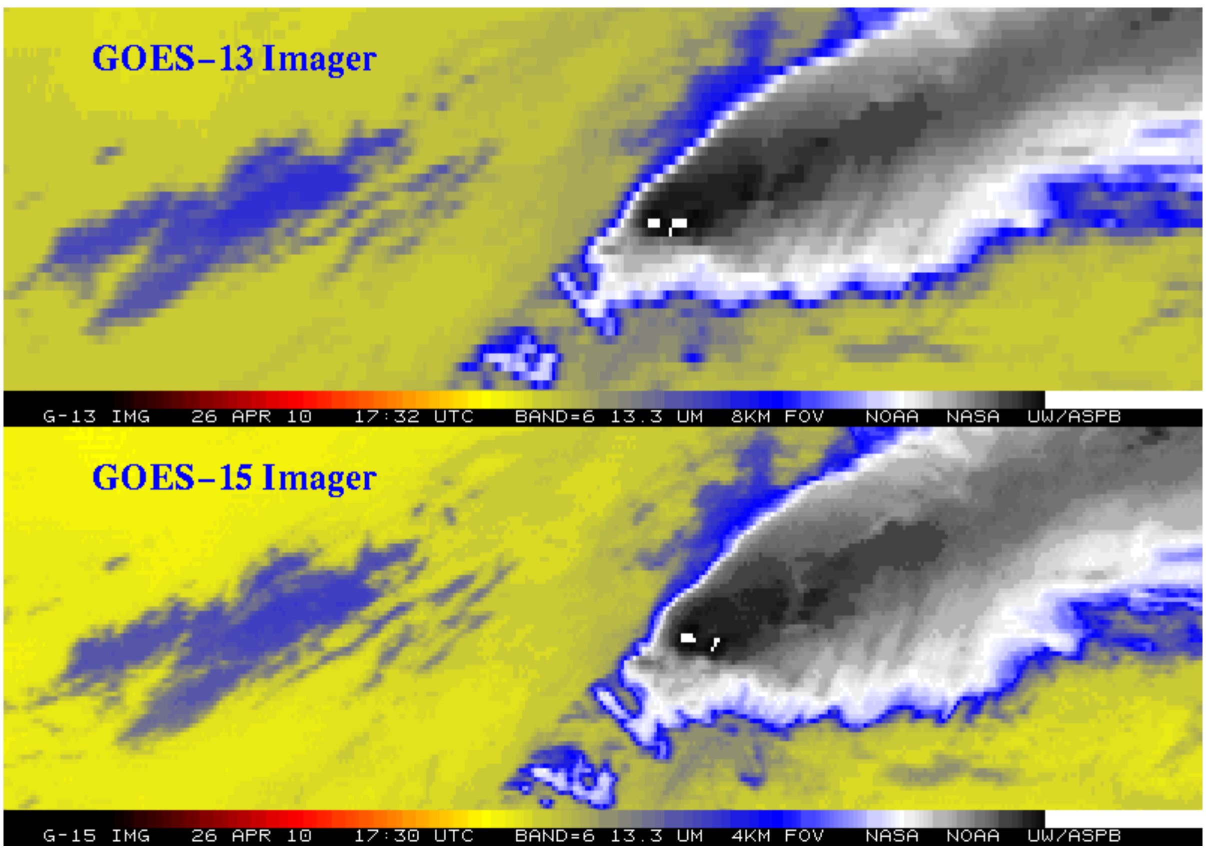


Figure 1 A comparison of GOES-13 (8 km Instantaneous Geometric Field of View) and GOES-15 (4 km) Imager Band 6 (13.3µm) on 26 April 2010. Note the 'cleaner' image from GOES-15.

Publications/Conference Presentations

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

GIMPAP: GOES Biomass Burning Research and Applications

CIMSS Personnel: Christopher Schmidt, Jason Brunner, Elaine Prins (Consultant), Joleen Feltz, Jay Hoffman
Funded by: NOAA

Project Description
Initially the GIMPAP biomass burning program focused on development, testing, and implementation of GOES active fire monitoring in the Western Hemisphere. Currently GIMPAP funding is being used to support innovative research applications of the GOES WF_ABBA fire product through collaborative efforts with a broad user community including hazards monitoring/assessment, resource management, fire weather, global change research, land-use/land-cover change analyses, fire dynamics research, emissions monitoring/modeling, and air quality. In many instances these collaborations are not funded by any other source and often lead to more in-depth studies funded by NOAA, NASA, and other agencies. Furthermore, active collaborations with the user community have provided valuable insight to improve the GOES WF_ABBA and advance geostationary fire monitoring efforts around the globe through international working groups and initiatives (GOFC/GOLD, CGMS, and GEOSS). For the past two years efforts have focused on the following tasks:

- Creation of a climatology of WF_ABBA fires from 1995 to present day;
- Collaborations with NOAA/NSSL and NOAA/NWS/SPC on fire weather applications, specifically using the WF_ABBA climatology to research a "fire potential" product that uses ancillary data such as NDVI, the Fosberg Fire Weather Index, a cloud to ground lightning database, a surface type/land use database, and the WF_ABBA climatology to relate the likelihood of fires to those other parameters, in hopes of improving fire danger indices;
- Continued trend analysis of the GOES WF_ABBA for the Western Hemisphere which will be extended globally;
- Continued collaborations with the atmospheric modeling and air quality communities;
- Extended WF_ABBA support to GOES-15 and MTSAT-2; and
- Continued activities in support of a global geostationary fire detection and monitoring system in association with GTOS GOFC/GOLD and CGMS. These efforts also fit within the framework of GEOSS and fall under GEO Tasks DI-06-13 and DI-06-09.

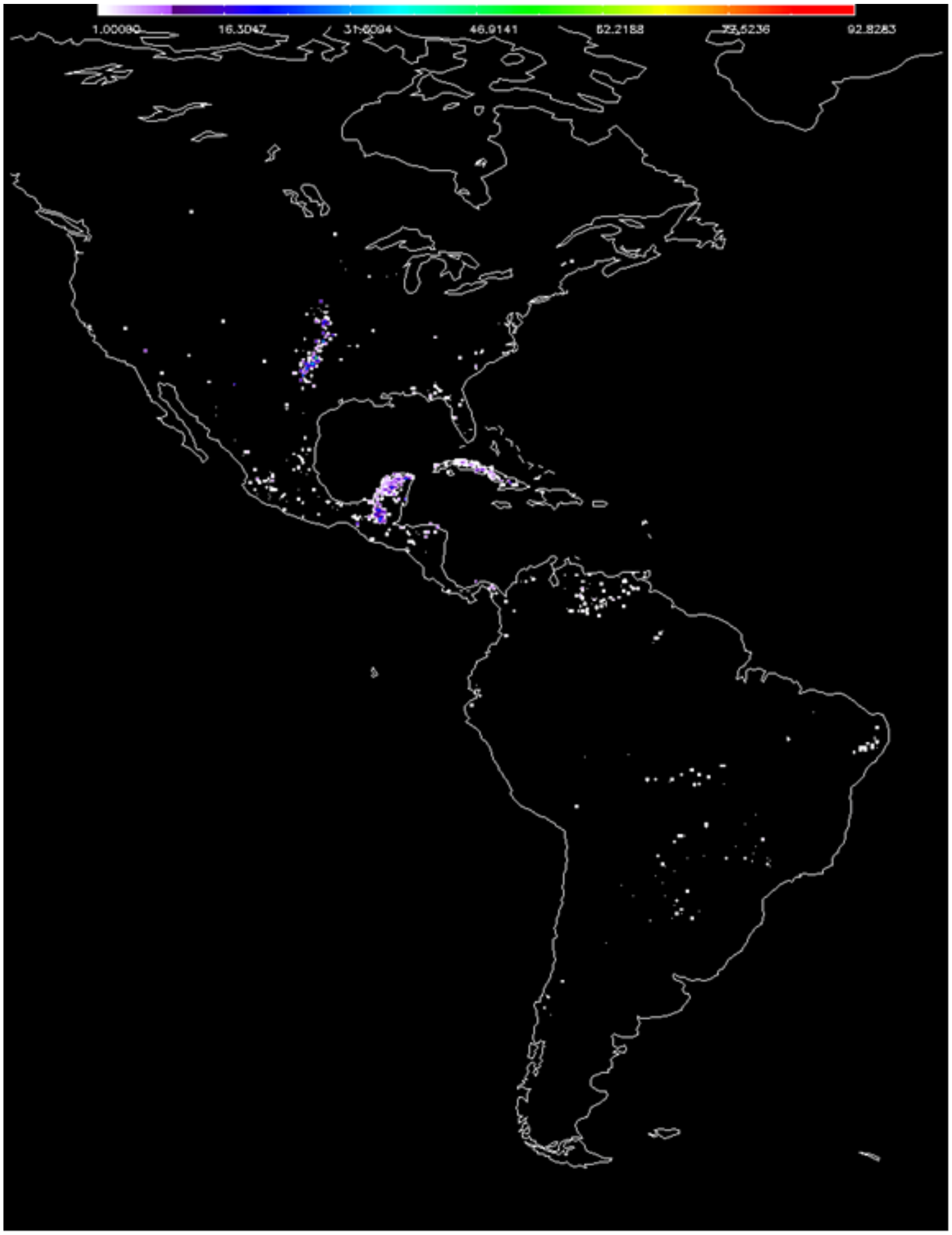


Figure 2 Example of the analysis that feeds the WF_ABBA climatology work that was developed under the FY2010-FY2011 GIMPAP project. GOES East WF_ABBA v65 satellite coverage corrected 0.25 degree binned total number of fires (all fire categories included but low possibility) for 9 April 2009 over the Western Hemisphere. Agricultural burning is active in the Central US, Cuba, and the Yucatan Peninsula. South America is quiet at this time of year. Coverage correction attempts to adjust for geographic differences in frequency of coverage and other factors like cloud coverage.

Publications/Conference Presentations

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

Brunner, J. C., C. C. Schmidt, R. M. Rabin, E. M. Prins, J. M. Feltz, J. P. Hoffman, and P. D. Bothwell, 2010: The development of a Western Hemisphere trend analysis of fires and United States fire potential product from version 6.5 WF_ABBA data. 17th Conference on

Satellite Meteorology and Oceanography. Annapolis, MD. September 2010, Amer. Meteor. Soc., P4.16.

Hoffman, J. P., C. C. Schmidt, J. C. Brunner, E. M. Prins, 2010: Geostationary fire detection with the Wildfire Automated Biomass Burning Algorithm. AGU Fall Meeting, San Francisco, CA, December 13-17, 2010.

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

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. *IEEE Journal of Selected Topics in Earth Observations and Remote Sensing*, **Vol. 2**, Issue 3, 144-162.

Schroeder, W., I. Csiszar, L. Giglio, and C. C. Schmidt, 2010: On the use of fire radiative power, area, and temperature estimates to characterize biomass burning via moderate to coarse spatial resolution remote sensing data in the Brazilian Amazon. *JGR*, **115**, D21121, doi:10.1029/2009JD013769.

GOES Cloud Algorithm

CIMSS Personnel: Andi Walther, William Straka
Federal Collaborator: Andy Heidinger
Funded by:

Project Description
This subproject (Daytime cloud optical and microphysical properties algorithm (DCOMP)) is responsible for the development of products Cloud Optical Depth (COD), Cloud Effective Radius (REF), Liquid and Ice Water Path (LWP, IWP) under daylight conditions for the future GOES-ABI sensor. The software code is embedded in the GEOCAT framework.

The past year of the DCOMP subproject development for GOES-ABI sensor was focused on the final work for the 100% software and ATBD delivery. Another important part of our work has been the work on ongoing validation efforts.

The FORTRAN-based software code was provided to the AIT team. It was successfully tested in the AIT framework software environment and met all 100% delivery standards. The software code and the ATBD were provided to the private cooperator Harris.

We also carried out an initial validation experiments. All accuracy requirements were met. The table below shows the results for comparisons to MODIS and AMSR-E products.

Table Error budget of DCOMP

Product	Validation Source	Accuracy	Specs	Precision	Specs
COD Water	MODIS	1.59/0.9%	2. or 20%	4.43/25.7%	2. or 20%
COD Ice	MODIS	1.81/3.6%	3. or 30%	5.02/31.1%	3. or 30%
CPS Water	MODIS	3.03µm	4µm	4.3µm	4µm
CPS Ice	MODIS	5.69µm	10µm	5.23µm	10µm
LWP	MODIS	10g/m2	50 g/m2	17 g/m2	50 g/m2
LWP	AMSR-E	17 g/m2	50 g/m2	47 g/m2	50 g/m2
IWP	MODIS	44 g/m2	100 g/m2	65 g/m2	100 g/m2

The next stage of the project will be focused on extended validation studies, which started in the past project period. We defined our plans on deep-dive and monitoring validation tools. Since DCOMP can be run on a number of similar sensors (MODIS, AVHRR, current GOES, SEVIRIR and others), we have a large amount of proxy data.

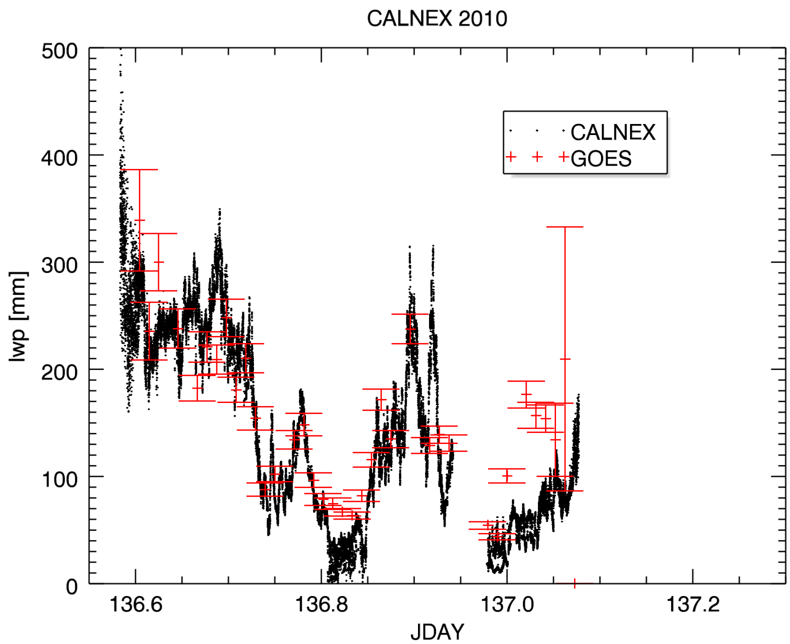


Figure 3 Validation of Liquid Water Path with ground-based Solar Spectral Flux Radiometer instrument (SSFR) during CALNEX 2010 project

We cooperated with Sebastian Schmidt from University of Colorado for ground-based validation efforts. The Figure 3 above shows a comparison of DCOMP Liquid water path with it's uncertainty estimates to liquid water path which is retrieved by transmission measurements in the visible range by a highly spectrally resolved solar irradiance instrument. Since the liquid water path in DCOMP is directly computed from COD and REF the shown results that all DCOMP products are in a good agreement with independent observations for the CALNEX 2010 campaign.

Significant Milestones:

TRR
100% ATBD
100% code delivery

Publications and Presentations

Walther, A., A. Heidinger and M. Foster, 2011: Implementation of the Daytime Cloud Optical and Microphysical Properties Algorithm (DCOMP) in PATMOS-x. Submitted to *Journal of Applied Meteorology and Climatology*.

Conference Presentations

Walther, A. and A. Heidinger, 2010: Microphysical cloud parameters (Poster presentation). AGU 2010, San Francisco, CA.

Volcanic Ash Detection and Physical Property Retrievals

CIMSS Personnel: Justin Sieglaff
Federal Collaborator: Michael Pavolonis
Funded by: NOAA-AWG and NOAA-GIMPAP

Project Description
Given the impact of volcanic ash on the aviation industry and public safety, the NOAA GOES-R Aviation Algorithm Working Group (AWG) funded the development of volcanic ash detection and physical property retrieval algorithms. These algorithms were developed for the GOES-R Advanced Baseline Imager (ABI). 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.

With the current series of GOES imagers, there are fewer spectral channels than will be on the GOES-R ABI. The current GOES imagers do not have an 8.5 μm channel, only the 11 and 12 or 13.3-micron channels are available. NOAA-GIMPAP provided funding to modify the GOES-R AWG volcanic ash algorithms to operate with more limited spectral information. Past research has shown that a two-channel "split-window" approach does not provide optimal results for ash detection, so we needed to utilize additional GOES channels. Thus, we developed a tri-spectral technique (3.9, 11, 12/13.3-μm) for detecting volcanic ash at night and a multi-spectral (0.64, 3.9, 11, 12/13.3-μm) technique during the day. The volcanic ash height/mass loading algorithm reduces to a bi-spectral technique for the current GOES imager (11 and 12/13.3 μm).

Recent Milestone
In addition to algorithm development, recent focus has been toward building a validation tool used to determine algorithm accuracy. The validation tool utilizes Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) data, which provides very accurate cloud height information. Figure 4 conceptualizes how the validation is performed. The CALIOP total attenuated backscatter cross section (truth height) for the Eyjafjallajökull (in Iceland) ash cloud is the underlying data and the tri-spectral GOES-R ABI retrieved ash height, the more spectrally limited current GOES retrieved ash heights, and a single channel ash height retrieval are plotted. In this example, the GOES-R AWG ash heights show good agreement with the CALIOP indicated cloud height. The more spectrally limited current GOES ash heights are less accurate than the GOES-R ash heights, but still are more accurate than the single channel heights. The GOES-R AWG ash height algorithm has been validated using over 4,000 CALIOP/IR retrieval matchups (like those shown in Figure 4) with an accuracy of -1.31 km. A similar statistical analysis of the current GOES ash heights is being generated.

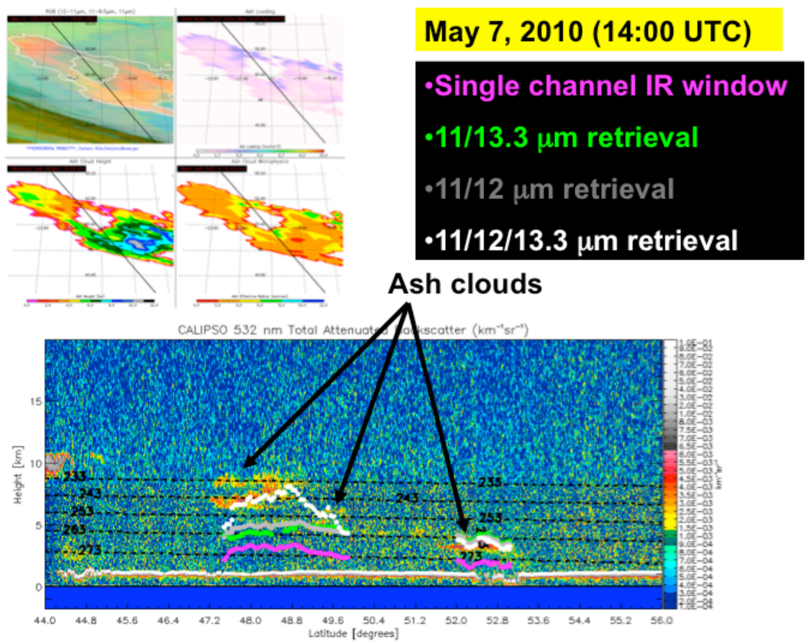


Figure 4 The ash cloud height retrieved using four different methodologies is compared to the ash cloud boundaries inferred from the total attenuated backscatter cross section measured by a spaceborne lidar (CALIOP). Eyjafjallajökull (in Iceland) produced the ash cloud depicted in the lidar data on May 7, 2010. The ash cloud height retrieved using the GOES-11 methodology is shown in gray, the ash cloud height retrieved using the GOES-12 – GOES-15 methodology is shown in green, the GOES-R methodology is shown in white, and the height inferred from a traditional single channel approach is shown in magenta.

Publications/Conference Presentations

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

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

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

Pavolonis, M. and J. Sieglaff, 2011: Validation of the GOES-R AWG Volcanic Ash Algorithm. 2011 GOES-R AWG Annual Meeting, Fort Collins, Colorado, June 2011. (Poster presentation)

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

CIMSS Personnel: Dan Hartung, Justin Sieglaff, Lee Cronce and Wayne Feltz
Federal Collaborators: Mike Pavolonis (NOAA/NESDIS/STAR), Robert Rabin
Funded by: NOAA-GIMPAP

Project Description
The UWCI/CTC algorithm is a GOES imager based product used to nowcast (diagnose) convective initiation (cloud top cooling rates). The algorithm uses GOES-11 (West) and GOES-13 (East) imager infrared channels, GOES cloud type (Pavolonis), and GOES cloud mask (Heidinger) to determine immature convective clouds that are growing vertically and hence cooling in infrared satellite imagery. The UWCI/CTC technique identifies pixels with a rapid 10.7 μm Cloud-Top Cooling (CTC) rate coupled with cloud microphysical transition (Sieglaff et al., 2011). The cloud phase information is utilized to deduce whether the cooling clouds are immature water clouds, mixed phase clouds or ice-topped (glaciating) clouds. Regions having a large amount of cirrus (ice) clouds, including thin cirrus, are omitted. The UWCI/CTC products provides a coherent signal (much like radar) that can be used as a direct nowcast product in AWIPS or N-AWIPS for forecaster decision support as demonstrated in the Storm Prediction Center (SPC) Proving Ground Hazardous Weather Testbed (HWT) and local Milwaukee-Sullivan (MKX) NWS from 2009-present. The methodology has been shown to provide up to a 45-minute lead-time before significant radar reflectivity thresholds are observed.

Significant Milestones
The UWCI/CTC decision support product was requested and is being provided to the SPC HWT, Aviation Weather Center (AWC), NWS Central /Eastern/Western Region Headquarters for dissemination to NWS WFO's, and the Space Meteorological Group (SMG), for use as a convective initiation decision support aid. The participation in the SPC HWT Spring Experiment and the CIMSS-MKX WFO local-area testbed has resulted in dramatic improvement of the algorithm through forecaster feedback.

Accomplishments
- Improved UWCI/CTC methodology by reducing false alarm ratio related to rapid anvil expansion and thin cirrus moving over small cumulus.
- GOES imager top of troposphere cloud emissivity (Pavolonis, 2010) has been successfully imported into the Warning Decision Support System- Integrated Information (WDSS-II; Lakshmanan et al., 2007) object tracking system and an optimized configuration for GOES imager object tracking has been completed. An example of top of troposphere cloud emissivity and associated cloud objects is shown in Figure 5.
- WDSS-II object tracking is currently being used to validate UWCI CTC with various radar fields in an automated manner. This research path was driven by feedback from NWS WFO forecasters who wanted to know the link between satellite-based convective cloud top cooling and anticipated future radar reflectivity, Vertically Integrated Liquid (VIL), etc., and associated lead-times. Figure 6 shows preliminary Probability of Detection as a function of VIL of cloud objects having valid UWCI cloud-top cooling rates.

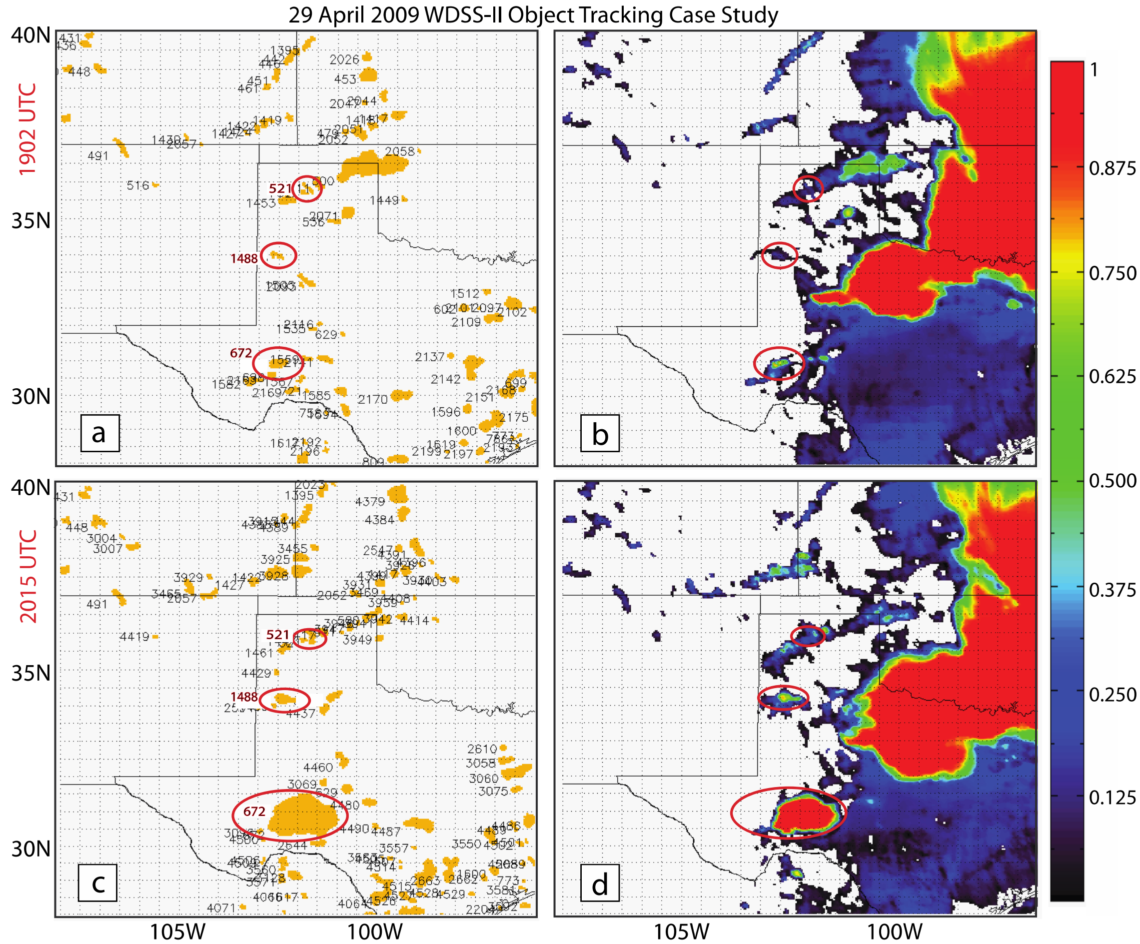


Figure 5 WDSS-II cloud objects tracked through space and time (panels a and c) with corresponding intermediate cloud property, top of troposphere emissivity (panels b and d) for reference on 29 April 2009 (times indicated to the left of panels a and c). The numbers to the southwest of each object reflect the WDSS-II object ID (panels a and c). Red circles and red object ID numbers highlight some of the developing convective clouds for this day. Object IDs are consistent over time, allowing developing storms to be automatically tracked while minimizing broken tracks. Any desired satellite or radar fields are tracked along with each object ID (UWCI Cloud Top Cooling Rate, Brightness Temperatures, Composite Reflectivity, Vertically Integrated Liquid, etc.).

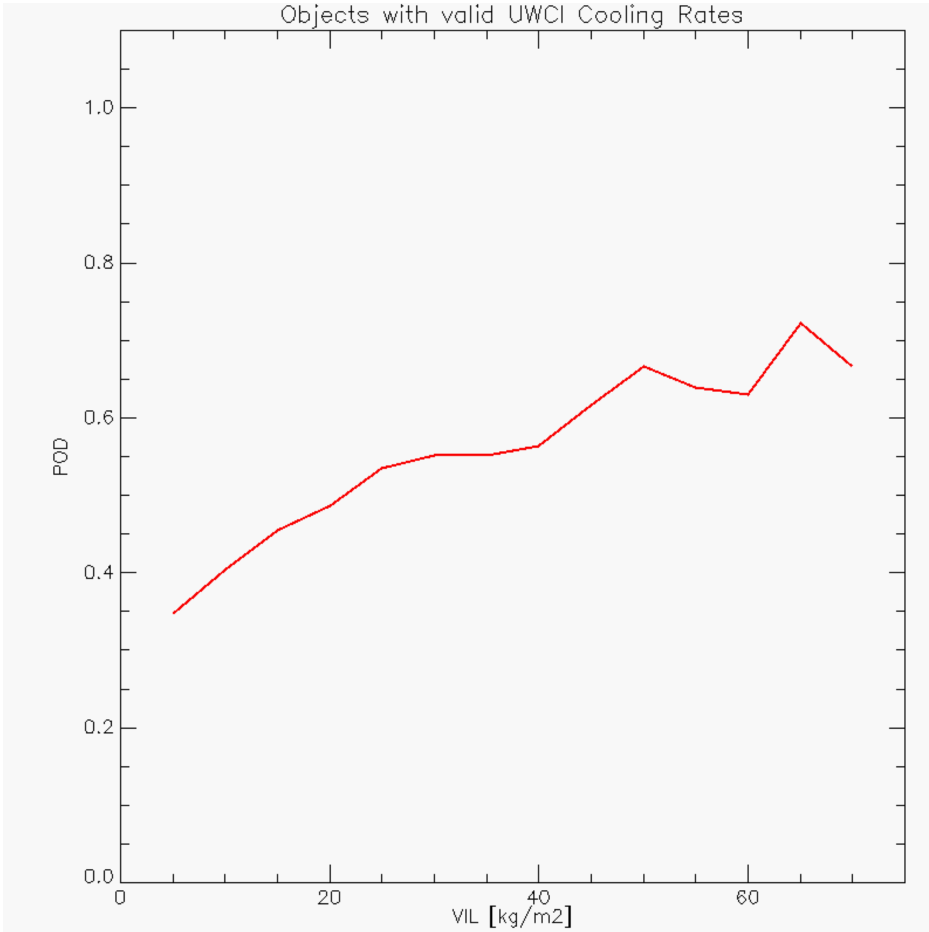


Figure 6 Preliminary Probability of Detection as function of the VIL of cloud objects having valid UWCI cloud-top cooling rates for 24 convective afternoons during the spring and summer of 2008 and 2009. Preliminary numbers indicate UWCI CTC hit roughly 50% of cloud objects that achieved a VIL of 20 kg/m^2 and approximately 67% of cloud objects that achieved a VIL of 50 kg/m2 or higher.

Publications and Conference Presentations

Sieglaff, Justin M., Lee M. Cronce, Wayne F. Feltz, Kristopher M. Bedka, Michael J. Pavolonis, and Andrew K. Heidinger, 2011: Nowcasting Convective Storm Initiation Using Satellite-Based Box-Averaged Cloud-Top Cooling and Cloud-Type Trends. *J. Appl. Meteor. Climatol.*, **50**, 110–126. doi: 10.1175/2010JAMC2496.1.

Cronce, Lee M., Justin M. Sieglaff, Wayne F. Feltz, Kristopher M. Bedka, Michael J. Pavolonis, and Andrew K. Heidinger, 2010: Validation of University of Wisconsin Convective Initiation (UWCI) Algorithm. 35th National Weather Association Annual Meeting, Tucson, Arizona. (Poster Presentation)

Sieglaff, Justin M., Lee M. Cronce, Wayne F. Feltz, Kristopher M. Bedka, Michael J. Pavolonis, and Andrew K. Heidinger, 2010: Validation of University of Wisconsin Convective Initiation (UWCI) Algorithm. 17th Conference on Satellite Meteorology and Oceanography, Annapolis, Maryland. (Poster Presentation)

Satellite-Based Hurricane Intensity Estimation Algorithm Development and Transition to Operations

CIMSS Personnel: Chris Velden, Tim Olander, Derrick Herndon, Tony Wimmers
Federal Collaborators: Jeff Hawkins (NRL), Mike Turk (NESDIS-SAB), Jack Beven (NWS-NHC)
Funded by: ONR/NRL, and NOAA GIMPAP, PSDI, GOES-R/AWG

Project Description
The CIMSS Tropical Team has been at the forefront of developing satellite-based algorithms designed to estimate hurricane intensity. Since most tropical cyclone basins do not have reconnaissance aircraft flights into storms to collect in situ measurements, satellites are relied upon to provide accurate estimates of intensity and intensity trends. Forecasters depend upon these estimates to get the current state of storm development, and numerical models utilize these estimates to initialize their forecasts. Especially in landfalling situations, the importance of these intensity estimates (wind, MSLP, structure) cannot be understated.

The Advanced Dvorak Technique (ADT) is an algorithm designed by CIMSS scientists to provide objective estimates of hurricane intensity from GOES and other geostationary satellites. Its long-term development has been partially supported by GIMPAP, and the latest algorithm (Sears et al., 2010) has recently been successfully transitioned through a PSDI effort into NESDIS operations at the Satellite Analysis Branch. The National Hurricane Center (NHC) now routinely accesses the ADT data as part of its hurricane analysis suite of tools. In fact, in support of the importance of the ADT in hurricane analysis at the U.S. operational centers, a joint User Request was recently submitted to the NESDIS SPSRB by NHC, CPHC (Central Pacific Hurricane Center), and JTWC (Joint Typhoon Warning Center) to continue ADT science upgrades and transition activities. The request was approved by the SPSRB for future PSDI funding considerations.

The latest addition to the ADT is the incorporation of polar satellite passive microwave information (Wimmers and Velden 2010). The microwave imagery offers a unique perspective on storm structure analysis, being it can view through the cirrus canopy. Developing eye structures can be discerned when the IR cannot yet view such structures when a central dense overcast is present. The microwave module has been implemented into the latest version of the ADT, and is showing notable improvements to the ADT performance metrics (see Figure 7).

In addition to the ADT, the CIMSS Tropical team continues to investigate alternative methods to estimate hurricane intensity from satellites. An AMSU-based technique is fully mature, and is used often by NHC as a microwave alternative to the IR-based ADT method. This technique has unique measuring characteristics (warm core strength), so can be used in tandem with the ADT in a consensus approach we call SATCON (Herndon and Velden 2011). SATCON has undergone extensive testing and validation, and shows promise in offering a consensus approach to estimating hurricane intensity.

Publications/Conference Presentations
Herndon, D. and C. Velden, 2011: SATellite Intensity CONsensus (SATCON) Evaluation and

Recent Changes. 65th Interdepartmental Hurricane Conference.
Olander, T. and C. Velden, 2009: Tropical cyclone convection and intensity analysis using differenced infrared and water vapor imagery. *Weather and Forecasting,* **Vol. 24**, pp. 1558-1572.
Sears, J., C. Velden and T. Olander, 2010: Recent Statistical Analyses of the Advanced Dvorak Technique (ADT). 29th AMS Conference on Hurricanes and Tropical Meteorology.
Wimmers, A., and C. Velden, 2010: Tropical Cyclone Center-Fixing in Microwave or Infrared Imagery. 29th AMS Conference on Hurricanes and Tropical Meteorology.
Wimmers, A. J., and C. S. Velden, 2010: Objectively determining the rotational center of tropical cyclones in passive microwave satellite imagery. *Journal of App. Meteor and Clim.*, e-View doi: 10.1175/2010JAMC2490.1.

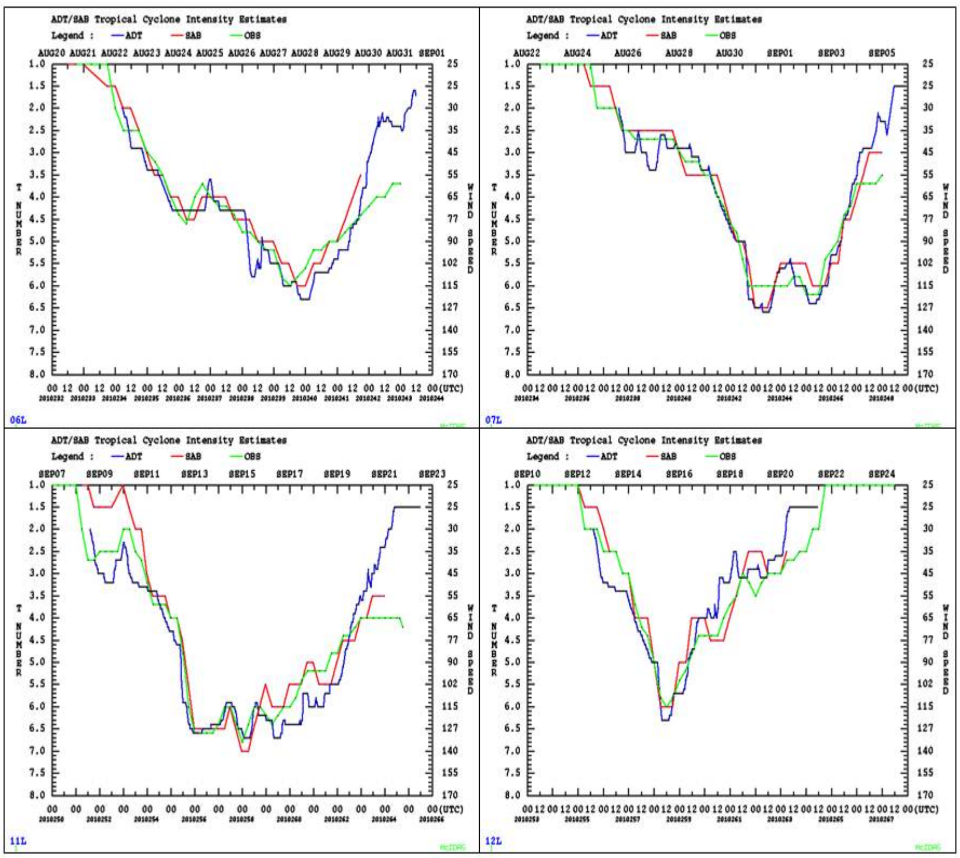


Figure 7 Examples of ADT hurricane strength estimates for selected Atlantic hurricanes in 2011. The ADT performance for estimating storm maximum winds is plotted against the NESDIS Satellite Analysis Branch (SAB) operational satellite estimates and the NHC Best Track validation

Continued Research and Development of GOES Atmospheric Motion Vectors (AMVs)

CIMSS Personnel: Chris Velden, Steve Wanzong, Dave Stettner
Federal Collaborator: Jaime Daniels (NOAA/NESDIS)
Funded by: NOAA GIMPAP, GOES-RRR, GOES-R/AWG

Project Description
CIMSS has been a long-term pioneer in the development and advancement of algorithms designed to extract atmospheric motion vectors (AMVs) from sequential satellite imagery. Most recently, attention has been turned to GOES-R readiness, and CIMSS is working in partnership with NOAA to prepare, test, document and deliver the software that will be used to derive AMVs from GOES-R.

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

The NESDIS/CIMSS winds team has developed and demonstrated AMV fields and products from proxy/simulated GOES-R ABI data. The algorithm in place for our proposed study will make use of the Version 5 GEOCAT Framework, Cloud Mask Software, Cloud Phase/Type Software, Cloud Height Software, and Winds Software. These versions represent fairly stable and well-validated algorithms (they meet benchmarks from the GOES-R program office) that are being delivered to the Harris Corporation under the GOES-R program. Thus far, the simulated ABI winds software has been designed to meet its benchmarks in accuracy and precision while using mostly SEVIRI proxy datasets. The software can produce AMVs in the following ABI bands: 1) visible (.62 μm), 2) swir (3.9 μm), 3) upper-level cloudy wv (6.2 μm), 4) upper-level clear sky wv (6.2 μm), 5) mid-level clear sky wv (7.3 μm), and 6) IR window (11.2 μm).

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

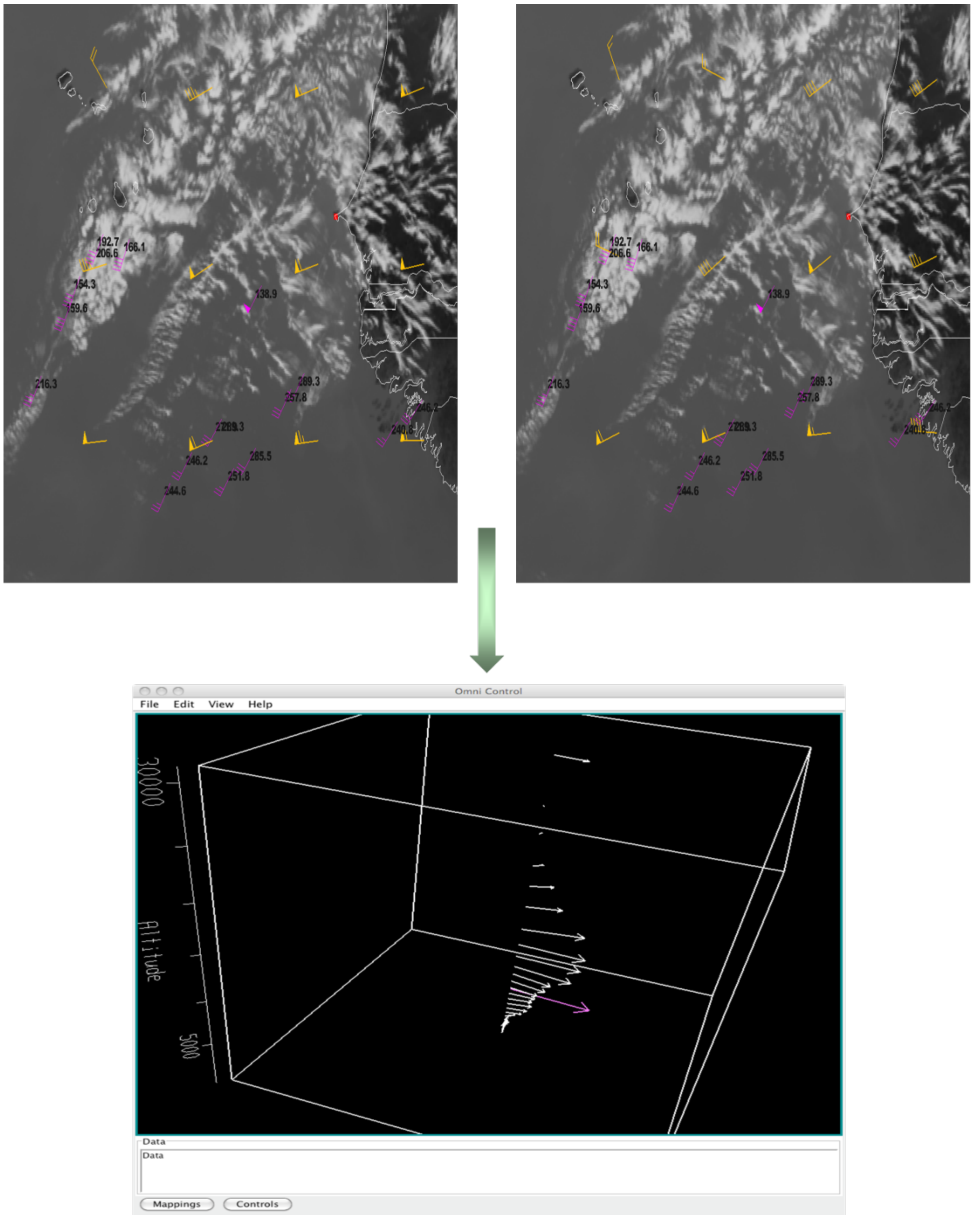
The AMV processing algorithm uses upstream cloud team algorithms for AMV height assignment. Included in the pixel-level cloud height output structure are estimated pressure and temperature errors. It is still hoped that this will eventually be a way to estimate AMV tracer cloud height uncertainty for use in NWP. Also included in the cloud team output structure are quality flags with respect to the cloud height retrieval for each pixel. We are looking at cloud retrieval quality estimates and 11-micron emissivity values compared against AMV-CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) cloud height comparisons. To facilitate this investigation, deep-dive validation tools are being developed with the McIDAS-V framework to allow for easy visualization and analysis of multiple data sources (see figure). From these investigations, we hope to not only validate the GOES-R AMV product, but also identify problem areas in need of further refinement or research.

On another research front, mesoscale AMVs, which can be derived from simulated GOES-R ABI data, will be used to provide information on the mesoscale wind field. The added value of the simulated AMVs in locating low-level moisture convergence, upper-level divergence, and identifying jet streaks will be explored in the context of pre-convective environments. In this study we propose to start with current meso-AMV processing routines developed and modified at CIMSS using GOES rapid-scan datasets, and adapt the settings to the GOES-R AMV processing algorithm. The simulated ABI cases using 5-minute data will be used to test and validate the products. The ultimate goal will be to produce high temporal AMV datasets from the simulated analyses that cannot be replicated with the current GOES (unless in Rapid Scan). From these datasets, we will produce fields of convergence, divergence, vorticity, and shear plots that can be combined and integrated with analyses produced by the co-investigators from common case studies toward the ultimate goal of creating an objective system for predicting convective initiation (CI).

Publications/Conference Presentations

Velden, C. S., and K. M. Bedka, 2009: Identifying the uncertainty in determining satellite-derived atmospheric motion vector height attribution. *J. Appl. Meteor. Clim.*, **Vol. 48**, Issue 3, pages 450–463.

Wanzong, S. and C. Velden, 2010: Exploring the behavior of atmospheric motion vector (AMV) errors through simulation studies. 10th WMO International Winds Workshop.



AMV-GFS Analysis Comparison

Example of the advanced validation tools being employed to investigate the quality of AMVs. Magenta vectors are AMWs with vector difference values of 20 m/s or greater than the collocated GFS analysis, and vector heights in hPa. Gold vectors are the GFS analysis winds at two different levels. The plot on the right shows one of these AMWs plotted within the nearest GFS analysis grid point. The McIDAS-V 3-dimensional view (bottom panel) allows for an improved interpretation of the comparison and validation.

GOES Cloud Algorithm (ACHA)

CIMSS Personnel: William Straka, Tony Schreiner
Federal Collaborator: Andy Heidinger
Funded by: NOAA/NESDIS - PSDI

Project Description
The ABI Cloud Height Algorithm (ACHA) has been improved over the course of the last year, including the ability to run the cloud height utilizing a variety of different modes. These modes include

MODE 0 – 11 µm
MODE 1 – 11/12 µm
MODE 2 – 11/13.3 µm
MODE 3 – 11/12/13.3 µm
MODE 4 – 8.5/11/12 µm
MODE 5 – 6.7/11/12 µm
MODE 6 – 6.7/11/13.3 µm

Each of these channel combinations corresponds to a set of sensors. MODE 0 can be run on just about any satellite, MODEs 1 and 5 can be run on the GOES-11 series of satellites, MODEs 2 and 6 can be run on the GOES-12 series of satellites, MODE 3 is the ABI algorithm, and MODE 4 is the VIIRS channel combination. Typically, the ACHA algorithm is run in the 3-channel mode, which means that for the current GOES instruments, MODEs 5 and 6 are used, depending on which satellite is being processed

Some early comparisons between the ACHA and the CO_2/IRW ratio technique for generating cloud top pressure have been made. As shown in the figure below both the ACHA and the CO_2/IRW agree quite well, qualitatively with respect to high clouds (the white and light blue regions in Figure 9). There are still some discrepancies in the mid and low cloud top pressure regions (i.e., off the west coast of North and South America). In order to ameliorate these differences independent comparisons using the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) will be utilized to determine which technique is more correct in these regions. This will be the next step in this project.

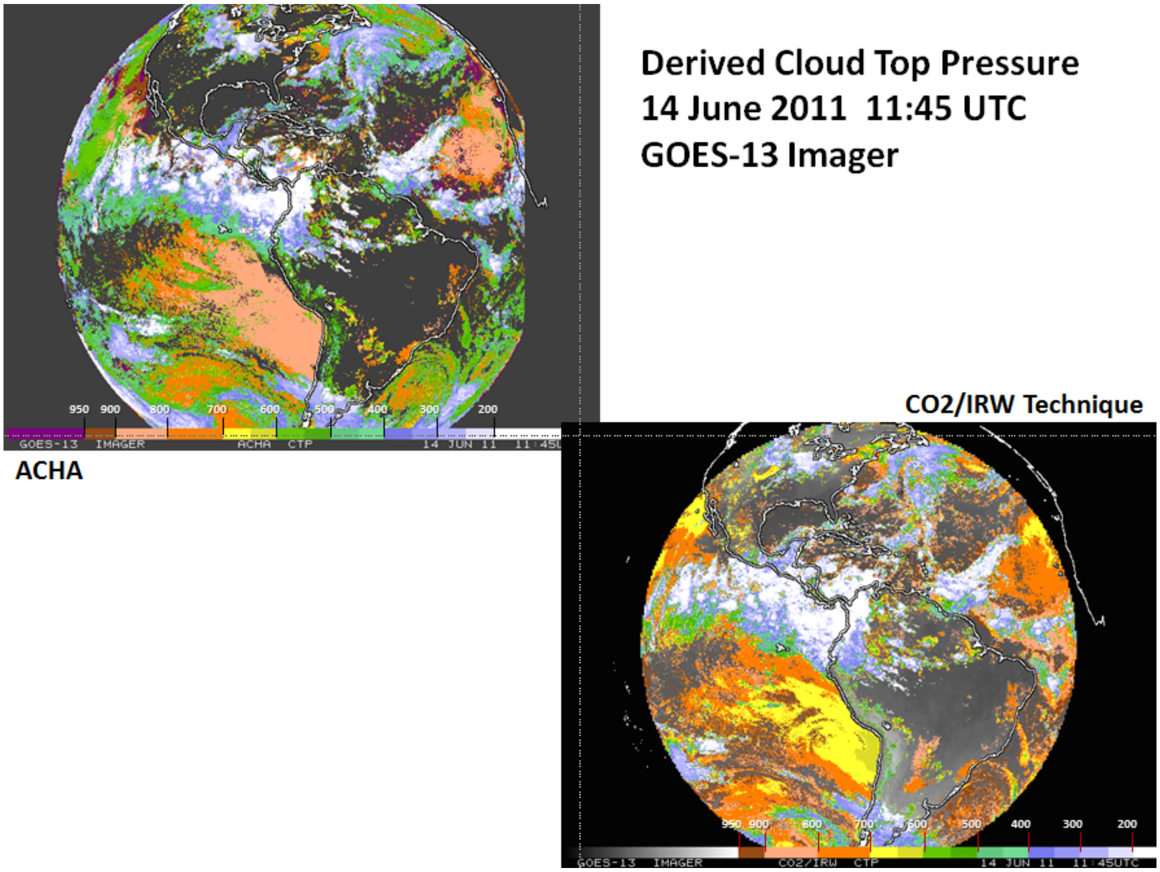


Figure 9 Comparison of Cloud Top Pressure based on the ABI Cloud Height Algorithm (ACHA) and the CO_2/IRW Techniques. The color bar along the bottom represents Cloud Top Pressure in hPa. The CO_2/IRW Technique only determines cloud information to a Local Zenith Angle of 62.5 degrees or less. This explains the difference in coverage.

GOES Cloud Algorithm (ACM)

CIMSS Personnel: William Straka
Federal Collaborator: Andy Heidinger
Funded by: NOAA/NESDIS - PSDI

Project Description
The ABI Cloud mask (ACM) was developed to work across numerous satellites, including the Spinning Environmental Visible and InfraRed Instrument (SEVIRI), the Geostationary Operational Environmental Satellite (GOES), the Advanced Very High Resolution Radiometer (AVHRR), and the Multi-Functional Transport Satellite (MTSAT) series of remote sensing platforms. In support of the cloud properties PSDI project, the ACM, as applied to the GOES was integrated into the GOES-R Framework. The ACM is also applied to the GOES in near realtime in the Geostationary Cloud Algorithm Test-bed (GEOCAT). This is being run in support of the Fog Algorithm Working Group (AWG) team and is displayed on the Internet (http://cimss.ssec.wisc.edu/geocat/) in addition to being distributed the NWS forecast office in Sullivan, WI, as part of the Local Test Bed activities for usage in their sky cover analysis and forecasting. Finally, the ACM is being integrated in near realtime as part of the Pathfinder Atmospheres - Extended (PATMOS-x) project. Within PATMOS-x the ACM is used as input into the GOES-R Advanced Baseline Imager (ABI) Cloud Height Algorithm.

As part of the development of the GOES-R processes, the ACM, as applied to SEVIRI and MODIS, have been compared against CALIPSO and the MOD35 products respectively. An example of the comparison with the MOD35 product is shown in Figure 10.

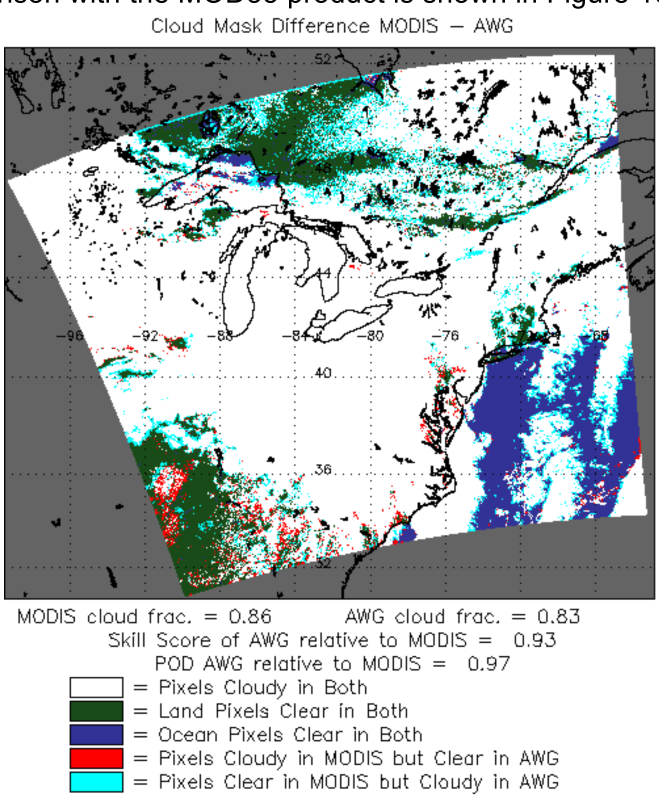


Figure 10 Comparison of ACM, as applied to MODIS, against the MOD35 cloud mask product.

In the near future, we will expand this comparison to the ACM as applied to GOES.

CIMSS Cal/Val Activities with the GOES Sounder

CIMSS Personnel: Mat Gunshor, Jim Nelson, Tony Schreiner
Federal Collaborator: Tim Schmit
Funded by: NOAA/NESDIS

Project Description
There are two primary objectives to this research. The first is to improve Infrared band calibration and the second is to develop an algorithm and process for improving cal/val for current and future GOES Sounder IR bands. The method proposed to improve IR calibration is to investigate the diurnal variation of Sounder performance. The diurnal variation will be studied over the operational lifetime of the GOES Sounder and investigated for seasonal trends. This process will lead to the development of an algorithm for improving cal/val for the Sounder.

GOES Sounder calibration performance will be assessed by comparing calculated radiances (“calc”) to the actual observed radiances (“obs”). Calculated radiances can be determined using atmospheric profiles in a forward model calculation. Atmospheric profiles will be obtained from both forecast model profiles obtained from Gridded Forecast System (GFS) forecasts and from RAOB data obtained from U.S. weather stations.

Thus far a processing system has been developed at the University of Wisconsin – Madison Cooperative Institute for Meteorological Satellite Studies (CIMSS) that will generate hourly averages of observed and calculated (based on output from the Global Forecast System) brightness temperatures. From these hourly averages differences are determined. An example of this hourly output for the 14.08 µm band (Band 3) of the GOES-13 Sounder is shown in Figure 11.

The next step is to develop a Web site so that the trends noted in Figure 11 can be monitored on a daily basis for all eighteen IR bands. Additional work will be completed to compare both the observed and calculated brightness temperatures from the GOES Sounder to twice-daily forward calculated brightness temperatures based on radiosonde data.

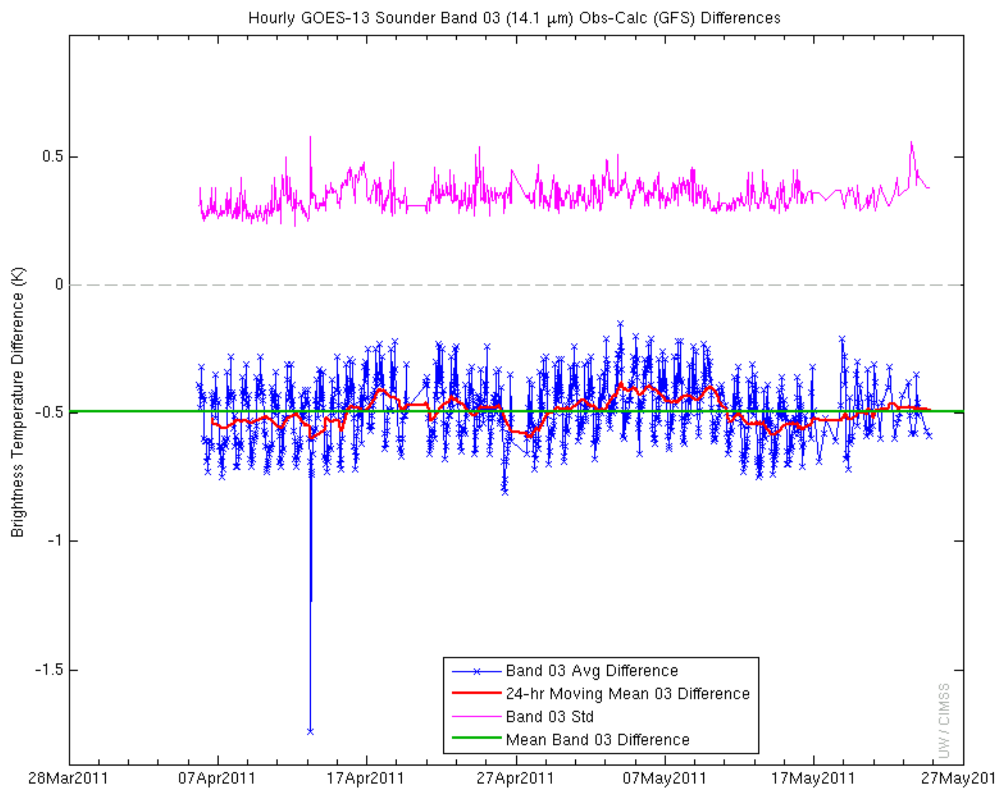


Figure 11 A comparison of hourly GOES-13 Sounder Band 3 (14.08µm) Observed minus Calculated brightness temperature differences from 7 April 2011 through 27 May 2011. The blue curve represents the hourly change in the bias, while the red curve portrays a 24 hour moving mean difference, and the green curve is the mean bias for the duration defined above. The magenta curve denotes the hourly standard deviation.

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

CIMSS Personnel: Dan Hartung, Justin Sieglaff
Federal Collaborators: Mike Pavolonis (NOAA/NESDIS/STAR), Andy Heidinger (NOAA/NESDIS/STAR)
Funded by: NOAA-GIMPAP

Project Description

GIMPAP presently supports the real-time implementation of GOES-R ABI cloud property retrieval algorithms (the GOES-NOP version of the GOES-R ABI algorithms developed by the Algorithm Working Group (AWG) Cloud Application Team) on current GOES imager data. The goal of this project is to extract information from under-utilized quantitative cloud properties that can be used to make short-term predictions on convective storm evolution, at the early stages of the convective lifecycle. By treating individual clouds as objects and tracking them over time through space using the automated object tracking of the Warning Decision Support System-Integrated Information (WDSS-II developed at OU-CIMMS; Lakshmanan et al., 2007), we are able to capture and study the unique temporal trends of physical cloud properties (i.e., cloud phase, effective particle radius, cloud optical depth, and 11 μm top of troposphere cloud emissivity) of individual objects. Most recently, the similarities and differences in the temporal trends of convective cloud properties for severe (warning issued and storm report received by NWS) and non-severe convection (no warning issued or storm report received) have been used to train a naïve Bayesian probabilistic severe thunderstorm detection algorithm. Extensive testing of this unique probabilistic approach is currently underway.

Significant Milestone

Initial testing of various combinations of the temporal trends of these cloud properties as predictors in a naïve Bayesian framework has suggested that such a probabilistic approach is capable of providing at least 20-40 minutes of lead-time *prior to* radar-indicated severe criteria for a developing future severe thunderstorm. This work lends new insight into the use of real-time satellite data in the predictability of severe thunderstorms and the subsequent addition of lead-time to public warning of approaching severe weather.

Accomplishments

- Generated robust climatology training data sets for strong (severe) and weak (non-severe) convection using temporal trends in cloud properties from 48 supercells during 18 unique severe weather outbreaks, as well as the full cloud field from two non-severe convective days, respectively.
- Implemented the above training data sets in a naïve Bayesian probabilistic framework and generated probabilities for one test case study thus far.
- Developed the capability to display the severe convective probabilities on top of 4-km IR GOES imagery (Example below)

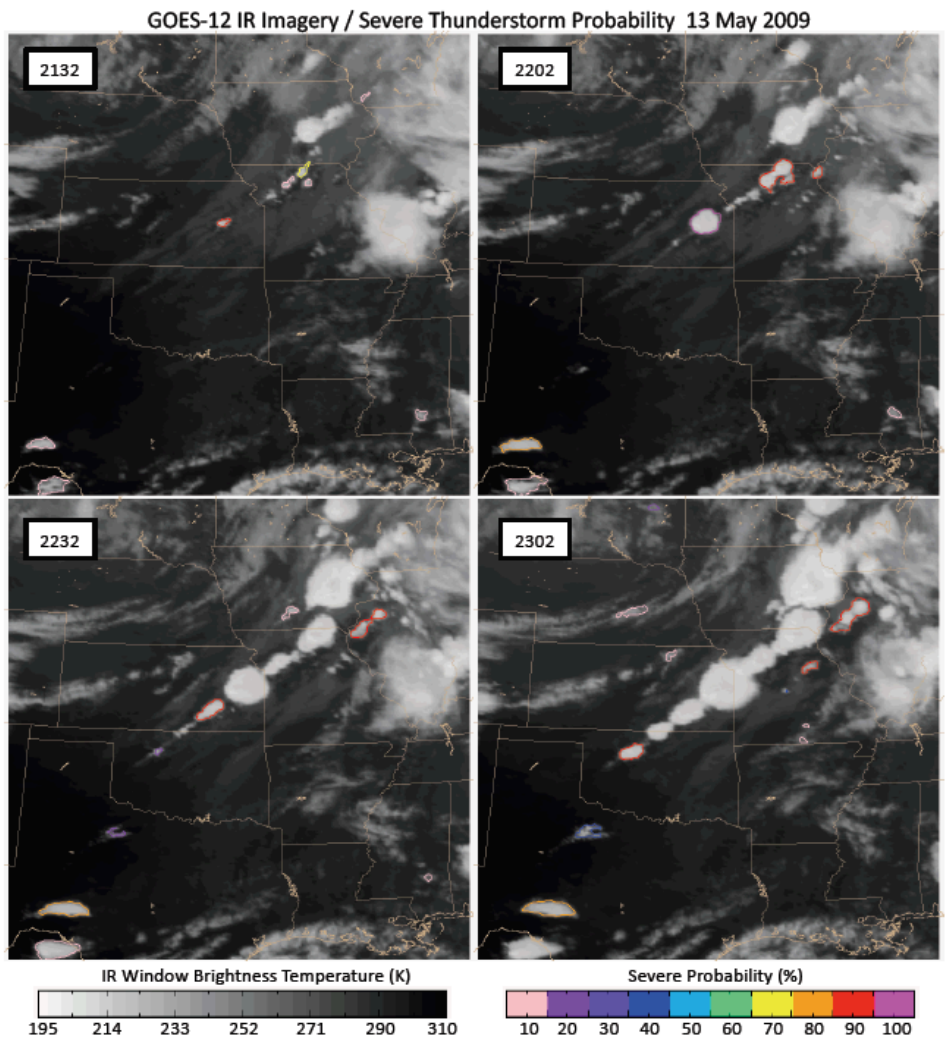


Figure 12 GOES-12 Infrared (IR) satellite imagery (grayscale) with severe thunderstorm detection algorithm probabilities contoured in various colors on top from the following times (UTC) on 13 May 2009: 2131 (top left), 2202 (top right), 2232 (bottom left), and 2302 (bottom right).

Publications and Conference Presentations

Pavolonis, M.J. and J. Sieglaff, 2010: The evolution of convective cloud properties: Meteorological vs. volcanically driven convection, presentation at the CoRP Symposium, Fort Collins, CO.

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

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

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

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

CIMSS Personnel: Ralph Petersen
Federal Collaborator: Robert Aune
Funded by: GOES-R Risk Reduction (Newly funded, existing project)

Project Description
Information from the GOES-12 sounder water vapor channels was used during previous years to develop methods to predict regions most susceptible to convection in the next 1-9 hours (called NearCasts). This technique initializes a trajectory at every GOES Sounder observation point to drive multi-layered precipitable water and Equivalent Potential Temperature (Θe) data forward in time. The retrievals use a combination of radiance data from all channels of the GOES sounder and contemporaneous surface data to update first-guess fields from NCEP's GFS model to define the distribution of water vapor and total thermal energy in the atmosphere at different levels. Such a multi-layer description of the atmospheric water vapor is not possible with the single water vapor channel on the GOES imager. These data are not being used over land in conventional NWP products. The hourly-updated NearCast model output displays can then be used by forecasters both to identify detailed horizontal gradients of low-level moisture needed to support strong convection, as well isolate areas where destabilization (convective potential) will occur in the near future as areas where differential advection moves mid-tropospheric dry/cool over concentrated areas of large "low" level moisture/ Θe.

The system has proved extremely useful at projecting conservative parameters forward in both time and space. An example of the utility of the NearCasting system is shown in Figure 13 below for a case of the formation of an un-forecasted tornado in south-central Poland on 20 July 2007. The figure shows a combination of Convective Instability (Δθe/ΔP) and lower-level total thermal energy (θe). This example and many other cases over the US have shown that the NearCasts are able to use geostationary satellite products to isolate areas conducive to rapid and sustained development of severe convection at the correct location and time. The system is being demonstrated and evaluated at NCEP's SPC and AWC during this summer, with the objective of determining the utility of the products to identify both 1) areas where convection is likely to occur and 2) regions where existing threats of convection will decrease over time.

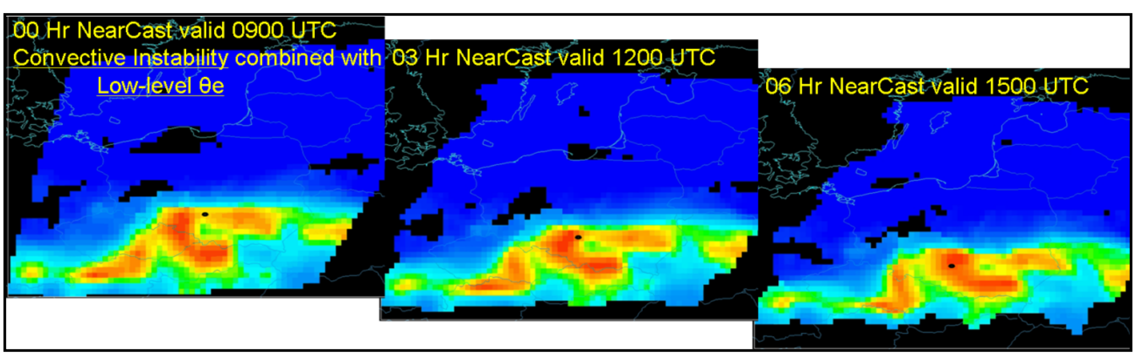


Figure 13 Three-hourly interval NearCasts of UTC for product of 840 hPa Equivalent Potential Temperature (θe) and vertical difference of θe between layers centered at 840 hPa and 480 hPa during the 6 hours prior to the formation of a tornado at the end of the period noted by a small black oval. Largest values in red indicate support for rapid and sustained growth of convection.

Over the next three years, the NearCasting effort will focus on: 1) determining how information contained in hyperspectral POES retrievals can be used to enhance GOES-R products by "extending" the high-resolution POES data from their native 6-hourly observing frequency to the much shorter time and higher spatial resolution GOES observation intervals and then using these products in NearCasts covering the 6-8 hours interval until the next POES products are available, and 2) performing a comprehensive assessment and validation of the NearCasting products across all of the participating GOES-R Proving Ground sites.

The primary developmental effort will be to meld information from POES and GOES retrievals as a means of improving upon the GOES. The inclusion of improved vertical resolving power of the POES hyper-spectral products will be especially important prior to hazardous weather events when the vertical structure of the thermodynamic fields is key in determining where the events are and are not likely to occur. The GOES data, in return, will increase the horizontal detail and fill the time gaps between POES overpasses. Converting the NearCasting system from an Isobaric to an Isentropic framework will add further to the importance of the satellite products and short-range forecasts, by providing both a better picture of the total amount of moisture and energy being transported adiabatically into areas of interest and an improved understanding of near-term vertical transports. These efforts 1) will give forecasters better and more time consistent real-time products than could be provided by GOES alone, 2) will provide an opportunity to use the higher time/space resolution products in extended NearCasting applications, and 3) may provide an alternative for developing bias-removal procedures needed for using GOES data in short-range NWP systems.

The related comprehensive validation effort will be conducted at several of the GOES Proving Grounds sites, including already planned tests at NCEP's Storm Prediction Center (SPC) and Aviation Weather Center (AWC) and anticipated tests at the Hydrological Prediction Center (HPC) and Ocean Prediction Center (OPC) in the next several years. Validations at each of the Centers will likely use a variety of different parameters, e.g., SPC will need to focus on Convective Instability, while HPC may be more interested in the structure and timing of small-scale moisture plumes and AWC will focus on identifying flight routes that can be confidently used over the next few hours. Quantitative validations will also be made to assess the performance and utility of the system using a number of methodologies including both observed data and gridded data sets. The validation results will be used to update training materials so that forecasters can better understand the situations when the NearCasts are more (or less) useful to their individual forecast problems.

Publications/Conference Presentations

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

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

GOES-R Meteorological Proving Ground Support

CIMSS Personnel: Wayne Feltz, Jordan Gerth, Justin Seiglaff, Lee Cronce, Kaba Bah, Scott Bachmeier, and Scott Lindstrom
NOAA Collaborators: Tim Schmit, Michael Pavolonis, Andrew Heidinger, Bradley Pierce
Funded by: NOAA

Project Description
The goal of this research is to support the NOAA GOES-R Proving Ground that will test and validate ideas, technologies and products before they are integrated into operational use. The Proving Ground mission is designed to ensure User Readiness on Day 1 for GOES-R. To this end, we are seeking assistance via the GOES-R Proving Ground in evaluating the GOES-R Algorithm Working Group demonstration algorithms and baseline products, testing enhancements and advanced products (Risk Reduction), and providing user assessments and feedback to the product developers. The development of the algorithms and associated research and validation are considered to be out of the scope for the Proving Ground part of the program. However, CIMSS scientists will develop GOES-R era products from existing measurement systems and simulations. They will expand partnerships with NWS Forecast Offices to provide these products, train forecasters in their applications, and evaluate their utility. This work will help to ensure that GOES-R products will be available and useful to forecasters soon after launch. The primary focus is to test, apply, and improve select GOES-R AWG satellite baseline and option 2 imagery/products in support of National Centers and Local NWS offices. Develop GOES-R ABI Weather Event Simulations (WES) for NWS office AWIPS training and provide simulated ABI radiance bands using WRF NWP modeling output. Table below indicates the multiple satellite-derived decision support products from CIMSS that are currently or will be tested in national center or local NWS WFOs.

Table : A summary of CIMSS supported GOES-R baseline/option2 decision support aids, leads, and testbeds to be used in 2011-2012 timeframe.

Clouds (Chair: Andy Heidinger, NOAA)		
Product	**Lead Developer**	**Testbed**
Cloud Mask	Andy Heidinger (NOAA)	AAWU/HLT
Cloud Layers/Heights and Thickness/Temp	Andy Heidinger (NOAA)	AAWU/HLT/OPC
Cloud Phase and Type	Mike Pavolonis (NOAA)	AAWU/HLT/OPC
Land (Chair: Bob Yu, NOAA)		
Product	**Lead Developer**	
Fire	Chris Schmidt (CIMSS)	HWT
Soundings (Chair: Tim Schmit, NOAA)		
Product	**Lead Developer**	
Moisture/Temperature Profile/TPW	Jun Li (CIMSS)	HWT/PR
Winds (Chair: Jaime Daniels, NOAA)		
Product	**Lead Developer**	
Hurricane Intensity	Tim Olander (CIMSS) and Chris Velden (CIMSS	NHC/PR
Aviation (Chairs: Ken Pryor, NOAA and Wayne Feltz, CIMSS)		
Product	**Lead Developer**	
Volcanic Ash	Mike Pavolonis (NOAA)	AWC/AAWU/HLT/PR
Turbulence	Tony Wimmers (CIMSS)	AWC
Low Cloud and Fog	Mike Pavolonis (NOAA)	AWC/AAWU/HLT
SO2 Detection	Mike Pavolonis (NOAA)	AWC/AAWU/HLT/PR
Icing	Bill Smith Jr (NASA) - CIMSS provide N-AWIPS	AWC/HLT/AAWU
Convective Initiation	John Mecikalski (UAH), UWCI (CIMSS) used u	HWT/AWC/PR/AAWU
Overshooting Top Detection	Kris Bedka (NASA contractor)/Jason Brunner (	OPC/HWT/NHC
Imagery (Chair: Tim Schmit, NOAA)		
Product	**Lead Developer**	
Imagery	Tim Schmit (NOAA)	HWT/OPC/HPC

Testbed Legend
HWT-Hazardous Weather Testbed
AWC - Aviaition Weather Center
HPC - Hydrological Prediction Center
AAWU - Alaskan Aviation Weather Unit
HLT - High Latitude Testbed - Alaska
NHC - National Hurricane Center
PR - Pacific Region
OPC - Ocean Prediction Center

UW-CIMSS has been engaged in multiple GOES-R proving ground decision support product demonstrations within newly formed testbed opportunities. Main focus has been most mature testbed, the NOAA Hazardous Weather Testbed (HWT) where University of Wisconsin Convective Initiation (UWCI), GOES overshooting-top/enhanced-V (OTTC), and WRF ARW simulated decision support products where made available and NWS end user evaluation accomplished as GOES-R proxy information. UW-CIMSS is providing real-time access to University of Wisconsin Convective Initiation (UWCI) and GOES overshooting-top/enhanced-V (OTTC) decision support products via AWIPS and N-AWIPS to the Storm Prediction Center (SPC) as part of the Hazardous Weather Testbed Experimental Warning Program (HWT EWP) Spring 2011 experiment as a proxy for future GOES-R option 2 detection capabilities. The UWCI decision support products were provided within the HWT via N-AWIPS gridded format, and the EWP in AWIPS gridded format for the 2011 Spring Experiment. The product utilizes GOES-13 infrared (IR) window brightness temperature changes based on an operational day/night cloud mask to infer cloud-top cooling as a proxy for vertical development in growing cumulus clouds as described by Sieglaff et al. (2011). UWCI is generated at the University of Wisconsin for each GOES-13 scan, including rapid-scans, and distributed via LDM in GRIB2 format.

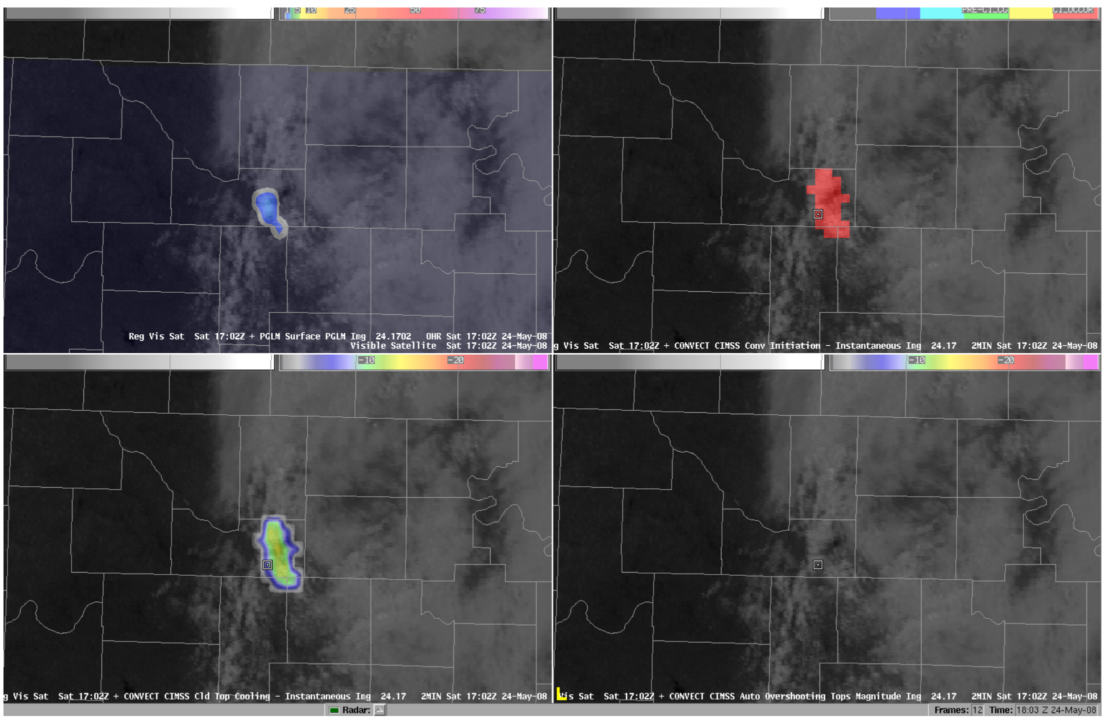


Figure 14 4-panel display within AWIPS of the GOES-R products provided within the EWP including 8-km Pseudo-GLM (top left), UWCI convective initiation (top right), UWCI cloud-top cooling rate (bottom left), and overshooting-top magnitude (bottom right) for the 24 May 2008 archive case event.

The OTTC product is a new addition within the 2011 Spring Experiment. The product utilizes GOES-13 IR window brightness temperature spatial testing to identify overshooting-top and thermal couplet (also known as enhanced-V) features within mature convective storm cloud-tops as described by Bedka et al. (2010). The OTTC product provides detections and relative magnitudes of overshooting-top and thermal couplet features in real-time. Similar to the UWCI product, the OTTC product is generated at the University of Wisconsin for each GOES-13 scan, including rapid-scans, and distributed via LDM in GRIB2 format to AWIPS and N-AWIPS systems. Figure 14 shows both UWCI and OTTC simultaneously displayed on AWIPS four-panel image.

CIMSS remains committed to assuring a smooth transition of all CIMSS research to operations products from the existing AWIPS software to the upcoming AWIPS II. Preliminary work has been done finding a new product implementation approach for AWIPS II. AWIPS II activities are rapidly accelerating on the national scale to transition local applications between the two software environments. CIMSS is following this work. AWIPS II will soon be accessible for use at CIMSS, with training modules employing the new AWIPS software included as part of the VISIT/COMET training programs for operational satellite meteorology professional development. UW-CIMSS participated in multiple GOES-R Proving Ground organizational telecons.

Publications/Conference Presentations

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

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

Feltz, W. F., Overview of UW-CIMSS GOES-R PG Decision Support Products: Pacific Region Testbed Planning Workshop, Honolulu, Hawaii, July 28-29, 2010 (oral)

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

Feltz, W. F., K. Bah, K. Bedka, L. M. Cronce, J. Gerth, J. S. Kain, S. S. Lindstrom, J. A. Otkin, T. J. Schmit, J. Sieglaff, C. W. Siewert, and R. Rabin, University of Wisconsin proving ground participation within the NOAA Hazardous Weather Testbed , Symposium on Future Satellites and Observations, 91st AMS Annual Meeting, Seattle, Washington, January 24-27, 2011. (Poster)

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

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

Gerth, Jordan J., An Outline in Transferring Satellite Research Products to National Weather Service Operations, 91st AMS Annual Meeting, Seattle, Washington, January 24-27, 2011. (Oral)

Kaba Bah, Tim Schmit, James Gurka, Tom Achtor, Justin Sieglaff, Jordan Gerth, Marcia Cronce, Joleen Feltz, Gary Wade, Jason Otkin: Preparation for use of GOES-R Advance baseline Imager (ABI). 35th National Weather Association (NWA) annual meeting, Tucson, Arizona, October 02- 07, 2010. (Poster)

Kaba Bah, Tim Schmit, James Gurka, Tom Achtor, Justin Sieglaff, Jordan Gerth, Marcia Cronce, Joleen Feltz, Gary Wade, Jason Otkin : Visualizing and analyzing simulated ABI data using AWIPS, McIDAS-V and Google earth. 91st American Meteorological Society (AMS) Annual Meeting, Seattle, Washington, January 24-27, 2011. (poster)

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

References

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

Sieglaff, J.M., L.M. Cronce, W.F. Feltz, K.M. Bedka, M.J. Pavolonis, and A. Heidinger, 2010: Nowcasting convective storm initiation using box-averaged cloud-top cooling and microphysical phase trends. *J. Appl. Meteor. Climatol.*, **50**, 110-126.

Imagery and Visualization

CIMSS Personnel: Tom Achtor, Tom Rink, Matt Gunshor, William Straka, Kaba Bah, Tommy Jasmin
Federal Collaborators: Walter Wolf, Tim Schmit, Shanna Simpson, Wendy Zhang
Funded by: NOAA GOES-R Proving Ground

Project Description
The use of NetCDF as a storage format for GOES-R was mandated by the Program Office. To support this requirement, version 1.0 of the ABI radiance product NetCDF files, which follow community conventions for internal structure and metadata (CF-compliant), has been developed. This effort required determination and implementation of the ABI Fixed Grid Format (FGF) pixel navigation. The FGF comprises a set of fixed view angles at regular intervals, and their respective intersections with the GRS80 Earth geoid, from an ideal or nominal point in space in the equatorial plane. The geometric transformations from FGF coordinate to Earth location, and vice-versa, have been implemented in the McIDAS-V geo-location framework, and necessary CF-compliant description metadata have been added to NetCDF files. FGF longitude/latitude full disk master files have also been generated for reference.

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

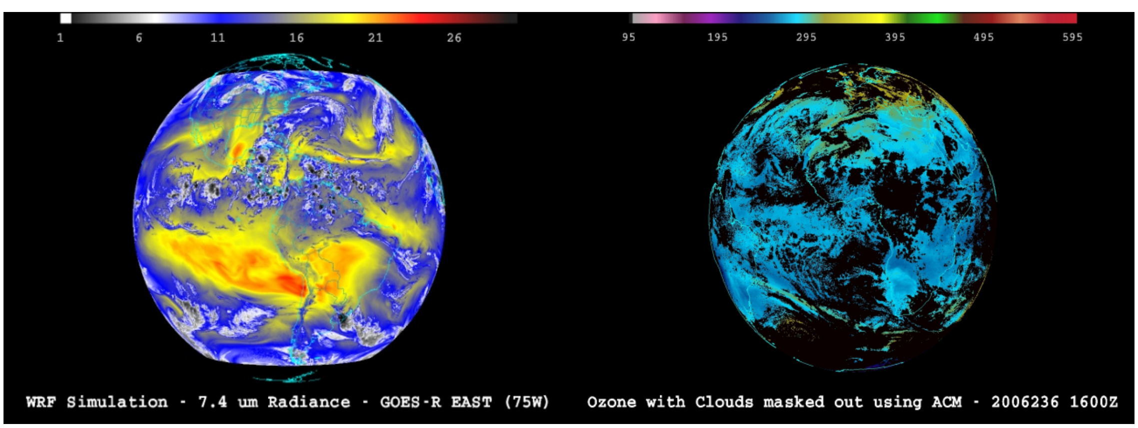


Figure 15 Simulated GOES-R ABI radiance (left), and Ozone product derived from proxy data (right). Both displayed on the FGF, and displayed in McIDAS-V.

From these standardized product datasets, interactive tools are being in developed to support validation of AWG products by leveraging the wide array of data type (satellite, NWP, obs) and format (NetCDF, HDF, GRIB, AREA) support, as well as, the data integration capability of McIDAS-V. An example is shown in Figure 16.

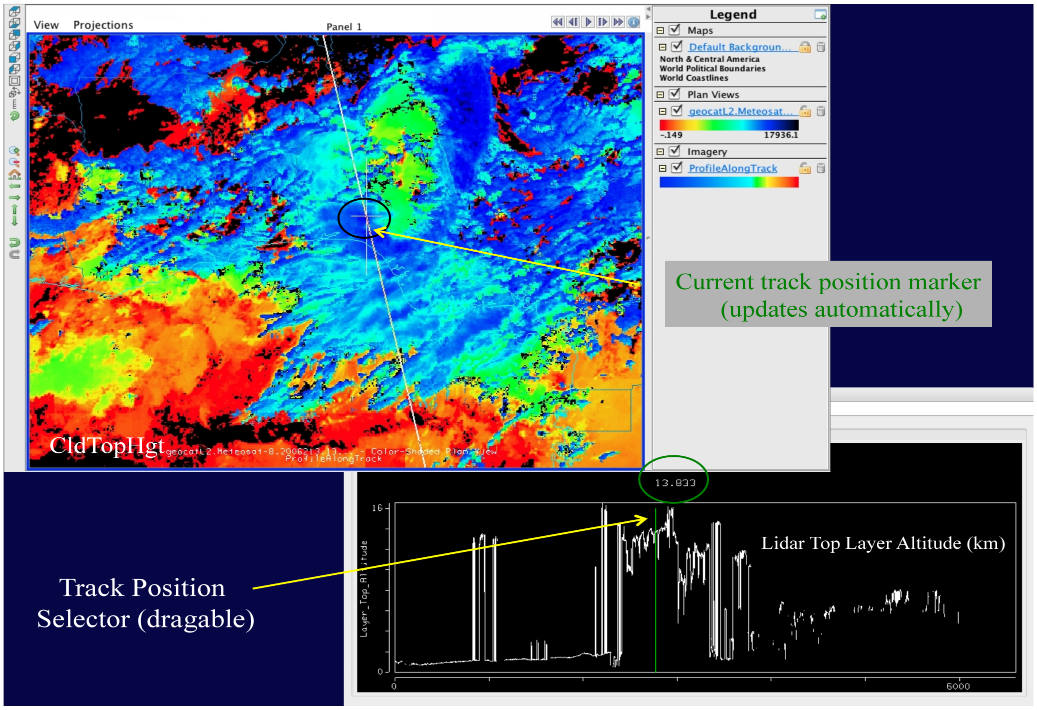


Figure 16 AWG Cloud Top Height with CALIPSO Lidar top layer altitude for comparison.

Significant progress has been made adapting JPSS NPP proxy data, provided by the NOAA GRAVITE archive and server (Government Resource for Algorithm Verification, Independent Testing, and Evaluation), into the McIDAS-V framework. McIDAS-V allows users to aggregate an arbitrary set of NPP granules for display and automatically combines separate data, geo-location and metadata files allowing sub-setting, re-projecting and user specified computation. (Figure 17)

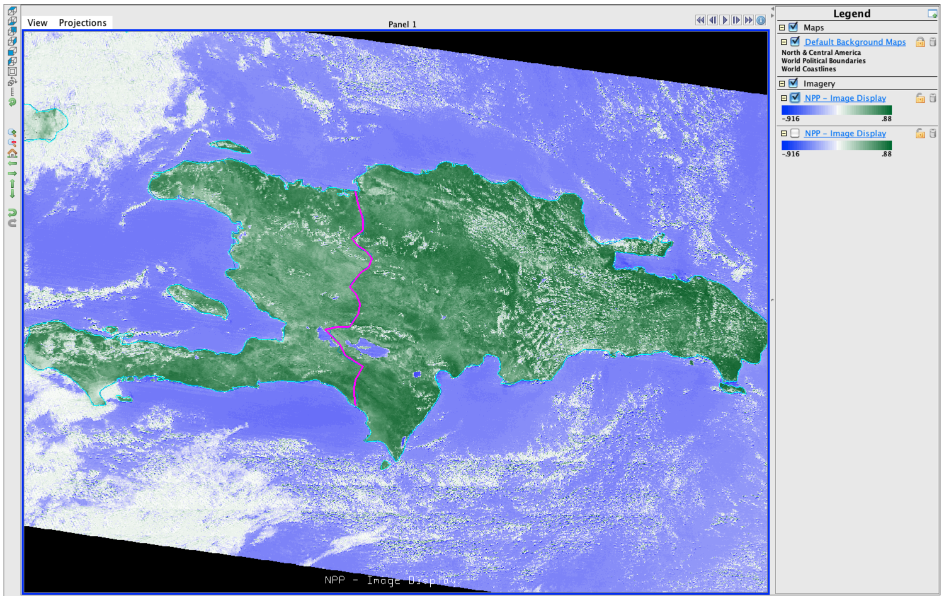


Figure 17 NDVI computed and display in McIDAS-V from NPP Proxy VIIRS 380m resolution I-Bands 1 and 2.

McIDAS-V supports scripting, including background processing, via a Python interface, wherein users can define their own computations to create new data, and/or configure the display components like color-tables, map projection settings, display labels, etc. The scripts can be processed interactively, plugged into the GUI, or run in the background to generate display captures in various file formats including KMZ, which can be fed into Google Earth (Figure 18).

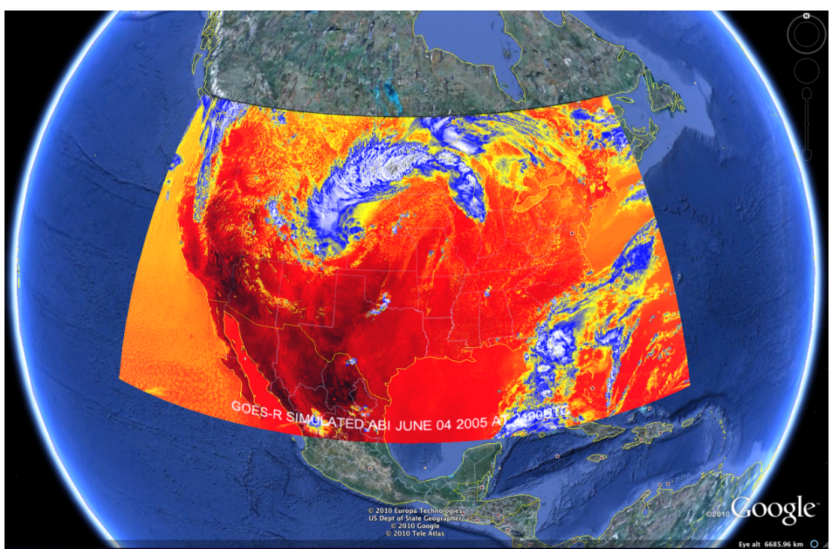


Figure 18 Simulated GOES-R data in KMZ format generated by McIDAS-V

Publications/Conference Presentations

Timothy Schmit, Kaba Bah, Jordan Gerth, Marcia Cronce, Jason Otkin, Justin Sieglaff, Gary Wade, 2010: A Weather Event Simulator (WES) for the GOES-R Advanced Baseline Imager (ABI). American Meteorological Society (AMS) Annual Meeting, 17-21 January 2010, Atlanta, GA.

Kaba Bah, Tim Schmit, James Gurka, Tom Achtor, Justin Sieglaff, Jordan Gerth, Marcia Cronce, Joleen Feltz, Gary Wade, Jason Otkin, 2010: Preparation for use of GOES-R Advance baseline Imager (ABI). 35th National Weather Association (NWA) annual meeting, Tucson, Arizona, October 02- 07, 2010. (Graduate student poster of the year).

Kaba Bah, Tim Schmit, James Gurka, Tom Achtor, Justin Sieglaff, Jordan Gerth, Marcia Cronce, Joleen Feltz, Gary Wade, Jason Otkin, 2011 : Visualizing and analyzing simulated ABI data using AWIPS, McIDAS-V and Google earth. 91st American Meteorological Society (AMS) Annual Meeting, Seattle, Washington, January 24-27, 2011. (Poster)

Wayne Feltz, Jordan Gerth, and Tim Schmit, 2010: CIMSS Status and Plans, 3rd Annual Proving Ground All-hands, Boulder, Colorado, May 18-19, 2010. (Oral)

Wayne Feltz, 2010: Overview of UW-CIMSS GOES-R PG Decision Support Products: Pacific Region Testbed Planning Workshop, Honolulu, Hawaii, July 28-29, 2010. (oral)

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

Hurricane Wind Structure and Secondary Eyewall Formation

CIMSS Personnel: Christopher Rozoff
Federal Collaborator: James P. Kossin
Funded by: GOES-RRR

Project Description and Milestones
Eyewall replacement cycles (ERCs) and rapid structure changes are fairly common occurrences in intense tropical cyclones (TCs). In a typical ERC, an outer eyewall forms outside of a TC's primary eyewall. Such an event can lead to a temporary weakening of the maximum low-level winds, yet it can also widen the swath of damaging winds. Despite this, the predictability and physical understanding of secondary eyewall formation (SEF) is still relatively poor.

The focus of this research has been to utilize real and synthetic geostationary satellite imagery to improve the predictability of SEF and structure changes. Synthetic Advanced Baseline Imager (ABI) data have been obtained for ERC case studies captured in MSG-SEVIRI observations and a high-resolution WRF simulation. In addition, new theoretical insight into the roles of latent heating in the initiation of ERCs has been achieved through the analysis of the idealized WRF simulation.

Using synthetic ABI data from MSG-SEVIRI data for the North Atlantic Hurricane Helene (2006), multi-channel products derived from the synthetic ABI data have been investigated. For example, the bi-spectral water vapor-infrared difference product of Olander and Velden (2009; *Wea. Forecasting*) can be generalized to a number of water vapor bands, including the 6.19, 6.95, and 7.34 μm bands, and various infrared bands as well. These products help emphasize regions of vigorous convection associated with SEF in the TC. Using synthetic data from an idealized, full-physics WRF simulation (1-km horizontal grid spacing) of a TC with an ERC, similar results are found. The various water vapor-infrared difference channel depictions of the double eyewall precipitation structure is quite vivid; these products may help reduce the shortcomings of the limited temporal resolution of microwave imagery. Currently, efforts are underway to study more general structure changes in other MSG-SEVIRI datasets of other TCs and other unique WRF simulations.

The idealized WRF simulation has led to some significant findings on latent heating processes that occur during SEF (e.g., Rozoff et al., 2011). First, it has been found, through the use of absolute angular momentum budget calculations, that SEF and the expansion of the tangential wind field is primarily accomplished through the secondary circulation associated with strong rainband activity. A balanced vortex model has been used to diagnose and isolate important processes occurring in the WRF model output as well. Remarkably, the balanced vortex model results suggest that much of the SEF process can be explained via balanced vortex dynamics. In particular, inertial stability plays an important role in the generation of an outer wind maximum. As inertial stability expands outward with sustained rainband activity, latent heating subsequently becomes increasingly effective at generating an outer wind maximum.

Data from the WRF model support the idealized calculations. Figure 19 depicts the evolution of midlevel, azimuthal-mean inertial stability and vertical motion and various integrated fields during SEF. In particular, an outer eyewall forms around 110-115 h, contracts inward, and eventually replaces the inner eyewall after about 130 h. Within the outer eyewall, the inertial stability rapidly increases as it contracts inward to a region of higher inertial stability and due to the outward expansion of inertial stability. Both the volumetric-mean kinetic energy and latent heat injected within the secondary eyewall increase in tandem during this time period. The kinetic energy efficiency (KEE), defined as the ratio of kinetic energy to the injected heat, increases throughout the entire process. Thus, the WRF model output suggests that as SEF progresses, the outer eyewall becomes increasingly efficient at intensifying. These results suggest that any sustained latent heating outside of an inner eyewall will eventually generate a secondary eyewall if given adequate time.

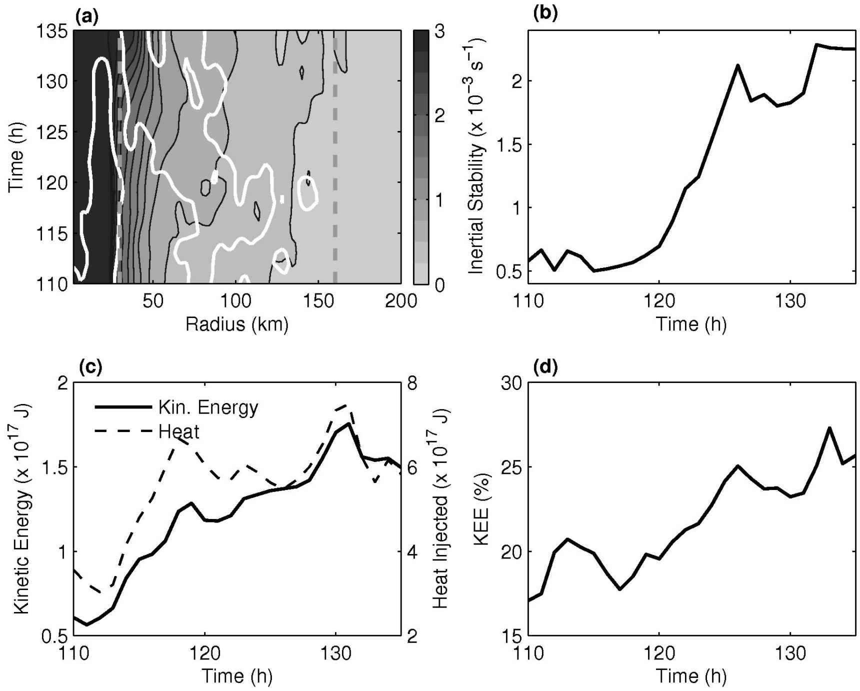


Figure 19(a) A hovmöller diagram of the azimuthal-mean inertial stability parameter *I* (10^{-3} s^{-1}; shaded) and the 0.2 m s^{-1} contour (white) of vertical velocity at *z* = 5 km. (b) The area-average *I* (10^{-3} s^{-1}) at *z* = 5 km for the region bounded by vertical velocities of 0.2 m s^{-1} and the vertical dashed lines in (a). The (c) kinetic energy (10^{17} J; solid) and latent heat (10^{17} J) and (d) kinetic energy efficiency (KEE) (%) for the region bounded by vertical velocities of 0.2 m s^{-1} and the vertical dashed lines in (a).

Publications/Conference Presentations

Rozoff, C. M., D. S. Nolan, J. P. Kossin, F. Zhang, and J. Fang, 2011: On the efficiency of secondary eyewall formation in tropical cyclones. *Mon. Wea. Rev.*, to be submitted.

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

Tropical Cyclone Rapid Intensification

CIMSS Personnel: Christopher Velden and Christopher Rozoff
Federal Collaborator: James P. Kossin
Funded by: NOAA GOES-RRR and NOAA GIMPAP

Project Description and Milestones
NOAA's National Hurricane Center (NHC) currently uses a skillful probabilistic rapid intensification (RI) index (RII) based on linear discriminant analysis of the environmental and satellite-derived features from the Statistical Hurricane Prediction Scheme (SHIPS) dataset. Still, there is much room for further improvement for this top forecast priority. Recently, two new probabilistic models and an ensemble-mean method for the prediction of RI that improve forecasting skill have been developed at CIMSS. In addition, new structural predictors based on microwave imagery are being developed to further enhance probabilistic prediction of RI.

Two new probabilistic RI models, one based on logistic regression and the other on a naïve Bayes framework, have been evaluated to see if they can perform competitively with the SHIPS-RII at NHC. Both models incorporate certain environmental and GOES infrared predictors from the SHIPS dataset for the years 1995-2009 and have been developed for a variety of RI thresholds for both the Atlantic and eastern Pacific Ocean basins. Cross-validation demonstrates that both models are skillful with respect to climatology and that their skill is competitive with SHIPS-RII. Finally, a three-member ensemble-mean of the logistic, Bayesian, and SHIPS-RII models provides superior skill to any of the individual members. For a rapid intensification threshold of 25 kt per 24 h, the three-member ensemble-mean improves the Brier skill scores relative to the current operational SHIPS-RII by 33% in the Atlantic and 52% in the eastern Pacific. Similar improvements are seen at other RI thresholds (Figure 20). These results have been published in Rozoff and Kossin (2011).

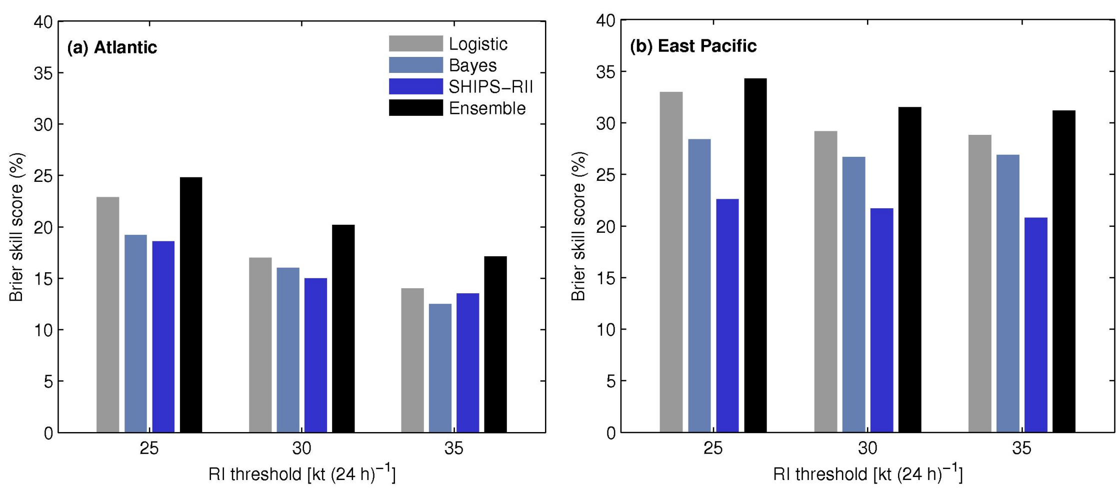


Figure 20 The Brier skill scores (%) determined from dependent testing (1995-2009) for the logistic regression, Bayesian, SHIPS-RII, and ensemble-mean models over the (a) Atlantic and (b) eastern Pacific and for the RI thresholds of 25, 30, and 35 kt per 24 h.

The use of GOES infrared data in probabilistic RI schemes has shown that improvements can be achieved in the probabilistic prediction of RI by incorporating details of a TC's internal organization of precipitation. Passive microwave imagery from low-earth orbiting satellites provides just a way to peer through overlying cirrus clouds and detect the internal structure of TCs. As such, a variety of structural predictors have been derived from 37-GHz microwave imagery from SSM/I, WINDSAT, AMSR-E, and TRMM-TMI data for the years 1995-2008 in both the Atlantic and East Pacific. Generally, these predictors are designed to capture the degree of organization and intensity of internal features such as eyes, eyewalls, and rainbands. Objectively selected microwave predictors have been added to the list of existing SHIPS environmental and GOES infrared predictors for use in the logistic regression scheme described in Rozoff and Kossin (2011).

When the SHIPS data are interpolated to the times of satellite overpasses, significant improvements are seen in the Brier skill scores and probability of detection with the inclusion of microwave imagery. In the Atlantic, the Brier skill score increases by nearly 5% for all RI thresholds. Probability of detection improves by over 10% in some cases. Currently, efforts are underway to improve the prediction of RI at synoptic forecasting times (i.e., 0000, 0600, 1200, and 1800 UTC). Dr. John Kaplan at NOAA's Hurricane Research Division is also testing these microwave structural predictors in SHIPS-RII. By the end of the year, new predictors from the 19- and 85-GHz microwave frequencies will also be available.

Publications/Conference Presentations

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

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

Combined GEO/LEO High Latitude Atmospheric Motion Vectors

CIMSS Personnel: Matthew Lazzara, Dave Santek, Nick Bearson, Rich Dworak, Rick Kohrs, and Chris Velden
Federal Collaborators: Jeff Key and Jamie Daniels
Funded by: NOAA GOES-R Risk Reduction program

Project Description
The spatial coverage of satellite-derived Atmospheric Motion Vectors (AMV) is generally equatorward of 60° latitude for geostationary satellites and poleward of 70° latitude for the polar satellites. This coverage results in a 10-degree gap, which has been noted as a problem by numerical weather prediction (NWP) centers. Specifically, the dynamically active polar jet stream can be located in this latitudinal zone and improper model initialization can lead to rapidly growing errors in the forecasts. Therefore, developing novel ways to fill this AMV-void gap is the next logical step toward providing complete wind coverage for the NWP applications. This will require an Advanced Image Compositing Technique (AICT) designed to blend the data from the many polar and geostationary weather satellites.

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

The satellite image composites are routinely generated for the infrared window channel at 4 km resolution in polar stereographic projection over each pole. The AMVs are generated using three 1/2-hourly composites (Figure 21). The quality of these winds matches that of geostationary and polar orbiting satellite-derived winds.

Beginning in November 2010, we have been providing the composite AMVs product to Nancy Baker (NRL) and Randy Pauley (FNMOC) for inclusion into the US Navy numerical modeling system. Initial results in the NRL Atmospheric Variational Data Assimilation System Accelerated Representer (NAVDAS-AR) show a positive impact, similar to that of the MODIS polar winds (Figure 22). Additionally, they have commented that receipt of the product has been timely and reliable.

Publications/Conference Presentations
Lazzara, M.A., R. Dworak, D.A. Santek, N.A. Bearson, J.R. Key, and C.S. Velden, 2011: Polar satellite composite atmospheric motion vectors. 11th Conference on Polar Meteorology and Oceanography. American Meteorological Society, Boston, MA May 2-5, 2011.
Lazzara, M.A., D.A. Santek, R.A. Kohrs, N.A. Bearson, J. Robaidek, and S.L. Knuth, 2010a: Satellite composites: techniques in combining geostationary and polar orbiting observations. 17th Conference on Satellite Meteorology and Oceanography. American Meteorological Society, Annapolis, MD Sept 27-30, 2010.
Lazzara, M.A., D.A. Santek, R. Dworak, J.R. Key, C.S. Velden, and S. Wanzong, 2010b: High latitude atmospheric motion vectors from combined geostationary and polar orbiting observations. 17th Conference on Satellite Meteorology and Oceanography. American Meteorological Society. Annapolis, MD Sept 27-30, 2010.

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

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

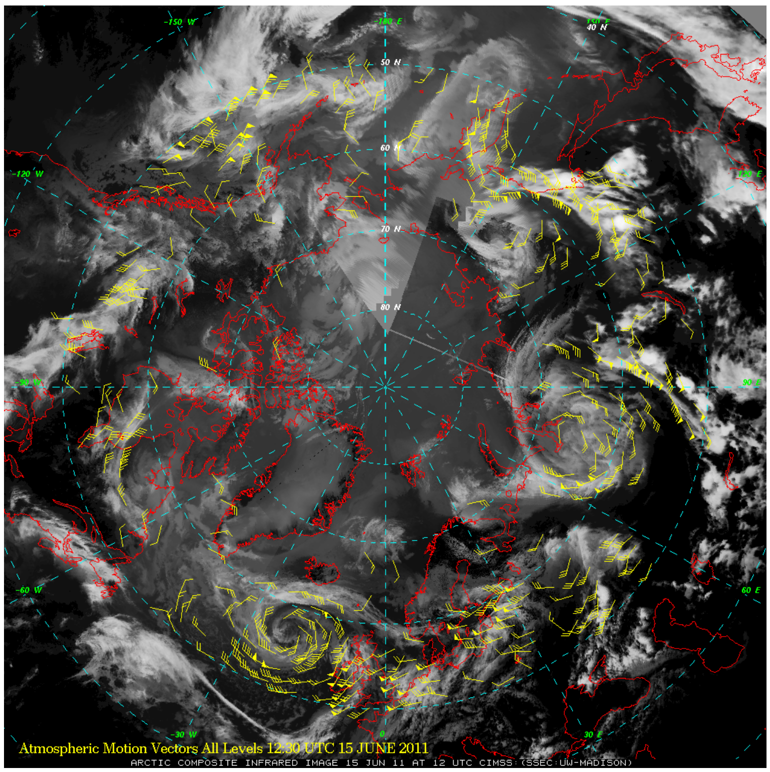


Figure 21: An Arctic composite satellite image with overlain atmospheric motion vectors from 12:30 UTC on 15 June 2011.

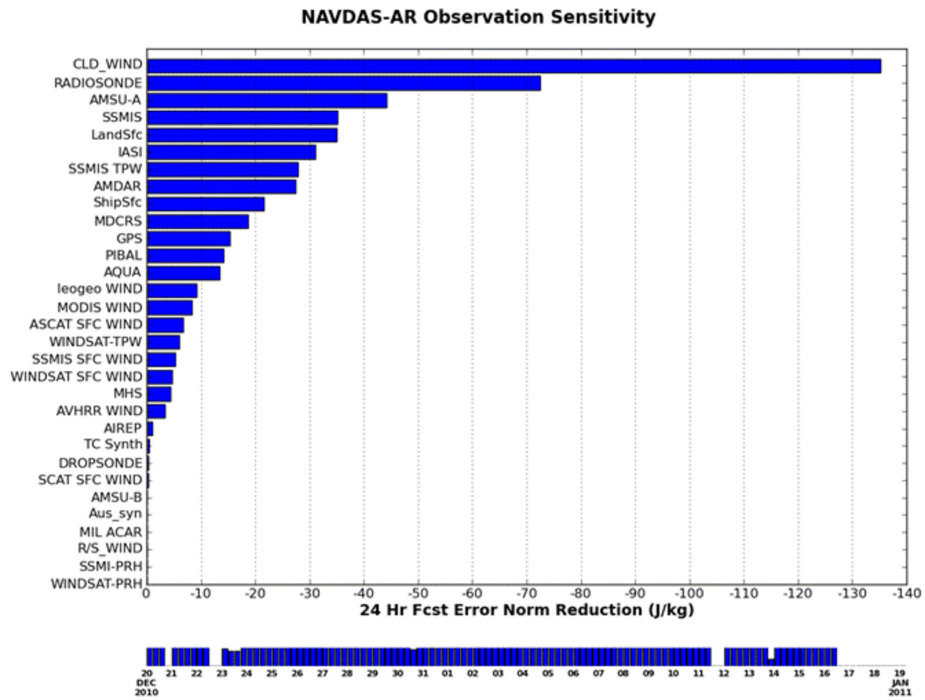


Figure 22 Observation sensitivity of all data types assimilated into the NAVDAS-AR. The Leo/Geo winds have an impact similar to the MODIS polar winds. (Courtesy of Nancy Baker, NRL)

Efficient Collocation For GOES-R Inter-calibration And Product Validation

CIMSS Personnel: Bob Holz, Fred Nagle, Greg Quinn
Federal Collaborators: Walter Wolf, Haibing Sun
Funded by: NOAA

Decades of experience in applying vector algebra and analytic geometry to problems in satellite navigation at CIMSS have led to a variety of techniques for efficiently collocating observations from different sensors. These tools enable months or years of data to quickly be collocated and compared for statistical analysis. As part of the GOES-R AWG effort, the collocation project supports the following goals:

- Develop a maintainable and extensible toolkit capable of orbital analysis (overpass calculations for satellite-to-satellite or satellite-to-ground) and pixel-to-pixel collocation for both GEO and LEO instruments. This effort involves development of new techniques and algorithms in addition to refactoring and organizing legacy code.
- Support the collocation needs of GOES-R AWG teams as they work to validate their algorithms. The collocation toolkit will become part of a standard validation framework being developed by the AIT.
- Leverage the collocation tools to build an inter-calibration system to allow near real-time monitoring of instrument performance and long-term analysis of radiometric trends.

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

Results from a recent collaboration with the AWG cloud team are shown below. Collocation tools were used to compare the GOES-R cloud top height algorithm as applied to SEVIRI data against data from the CALIOP lidar.

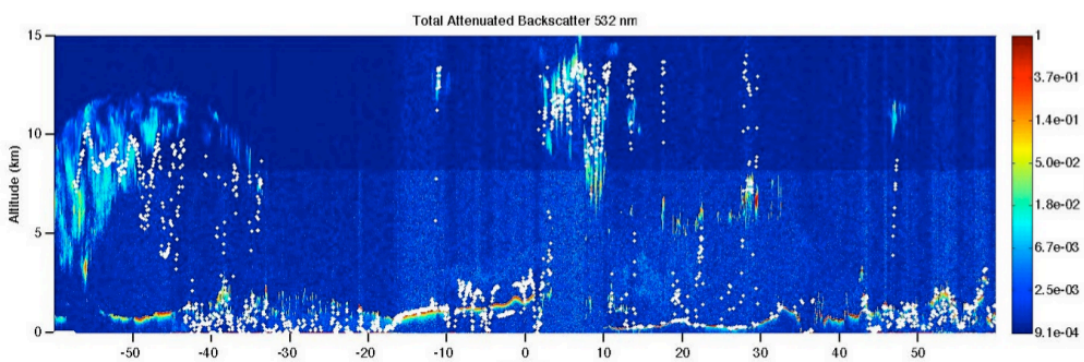


Figure 23 CALIOP attenuated backscatter profile with collocated AWG cloud top heights (white dots, run on SEVIRI). See below for location of CALIOP satellite track.

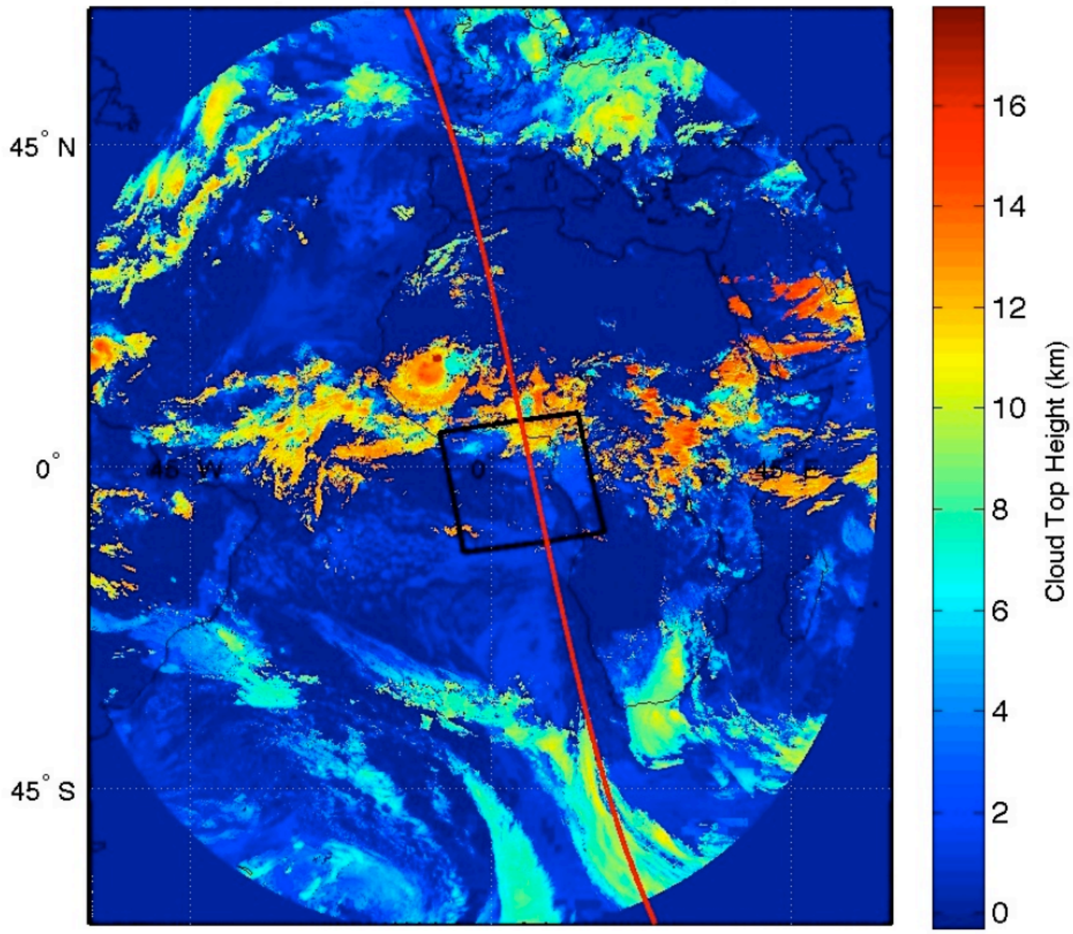


Figure 24 CALIOP track (red) and MODIS granule (black) overlaid on a SEVIRI AWG cloud height image.

Publications/Conference Presentations

Greg Quinn, Robert E. Holz, Frederick W. Nagle, Walter Wolf, Haibing Sun, 2011: Developing a product validation and inter-calibration system for GOES-R using advanced collocation methods. AMS Annual Meeting.

Greg Quinn, David Tobin, Frederick Nagle, Walter Wolf, Robert Holz, Liam Gumley, Steve Dutcher, 2009: An Efficient and Flexible Framework for Real-time Satellite Inter-calibration. AGU Fall Meeting.

Frederick W Nagle, Robert E. Holz, 2009: Computationally Efficient Methods of Collocating Satellite, Aircraft, and Ground Observations. *J. of Atmos. and Ocean Tech.*, **Volume 26**, Issue 8, pp. 1585-1595.

GOES-R AWG Overshooting-top/Enhanced-V Requirement

CIMSS Personnel: Jason Brunner, Wayne Feltz, and Rich Dworak
Federal Collaborator: Kristopher Bedka (Science Systems and Applications, Inc. at NASA Langley Research Center)
Funded by: NOAA

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

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

OTs found in combination with a U or V shaped region of cold infrared window brightness temperatures (BTs) are often indicative of an especially severe thunderstorm. Once OTs have been identified by the IRW-texture technique, the focus can be directed toward the objective detection of the enhanced-V signature. While the enhanced-V is often highly variable in infrared imagery, one aspect of the enhanced-V remains fairly constant in that the “arms” of the V signature enclose a warm region downwind of the overshooting top to form an “anvil thermal couplet.” Brunner et al. (2007) showed that these cold (or enhanced)-U/V producing storms with a minimum IRW BT of ≤ 205 K in the OT region and an anvil thermal couplet of ≥ 7 K magnitude produced severe weather for greater than 90% of all events during summers 2003 and 2004. UW-CIMSS and Kristopher Bedka (SSAI at NASA LaRC) have developed a technique with IRW imagery to objectively detect anvil thermal couplets associated with the enhanced-V signature.

The Code Unit Test Review for the enhanced-V and OT product was successfully completed on December 13, 2010. Also, the Version 4 and Version 5 enhanced-V and OT products were delivered to the Algorithm Implementation Team in November 2010 and June 2011, respectively. In addition, the 80% ATBD, the proxy test data sets, and the documentation of the proxy test data sets and validation for the enhanced-V and OT product were all delivered to the Algorithm Implementation Team in June 2010. The 100% ATBD will be delivered to AIT later this month.

A creative technique to validate objective OT detection output must be used since a large database of all OT locations throughout the world does not exist. This technique looks at deep convective storms through NASA CloudSat and CALIPSO profiles. Figure 25 shows that these satellites passed directly over an OT over the Atlantic Ocean offshore of North Carolina. Aqua MODIS IRW and WV BT data and IRW-texture OT detections are co-located with these two satellite profiles to compare IRW-texture and WV-IRW BTD performance. The comparison indicates that the IRW-texture technique performs well in detecting this OT. If a 2 K WV-IRW BTD threshold were used here for OT detection, no OT pixels would be detected. If simply a positive BTD were used here, nearly the entire anvil cloud would be detected which would produce a very high false alarm rate.

An example of objective enhanced-V/anvil thermal couplet detection is provided in Figure 26. ABI proxy IRW 2 km imagery from this 10 May 2004 2317 UTC event shows four enhanced-V producing severe storms. OTs and anvil thermal couplets were detected for all four of the severe storms. There were no false detections for this case. This detection algorithm was applied to 638 enhanced-V producing storms that occurred across 196 MODIS or AVHRR images. The validation indicates that the probability of enhanced-V detection was 53% and the false alarm rate was 25%. 76% of the storms detected by the algorithm produced severe weather within +/- 30 mins of the time of the image and within 60 km of the OT location while 63% of the undetected storms were severe, indicating that this algorithm is detecting a larger fraction of the severe storms in our database. Both the overshooting top (18% FAR) and enhanced-V detection products (25% FAR) meet the FP&S specifications for product accuracy (25% maximum FAR).

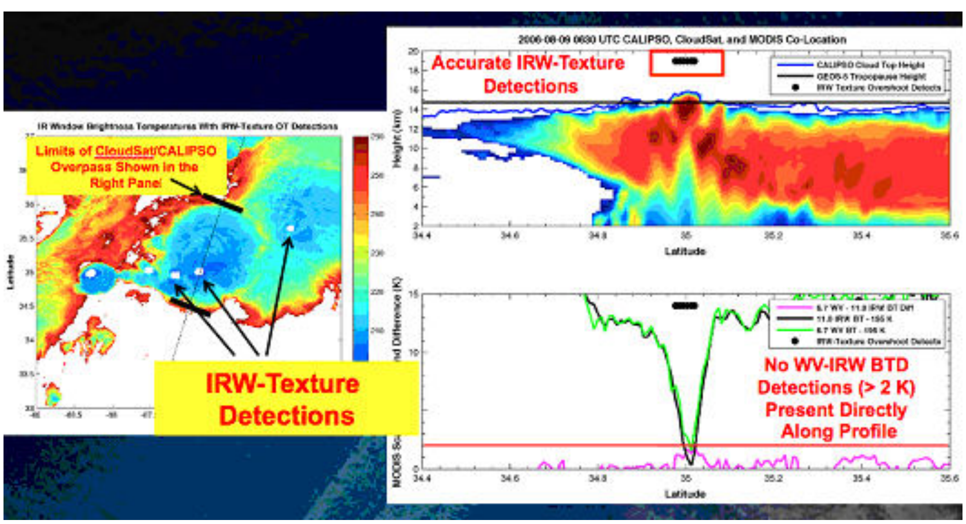


Figure 25 Aqua MODIS 1 km 10.7 µm brightness temperature imagery with IRW-texture OT detections (white dots). (right) IRW-texture OT detections co-located with MODIS brightness temperatures, CloudSat radar reflectivity, CALIPSO cloud top height, and the NASA GEOS-5 model tropopause height analysis.

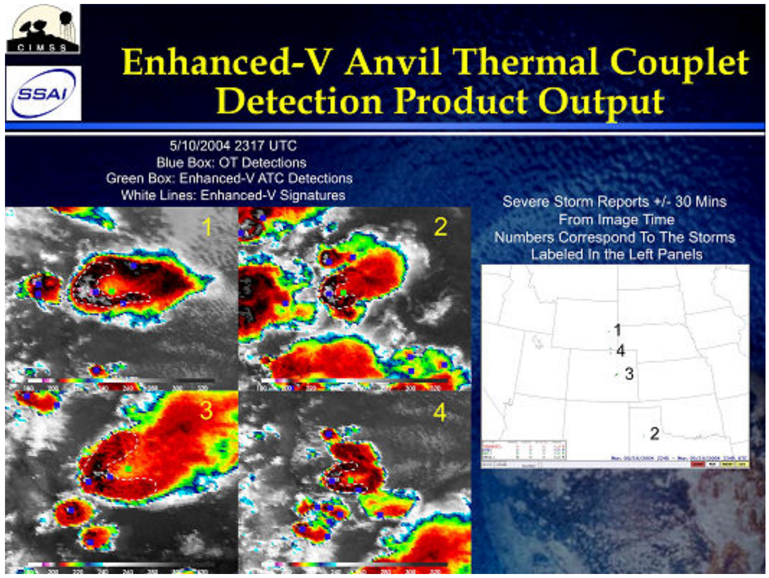


Figure 26 ABI proxy IRW (10.7 µm brightness temperature) 2 km imagery of a set of four enhanced-V producing severe storms that occurred on 10 May 2004 at 2317 UTC. Each enhanced-V signature is outlined with a white dashed line. Overshooting top detections are shown with blue squares and anvil thermal couplet detections are shown with green squares.

Publications/Conference Presentations

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

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

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

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GOES-R AWG Turbulence Requirement

CIMSS Personnel: Anthony Wimmers and Wayne Feltz
Federal Collaborators: Ken Pryor (Aviation team), GOES-R AWG members
Funded by: NOAA

Project Description
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 synoptic-scale gradients in moisture, which are evident in the ABI channel 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. This relationship between satellite-derived moisture gradients and dynamical turbulence was established with legacy GOES imagers (Wimmers and Moody 2001) and confirmed with related satellite data and aircraft observations (Wimmers and Moody 2004a, 2004b; Wimmers and Feltz 2005).

The project has progressed on track toward full algorithm maturity, completion of the first-principles algorithm documentation (the Algorithm Theoretical Basis Document), independent review, validation with independent in situ data and production of outreach materials.

Product calibration/validation was completed in September 2010. We compared the TFTP product to corresponding automated aircraft in-situ observations of turbulence from November 2005 to December 2007 (Figure 27). The dataset was composed of 996 product images and over 1000 cases of Moderate or Greater turbulence. The validation achieved 53% accuracy, which satisfies the 50% accuracy requirement from the AWG. In this calibration/validation process we demonstrated how to increase product accuracy with higher thresholds on tropopause fold intensity, direction and vertical location within the tropopause fold object.

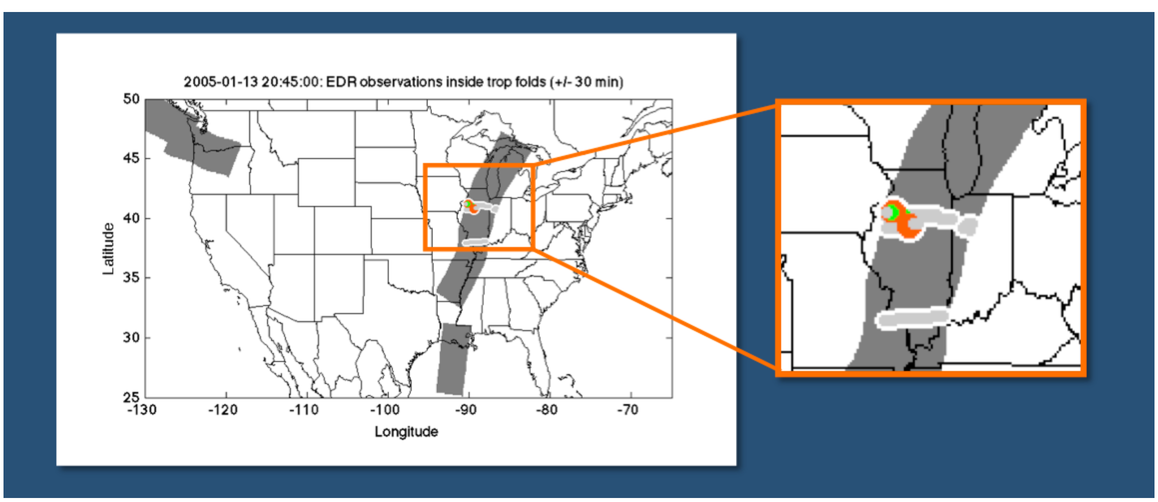


Figure 27 Left: Horizontal distribution of product-resolved tropopause folds for January 13 2005, 2045 UTC. Right: Detail of the left image, showing corresponding in-flight turbulence reports (as dots) inside the tropopause fold volume (gray is null, green is light turbulence and orange is moderate turbulence).

Publications/Conference Presentations

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

References

Wimmers, A.J., and J.L. Moody, 2001: A fixed-layer estimation of upper tropospheric specific humidity from the GOES water vapor channel: Parameterization and validation of the altered brightness temperature product. *J. Geophys. Res.*, **106** (D15), pp 17115-17132.

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

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

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

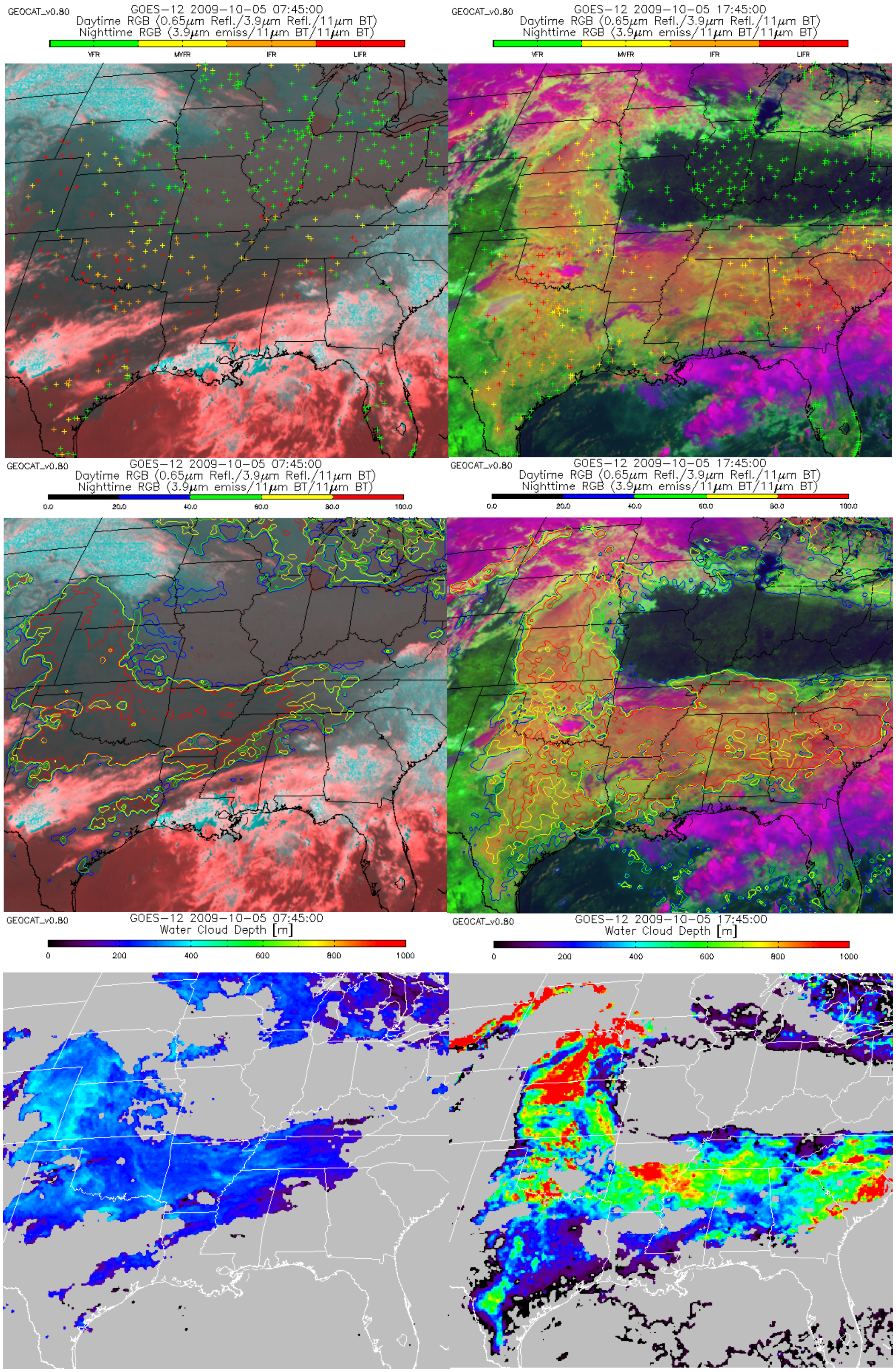
GOES-R AWG Fog/Low Stratus Detection and Depth

CIMSS Personnel: Corey Calvert
Federal Collaborator: Michael Pavolonis
Funded by: NOAA

Project Description
This project entails developing a fog/low stratus (FLS) cloud detection and thickness algorithm for use with the GOES-R Advanced Baseline Imager (ABI). The GOES-R FLS algorithm is designed to quantitatively identify clouds that produce Marginal Visual Flight Rules (MVFR) conditions, defined as having a cloud ceiling below 3000 ft above ground level, in the absence of overlapping water or ice clouds during both day and night. The fog detection algorithm utilizes textural and spectral information, as well as modeled relative humidity (RH) and the difference between the cloud radiative temperature and surface temperature (surface temperature bias). This project ensures the readiness of the fog/low stratus algorithm for the operational implementation upon the deployment of GOES-R.

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 to be associated with relatively stable environments with high RH but little spatial variance in vertical motion, which results in it being relatively uniform spatially in albedo and temperature. At night, the algorithm utilizes modeled RH and the 3.9 and 11 μm channels to detect MVFR conditions. FLS detection during the day is determined using modeled RH and the 0.65, 3.9, and 11 μm channels. Nighttime LUT's were created for modeled RH data as well as combined 3.9 μm pseudo-emissivity and surface temperature bias data from both fog and non-fog water clouds determined by surface observations and the GOES-R cloud type algorithm. Daytime LUT's were created for modeled RH data as well as combined 3.9 μm reflectance, a 3x3 pixel 0.65 μm reflectance spatial uniformity metric and the surface temperature bias for the same types of water clouds determined by surface observations and the GOES-R cloud type algorithm. A naïve Bayes probabilistic model is used to combine the information from the LUT's to produce a quantitative output providing the probability, as opposed to a binary yes/no output, that FLS is present for a given pixel. The FLS depth is calculated for each pixel with a valid probability from the detection algorithm based on a linear relationship between the 3.9 μm pseudo-emissivity (night) and liquid water path (day). Examples of the GOES-R FLS detection and depth algorithm are shown in Figure 28.

The 100% Algorithm Theoretical Basis Document (ATBD) for the fog/low cloud detection algorithm is on schedule to be delivered to the GOES-R Algorithm Working Group (AWG) at the end of June 2011. Various validation studies using surface observations and spacebourne lidar indicate that both the detection and depth products are in compliance with the 100% accuracy specification (70% detection accuracy and depth within 0.5 km).


GEOCAT_v0.80
GOES−12 2009−10−05 07:45:00
Daytime RGB (0.65μm Refl./3.9μm Refl./11μm BT)
Nighttime RGB (3.9μm emiss/11μm BT/11μm BT)
VFR
MVFR
IFR
LIFR
GEOCAT_v0.80
GOES−12 2009−10−05 17:45:00
Daytime RGB (0.65μm Refl./3.9μm Refl./11μm BT)
Nighttime RGB (3.9μm emiss/11μm BT/11μm BT)
VFR
MVFR
IFR
LIFR
GEOCAT_v0.80
GOES−12 2009−10−05 07:45:00
Daytime RGB (0.65μm Refl./3.9μm Refl./11μm BT)
Nighttime RGB (3.9μm emiss/11μm BT/11μm BT)
0.0
20.0
40.0
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80.0
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GEOCAT_v0.80
GOES−12 2009−10−05 17:45:00
Daytime RGB (0.65μm Refl./3.9μm Refl./11μm BT)
Nighttime RGB (3.9μm emiss/11μm BT/11μm BT)
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80.0
100.0
GEOCAT_v0.80
GOES−12 2009−10−05 07:45:00
Water Cloud Depth [m]
0
200
400
600
800
1000
GEOCAT_v0.80
GOES−12 2009−10−05 17:45:00
Water Cloud Depth [m]
0
200
400
600
800
1000

Figure 28 Example output from the GOES-R fog/low stratus (FLS) algorithm from October 5, 2009 at 07:45 UTC (left side images) and 17:45 UTC (right side images) centered over the Southeast United States. The top two panels are false color RGB images with surface observations showing instrument flight rules (IFR) conditions where no overlapping water or ice clouds are detected by the GOES-R cloud type algorithm. The middle two panels are false color RGB images with the Bayesian FLS probability from the algorithm contoured over top. The bottom two panels show the estimated fog depth output from the GOES-R FLS algorithm.

Publications/Conference Presentations

Pavolonis, M.J. and C. Calvert: GOES-R Fog and Low Cloud Detection Algorithm Theoretical Basis Document (ATBD), Third Draft (100%) submitted June 2011.

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

Calvert, C. and M. Pavolonis, 2010: Introduction of a Day/Night, Object-Based Probabilistic Fog/Low Stratus Detection Algorithm for GOES-R. AGU Fall Meeting. San Francisco, CA, December 2010. (Poster presentation)

Calvert, C. and M. Pavolonis, 2011: Introduction of a Day/Night, Object-Based, Quantitative Fog/Low Stratus Detection Algorithm for GOES-R. EGU General Assembly. Vienna, Austria, April 2011. (Poster presentation)

Pavolonis, M. and C. Calvert, 2011: GOES-R AWG Aviation Team: Fog/Low Cloud Detection. AWG Annual Meeting. Fort Collins, CO, June 2011. (Oral presentation)

GOES-R Aerosol and Ozone Proxy Data Studies

CIMSS Personnel: Todd Schaack, Allen Lenzen
Federal Collaborator: R. Bradley Pierce
Funded by: NESDIS/STAR

Project Description
The main focus of this project is to augment the current GOES-R Algorithm Working Group (AWG) WRF Advanced Baseline Imager (ABI) proxy data capabilities with synthetic proxy data sets including realistic distributions of aerosols, clouds and ozone. The addition of aerosol and ozone distributions into the WRF proxy data set allows generation of synthetic radiances for all GOES ABI bands. This will facilitate the development of algorithms supporting retrievals of clouds, aerosol properties, total column ozone, and detection of dust, smoke and SO2 in preparation for deployment of GOES-R. The aerosol and ozone proxy data sets are generated with WRF-CHEM air quality simulations coupled to global chemical and aerosol analyses from the Real-time Air Quality Modeling System (RAQMS). Output from the coupled RAQMS/WRF-CHEM ozone and aerosol simulations is then used to construct simulated radiances using the NOAA Community Radiative Transfer Model (CRTM).

Activities during the past year have focused on delivery of updated 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 aerosol optical depth (AOD) retrievals were assimilated within 36km WRF-CHEM African simulations to provide improved initial conditions for the high resolution African simulations. Synthetic radiances were computed based on CRTM version 2. Validation of the simulated infrared radiance and visible reflectance datasets used SEVIRI observations. Results of these validation studies show that the surface reflectance and surface emissivity data base used by the CRTM results in large errors in simulated brightness temperatures and top of atmosphere reflectivity. Comparisons between UWIR (MODIS based) and the CRTM (land used based) surface emissivity over desert regions have been used to show that differences in surface emissivity accounts for much of the overestimate of simulated Brightness Temperatures (BT) relative to SEVIRI over clear land scenes.

CIMSS and ASPB GOES-R AWG Proxy Team members recently submitted WRF-CHEM 12km Full disk ABI Domain GRB proxy data sets to the GOES-R Algorithm Integration Team. ABI simulated radiances were generated using Version 2.02 of the CRTM with input from nested WRF-CHEM 36km and 12km full disk aerosol, ozone, and cloud simulations that used lateral boundary conditions RAQMS. Validation of the simulated Cloud Optical Thickness (COT) has been conducted using measurements from the Solar Spectral Flux Radiometer (SSFR) provided by Sebastian Schmidt, University of Colorado, Boulder. SSRF was deployed onboard the Woods Hole Oceanographic Institution research vessel "Atlantis" during the NOAA Research at the Nexus of Air Quality and Climate Change (CalNex) field study.

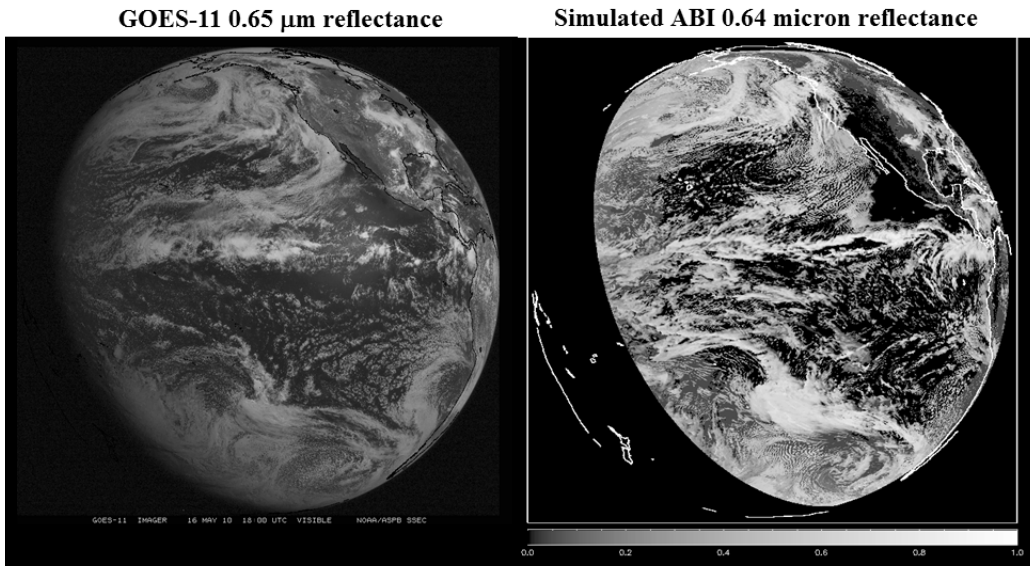

Figure 29 Comparison between GOES-11 0.65 μm (left) and simulated ABI 0.64 μm (right) reflectances at 18Z on May 16, 2010.

Publications/Conference Presentations

Schaack, T. et al., 2009: High Resolution Coupled RAQMS/WRF-Chem Ozone and Aerosol Simulations for GOES-R Research, 10th WRF Users' Workshop, June 23-26, 2009, Boulder, Colorado, available online at (http://www.mmm.ucar.edu/wrf/users/workshops/WS2009/abstracts/5A-04.pdf).

Pierce, R. B. et al., 2010: Development of Simulated ABI Data for the GOES-R Air Quality Proving Ground (AQPG), NOAA Air Quality Proving Ground Advisory Group Workshop, September 14, 2010, Baltimore, MD.

Greenwald, T et al., 2011: Proxy Team Status and Activities, 2011 GOES-R Algorithm Working Group Review, 14-16 June 2011, Fort Collins, Colorado.

GOES-R AWG Ozone

CIMSS Personnel: Christopher Schmidt, Jay Hoffman, Jun Li, Xin Jin
Funded by: NOAA

Project Description
CIMSS has transitioned the ozone algorithm from the current GOES Sounder to the next generation Advanced Baseline Imager (ABI). This transition was possible due to the inclusion on the ABI of several, but not all, of the long-wave infrared bands used for ozone estimation with the Sounder. The missing bands are sensitive to upper atmospheric temperature (commonly called the CO_2 bands) and to make up for their loss numerical weather prediction (NWP) temperature profiles have been added to the regression used to estimate ozone. The ozone product is a clear-sky product and relies upon the ABI cloud algorithm, also provided by CIMSS, for its operation.

Geostationary total column ozone estimation allows for monitoring of ozone features that move with the weather, reflecting the height of the tropopause and providing valuable information for air quality monitors who are looking for tropopause folds that bring stratospheric ozone close the surface, at times augmenting anthropogenic ozone to unhealthy levels. Ozone can also be used to monitor turbulence, though users have not taken up that application given the lack of high resolution, high frequency ozone data, something that may change in the GOES-R era.

The GOES-R ABI Ozone algorithm has been delivered to NOAA and is awaiting implementation. SEVIRI is used for ABI proxy data given its similarities, and CIMSS does produce SEVIRI ozone in realtime for ongoing development of validation tools. The algorithm meets its requirements to keep precision within 25 Dobson Units (DU) and accuracy within 15 DU, achieving approximately 15 DU and 3-4 DU respectively. Routine validation in the GOES-R era will be performed against total column ozone from polar orbiting satellites with UV total column ozone detection instruments, such as the current OMI on NASA's Aura. That validation requires collocation in time and space and the matching of footprints between satellites, tools for which have been developed at CIMSS.

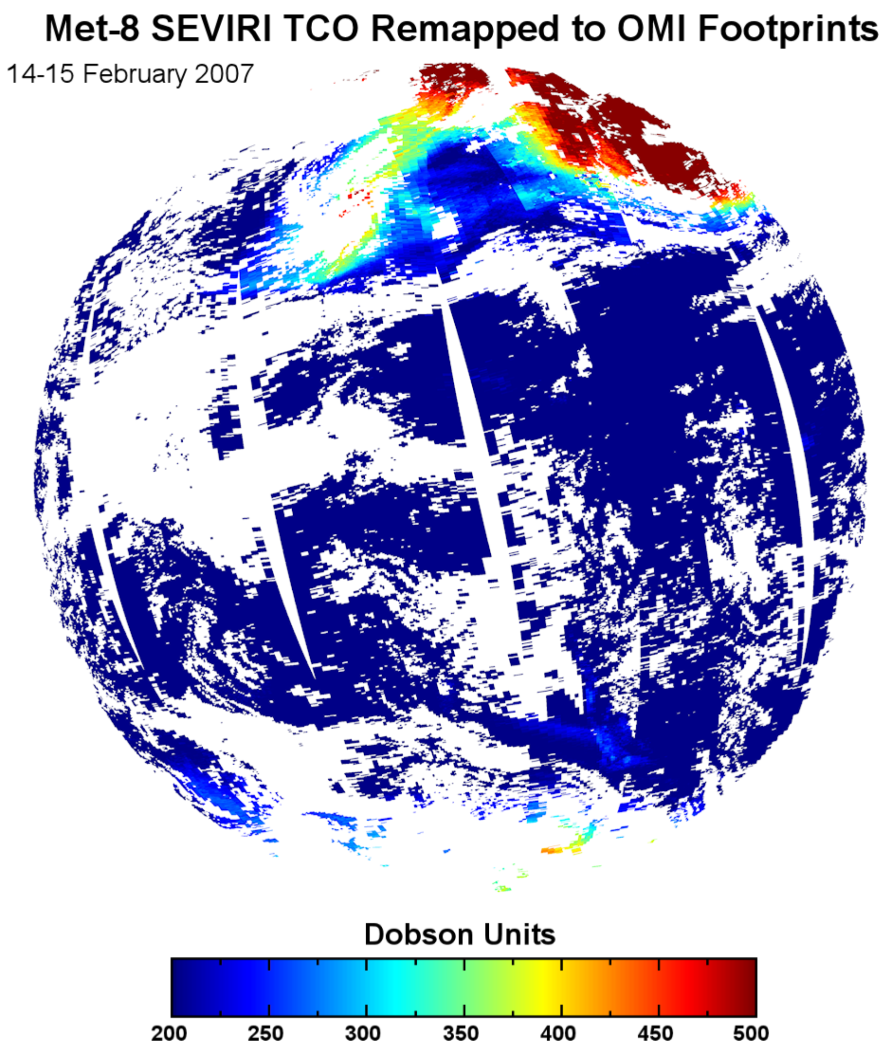

Figure 30 Met-8 SEVIRI total column ozone co-located in time and space with OMI total column ozone for 14-15 February 2007. This colocation and remapping of clear-sky total ozone data with OMI is a key step in the routine validation process proposed for GOES-R ABI.

Publications/Conference Presentations

Schmidt, Christopher C and Hoffman, J. P. 2010: ABI Ozone Detection Algorithm Theoretical Basis Document, version 2.0, NOAA/NESDIS, STAR, 44 pp.

Schmidt, Christopher and Hoffman, J. P., 2011: Ozone estimation with the ABI. Annual Symposium on Future Operational Environmental Satellite Systems, 7th, Seattle, WA, 23-27 January 2011. American Meteorological Society (AMS), Boston, MA. Manuscript not available for publication.

GOES-R AWG ABI Visibility Algorithm Development

CIMSS Personnel: Allen Lenzen, Wayne Feltz
Federal Collaborator: R. Bradley Pierce
Funded by: NESDIS/STAR

Project Description
The GOES-R Algorithm Working Group (AWG) Advanced Baseline Imager (ABI) visibility product is produced using a number of other ABI products including the low-cloud/fog detection, cloud optical thickness (COT), and aerosol optical depth (AOD). Visibility is inversely proportional to extinction which is measured at surface sites under the NWS Automated Surface Observing System (ASOS) program. For measurement of visibility in the daytime the NWS uses:

$$V = 3.0/\sigma \qquad \text{1a}$$

Where V is the visibility (in km), and σ is the extinction coefficient (km^{-1}). Optical depth τ is defined as σx. Expressing visibility in terms of τ gives:

$$V = 3.0/(\tau/x) \qquad \text{1b}$$

The Visibility algorithm uses ABI Aerosol Optical Depth (AOD) to estimate τ under clear-sky conditions and uses ABI Cloud Optical Thickness (COT) to estimate τ under cloudy conditions when Fog or Low Clouds have been detected. The Visibility algorithm uses NWS Planetary Boundary Layer (PBL) depth to estimate x under clear-sky conditions and uses retrieved Fog and Low Cloud depth to estimate x under cloudy conditions when Fog or Low Clouds have been detected.

Statistical analysis of historical ASOS visibilities verses “First Guess” ABI aerosol and fog visibilities computed from Eq 1b. has been used to determine Look Up Tables (LUT) of monthly categorical bias corrections (offsets and scale factors) for aerosol and fog visibility. A “blended” visibility retrieval is constructed using a weighted combination of the First Guess and bias corrected visibility estimates for both aerosol and low-cloud/Fog visibilities. Optimal weighting is determined based on assessment of required categorical accuracy (percent correct classification), required precision (standard deviation of categorical error), Heidke Skill Score (fractional improvement relative to chance), and false alarm rate. Primary validation uses NWS Automated Surface Observing Systems (ASOS) raw (1 minute) extinction measurements Archived at NCDC Class. To date, 9868 V3 visibility retrieval pixels have been collocated with ASOS harmonic mean 1-minute visibility measurements during May-June 2010. The precision of the V3 Algorithm (0.6) meets the required precisions of 1.5 classes. However, the categorical accuracy (59%) of the V3 visibility Algorithm does not meet the ABI requirement (80%).

Secondary validation data sets include High Spectral Resolution Lidar (HSRL) 550 nanometer extinction coefficients, Solar Spectral Flux Radiometer (SSFR) Cloud Optical Depth retrievals, and airborne in situ cloud microphysics measurements. The figure below shows validation of the ABI visibility retrieval using HSRL lidar aerosol backscatter and aerosol optical depth measurements (E. Eloranta, UW-Madison/SSEC) to estimate x and τ over Boulder, CO on June 04th, 2011. Smoke from Wallow fire in Arizona led to reduced visibility in NE Colorado and Nebraska at this time. The ABI retrieved visibility at Boulder, CO is 15km. From Eq 1b, the

HSRL visibility over the depth of the PBL (4km) where the AOD reaches 0.8 is also 15km (3.0/(0.8/4.0). However, the HSRL AOD is only 0.1 in the lowest 1km, so the visibility near the surface is 30km (3.0/(0.1/1.0). Since the ABI visibility retrieval represents a column visibility it can be decoupled from ASOS surface measurement if aerosols are aloft or PBL is not well mixed. This makes it difficult to validate the ABI visibility retrieval with surface ASOS measurements. However, the ABI Visibility Algorithm provides a new capability for estimating visibility from geostationary orbit that complements existing ASOS surface measurements.

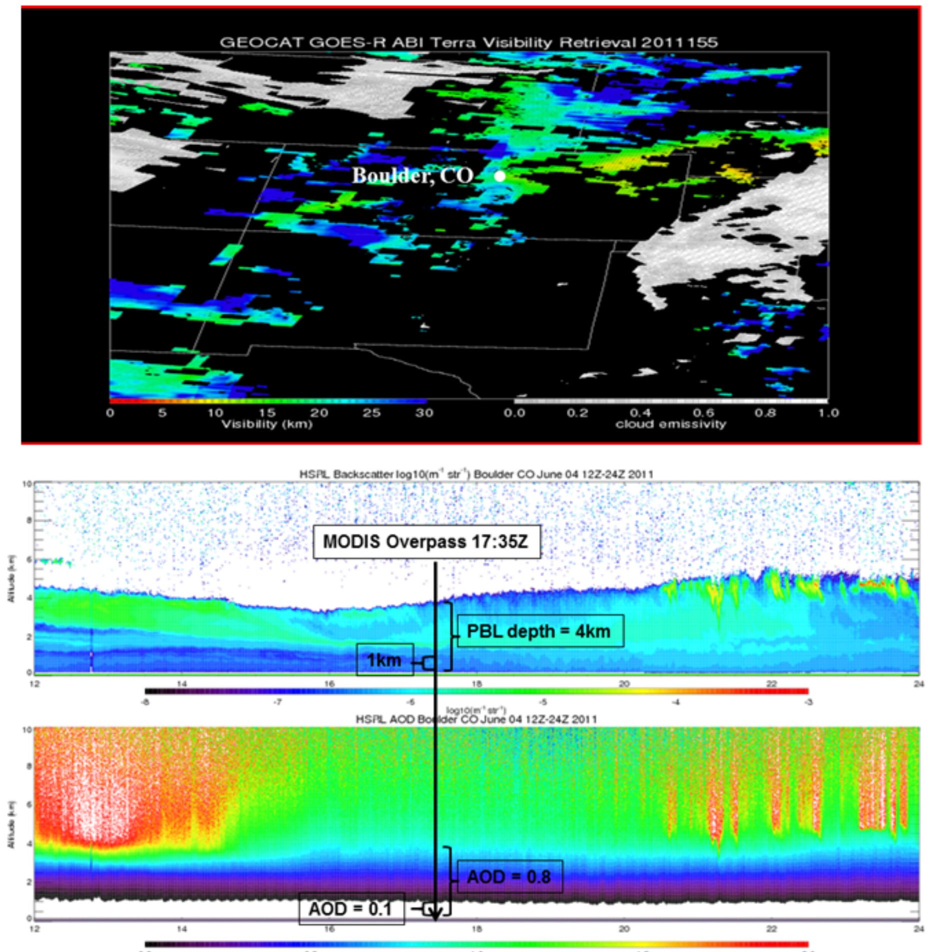

Figure 31 GOES-R ABI Visibility retrieval based on MODIS Terra proxy data (upper panel) and HSRL aerosol backscatter (middle panel) and AOD (lower panel) on June 04, 2011.

Publications/Conference Presentations

Pierce, R. B., 2010: GOES-R Aviation Team Visibility Status Report, 2010 GOES-R Algorithm Working Group And GOES-R Risk Reduction Review, 7-11 June 2010, Madison, WI

Pierce, R. B., 2011: GOES-R Aviation Team Visibility Status Report, 2011 GOES-R Algorithm Working Group Review, 14-16 June 2011, Fort Collins, Colorado

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

CIMSS Personnel: Tom Greenwald, Allen Huang, Jason Otkin, Yong-Keun Lee, Eva Borbas, Jim Davies, Justin Sieglaff
Federal Collaborators: Tim Schmit and R. Bradley Pierce
Funded by: NOAA

Project Description
This project's purpose is to use NWP models and computing infrastructure and software tools developed at CIMSS (including radiative transfer models) to provide validated, high quality Advanced Baseline Imager (ABI) proxy data sets for supporting numerous GOES-R activities, such as GOES-R Proving Ground, the Algorithm Integration Team, the GRAFIIR, and the AWG Sounding, Winds, Clouds, Aerosol and Ozone, Imagery/Visualization, and Aviation teams.

Major Accomplishments

New proxy datasets:
- WRF model simulation of a winter storm in the U.S. Midwest for 6-7 Jan 2010. Model horizontal grid spacing was 4 km. ABI proxy datasets were produced for 30-min intervals (remapped to 2 km resolution grid) for the IR bands (8-16)
- 3-day (7-10 Sept 2008) WRF model simulation of hurricane Ike. Model horizontal grid spacing was 4 km. ABI proxy datasets were produced for 15-min intervals (remapped to 2 km resolution grid) for the IR bands (8-16)

Validation:
- Published an article (Greenwald et al., 2010) describing the quality of model generated clouds from the 3-km fulldisk WRF model simulation for the SEVIRI domain. It was shown in the mid-latitudes that the simulation was able to reproduce the vertical structure of the four objectively-determined cloud types in comparison to time/space matched CloudSat observations. Since the same microphysics parameterization was used in all of our WRF model simulations, it suggests that mid-latitude clouds in the other simulations will have similar quality.
- Compared the UW land surface IR emissivity database (UWemis) to the CRTM v2.0.2 and an IASI-based land surface emissivity database produced by Dan Zhou at LaRC. There was overall good agreement over most of the IR spectrum (< 1% mean difference) with the IASI-based database but large differences over CONUS and the Sahara with the CRTM.
- Used collocated MODIS and CloudSat observations to evaluate ice cloud IR single-scattering properties in the CIMSS radiative transfer model (RTM) and the CRTM v2.0.2. Comparing MODIS band 31 (11 μm) data simulated by the two RTMs to observations for thin to moderately optically thick (< 6) high-level ice clouds showed that the CIMSS RTM had good behavior over the full range of brightness temperatures but exhibited a +5 K offset. However, the CRTM was found to have a large bias (sometimes reaching 20 K) for optically thicker clouds (see figure).

Software development:

- Built an f90/95 interface between the CRTM and WRF model to make it easier to do comparisons with the CIMSS RTM or other RTMs and for users to produce ABI proxy datasets using the CRTM. It was also important to produce CF-compliant netCDF files so that they can be visualized, for example, by McIDAS-V.

Publications/Conference Presentations

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

Davies, J., T. Greenwald, J. A. Otkin, Y.-K. Lee, J. Sieglaff, and A. Huang, 2011: A comparison of forward radiative transfer models used in the production of simulated proxy data for the GOES-R ABI. 7th Annual Symposium on Future Operational Environmental Satellite Systems, Seattle, WA, 23-27 January.

Greenwald, T. J., Y.-K. Lee, J. Otkin, T. S. L'Ecuyer, 2010: Evaluation of midlatitude clouds in a large-scale high-resolution simulation using CloudSat observations. *J. Geophys. Res.*, **115**, doi:10.1029/2009JD013552.

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

Li, Z., J. Li, X. Jin, T. J. Schmit, E. Borbas, and M. Goldberg, 2010: An objective methodology for infrared land surface emissivity evaluation. *J. Geophys. Res.*, doi:10.1029/2010JD014249.

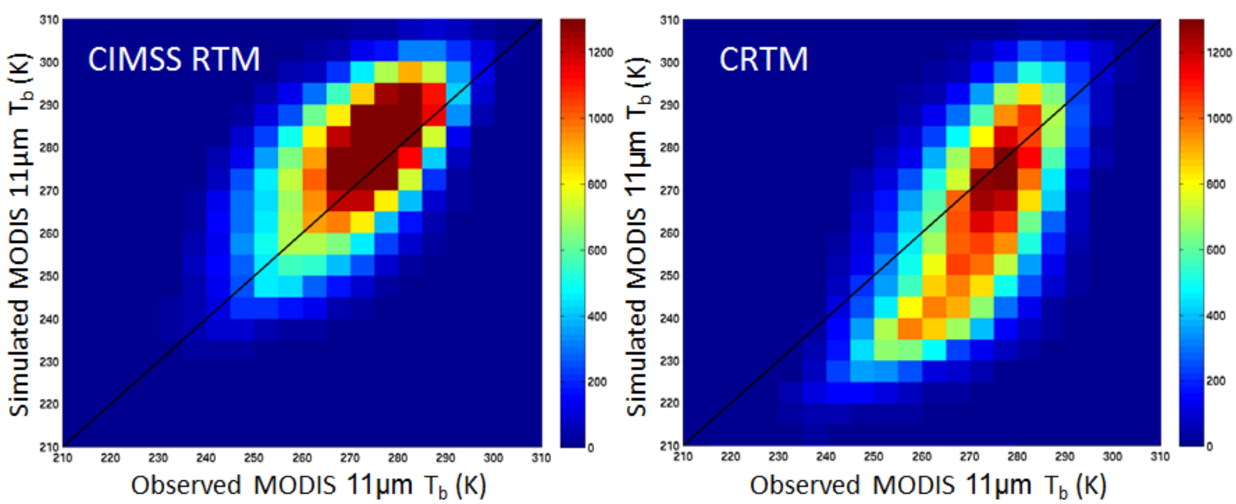

Figure 32 Comparison of simulated and observed MODIS band 31 brightness temperatures from the CIMSS RTM (left) and CRTM v.2.0.2 (right) for high-level ice clouds over the oceans for 2007. CloudSat ice water content profiles, MODIS (MOD06) effective radius observations, and ECMWF thermodynamic profiles were used as input to the two RTMs. These results have a bearing on the quality of the ABI IR band proxy datasets since ice scattering properties have a dominant influence on top-of-atmosphere radiances.

GOES-R AWG SO_2 Detection

CIMSS Personnel: Rich Dworak, Justin Sieglaff
Federal Collaborator: Michael Pavolonis
Funded by: NOAA-AWG

Project Description
The GOES-R AWG SO_2 detection algorithm developed utilizes the five infrared channels: 6.2, 7.3, 8.5, 11 and 12 μm. The 7.3 and 8.5 μm channels are sensitive to SO_2 absorption, while the 6.2, 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 of the five 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. The β ratios are calculated for each pixel within a satellite scan and pixels containing 'anomalous' values (values not consistent with purely water or ice clouds) are grouped into cloud objects. Spatial and spectral cloud statistics are computed for the cloud objects and are used to determine whether all the pixels of the cloud object contain SO_2 or do not contain SO_2. In addition to the yes/no SO_2 detection flag, approximate SO_2 loading is also produced. Future enhancements of the algorithm include expressing results as a probability instead of a yes/no mask.

Recent Milestone
Recent focus has been on validating the SO_2 detection algorithm. The truth data source is the Ozone Monitoring Instrument (OMI), which flies on board the Aura satellite in NASA's A-Train. The OMI uses measurements of backscattered solar UV radiation to detect SO_2. OMI can detect SO_2 at levels less than 1 DU. The OMI SO_2 loading product and GOES-R proxy data (MODIS or SEVIRI) are matched up in time and remapped to the same grid to allow for quantitative comparisons. The GOES-R AWG SO_2 detection algorithm is validated as a function of OMI SO_2 loading. Only scenes that contained SO_2 clouds were used so this analysis reflects how the algorithm will perform in relevant situations. The GOES-R SO_2 detection algorithm is clearly meeting the specified accuracy requirement (Figure 33).

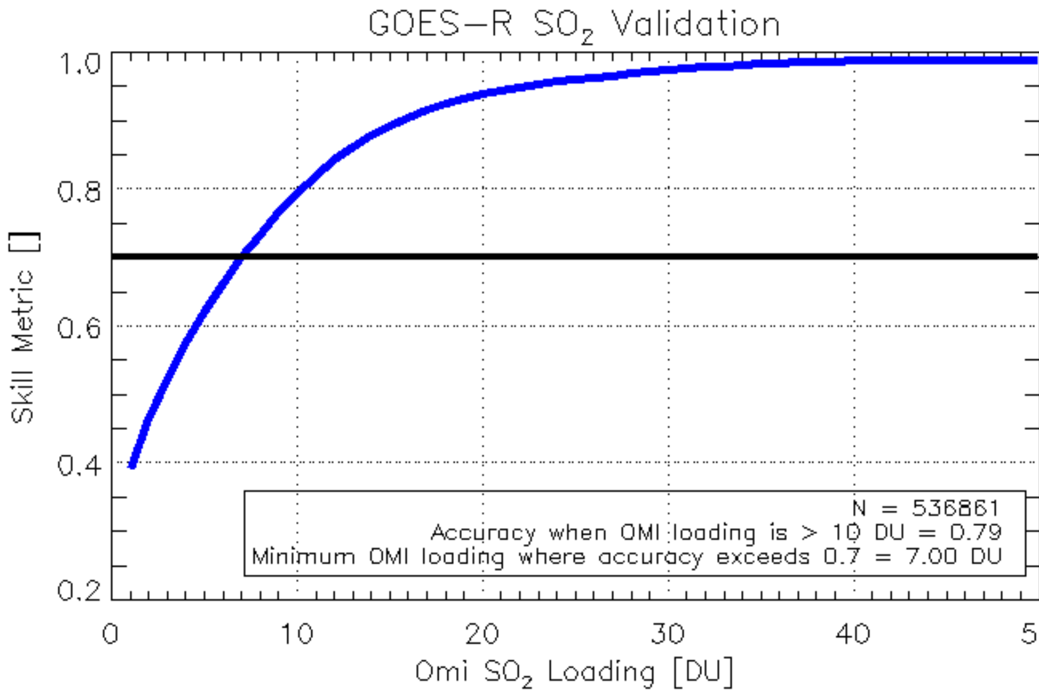

Figure 33 GOES-R SO_2 detection algorithm accuracy as a function of OMI SO_2 loading (blue line) for over 500,000 pixel matchups. The black line is the GOES-R AWG SO_2 accuracy requirement. The GOES-R SO_2 detection algorithm meets accuracy specifications down to 7 DU (GOES-R requirements specified accuracy metric was for at least 10 DU).

Publications/Conference Presentations

Pavolonis, Michael J., 2011: GOES-R AWG Aviation Team: SO_2 Detection, 2011 Annual GOES-R AWG Annual Meeting, Fort Collins, Colorado, June 2011. (Oral Presentation)

GOES-R SO_2 Algorithm Theoretical Basis Document (ATBD) and Algorithm Code, 80% delivery, submitted September 2010.

Algorithm Development for GOES-R Legacy Atmospheric Profiles and Atmospheric Instability Indices

CIMSS Personnel: Jun Li, Zhenglong Li, Yong-Keun Lee, Eva Borbas, Graeme Martin, and Jinlong Li
Federal Collaborators: Tim Schmit, Chris Barnet
Funded by: NOAA

Project Description
Since the Hyperspectral Environmental Suite (HES) was removed from GOES-R, decision has been made by the GOES-R program office to use the Advanced Baseline Imager (ABI) (Schmit et al., 2005) to continue the current GOES Sounder legacy atmospheric profiles (LAP) (Schmit et al., 2008). The main focus of this project is to develop algorithm for GOES-R LAP and atmospheric instability indices products. The algorithm retrieves atmospheric temperature and moisture profiles, and the derived products including total precipitable water (TPW), layer precipitable water (LPW), lifted index (LI), convective available potential energy (CAPE), total totals index (TT), Showalter index (SI), and the K-index (KI) from the clear sky radiances within a 5 by 5 ABI field-of-view (FOV) box area (10 km spatial resolution). This project requires CIMSS scientists to develop the GOES-R LAP algorithm to be able to process high temporal and high spatial resolution ABI data efficiently. The important milestone is that CIMSS sounding team has provided prototype science codes and the algorithm theoretic baseline document (ATBD) to GOES-R program office for operational implementation. CIMSS scientists have also evaluated and validated the GOES-R LAP algorithm using SEVIRI, MODIS and GOES Sounder as proxy to assure that the GOES-R LAP and atmospheric instability indices products meet the requirement. The GOES-R ABI LAP algorithm performance has been evaluated using an 18-month collocated SEVIRI radiances and ECMWF analysis products, the dataset is provided by EUMETSAT nowcasting Satellite Application Facility (SAF) through collaboration efforts. The SEVIRI database was collected between April 1st, 2007 and September 30th, 2008, and ECMWF 12-hour analysis at 00 UTC and 12 UTC is used as truth. Figure 34 shows the evolution of retrieved relative humidity profile RMSE (against ECMWF analysis) between April 2007 and September 2008 over land. The reduction of moisture profile RMSE is remarkable, especially above 700 hPa.

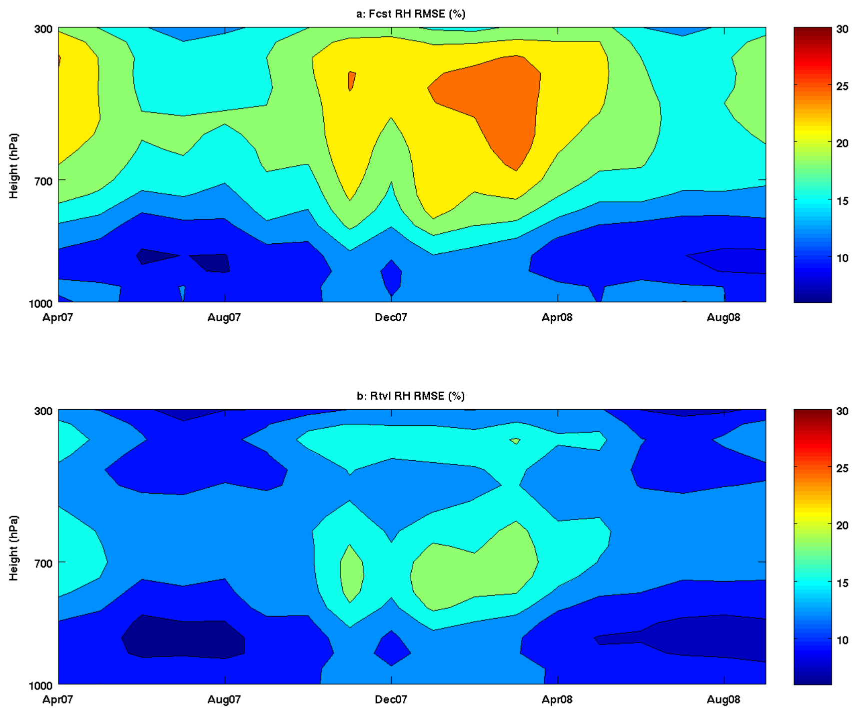

Figure 34 The retrieved relative humidity profile RMSE against ECMWF analysis between April 2007 and September 2008 over land. The upper panel is forecast and the lower panel is retrieval from SEVIRI.

CIMSS scientists will continue to develop validation tools for GOES-R LAP and derived atmospheric instability index products.

Publications/Conference Presentations

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

Jin X., and J. Li, 2010: Improving moisture profile retrieval from broad band infrared radiances with an optimized first-guess scheme. *Remote Sensing Letters*, **1**, 231 - 238.

Algorithm development for GOES-R land surface emissivity product

CIMSS Personnel: Jun Li, Zhenglong Li, Graeme Martin, and Yong Zhang
Federal Collaborators: Tim Schmit, Yuyue (Bob) Yu
Funded by: NOAA

Project Description
The CIMSS sounding team is responsible for the development of the algorithm for GOES-R ABI land surface emissivity product which is very important for other products such as land surface temperature, radiation budget and cloud-top height. CIMSS scientists has developed a unique LSE retrieval algorithm that uses the high temporal information of GOES-R and have provided prototype science codes to the GOES-R algorithm integration team (AIT) for software implementation and process demonstration. The GOES-R ABI LSE algorithm is based on the assumption that the surface skin temperature is temporally variable while the GOES-R ABI LSE is temporally invariable within a time period, so that ABI radiances from multiple time steps can be used to retrieve the temporally variable surface skin temperatures and temporally invariable ABI LSE. The algorithm evaluation has been performed by comparing ABI LSE products with hyperspectral IR LSE spectrum retrievals derived from IASI (Infrared Atmospheric Sounding Interferometer) radiance measurements. Quantitative evaluation has also been conducted for GOES-R LSE using SEVIRI as proxy (Li et al., 2011). Figure 35 shows the LSE retrievals at 8.7 μm (upper left), 10.8 μm (upper right) and 12.0 μm (lower left) along with the surface skin temperature (lower right) for 01 August 2006 using SEVIRI observations at three time steps (00 UTC, 03 UTC and 06 UTC). The GOES-R ABI LSE algorithm is used. Surface skin temperatures are for 06 UTC. The product resolution is 3 by 3 FOVs. Results are from CIMSS GEOCAT system.

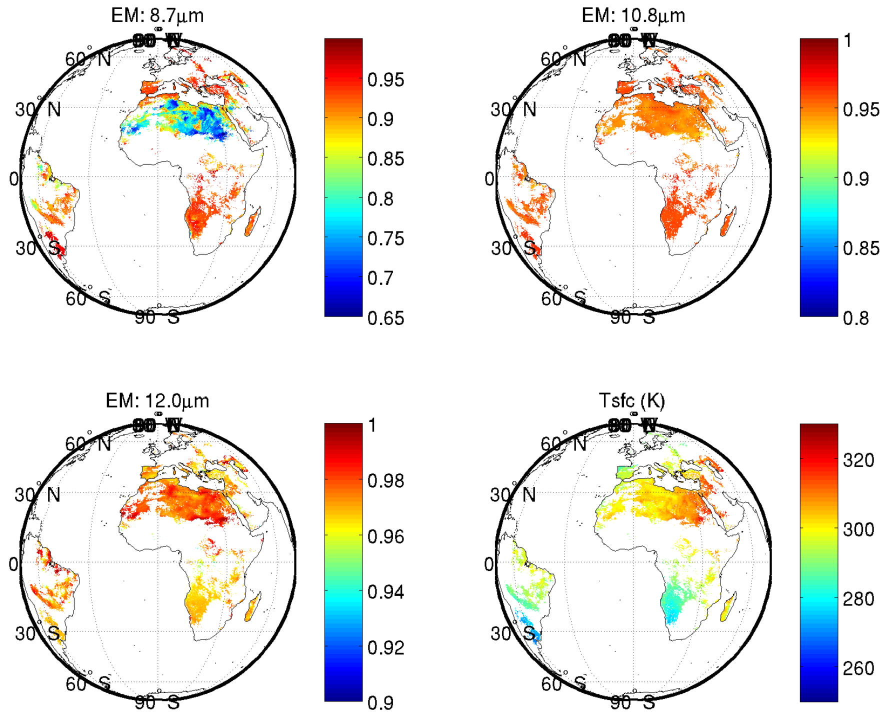

Figure 35 The land surface emissivity retrievals at 8.7 µm (upper left), 10.8 µm (upper right) and 12.0 µm (lower left) along with the surface skin temperature (lower right) for 01 August 2006 using the SEVIRI observations at 00 UTC, 03 UTC and 06 UTC. Surface skin temperature retrievals are for 06 UTC.

CIMSS scientists will also develop the 100% Algorithm Theoretical Basis Document (ATBD) for GOES-R LSE.

Publications/Conference Presentations

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

Li, Z., J. Li, X. Jin, T. J. Schmit, E. Borbas, and M. D. Goldberg, 2010: An objective methodology for infrared land surface emissivity evaluation. *Journal of Geophysical Research - Atmospheres*, **115**, D22308, doi:10.1029/2010JD014249.

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

CIMSS Personnel: Allen Huang, Mat Gunshor, Hong Zhang, Eva Schiffer, Ray Garcia, Graeme Martin, Jim Nelson, Erik Olson, Jason Otkin, Justin Sieglaff, Steve Wanzong
Federal Collaborator: Tim Schmit
Funded by: NOAA/NESDIS (GOES-R AWG)

Project Description
The GRAFIIR project has been developed by the scientists and researchers that are also GOES-R Algorithm Working Group (AWG) product team members and system developers working on the GOES-R Advanced Baseline Imager (ABI). GRAFIIR provides a system by which AWG algorithms can be tested under a consistent processing framework and utilizes a statistical analysis package called Glance (developed at CIMSS) which generates HTML reports detailing the differences between two datasets that includes histograms, scatter plots, difference images, and other statistics. The GRAFIIR team is a key component used in ABI waiver analysis.

An ABI waiver occurs when the instrument vendor cannot meet the specifications for a particular instrument component and must therefore request that the government waive the requirement. The vendor must then provide the government with detailed information on how this will impact the data. This information is used by CIMSS to alter simulated ABI data which are then used in ABI product generation. By comparing the product outputs of unaltered data with the product outputs generated using the altered data, an analysis of the impacts on products can proceed.

When instrument specifications are changed, new data files are produced, products are run, and then products are evaluated in regards to the instrument specification changes. The CIMSS GRAFIIR team analyzes the products to assess the impact of various instrument effects using the file comparison tool the team developed called "Glance."

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

Glance has undergone many upgrades in response to the needs of various AWG algorithm developers and system testers. These upgrades included more granular control over plots, improved speed and memory usage, the ability to plot original data in the same range (i.e., the same colorbar), the ability to load lon/lat from a separate file, improved HDF5 support, provisions for collocating winds, and the ability to filter on additional variable data. Glance was also updated to be able to display statistics on various sounding retrieval pressure levels.

The GRAFIIR team at CIMSS has become an integral part of the plan for assessing the potential impact on Level-1B and Level-2+ products of an ABI waiver. CIMSS has helped the government in the analysis of, and response to, 5 waivers/deviations for the ABI.

Publications/Conference Presentations

Zhang, Hong, Gunshor, M., Straka, W., Marti, G., Wanzong, S., Schiffer, E., Garcia, R. and Huang, A. GRAFIIR - An efficient end-to-end semi automated GOES-R ABI algorithm performance analysis and implementation verification system. Annual Symposium on Future Operational Environmental Satellite Systems, 7th, Seattle, WA, 23-27 January 2011. American Meteorological Society (AMS), Boston, MA, 2011. (Poster)

Gunshor, Mathew, Huang, A., Zhang, H., Schiffer, E. GRAFIIR Tools and Practical Uses. GOES-R Annual Algorithm Working Group (AWG) Review. Fort Collins, CO, 16 June 2011. (Presentation)

Support for CIMSS Satellite Rooftop Validation Infrastructure

CIMSS Personnel: Wayne Feltz, Erik Olson, Bruce Flynn, and Joe Garcia
NOAA Collaborator: Brad Pierce
Funded by: NOAA Ground Systems

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

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

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

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

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

This project has developed the control system for these instrument data to acquire, manage and distribute instrument data as needed by the science community (Figure 36). 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.

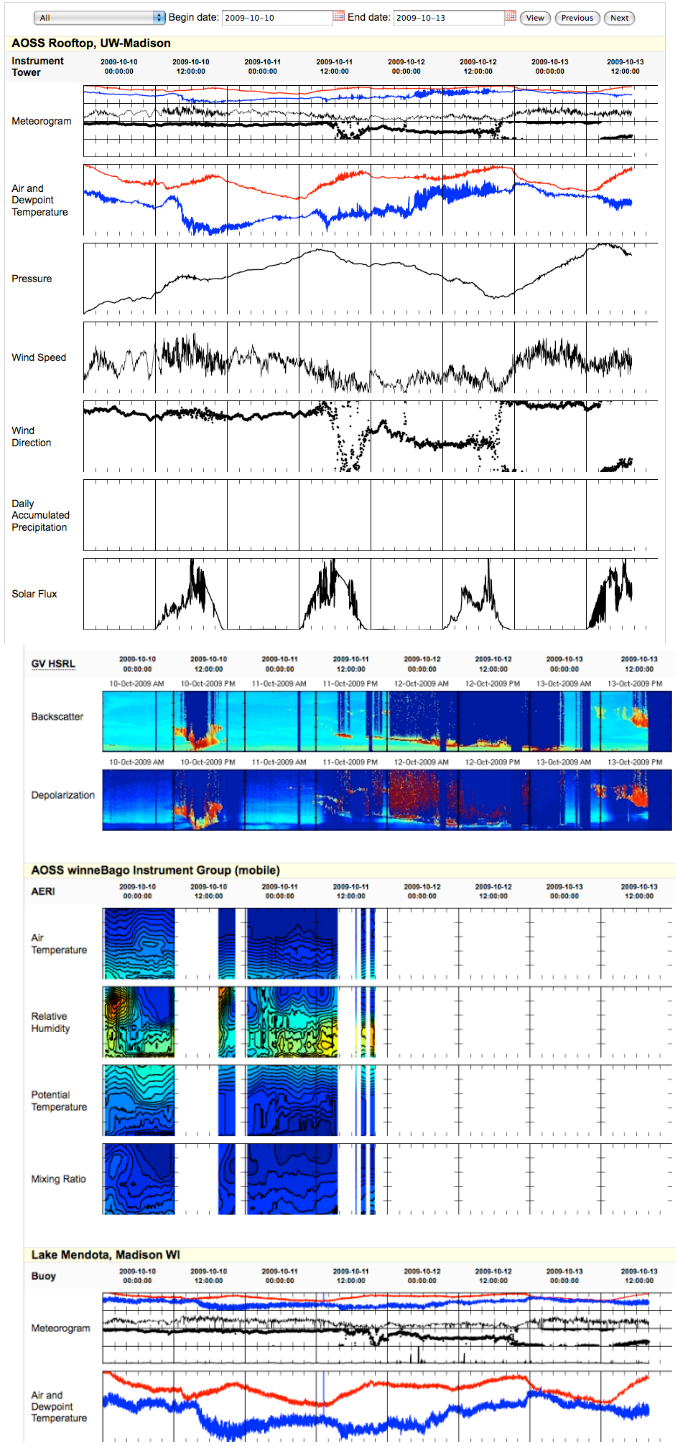

Figure 36 Example of quicklook interface to AOSS rooftop data.

Cloud Properties: VIIRS Cloud Studies for NPOESS

CIMSS Personnel: Richard Frey
Federal Collaborators: Andrew Heidinger
Funded by: NOAA

Project Description
The goal of this project is to support VIIRS Calibration and Validation Teams. Half of this funding supports our efforts to improve and validate the VIIRS 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.

Four months (January, April, July, October, 2007) of MODIS proxy data has been processed by the latest available VIIRS cloud mask (VCM) science code, where the VCM cloud test thresholds have been specifically “tuned” to MODIS spectral radiance characteristics. Monthly global cloud amounts are being compared to those of other well known algorithms (ISCCP, PATMOS-x, MODIS (MOD35), MODIS CERES, CALIOP) with data obtained through the GEWEX (Global Energy and Water Cycle Experiment) project.

This work is in its early stages, but some characteristics of the VCM are evident when compared to the other algorithms. Figure 37 below shows monthly mean latitude zone cloud amounts as calculated from VCM output and several other algorithms. It is clear that in this month at least, the VCM detects fewer clouds overall than the other algorithms/measurements. Keep in mind that the VCM, MODIS (MOD35), and MODIS CERES used the same input data. PATMOS-x uses AVHRR, ISCCP uses a combination of AVHRR and GOES, and CALIOP is an active lidar sensor. The lidar has excellent sensitivity to high, thin clouds that are difficult for traditional radiometers to detect, hence the generally higher cloud amounts for CALIOP.

Figure 38 shows a map of VCM minus MODIS (MOD35) cloud amount differences. One can see that the negative differences are mostly from oceanic regions while land areas generally show smaller (negative) differences or even positive values in some areas. Evaluation of collocated VCM and CALIOP data will give insights into which cloud types are under-detected in the VCM data (i.e., heights, optical depths, temperatures, etc.). This work will be completed with the aid of the Atmosphere PEATE. Knowing general characteristics of the VCM before launch will lead to quicker and more efficient use of time and other resources when tuning the VCM during the Intensive CAL/VAL period after VIIRS is launched.

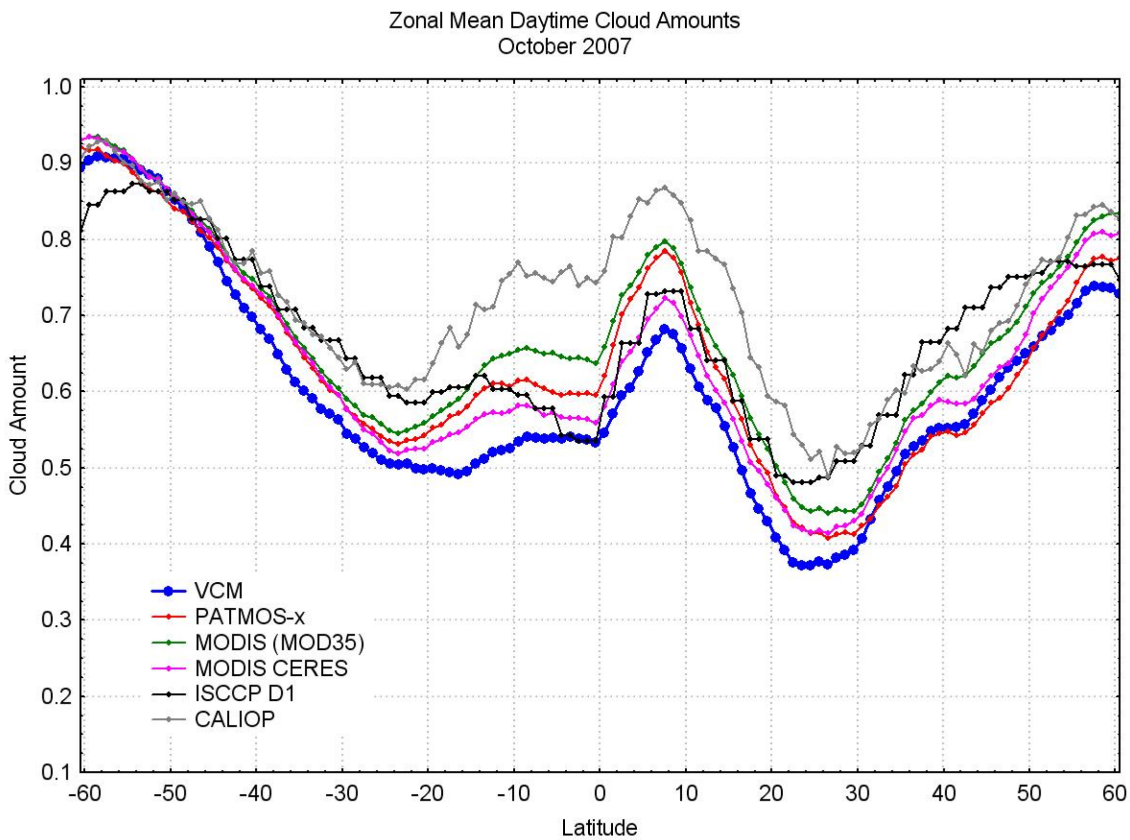

Figure 37 October 2007 mean monthly latitude zone cloud amounts for the VCM and various cloud detection algorithms. Proxy MODIS data was used as input to the VCM.

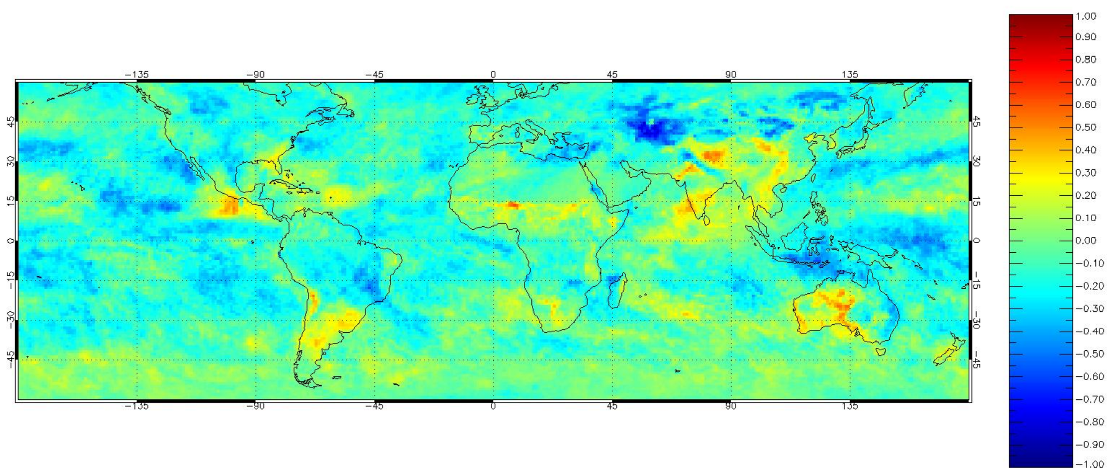

Figure 38 October 2007 mean monthly VCM minus MODIS (MOD35) cloud amounts on a 1-degree by 1-degree grid from 60S to 60N.

Aerosol Optical Depth from MODIS and CALIOP Observations

CIMSS Personnel: Robert Holz, Min Oo and Geoff Cureton
Federal Collaborators: JPSS
Funded by: JPSS

1. Improving the CALIOP aerosol optical depth using combined MODIS-CALIOP observations and CALIOP integrated attenuated total color ratio

This project aims to evaluate CALIOP Aerosol Optical Depth (AOD) retrieval using MODIS AOD with the goal of improving the CALIOP selection of the lidar ratio leveraging the vertical resolved CALIOP and multi-spectral MODIS observations. Comparing the MODIS fine mode ratio to CALIOP, we find the CALIOP integrated attenuated color ratio provides sensitivity to the aerosol size and type. This finding can be used to better constrain the lidar ratio and improve the CALIOP AOD independent from MODIS. We demonstrate that the CALIOP integrated attenuated total color ratio is correlated with the MODIS fine and coarse mixing ratios in marine environments. This finding suggests that for a CALIOP only AOD retrieval, the integrated attenuated total color ratio can be used to better constrain the lidar ratio. Using the CALIOP integrated attenuated total color ratio, the CALIOP only AOD retrieval improves the AOD mean biases (from |0.064| to |0.007|) when compared to the MODIS AOD as presented in Figure 40.

CALIOP AOD retrieval with constraining aerosol lidar ratio

To retrieve the aerosol optical depth from CALIOP requires knowledge of the aerosol lidar ratio that varies significantly as a function of aerosol type. For most CALIOP retrievals the lidar ratio is estimated by correlating CALIOP observables (depolarization and backscatter) with pre-computed lidar ratio climatologies. Applying a lidar ratio not representative of the observed aerosols can result in significant AOD biases and is one of the primary sources of uncertainty in the current CALIOP AOD. We find that when CALIOP selects the Marine (coarse) aerosol lidar ratio, collocated MODIS often detected a mixture of fine and coarse aerosols. Incorrectly defining the aerosol type as Marine and missing the fractional presence of fine mode aerosols in the scene results in an underestimation of the lidar ratio and CALIOP underestimating the AOD relative to MODIS (blue) as shown in Figure 40. We find that the biases are associated with MODIS AOD fine mode fraction (FMF). Combining the MODIS spectral sensitivity to the fine and coarse mode aerosol distribution with CALIOP improves the AOD retrievals using Equation 1.

$$\tau_{total} = (R^{fineAOD})\frac{\ln(1-\eta\gamma'_{feature}S_{fine})}{-2\eta} + (1-R^{fineAOD})\frac{\ln(1-\eta\gamma'_{feature}S_{coarse})}{-2\eta} \qquad (1)$$

Where R is ratios of fine and coarse mode aerosol, S is the aerosol lidar ratio of fine and coarse mode, γ' is the feature integrated attenuated backscatter and η is the multiple scattering factor. We also find the correlation between the MODIS AOD FMF and the CALIOP integrated attenuated total color ratio. Leveraging this relationship and modifying CALIOP AOD retrieval using equation 1 show significant improvement in CALIOP AOD retrieval (red) independent of MODIS.

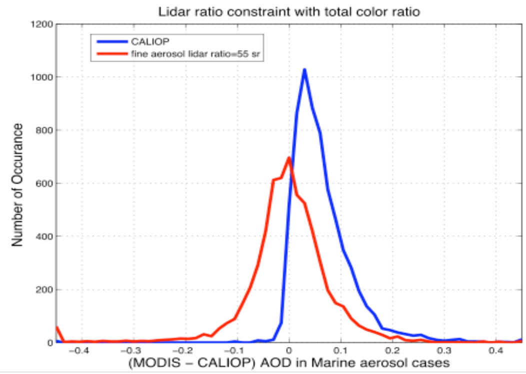

Figure 39 Frequency of MODIS-CALIOP AOS differences for CALIP V3 and modified CALIOP retrieval in marine cases.

Publications/Conference Presentations

Oo, M., and R. Holz, Improving the CALIOP aerosol optical depth using combined MODIS-CALIOP observations and CALIOP integrated attenuated total color ratio, *J. Geophys. Res., doi:10.1029/2010JD014894, in press.* (accepted 18 April 2011).

Oo, M., and R. Holz, Improving the CALIOP aerosol optical depth using combined MODIS-CALIOP observations and CALIOP integrated attenuated total color ratio, CALIPSO-CloudSat science team meeting, Montreal, Canada, June 14-16, 2011.

2 Comparison between LEOCAT (Linux) with mini-IDPS and NGAS

The UW-Madison implementation of the VIIRS contractor algorithms LEOCAT (Low Earth Orbit Cloud Algorithm Testbed) VIIRS algorithm works in a Linux environment and can produce both VIIRS and MODIS resolution products. For the VIIRS resolution processing flow, SDR granules from mini-IDPS processing chain are directly used as input to LEOCAT VIIRS software. For the MODIS resolution processing, MODIS L1 B is used as input to VIIRS algorithm in LEOCAT. The same algorithm (and code) is used for both processing streams. For both VIIRS and MODIS processing, LEOCAT uses GDAS and NCEP model data. The VIIRS resolution processing applies the VIIRS LUT while the MODIS resolution processing applies MODIS LUT. The MODIS resolution LEOCAT implementation runs on MODIS Level 1b granules providing the capability to produce years of retrievals leveraging the UW-Madison SSEC processing capability.

Due to limited VIIRS proxy data, we can only compare min-IDPS and NGAS data to the LEOCAT for Jan 25, 2003. Based on AOT comparison we found significant differences between the LEOCAT, mini-IDPS, and NGAS results with a granule level comparison. We find that LEOCAT has better agreement with the min-IDPS. For NGAS the largest differences are over land. Further investigation has revealed LEOCAT uses a different granulation (gridding) method to the 1-degree ancillary data (NCEP) used by mini-IDPS and NGAS proxy data. We also found significant differences in the cloud filtering between the LEOCAT and contractor implementations. Much of our efforts have focused on addressing these issues to improve the closure between LEOCAT, min-IDPS and NGAS.

MODIS resolution LEOCAT VIIRS algorithm

Using the LEOCAT MODIS resolution processing we created a 6-month AOT data set leveraging the UW-Madison processing capabilities. We also compared the LEOCAT VIIRS results to the collection 5 MODIS MYD04. Because the MODIS MYD04 is at 10km resolution and LEOCAT (VIIRS) IP is 1km resolution, we select every 10th LEOCAT pixel to aggregate up to the 10km MODIS resolution. We find that the majority of the large AOT differences occur over land or in heavy aerosol regions when compared to MODIS AOT. Further investigation has revealed that much of the differences can be attributed to the cloud/aerosol masking in LEOCAT.

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

CIMSS Personnel: Hank Revercomb, Fred Best, Bob Knuteson, Joe Taylor, Lori Borg, Dave Tobin
Federal Collaborator: Yong Han
Funded by: JPSS

Project Description
The University of Wisconsin-Madison (UW-Madison) Space Science and Engineering Center (SSEC) has proposed to support a broad scope of activities aimed at providing the government with expertise in specific technical areas related to the NPOESS mission. The general purpose of these efforts is to provide expertise to the IPO that (1) reduces schedule, cost, and performance risk, (2) helps assess performance of industry, (3) points to feasible observing system improvements, and (4) leads to increased positive impact of NPOESS goals, by making use of the broad experience in instrument design, testing, algorithms, and science gained from previous and ongoing UW-Madison SSEC research activities. Special focus is in the areas of (1) pre-launch CrIS instrument performance assessments, (2) pre- and post-launch CrIS and IASI calibration and validation, and (3) independent verification and validation of SDR and EDR products through development of test cases and detailed evaluation of industry provided code performance.

Summary of Accomplishments and Findings
Efforts in this period have focused on evaluation of the CrIS SDR algorithm, and various efforts related to being prepared for post-launch cal/val activities of the CrIS SDRs.

Most recently, we have helped to develop a comprehensive and efficient plan for optimization and validation of the CrIS performance in the Sensor Checkout and Intensive Cal/Val periods following launch. To assess the CrIS radiances in the post-launch sensor checkout period, we are preparing for the following tasks:

1. Internal consistency checks on Radiometric Calibration,
2. Radiometric Non-linearity Evaluation,
3. Radiometric Noise assessment,
4. Variable artifact assessment using Principle Component Analysis,
5. Early broadband comparisons with GOES and other GEOs,
6. Clear sky Observed minus Calculated Analysis,
7. Internal Consistency checks on spectral self-apodization correction and resampling,
8. Analysis of non-uniform scene effects on the ILS,
9. SDR evaluations using SNO comparisons with IASI and AIRS,
10. CrIS/VIIRS Radiance Comparisons,
11. ICT Environmental Model Evaluation and Refinement, and
12. In-orbit RU Estimation.

Our analysis will involve several types of processing. In the early Sensor Checkout period, efforts will be focused on adjusting the various calibration coefficients in the CrIS engineering packets to obtain optimal performance. This will be done in the context of the operational SDR algorithm, implemented with the ADL environment and used as given in Figure 40. An Engineering Packet Editor will be used to produce alternate sets of SDRs which will then be used to compare to SDRs produced with the nominal at-launch calibration parameters, and evaluated in various ways using selected validation data sets. An ADL implementation of the SDR algorithm will allow us to ensure that the candidate changes to the calibration parameters will be optimal for the operational IDPS SDR algorithm. For example, the nonlinearity coefficients, a2, will be adjusted using the Engineering Packet Editor to produce alternate SDRs, and this process will be iterated until there is agreement between all nine FOVs in all spectral bands and optimal agreement is found with external validation datasets such as AIRS and IASI.

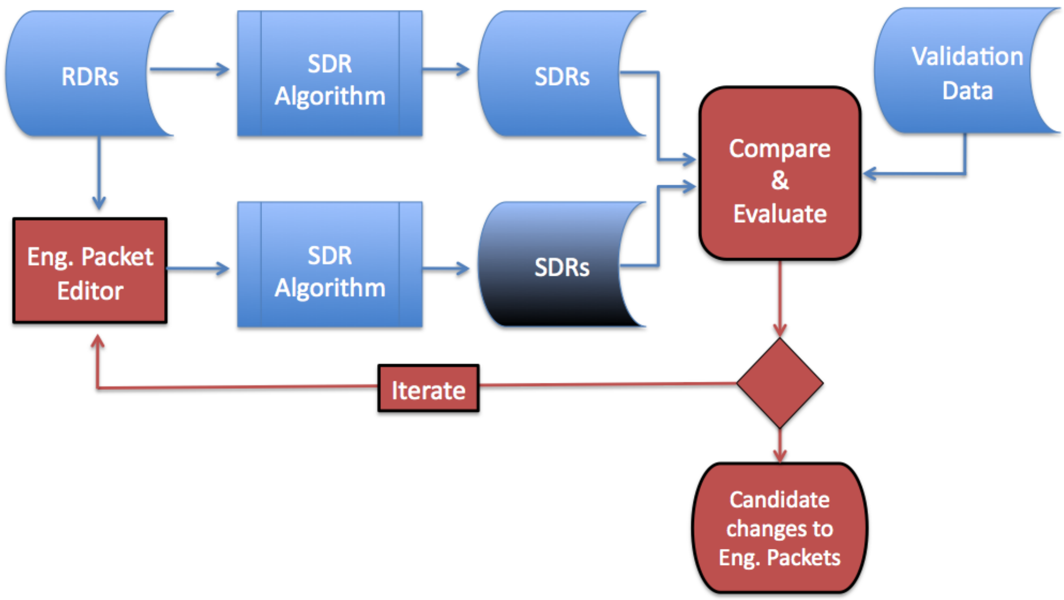

Figure 40 CrIS Sensor Checkout Data Analysis Flow.

We are also developing an independent set of SDR analysis software for use in the post-launch cal/val phase. This software is based on developments during the CrIS TVAC analysis phase and also follows the basic FTS processing flow that we have used for all of our in-house calibration efforts including those for HIS, AERI, Scanning-HIS, NAST-I, GIFTS, etc. The basic flow is shown in Figure 41. This software package will aid us in performing many of the SDR cal/val tasks listed above, and will also serve as an independent check on the official implementation of the SDR algorithm.

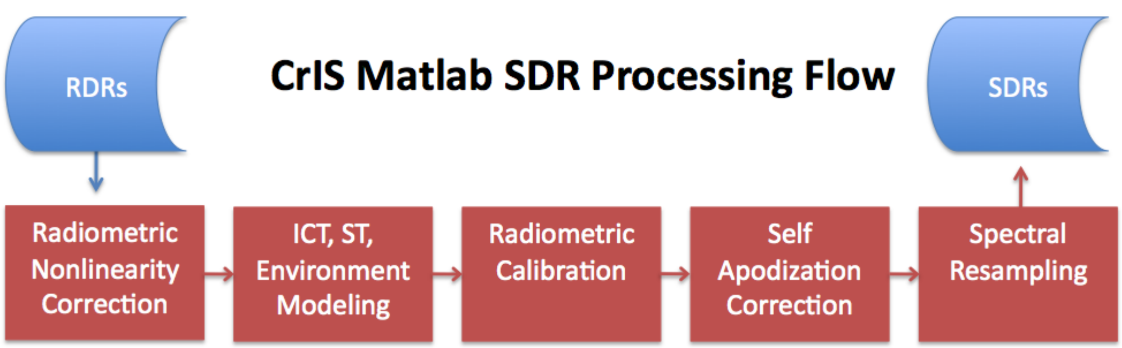

Figure 41 UW-Madison CrIS SDR Calibration code/flow.

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Gunshor, Mathew M.; Tobin, D.; Schmit, T. J. and Menzel, W. P., 2010: Intercalibration activities at CIMSS in preparation for the GOES-R era. Annual Symposium on Future National Operational Environmental Satellite Systems - NPOESS and GOES-R, 6th, Atlanta, GA, 17-21 January 2010. Proceedings. American Meteorological Society, Boston, MA, 2010, Manuscript not available for publication.

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VIIRS-CrIS Radiance Intercomparison and Validation

CIMSS Personnel: Dave Tobin, Greg Quinn, Steve Dutcher, Chris Moeller
Federal Collaborators: Yong Han, Dave Starr
Funded by: JPSS

Project Description
It is the intent of this work to perform studies with CrIS and IASI high spectral resolution measurements to create highly accurate comparisons with VIIRS broadband sensor observations. AIRS and MODIS measurements will be used as surrogates. IASI intercomparisons with Aqua and Terra MODIS will also be used as surrogates for IASI/VIIRS intercomparisons that will be performed initially after NPP launch. 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 proposed activities include:
- Intercomparing IASI and Aqua MODIS and IASI and Terra MODIS to simulate IASI/VIIRS post-launch processing,
- Intercomparing IASI and HIRS measurements from METOP and studying the effects of suggested spectral shifts on HIRS cloud products.,
- Intercomparing VIIRS and CrIS and studying the effects of suggested spectral shifts on HIRS cloud products and TPW, and
- Paying special attention to VIIRS IRW cold scene behavior and any impact on cloud products.

Summary of Accomplishments and Findings
In previous years the impact of spectral shifts in MODIS bands 34, 35, and 36 on the cloud top pressure product were determined. More high thin clouds and fewer low opaque clouds were found. CALIOP was used to confirm this MODIS cloud product improvement. The impact of AIRS derived spectral shifts on the Aqua MODIS water vapor bands and associated products was also investigated.

A major accomplishment regarding this work is the incorporation of the AIRS-derived MODIS SRF spectral shifts into the MODIS Collection 6 processing software and datasets. This is described in a paper in preparation (Baum et al., 2011)

Our most recent efforts have focused on the intercomparison of IASI and MODIS radiances. For VIIRS, one of the most useful evaluation analyses that will be performed soon after launch is the intercomparison of VIIRS infrared radiance observations with METOP-A IASI observations for Simultaneous Nadir Overpass (SNO) conditions. To prepare for this analysis and for its own merit for MODIS, we have conducted MODIS/IASI SNO analyses, which exercises the same methodology and code. Using techniques developed previously for SNOs and Aqua AIRS/MODIS evaluations, here we present some initial results of evaluating both Terra and Aqua MODIS using SNO based comparisons with METOP-A IASI. Based on evaluations of IASI using numerous techniques, IASI is an excellent reference for evaluating MODIS. Particularly regarding previous evaluations using AIRS, a so-called “convolution correction” to account for spectral gaps, is not required for IASI due to its continuous spectral coverage.

The approach used for these initial evaluations is to determine the exact nadir crossings of the Aqua and METOP-A and Terra and METOP-A platforms. Criteria for spatial and temporal “simultaneity” are then defined and mean MODIS and IASI spectra are computed for each SNO. Data within calendar year 2009 are included for approximately 3500 cases. Nominal (i.e., not spectrally shifted) detector averaged MODIS SRFs are used for this analysis. Results for all IR bands are shown below. The Figure 42 shows mean differences between Terra MODIS and IASI and Aqua MODIS and IASI using SNOs from 2009. Also shown is the difference between Terra MODIS and Aqua MODIS. For the longwave CO2 bands, the result here using IASI to assess Aqua MODIS is very similar to the result obtained using AIRS to assess Aqua MODIS. This analysis using IASI also shows very good agreement between Terra and Aqua MODIS for the longwave CO2 bands.

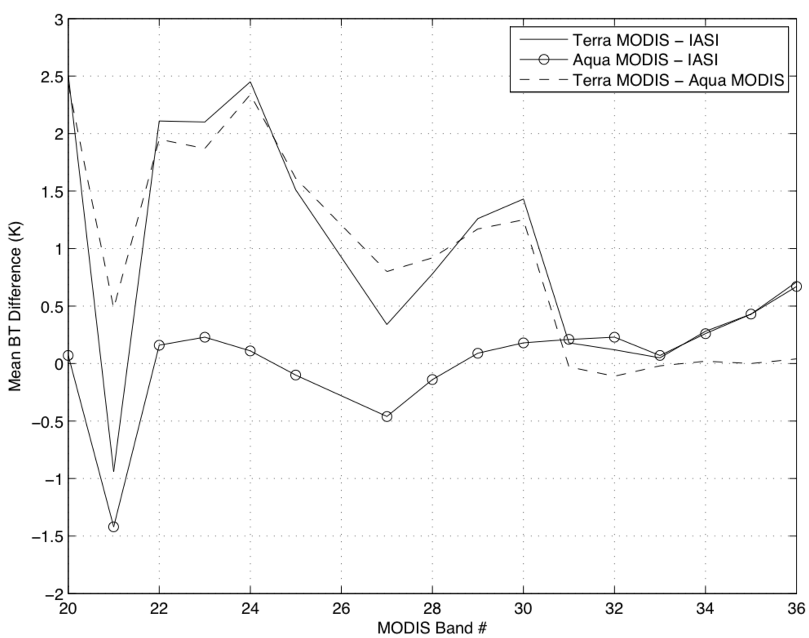

Figure 42 Analysis of Aqua and Terra MODIS version 5 using SNOs with IASI.

Publications and Conference Reports

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VIIRS Polar Winds

CIMSS Personnel: Dave Santek and Chris Velden
Federal Collaborator: Jeff Key
Funded by: NOAA PSDI

Project Description
Fully automated cloud-drift wind production from GOES became operational in 1996, and wind vectors are routinely used in operational numerical models of the National Centers for Environmental Prediction (NCEP) and other numerical weather prediction (NWP) centers. Winds over the polar regions have been generated with the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra and Aqua satellites and the Advanced Very High Resolution Radiometer (AVHRR) on NOAA satellites at CIMSS since 2001, and by NESDIS operations since 2005 (MODIS) and later (AVHRR). MODIS and AVHRR winds are also generated at four direct broadcast/readout sites in the Arctic and two in the Antarctic. Polar wind products are:

Sensor	Satellites	NESDIS ops	CIMSS	DB sites
MODIS	Terra, Aqua	✓	✓	✓ (4)
MODIS	Terra + Aqua (combined)		✓	
AVHRR	NOAA-16, -17, -18, -19	✓	✓	✓ (2)
AVHRR	Metop-A	✓	✓	
GEO + LEO*	Various		✓	

*The composite GEO/LEO winds are described in a separate project summary.

An example is shown in Figure 43. MODIS and AVHRR polar wind products are used operationally by 12 NWP centers in eight countries.

In preparation for the NPOESS Preparatory Project (NPP) satellite and the future Joint Polar Satellite System (JPSS), this project will adapt the MODIS and AVHRR polar winds algorithm for use with the Visible/Infrared Imager/Radiometer Suite (VIIRS) instrument. The MODIS and AVHRR infrared window (IR) channels serve as proxy data for VIIRS, given that VIIRS will not have a water vapor channel. The spatial resolution of VIIRS is higher than that of MODIS and AVHRR, at 750 m pixels compared to 1 km for the IR window channels. We do not anticipate that the improved spatial resolution of VIIRS will add to product quality, as earlier studies have indicated that remapping to a 2 km equal-area grid provides the best compromise between computational efficiency and accuracy of the derived product.

A significant effort is being devoted to changing the wind retrieval code base. We have decided to employ the code developed for the GOES-R Advanced Baseline Imager (ABI), which has some fundamental differences from our traditional procedure. Most importantly, cloud-drift wind heights are determined by using an externally generated cloud height product rather than internal routines.

Publications/Conference Presentations
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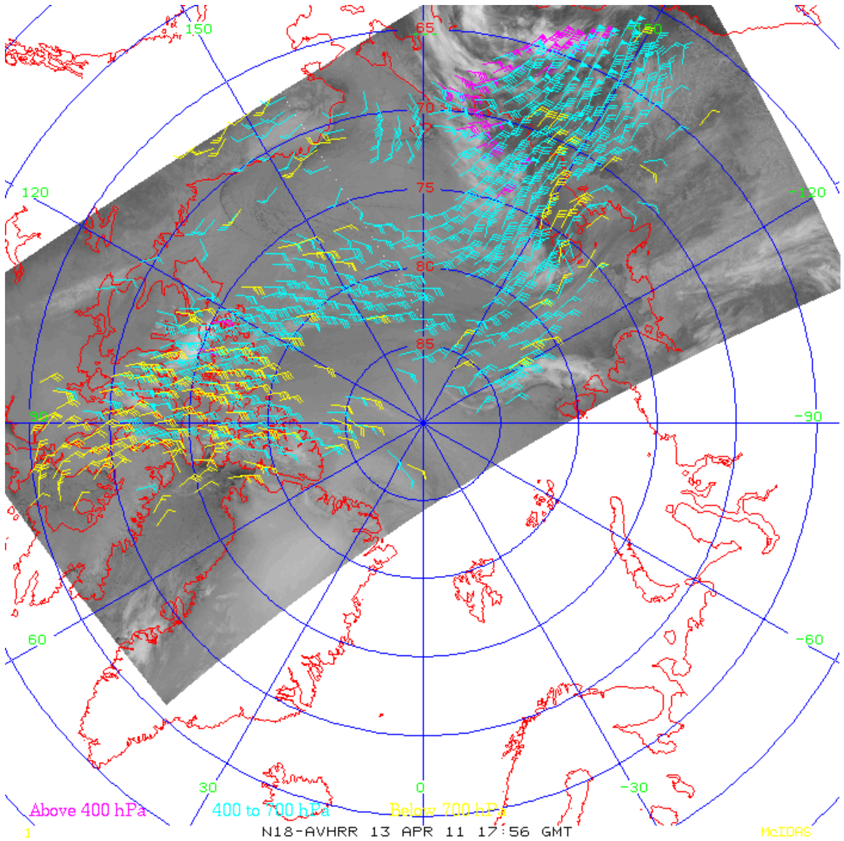

Figure 43 Polar winds from AVHRR HRPT (direct readout) data collected at Barrow, Alaska, on 13 April 2011. The AVHRR data are 1 km at nadir, remapped to 2 km.

NPP VIIRS Performance Characterization and Assessment

CIMSS Personnel: Chris Moeller, Dan LaPorte, W. Paul Menzel
Funded by: NASA, IPO

Project Description

The University of Wisconsin-Madison is participating in the pre-launch characterization and post-launch evaluation of the NPP VIIRS instrument performance. UW-Madison's activity on the VIIRS government team began in 2003, including a leading role in the spectral characterization of Flight 1 (F1), on-site participation in F1 pre-launch test program and performance evaluation, participation in the development of the post-launch Cal/Val task network, and planning for F2 and beyond. In the past year as the government team POC on spectral characterization, Wisconsin has been heavily focused in leading the government team effort to characterize the VIIRS F1 spectral performance through analysis and review of pre-launch test data both at the sensor and spacecraft level. Wisconsin is also participating in other aspects of hardware component and system performance, performance specification compliance, performance anomaly detection and mitigation, and product algorithm evaluation. These efforts are continuing towards the launch of NPP, planned for Fall 2011, and into the post-launch intensive Cal/Val (ICV) effort and beyond.

Personnel on this project are active on the VIIRS government and JPSS SDR teams, and interact with industry elements (Raytheon Corporation, Northrop Grumman) of the NPP program.

Summary of Accomplishments and Findings

Important accomplishments of the previous year include the development and release of government team relative spectral response (RSR) from both the sensor level and spacecraft level pre-launch test program for VIIRS F1 (Figure 44). This effort was led by UW-Madison and included government team elements from NASA, Aerospace Corp. and Lincoln Labs/MIT. These accomplishments support the government team's objective of independently assessing all aspects of F1 performance before launch of NPP.

- Differences exist between industry and government team RSR products. The impact on VIIRS science products will be evaluated by other components of the government team.
- Non-compliances in integrated out-of-band performance for VIIRS bands are confirmed. The impact of these non-compliances on science products is generally felt to be small but is the subject of ongoing investigation by other elements of the government team.
- Band averaged SNR is an effective metric for discriminating "real" from noise-driven response. SNR filter thresholds were applied and fine tuned for the RSR of each band.
- Spacecraft level VisNIR RSR measurements using flood illumination were useful in guiding the interpretation of sensor level VisNIR RSR features.
- Bands M9 and M13 RSR are affected by ambient atmospheric absorption in the test laboratory. Mitigation of these influences is beneficial to the RSR of these bands.
- Spacecraft level RSR have confirmed the existence of optical and electronic cross talk in the VIIRS VisNIR bands and contributed towards the characterization of its behavior.
- Spacecraft level RSR eliminated the influence of source polarization on the VisNIR band RSR characterization, an important clarification of VisNIR band on-orbit performance.
- Spacecraft level RSR have been adopted by industry to supplement their RSR analysis.

- This effort has resulted in the Sept. 2010 release of government team "best" *sensor level* RSR (all bands except DNB), and the May 2011 release of government team "best" *spacecraft level* RSR (VisNIR bands only). These RSR are available to the science community in the public domain (http://www.star.nesdis.noaa.gov/star/jpss).

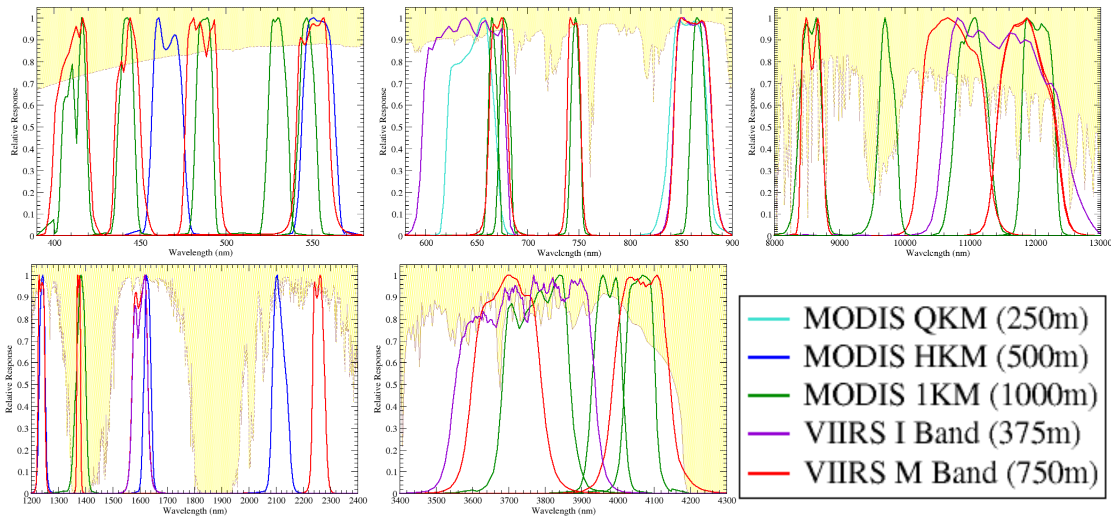

Figure 44 Government team "best" sensor level in-band Relative Spectral Response (RSR) for VIIRS Flight 1 instrument, shown with Aqua MODIS RSR. The VIIRS government team independently derived VIIRS RSR to verify industry RSR specification compliance, as well as to improve the RSR information content. Color coded legend applies to all panels. Model based atmospheric extinction is represented by the yellow background of each panel.

Publications/Conference Presentations

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NPP/NPOESS Cryospheric Products Calibration & Validation Activities

CIMSS Personnel: Yinghui Liu and Xuanji Wang
Federal Collaborator: Jeff Key
Funded by: NOAA

Project Description
The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) (launch expected in 2011) and afternoon overpass JPSS satellites (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 cryosphere products, including Environmental Data Records (EDRs), Application Required Products (ARPs) and Intermediate Products (IPs). The purpose of this project is to evaluate the accuracy of VIIRS algorithms for snow and ice products, increase our understanding of their limitations, and suggest improvements where appropriate. The project is reducing risk and assuring a successful transition from current polar orbiting operational environmental satellites to the future systems. 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.

Validation data sets have been acquired. These datasets include AVHRR-derived surface temperature, NCEP reanalysis (surface temperature), buoy observations from the International Arctic Buoy Programme (surface temperature), AMSR-E passive microwave imagery for ice concentration and extent, National Ice Center charts, high spatial resolution data from Landsat, upward-looking submarine sonar from Scientific Ice Expeditions (SCICEX), in situ ice thickness and on-ice snow depth measurements from the Canadian Ice Service, and ice draft data from the Beaufort Gyre Exploration Project. Validation data sets also include products generated with our own algorithms: ice age, thickness (One-dimensional Thermodynamic Ice Model (OTIM), Wang et al., 2010), surface temperature data, and ice concentration. These products have been validated with collocated in situ observations and other satellite observations. Results show high accuracy and high precision of these products. These products are ready to be compared to NPP/JPSS products using the VIIRS proxy data from Land PEATE.

MODIS swath data has been acquired corresponding to dates used by Northrop Grumman (NG), which developed the algorithm for NPP/JPSS. In-house algorithms have been applied on these swath data to produce ice surface temperature, ice cover and concentration, ice thickness and ice age. Products from NG and from our own algorithm have been compared (Figure 45).

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

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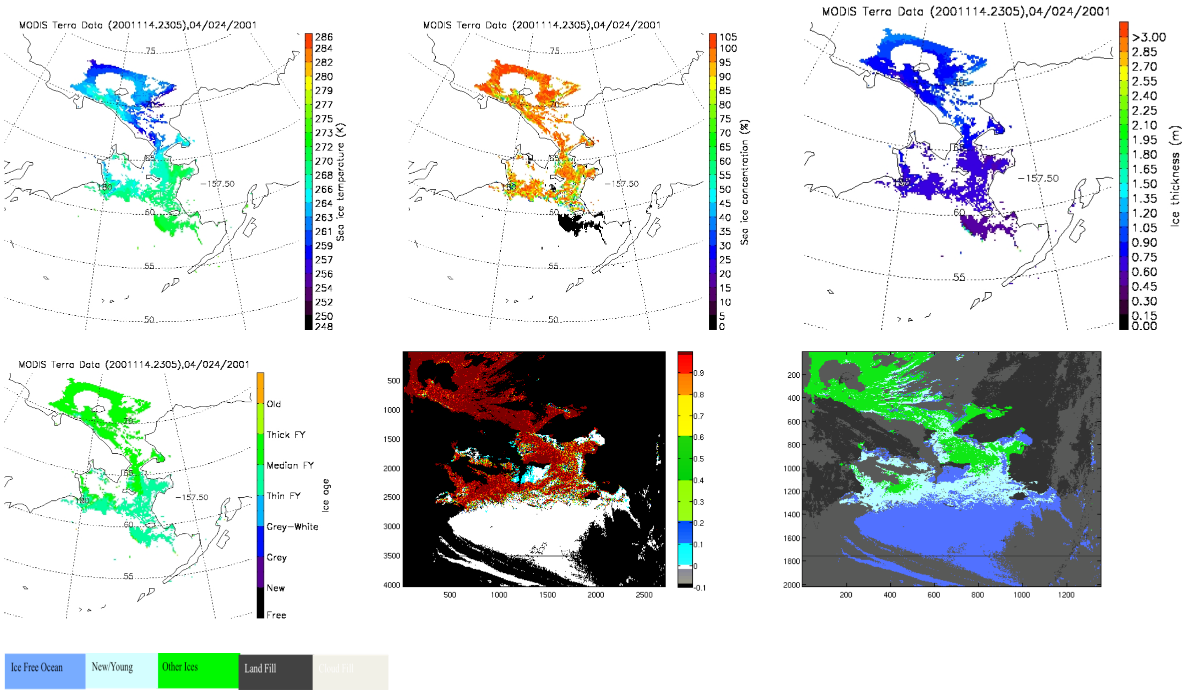


Figure 45 Sea ice surface temperature, concentration, thickness (top panel, left to right), and age (left bottom panel) from our own algorithm OTIM, and sea ice concentration and age (middle and right bottom panel) from NG.

NPP/JPSS Direct Broadcast Support

CIMSS Personnel: Allen Huang (PI), Liam Gumley (Co-I/PM), Geoff Cureton, Ray Garcia, Graeme Martin, Nadia Smith, Kathy Strabala
Federal Collaborator: Richard Ullman
Funded by: Joint Polar Satellite System Program Office, Data Products Engineering Group

CIMSS/SSEC is adapting existing IDPS PRO SDR and EDR algorithms to operate in a Linux environment for processing NPP direct broadcast data in real-time. The goal is to create a freely available, open source, easy to install, and flexible software package to support the use of NPP by the global direct broadcast community.

In 2010, planning commenced at SSEC for the procurement and installation of a new polar orbiter direct broadcast reception system. While the existing X-band antenna at SSEC remains fully operational for receiving data from Terra and Aqua, it is not capable of receiving data from NPP and future polar orbiting satellites that are of interest to CIMSS/SSEC. With this in mind, CIMSS/SSEC prepared a set of requirements for a dual X/L-band receiving system with a reflector diameter of approximately 2.4 meters, and the appropriate feeds, demodulators, and associated hardware to allow direct reception of Level 0 data from Terra, Aqua, NPP, JPSS-1, POES, Metop, FY-1D, FY-3A, and FY-3B. A request for bids was released in March 2011, and the successful bidder was Orbital Systems of Dallas, Texas. A site location surveys was conducted, and the Engineering Research Building on the UW-Madison campus was selected as the site for the new antenna. Installation is expected in the summer of 2011.

Virtual Appliance technology for direct broadcast applications continued to be improved and enhanced with the addition of several new features to the IMAPP Virtual Appliance (VA). The IMAPP VA is a prototype of the processing system that will be released by CIMSS/SSEC to support NPP/JPSS direct broadcast users. New features added to the IMAPP VA included:

- MODISL1DB updated to version 1.7. This new version of the MODIS geolocation and calibration software fixes a persistent problem with direct broadcast processing, where invalid geolocation data are created for large vertical stripes in a DB pass. This also brings DB users into line with the latest MODIS calibration lookup table updates being used operationally by NASA.
- SeaDAS updated to version 6.2. This brings the MODIS Level 2 ocean product generation algorithms up to date with the latest versions being used by NASA.
- User defined processing was added to the IMAPP VA. This feature allows a user to easily add their own locally developed algorithm to the VA processing system. This feature was demonstrated by the CIMSS/SSEC Volcanic Ash team, when they deployed the IMAPP VA on their own Linux system to process MODIS direct broadcast data from Alaska. The MODIS Volcanic Ash retrieval software was incorporated into the VA processing system in less than a day, and is now supporting GOES-R Proving Ground activities.

The JPSS Common Ground System Algorithm Development Library (ADL) version 2.0 was received at CIMSS/SSEC in Dec. 2010. Developed by Raytheon, ADL is an environment that allows NPP/JPSS IDPS PRO operational algorithms to run on little-endian Linux platforms outside the IDPS environment. The algorithms in ADL (limited to VIIRS and ATMS in ADL v2.0) are exactly the same as the algorithms running in IDPS, since ADL and IDPS share a common source code management system. CIMSS/SSEC has started examining ADL to determine what features will need to be added to make it compatible with real-time NPP direct broadcast processing. Some of the efforts currently underway to enable DB support in ADL include:

- Testing the package on free Linux distributions (e.g., CentOS, Fedora, Ubuntu);
- Automating the ADL installation and build process;
- Creating specifications and a design for a VIIRS SDR granule aggregator (by time and band);
- Creating Python scripts for ingesting and decoding binary BLOB files;
- Creating Python scripts for visualizing VIIRS and CrIS RDR, SDR, EDR, IP, and ancillary data;
- Designing prototypes for simple algorithm chaining that do not require additional complicated software systems, such as SQL databases, XML files, or Java code; and
- Creating specifications and a design for an ancillary data ingestor and preprocessor for ADL that does not require the IDPS Ingest subsystem.

In order to support real-time true color image creation from VIIRS, MODIS, and MERSI, CIMSS/SSEC has developed a Multi-sensor Image Processing System (MIPS). This system allows a user to create high resolution (up to 250 meters/pixel) imagery over user-specified regions in real-time from MODIS, MERSI, and in the coming months VIIRS. It is designed to be simple to install, configure, and operate in automated mode, and image products are created in JPEG, GeoTIFF, and KML. The system runs on Intel Linux host computers, and all source code is included and freely available. Public release of the first version of MIPS is expected in Q3 2011.

Figure 46 Orbital Systems 2.4 meter X/L band antenna System of the type to be installed at SSEC.

Algorithm Development Library

CIMSS Personnel: Liam Gumley (PI), Scott Mindock (PM), Geoff Cureton, Ray Garcia, Graeme Martin, Kathy Strabala
Federal Collaborators: Richard Ullman, Richard Cember, Paul Meade
Funded by: Joint Polar Satellite System Program Office, Data Products Engineering Group

The Algorithm Development Library (ADL) was developed by Raytheon (starting in 2009) at the direction of the NPOESS Integrated Program Office to provide a framework for developing and testing NPP/NPOESS IDPS algorithms outside the operational IDPS environment. ADL simulates the interfaces from IDPS SDR and EDR algorithms to other IDPS subsystems to allow the algorithms to receive input data, process, and save output data without requiring changes to the algorithm source code. ADL is also intended to allow algorithm developers and maintainers to more easily make changes to the algorithm code and then send the code back to the operational IDPS without requiring a “Sci to Ops” conversion process.

CIMSS/SSEC is a member of the ADL Team in cooperation with the JPSS Program Office and Raytheon, and contributes to the following specific areas of the ADL effort:

1. Porting of additional algorithms to ADL;
2. Adapting ADL ported algorithms to work in NPP Direct Broadcast mode;
3. Testing algorithms ported to ADL by other parties including Raytheon;
4. Providing ADL distribution, installation, and operation support to end users (including the NPP Direct Broadcast community); and
5. Providing ADL training to end users.

CIMSS/SSEC received the ADL version 2.0 distribution from Raytheon in December, 2010. SSEC created and published a Web site for authorized users to download the ADL package and associated data files and documentation, now available at https://jpss.ssec.wisc.edu/adl/. In addition, SSEC created a user forum for the ADL user group, now available at https://forums.ssec.wisc.edu/viewforum.php?f=23. The forum is a resource for the ADL user community to interact and share the experiences with installing and using ADL.

The CIMSS/SSEC ADL team built the ADL v2.0 package from source code using the instructions supplied by Raytheon. A variety of Linux host platforms, operating systems, and compilers were used. It was found that the ADL install and build process could be somewhat complicated for those who are not Linux experts, due to the multiple prerequisite software packages needed by ADL. In order to simplify and automate the build process, bash scripts were created to:

- Download all required prerequisite software,
- Build all required prerequisite software,
- Build the ADL software,
- Configure the ADL environment,
- Download and install the ADL v2.0 test data, and
- Execute the ADL v2.0 test suite.

These scripts make it much easier for an end user to install ADL, and they are now provided in the download area of the CIMSS/SSEC ADL Web site.

To support users of ADL who (a) do not have a Linux system, (b) do not have the necessary permissions to install the required prerequisite software on their Linux computer, or (c) find it more convenient to use a Windows or Apple computer as their environment for running ADL, CIMSS/SSEC has developed and released an ADL Virtual Appliance (VA). The ADL VA is implemented in the form of a VMware virtual machine running Fedora Linux v14 64-bit. Inside the VA, ADL and all the prerequisite software have been installed and are ready to run. The user simply needs to:

- Run a script to download and install the ADL v2.0 test data, and
- Run a script to execute the ADL v2.0 test suite.

The ADL VA is supported on Microsoft Windows 7, Vista, and XP; Apple OS X, and Intel Linux host platforms. The freely available VMware Player application is required to run the ADL VA on Windows and Linux, while VMware Fusion is required on Apple platforms. If the ADL VA user wishes to run the VIIRS RDR/SDR algorithms, then at least 6GB of RAM must be available to the ADL VA. The ADL VA has been tested on Windows platforms by users at NOAA and the JPSS project. It has proven to be a very successful way for users to quickly install and run the ADL v2.0 system in a complete development environment, where they can learn about and experiment with the IDPS PRO algorithms.

CIMSS/SSEC is providing all locally-developed ADL resources via the ADL Web site and ADL forum, and via an in-house ADL groups on the CIMSS/SSEC groups server. CIMSS/SSEC has also provided support to a number of ADL users at NOAA on issues related to ADL installation.

CIMSS/SSEC has created a set of requirements and specifications for real-time ingest and preprocessing of the ancillary data required by the algorithms in ADL. Applying experience developed over the last 10 years in supporting real-time users of MODIS algorithms in IMAPP, CIMSS/SSEC is designing a system that will:

- automatically determine the date and time of the granule being processed in ADL,
- check the local disk for the required native format ancillary data,
- download the required native format ancillary data if required from a SSEC HTTP or FTP site,
- preprocess the native format ancillary data into the format required by ADL,
- invoke ADL gridding and/or granulation processing, and
- supply the processed ancillary data to the science algorithm.

CIMSS/SSEC is developing the workflow necessary to run VIIRS SDR and EDR algorithms in ADL using alternative input data (i.e., other than the test data supplied by Raytheon). The goal of this effort is to allow an ADL end user to ingest VIIRS data from CLASS, SD3E, or Direct Broadcast, and to process it on their local system with automatic discovery and download of the required ancillary data, and output of all products in standard IDPS HDF5 format.

SSEC hosted a meeting of the ADL team at UW-Madison in January 2011.

Cloud Property Determination, Sounding Studies, and Multi- and Hyper-spectral Visualizations

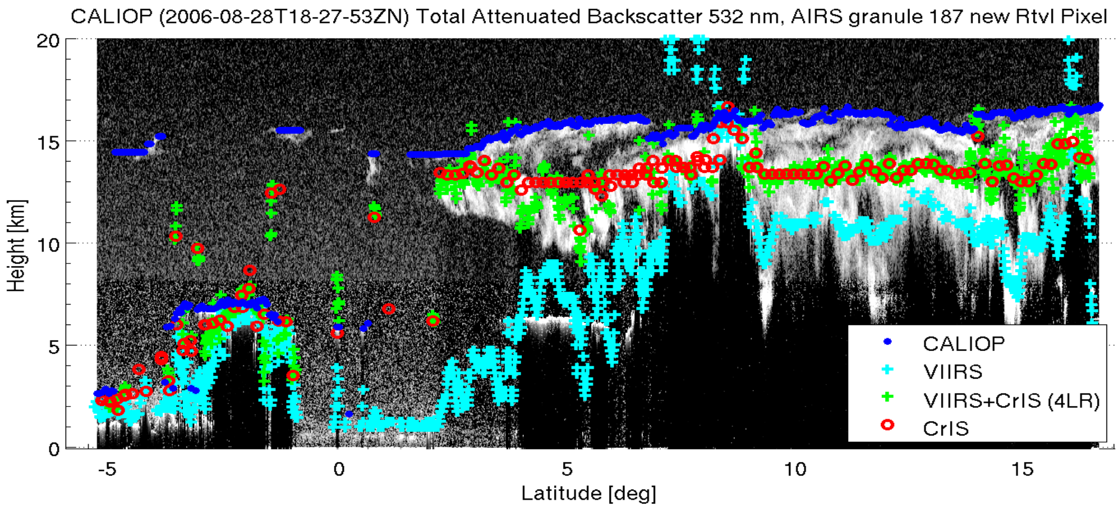
CIMSS Personnel: Eva Borbas, Youri Plokhenko, Tom Rink, Tommy Jasmin, Jun Li and W. Paul Menzel
Funded by: IPO

Project Description
Data and products from MODIS, AIRS and AMSU are being used as proxy for VIIRS, CrIS, and ATMS sensor capabilities to test algorithms that will produce the required JPSS EDRs. This work includes sensor inter-calibration studies, cloud property algorithm mitigation for absence of VIIRS IR opaque channels, multi-sensor profile retrieval studies, and visualization tool development. The goal is to reduce risk and assure successful transition from the current polar orbiting operational environmental satellites to the future NPOESS.

Accomplishments
- Estimating Cloud Top Pressure with VIIRS plus CrIS
- Estimating Cloud profiles form AIRS measurements
- Developing McIDAS-V/HDRA visualization tools for interrogation of multispectral data

Estimating Cloud Top Pressure with VIIRS
The VIIRS+CrIS (represented by MODIS+AIRS) combined cloud top pressures (CTP) were derived by two methods: (1) the 4-layer lapse rate (4LR) method using band 31, and (2) the 3-band Merging Gradient (3MG) approach using bands 29, 31 and 32. Recently the AIRS CTP retrievals (Weisz et al., 2010) were improved by including cloudy as well as clear temperature and moisture profile retrievals in the training data set. The effect of the resulting new AIRS CTPs (at 13.5 km resolution nadir) was investigated.

The focus of this work is to improve VIIRS detection and characterization of high, thin clouds at night time. Comparisons with CALIOP, since it is very sensitive to optically thin clouds, are used to indicate algorithm improvement. We estimate VIIRS-only CTH performance using a simplified IRW BT approach. The statistics (not shown) of the algorithm performance for granule 187 on 28 August 2006, the new AIRS CTH retrievals improve the VIIRS+CrIS 4LR bias (4.3 to 2.4 km) and standard deviation (2.8 to 2.3 km) significantly. The VIIRS+CrIS retrievals outperform the VIIRS only retrievals in bias (2.4 versus 3.9 km) and standard deviation (2.3 versus 6.4 km). Similar good results are evident in other granules as well. Figure 47 below shows the CTH comparison with CALIOP; VIIRS+CrIS corrects the VIIRS only CTH mistakes especially the high thin cloud between 3 and 5 N).



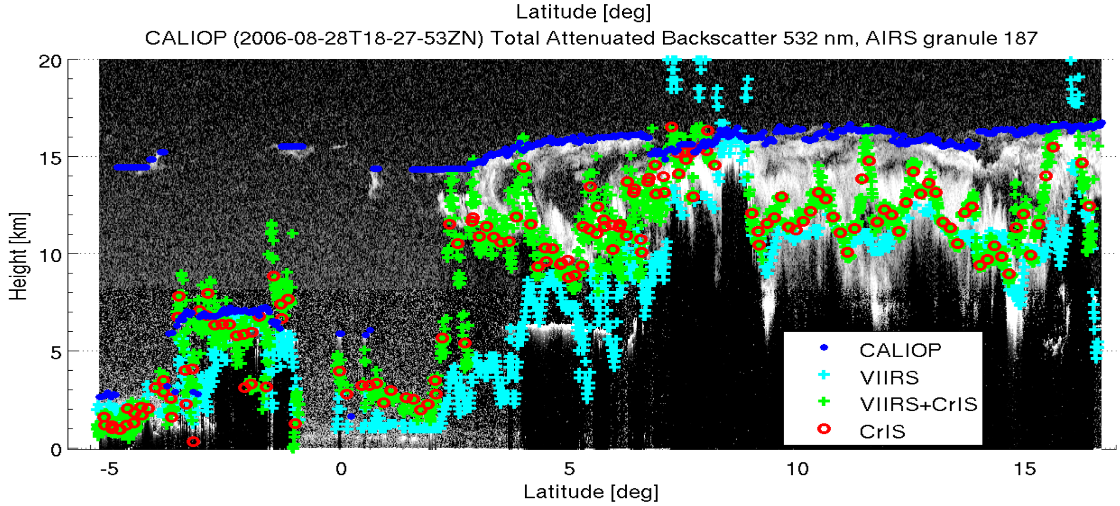


Figure 47 (top) Cross-section along the CloudSat/CALIPSO track for AIRS granule 187 (28 Aug 2006). CALIOP 532 nm total attenuated backscatter/km/steradian (grey background). Cloud Top Heights from CALIOP (blue), VIIRS-only CTH (cyan), VIIRS+CrIS CTH (3MG) (green, from MODIS+AIRS using Merging Gradient Approach), where the new AIRS CTP retrieval algorithm is used. (bottom) same as top figure except the old AIRS CTP retrieval algorithm is used to determine the CrIS CTP.

Combining CrIS and VIIRS for single footprint cloud-cleared radiance and cloud property products

The UW-Madison continued to study the use of one dimensional variational (1DVAR) methodology for cloud-top pressure retrieval. AIRS radiance measurements were used in the retrieval and the regression derived cloud parameters (Weisz et al., 2007) were used as the first guess in this iterative retrieval process. The retrieved results were evaluated by comparison with the operational MODIS cloud product and the active measurements from radar and lidar instruments onboard the EOS CloudSat and the CALIPSO) satellites. It was demonstrated that the 1DVAR algorithm can significantly improve the results over those from a statistical approach.

For AIRS granule 8 on 22 July 2006, retrieval results from the two algorithms are shown in Figure 48. Cloud boundaries from the CPR and CALIOP can be clearly observed in this figure. The regression retrieval seems less stable for the whole cloud system. However, the physical retrieval algorithm obtains more stable results. For the overlapping clouds the 1DVAR obtains results closer to the lower layer. Remote sensing multilayered clouds are one of the most challenging problems, especially when both layers are transparent.

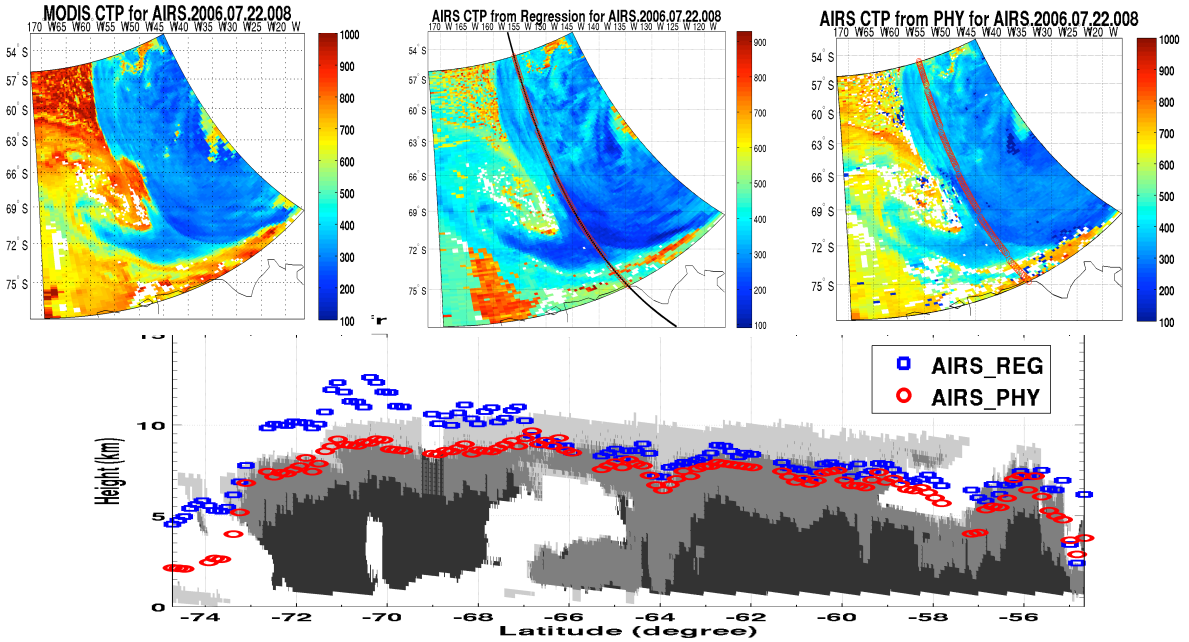


Figure 48 Comparison of AIRS cloud top height retrievals with MODIS, CPR and CALIOP for AIRS granule 008 on 22 July 2006: (top left) operational MODIS CTP (hPa); (top middle) AIRS regression CTP (hPa) and (top right) AIRS physical retrieval CTP. (bottom) Cloud detection from CPR (dark grey), CALIOP (light grey), and CTHs from AIRS regression (red) and physical (blue) retrievals.

Estimating Cloud Profiles from AIRS Measurements

AIRS IR hyperspectral measurements from 21 consecutive granules of 28 Aug 2006 were processed. Algorithms were tested for different surface and atmospheric conditions (over both polar areas with ice-snow low temperature surfaces and large atmospheric ozone spatial-temporal variability; over different land surfaces over Africa, Western Europe and Greenland with large scale spatial variability of atmospheric water vapor; over water surfaces). A first guess of the CO2 concentration is now calculated from a model that is a function of time year and location. Time interpolation of the first guess atmospheric state parameters estimated from numerical weather prediction models is pending. The number of cloud layers detected has been added as a new output parameter. Examples of the number of cloud layers detected and the total cloud absorption are shown in Figure 49. Good spatial continuity from fov to fov and orbit to orbit are found in the AIRS cloud profile product. The number of cloud layers shows structure not evident in the total cloud absorption (see for example the tropical cyclone located at 180 E and 20 N).

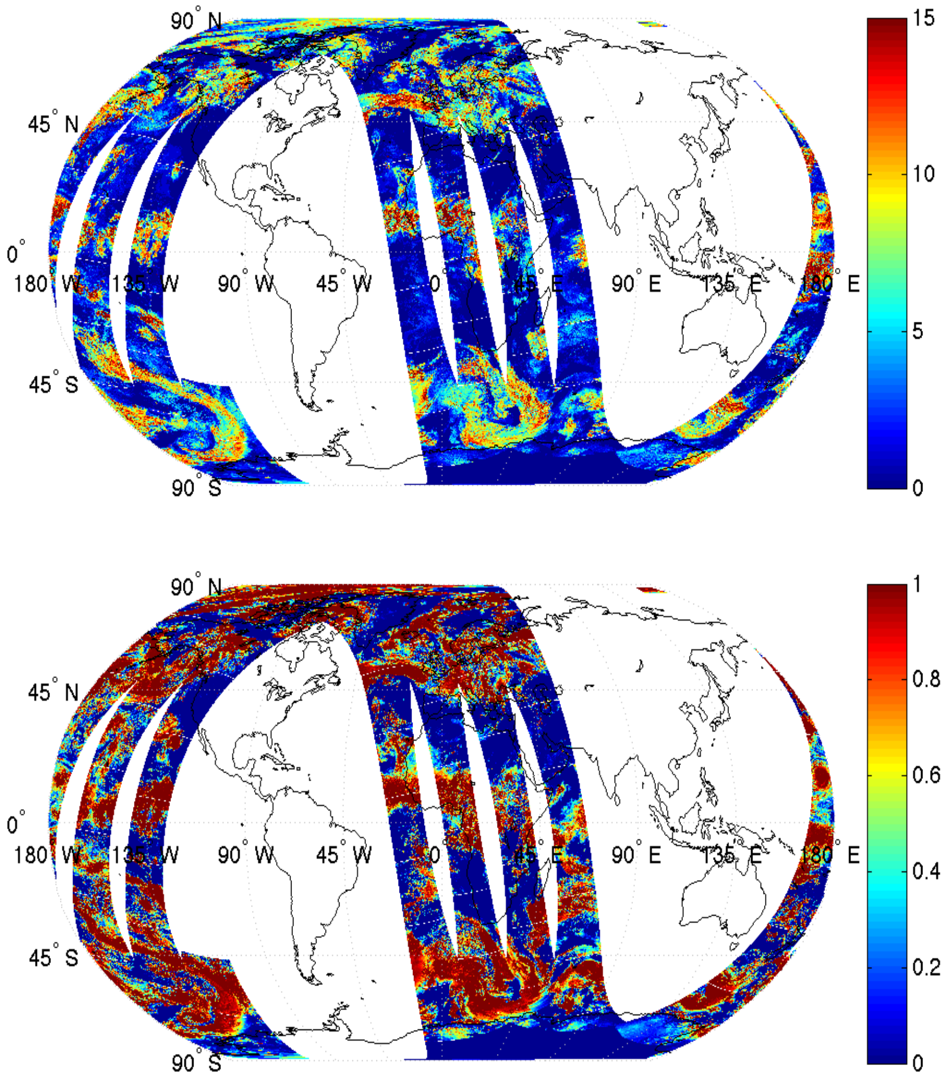


Figure 49 Cloud processing for 28 August 2006 showing (top) number of cloud layers detected and (bottom) total cloud absorption.

Visualization Tools

The ATMS and CrIS SDR proxy data has been intercorporated into the multi/hyper-spectral analysis and visualization component of McIDAS-V. Figure 50 shows four individual CrIS granules, from separate files, aggregated along the spacecraft polar track with the IFOVs reorganized to spatial coherence for display. The image depicts brightness temperature at 789.75 cm-1. The second figure below shows the CrIS long-wave spectra at the IFOV selected by the moveable probes in the main display. The spectra and pixel value readout update automatically while the user changes the probe's position in the display.

Considerable progress has been made to parse and analyze external XML metadata files and tie this metadata to the corresponding data file objects. In fact, the current set of metadata XML files for all of the JPSS proxy data are now carried along with McIDAS-V as a system resource. This means users will not have to retrieve the metadata files themselves, and possibly obtain the wrong file for a particular JPSS product.

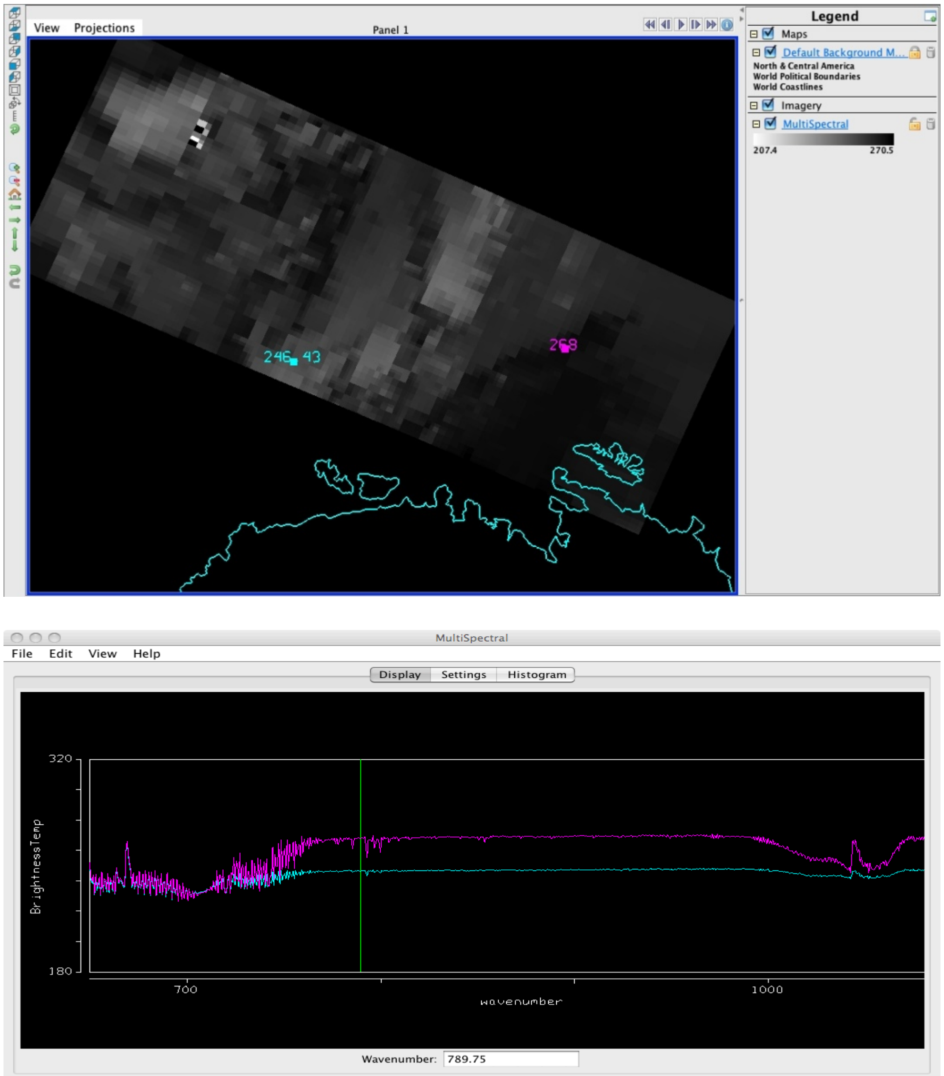


Figure 50 (top) Four individual CrIS granules of brightness temperature at 789.75 cm-1, from separate files, aggregated along the spacecraft polar track with the IFOVs reorganized to spatial coherence for display. (bottom) CrIS long-wave spectra at the IFOVs selected by the moveable probes (shown on top).

References/Presentations

Borbas, E.E., E. Weisz and W.P. Menzel, 2010: Estimation of the altitude of high thin clouds at night from VIIRS and CrIS. 2010 A-Train Symposium, New Orleans, LA, Oct 26-28, 2010. (Poster)

Tom Rink and Tommy Jasmin gave a software demonstration of NPP Data Visualization with McIDAS-V on IGARSS 30th, held in Honolulu, Hawaii 25-30 July 2010.

Li, J. et al., 2011: Improvement on the Cloud Top Height Retrieval from Hyperspectral Infrared Sounder Radiances. Submitted to *JAMC*.

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

CIMSS Personnel: James Jung
Federal Collaborators: John Derber, Chris Barnet
Funded by: NOAA/NESDIS/JCSDA

Project Description
The assimilation of infrared water vapor channels has always been problematic. Their multivariate and non-linear characteristics make them difficult to use. This is especially true for the hyperspectral instruments such as the Atmospheric Infrared Sounder (AIRS) and the Infrared Atmospheric Sounding Interferometer (IASI). We have developed a new assimilation technique which reduces the multivariate and non-linear assimilation problems. With this new assimilation technique and the use of AIRS and IASI water vapor radiances, adjustments to the model stratospheric specific humidity are also possible.

Several analysis and forecast improvements to the troposphere water vapor field have been identified by using our new assimilation technique. Significant improvements in the National Centers for Environmental Prediction (NCEP) Global Forecast System (GFS) model specific humidity comparison to rawinsondes are shown in Figure 51. The specific humidity Root-Mean-Square-Error (RMS) improvements to both the first guess and analysis are noted when compared to not using this technique (control). This figure shows both the bias (left) and RMS (right) model comparison to rawinsondes. The solid lines are the control, the dotted lines are the experiment. The prediction skill for water vapor is typically very short for the GFS and is usually less than 6 hours. This is confirmed in Figure 52a, where the 6 hour forecast already has roughly the same RMS error (comparison with rawinsondes) as the 12, 24, 36 and 48 hour forecast. The new water vapor assimilation technique has improved the skill to almost 12 hours as shown in Figure 52b where the RMS errors are much less at 6 hours than at 12, 24, 36, and 48.

Several improvements to the stratosphere water vapor field have also been identified by using our new assimilation technique. By assimilating the water vapor radiances from AIRS and IASI, which have sensitivities in the stratosphere, a reasonable estimation of the specific humidity in the stratosphere can be generated. An unexpected benefit of the stratospheric humidity is a reduction in the stratospheric temperature drift. Figure 53 is the GFS model comparison to rawinsonde temperatures in the stratosphere. In the control, Figure 53a, the temperature drift with time is observed in the bias. When the water vapor is assimilated in the stratosphere the temperature drift in the bias is greatly reduced (Figure 52b). The reduction in the temperature drift comes from the model radiation scheme having more reasonable moisture values to compute its heating and cooling rates.

Publications/Conference Presentations
Bi, L., J. A. Jung, M. C. Morgan, and J. F. Le Marshall, 2010: A Two-Season Impact Study of

the WindSat Surface Wind Retrievals in the NCEP Global Data Assimilation System., *Wea. and Forecasting*, **25**, 931-949.
Bi, L., J. A. Jung, M. C. Morgan, and J. F. Le Marshall, 2011: ASCAT Surface Wind Retrievals Impacts Study in the NCEP Global Data Assimilation System. *Accepted in Mon. Wea. Rev.*
Jung J. A., L. P. Riishojgaard, and J. F. Le Marshall 2010: Impacts of Assimilating Hyperspectral Infrared Water Vapor Channels in Numerical Weather Prediction. 17th Conference on Satellite Meteorology and Oceanography, Annapolis Maryland, 27 Sept – 1 Oct 2010.
Le Marshall, J. F., W. Smith, D. K. Zhou and J. A. Jung 2010: Improved Use of Ultraspectral Observations in Numerical Weather Prediction. Submitted to *Bull. Am. Meteorol. Soc.*

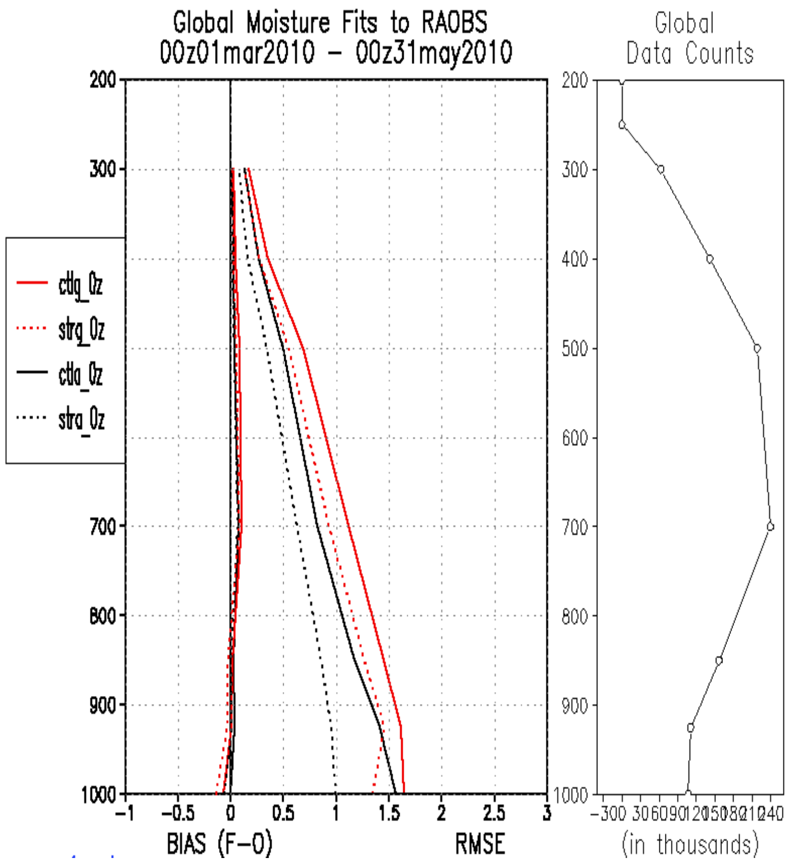


Figure 51 GFS model water vapor comparison to rawinsondes for March-April-May 2010. The solid lines are the control, the dotted lines are the experiment. Red is the first guess or 6 hour forecast, the black is the analysis. Note the experiment improvement in the analysis and first guess over the control.

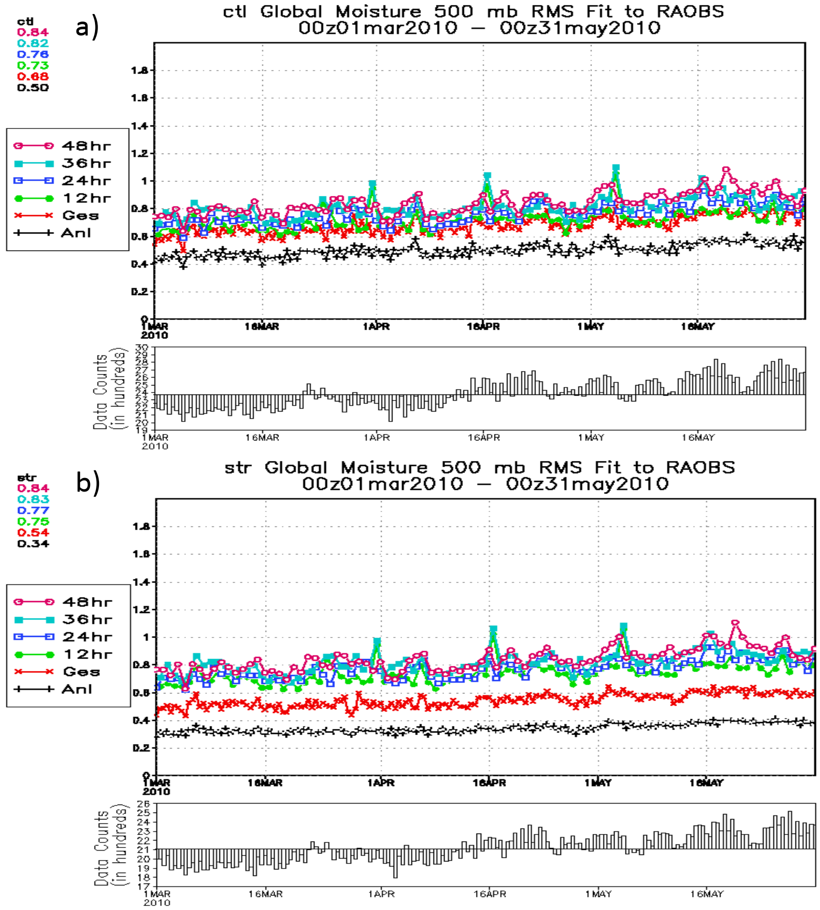


Figure 52 Time series of GFS model water vapor RMS compared to rawinsondes at 500 hPa for March-April-May 1010. a) is the control, b) is the water vapor assimilation experiment. Note the improvements in RMS for the analysis (black) and first guess (red).

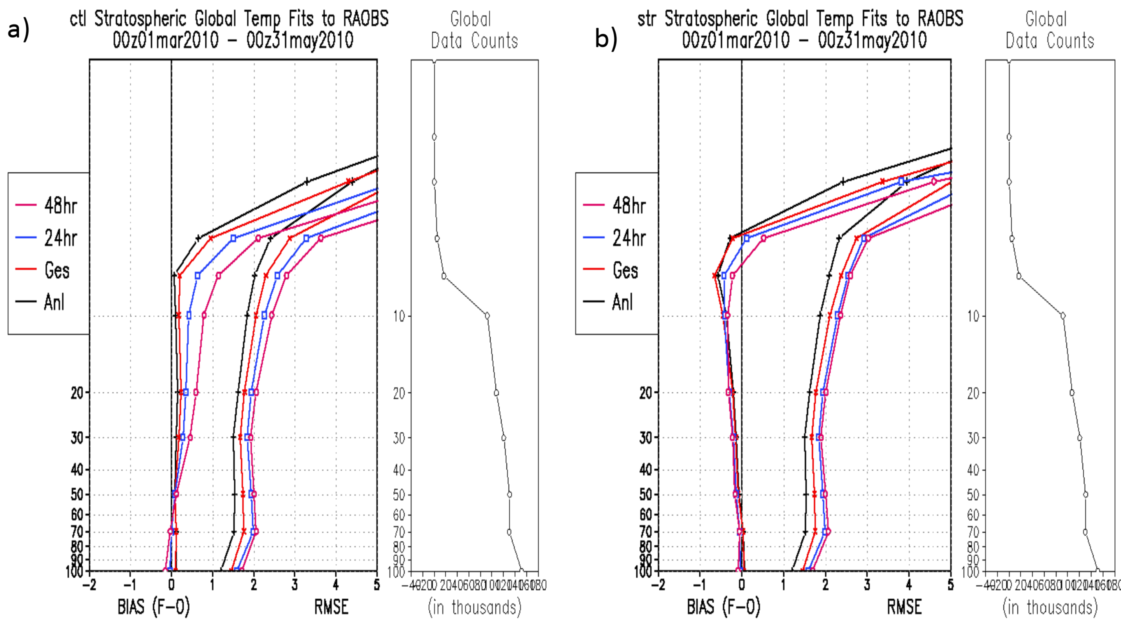


Figure 53 GFS model stratospheric temperature comparison to rawinsondes out to 48 hours for a) control and b) experiment for March-April-May 1020. Note the temperature drift in the bias with time from 50 to 10 hPa in the control (a) which is absent in the experiment (b)

Research in Support of Radiance Assimilation of Clouds and Precipitation

CIMSS Personnel: Tom Greenwald, Ralf Bennartz, Jim Davies
Federal Collaborators: Paul van Delst, Dave Groff, Quanhua Liu
Funded by: NOAA

Project Description

Project Description
Our goal is to provide support to certain components of NOAA's Cooperative Radiative Transfer Model (CRTM) that impact the assimilation of satellite radiance data in cloudy and precipitating regions, including radiative transfer (RT) solvers, single-scattering properties of ice and water particles, and cloud overlap.

Major Accomplishments

- Completed work on integrating the Successive Order of Interaction (SOI) RT solver, along with its tangent linear and adjoint models, into the CRTM, as well as testing the accuracy of these models.
- Developed a candidate scattering index or indicator for providing a quantitative measure of the degree of scattering in a given cloud/precipitation profile in order to determine ahead of time the angular resolution needed for the RT solver to provide a reasonably accurate solution. Figure 54 shows that for this particular case, a 2-stream solution can provide sufficient accuracy for values of the scattering index up to about 2 x 10^{-2} within the IR spectrum.

Publications/Conference Presentations

Greenwald, T., R. Bennartz, D. Groff, J. Davies, and P. van Delst, 2011: Modifications to scattering radiative transfer in the CRTM. Joint Center for Satellite Data Assimilation 9th Workshop on Satellite Data Assimilation, University of Maryland, College Park, MD, 24-25 May.

Kulie, M., R. Bennartz, T. Greenwald, Y. Chen, and F. Weng, 2010: Uncertainties in microwave properties of frozen precipitation: Implications for remote sensing and data assimilation. *J. Atmos. Sci.*, **67**, 3471-3487.

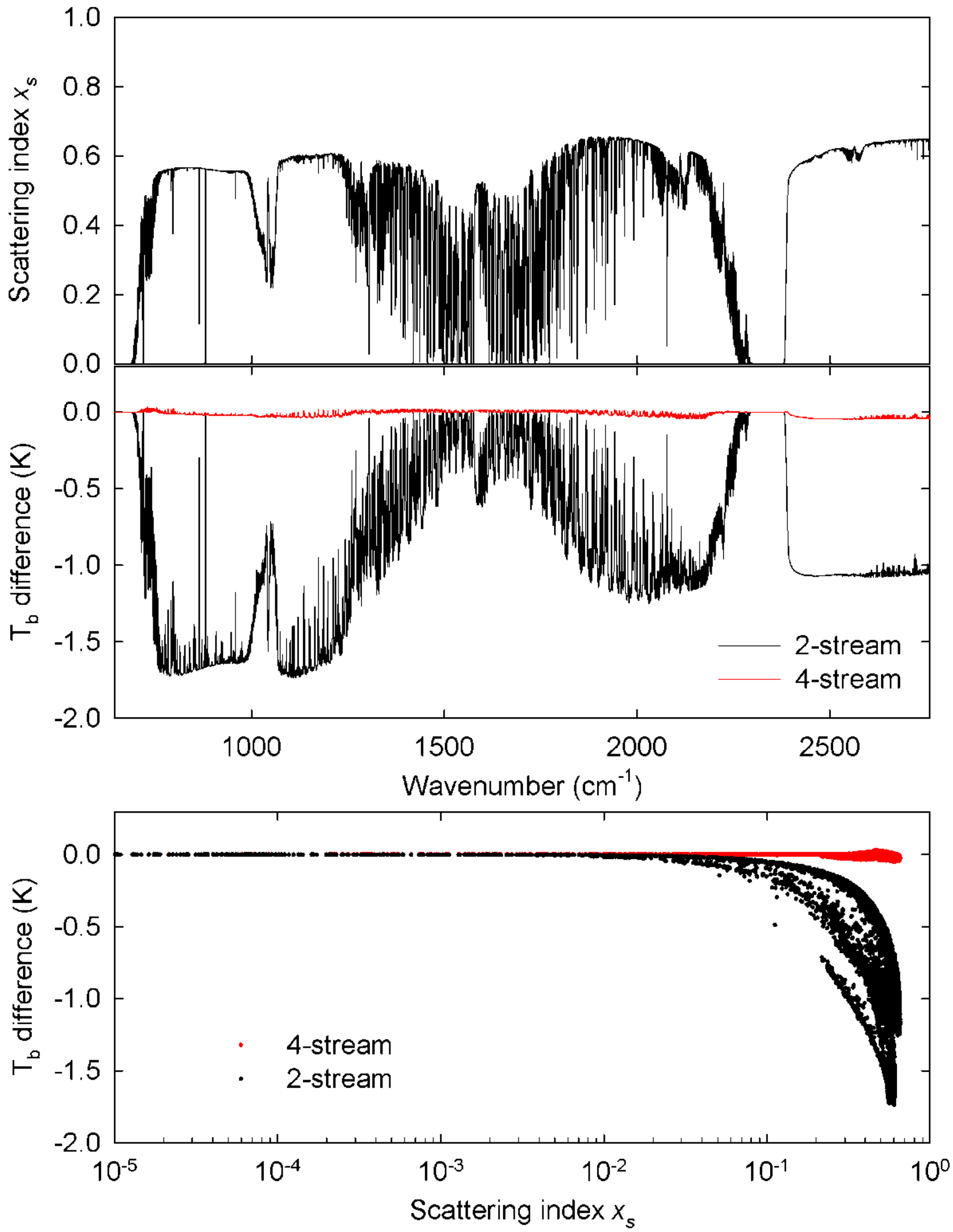


Figure 54 Top panel: Scattering index computed from CRTM v2.0.2 scattering properties as a function of the *Infrared Atmospheric Sounding Interferometer* (IASI) channels for a single-layer ice cloud at 300 hPa with optical depth of 1. The index varies between 0 and 1, with 0 meaning no scattering and 1 meaning complete scattering. Middle panel: Errors in the CRTM-computed IASI channel brightness temperatures as a function of wavenumber, assuming the 2- and 4-stream solutions use the 16-stream solution as reference. Bottom panel: When the 2- and 4-stream errors are plotted as a function of scattering index they show that a threshold can be used to switch to a higher order number of streams if the error becomes unacceptably large.

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

CIMSS Personnel: Allen Lenzen and Todd Schaack
Federal Collaborator: R. Bradley Pierce
Funded by: JCSDA Science Development and Implementation

Project Description
This Joint Center for Satellite Data Assimilation (JCSDA) Science Development and Implementation project focuses on development of capabilities to assimilate GOES Sounder Total Column Ozone (TCO) retrievals into the Community Multi-scale Air Quality (CMAQ; http://www.cmaq-model.org/) model using the NCEP Grid-point Statistical Interpolation (GSI) analysis scheme. CMAQ is driven by meteorological forecasts from the NCEP North American Model (NAM) and used by the NWS to provide air quality forecast guidance. Although GOES Sounder TCO retrievals are not sensitive to boundary layer ozone they are sensitive to upper troposphere/lower stratospheric ozone mixing ratios which is a region where regional air quality forecast models often show significant biases due to coarse vertical resolution and lack of realistic lateral boundary conditions. GOES Sounder TCO retrievals provide regional coverage with high spatial and temporal resolution during both day and night with an accuracy of about 4.6% RMSE and thus have potential applications for regional air quality forecasts.

NAM-CMAQ/GSI data assimilation experiments have been conducted using both operational fixed and experimental time dependent Lateral Boundary Conditions (LBC). Time dependent LBC were based on forecasts from the Real-time Air Quality Modeling System (RAQMS; http://raqms-ops.ssec.wisc.edu/). Bias corrected GOES-11 and GOES-13 TCO data was assimilated at 6 hour intervals from May 17th through June 30th, 2010. GFS 6 hour ozone forecasts were used to specify ozone profiles above the NAM-CMAQ model domain which only extends up to100hPa.

Figure 55 shows results of the GOES TCO assimilation experiments for both fixed and RAQMS LBC at 06Z on June 18, 2010. Both experiments show similar TCO analyses which are in very good agreement with the GOES observations (r^2=0.94). However, scatter plots of the first guess and GOES TCO observations shows that the experiment with RAQMS LBC is able to retain more information from previous GOES TCO assimilation cycles than the experiment with fixed LBC. The RAQMS LBC first guess accounts for 75% of the observed variance (r^2=0.75) and has relatively small mean biases (5.65 DU) while the fixed LBC first guess accounts for only 22% of the observed variance (r^2=0.22) and has larger mean biases (17.21 DU).

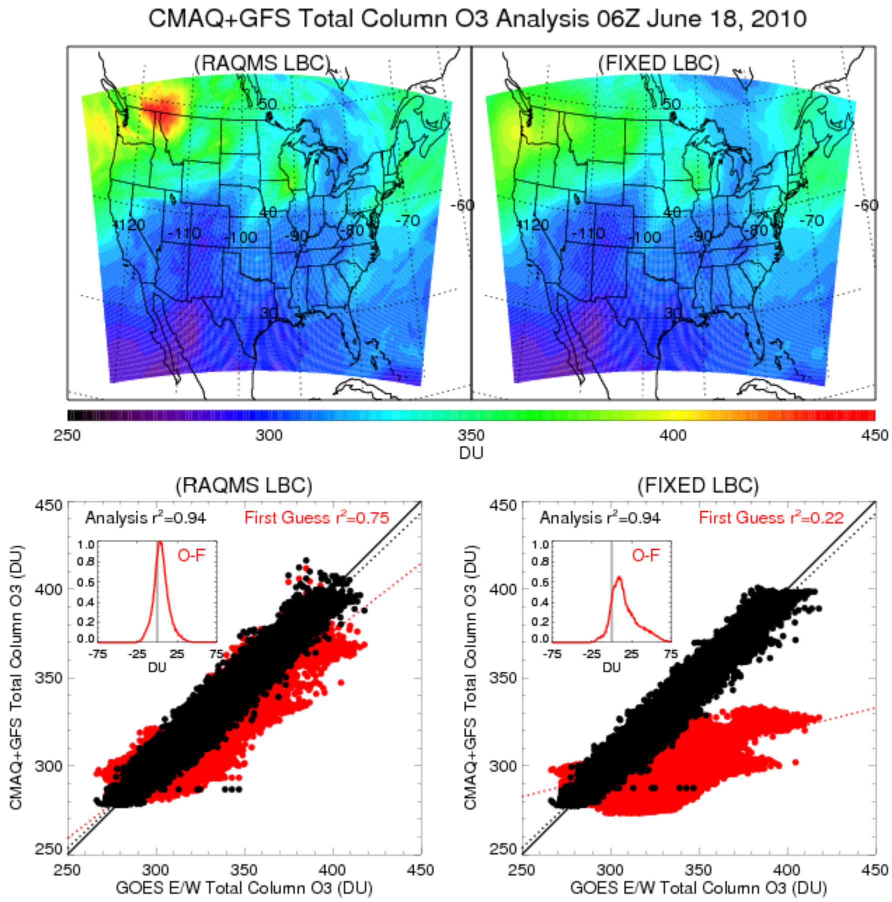


Figure 55 CMAQ+GFS Total Column Ozone (TCO) analyses (DU) at 06Z on June 18th, 2010. Results are shown for two experiments, one using Lateral Boundary Conditions (LBC) from the Real-time Air Quality Modeling System (RAQMS, left) and one using fixed LBC (right). The lower panels show scatter plots of CMAQ+GFS TCO analysis (black) and first guess (red) verses GOES TCO for experiments using RAQMS (left) and fixed (right) LBCs. The distribution of observation-first guess (O-F) is shown in the upper left corner of the scatter plots.

Publications/Conference Presentations

Pierce, R. B., A. Lenzen, and T. Schaack, 2011: GOES Total Column Ozone Assimilation within the Community Multi-scale Air Quality Forecast Model, Science Update, Joint Center for Satellite Data Assimilation Quarterly Newsletter, No. 34, March 2011, available online at http://www.jcsda.noaa.gov/documents/newsletters/201103JCSDAQuarterly.pdf

Pierce, R. B., T. Schaack, A. Lenzen, J. Li, P. Lee, 2011: Implementation of GOES and OMI Total Column Ozone Assimilation within NAM-CMAQ to Improve Operational Air Quality Forecasting Capabilities, Atmospheric Composition Session of the JCSDA 9th Workshop on Satellite Data Assimilation, available online at http://www.jcsda.noaa.gov/documents/meetings/wkshp2011/dayTwo/Pierce_B.pdf

MODIS- and AVHRR-derived Polar Winds Experiments using the NCEP GDAS/GFS

CIMSS Personnel: Dave Santek, Jim Jung, Brett Hoover
Federal Collaborator: Jeff Key
Funded by: NOAA Federal Funding Opportunity

Atmospheric Motion Vectors (AMV) are routinely generated from geostationary and polar orbiting satellites and they are incorporated into most global numerical weather prediction models throughout the world. However, advances to the AMV derivation process together with changes to assimilation systems and forecast models requires the strategies for use of the satellite-derived winds to be continually evaluated. We are investigating the impact of assimilating satellite-derived winds in NCEP's Global Forecast System (GFS) by applying quality control to the MODIS AMVs using the Expected Error (EE) that is supplied with each wind observation.

Satellite-derived AMVs are assigned individual quality flags. Most of these quality indicators are normalized scores (e.g., the Quality Indicator, QI), which are not in the units of the wind vector. The Expected Error, developed at the Bureau of Meteorology (BOM) in Australia, extends the usability of the QI by regressing the QI and other AMV parameters against co-located rawinsondes. This results in coefficients that are applied to individual AMVs to compute an EE in units of speed, which are more amenable to assimilation systems.

The first experiment used a BOM recommended criteria of eliminating winds where the EE > 5 ms^{-1}. In order to retain higher speed winds, which are usually assigned a high EE value, we additionally required the EE to be larger than 0.1*speed before discarding. We ran a control and an EE threshold experiment for late August through September 2010 using MODIS AMVs.

<u>Observation impact</u>: Differences between the two model runs in terms of accepted observations were examined over a 10-day period: 10-19 September 2010. There were 2.5 million vectors; in the control 800,000 were accepted, while in the experiment only 200,000 passed the EE threshold criteria. However, the observation minus background (O-B) and observation minus analysis (O-A) were very similar for the control and experiment for the u- and v-components:

u-component (ms^{-1})	Control (Mean)	Control (StdDev)	EE experiment (Mean)	EE experiment (StdDev)
O-B	-0.1	2.5	-0.1	2.2
O-A	0.0	2.2	0.0	1.9

The statistics for the v-component are nearly equivalent (not shown).

<u>Forecast impact</u>: One measure of the forecast impact, between the control and experiment, is the difference in the Anomaly Correlation (AC) scores. The southern hemisphere 500 hPa five-day forecast AC shows a nearly neutral impact between the two model runs (Figure 56) for the month of September 2010. A substantial improvement in the AC is found on 26 September 2010 when the experiment increased the score from 0.71 to 0.78.

These results are encouraging since using the EE provides a more quantitative screening of the data, whereas the previous quality control method discarded polar wind observations if either the u- or v- component deviated from the background by more than 7 ms^{-1}.

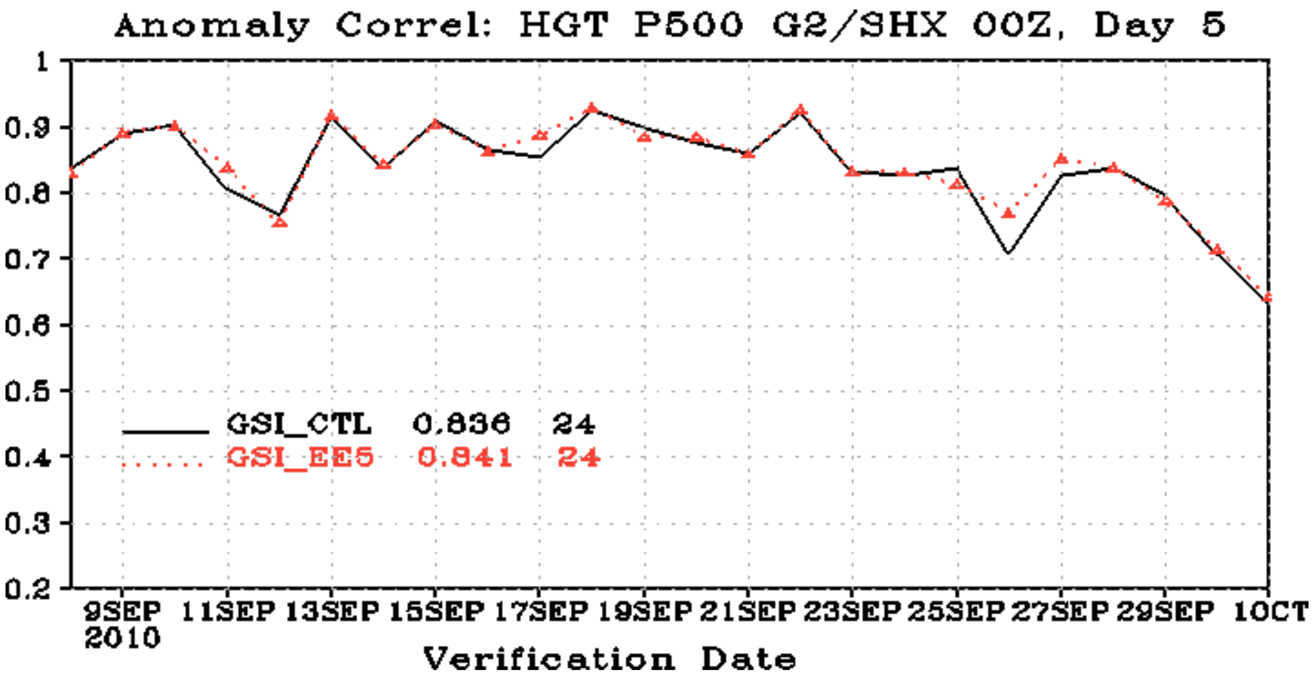


Figure 56 Day-5 anomaly correlation scores for 24 forecasts between 08 September 2010 and 01 October 2010. Scores are computed for 500 hPa geopotential heights over the southern hemisphere (20S-80S) for the control (black) and the experiment (red).

Mission 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 system science.

Advanced Satellite Aviation-weather Products (ASAP)

CIMSS Personnel: Wayne Feltz, Anthony Wimmers, Richard Dvorak, Justin Sieglaff, and Lee Cronce
Funded by: NASA

Project Description
This project is funded by NASA to provide satellite derived weather products to track, nowcast , and diagnose aviation weather hazards such as turbulence, convection, visibility, icing, and wind shear. The goals of the initiative are to test and evaluate existing satellite algorithms that have been developed or are proposed by AWRP team members, introduce new techniques and data sets to the FAA, MIT, and NCAR collaborators from the satellite community, and facilitate FAA access to satellite data sets for research and development available through UW-CIMSS. The project mission is to increase and optimize the use of satellite data sets within the existing FAA structure and to transfer satellite expertise.

A primary focus recently is the integration of various ways to nowcast convective initiation using the GOES imager. UW-CIMSS continues to collaborate with MIT/Lincoln Lab and UAH on transition of SATCAST into CoSPA algorithm. Implementation of ASAP-supported SATellite Convection AnalySis and Tracking (SATCAST) System software at MIT-Lincoln Labs within the Consolidated Storm Prediction for Aviation (CoSPA) system has occurred. SATCAST provides the satellite component to CoSPA, improving the 0-1 hour convective nowcasting time domain. UW-CIMSS has helped with optimizing wind algorithm and confirmed wind calculations were consistent at UAH and MIT. A 64-bit compatible version of WINCO was developed and sent to UAH and MIT.

UW-CIMSS has developed a SATCAST algorithm ingest software package which is Terascan compatible. This software has been delivered to the University of Alabama for integration into SATCAST. Also, intercomparison between McIDAS and Terascan derived wind fields is being conducted to verify that same end result is being produced. A capability has been established to convert Terascan-based GOES-East data feeds into a format that is suitable as input to SATCAST. MIT worked with CIMSS to correct an issue of weaker IR gradients in the Terascan data. The weaker gradients were leading to significant differences in satellite winds derived from AREA and Terascan data formats. After the gradient correction, the IR winds are in much better agreement. MIT has also worked with UAH to establish the capability to send Terascan-based satellite imagery to UAH in real-time for SATCAST testing. MIT established the capability to receive GFS NWP data from NCEP for use in SATCAST. Verification of successful wind calculation on GOES-West between CIMSS and UAH has also occurred.

Several methods to improve latency of wind field calculations are being investigated such as thinning winds, only calculating in areas of convective interest, and optimizing WINDCO code. Time latency test are being conducted to improve speed of wind field calculations. This will be transitioned to UAH to incorporate in SATCAST algorithm which will then be handed off to MIT for in-house evaluation. MIT has been involved with design hardware configuration and has purchased hardware to run SATCAST at MIT. MIT is conducting code profiling on SATCAST to understand time latency bottle necks. The CoSPA package will be implemented at the FAA Tech Center in New Jersey for widespread decision support dissemination. An example from SATCAST and UW-Madison convective initiation methodologies are compared from CoSPA algorithm in Figure 57.

Satellite-base algorithms developed or enhanced by ASAP resources were critical for eventual use in current GOES-R Aviation Algorithm Working Group science decision support algorithms. NASA ASAP resources provided initial basic research into scientific value-added decision support algorithms for forecasting/nowcasting aviation hazards such as those caused by convection initiation, turbulence, icing, and volcanic ash.

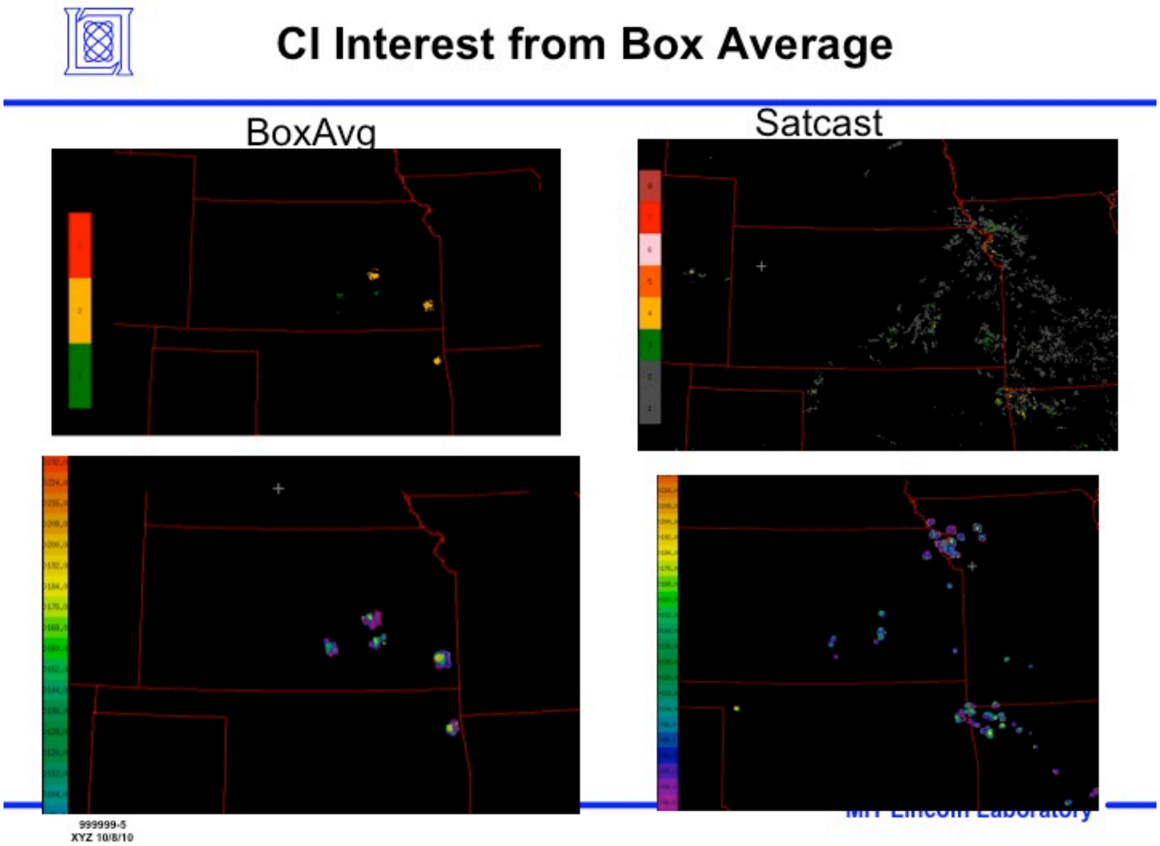


Figure 57 Comparison of convective initiation signal using box average vs atmospheric motion vectors to account for cellular movement between consecutive GOES-12 images.

Publications

Bedka, K. M., C. S. Velden, R. A. Petersen, W. F. Feltz, and J. R. Mecikalski, 2009: Comparisons of satellite-derived atmospheric motion vectors, rawinsondes, and NOAA Wind Profiler observations. Accepted with revisions to *J. Appl. Meteor*

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15 January 2009. American Meteorological Society, Boston, MA, 2009, 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. International Winds Workshop, 9th, Annapolis, MD, 14-18 April 2008. Proceedings. European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), Darmstadt, Germany, 2008, Unpaged. Call Number: Reprint # 5836.

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Atmosphere PEATE

CIMSS Personnel: Hank Revercomb (PI), Liam Gumley (Co-I/PM), Bob Holz, Greg Quinn, Bruce Flynn, Steve Dutcher, Geoff Cureton, Min Oo, Scott Mindock
Federal Collaborator: Robert Schweiss (NASA/GSFC)
Funded by: NASA NPP Project

NASA has established six Product Evaluation and Algorithm Test Elements (PEATEs) to enable the NPP Science Team to evaluate the operational SDRs and EDRs (both pre-launch and post-launch) from NPP in an efficient and effective manner. The PEATEs are organized into categories including Atmosphere, Land, Ocean, Ozone, Sounder, and CERES, and the Atmosphere PEATE is located at CIMSS/SSEC. The Atmosphere PEATE assists the NPP Science Team in: (a) evaluating the suitability of the NPP Atmosphere EDRs for continuing the NASA climate record; (b) assessing the performance of the NPP Atmosphere EDRs through comparison with other ground-based and satellite-based measurements; (c) incorporating new research advances to continually improve the products; and (d) developing improved or alternative Atmosphere NPP EDR algorithms for the NPP products that are shown to be of insufficient quality. The NPP EDRs assigned to the Atmosphere PEATE are Cloud Mask (IP), Cloud Cover/Layers, Cloud Effective Particle Size, Cloud Top Height, Cloud Top Pressure, Cloud Top Temperature, Cloud Base Height, Cloud Optical Thickness, Aerosol Optical Thickness, Aerosol Particle Size, and Suspended Matter.

In the NPP pre-launch period, the Atmosphere PEATE has developed algorithms, software tools, and systems to enable the NPP Science Team to assess the performance of the NPP atmosphere algorithms using proxy data including MODIS, AIRS, and IASI, and validation data from ground based, aircraft, and satellite sources including CALIPSO and CloudSat. The Atmosphere PEATE has built a Science Processing System (SPS) to enable theses analyses to be done rapidly using large global cloud and aerosol datasets. In the NPP post-launch period, the Atmosphere PEATE has developed a two-part strategy to examine the climate quality of the NPP SDRs and EDRs. The first part of the strategy is to leverage CIMSS/SSEC experience in both imager and interferometer radiance calibration by collocating VIIRS and CrIS SDR radiances with other SDR datasets, including MODIS, AIRS, and IASI. The second part of the strategy is to apply the techniques developed prior to launch (using Aqua MODIS and AIRS proxy data) to assess the NPP cloud and aerosol EDRs by collocation and comparison to CALIPSO and CloudSat data, as well as data from ground-based systems such as AERONET.

Inter-sensor and inter-satellite collocation and match up software has been developed and integrated in to the PEATE Science Processing System. Using the collocation algorithm, daily global match up files have been created, which contain the collocated MODIS/VIIRS and CALIPSO validation product. This product includes the CALIPSO validation measurements averaged to the MODIS/VIIRS spatial resolution and the sub pixel variability measured by CALIPSO for each MODIS/VIIRS Field of View (FOV). These match up files allow global EDR algorithm performance statistics to be generated. Because the validation system is integrated into the Atmosphere PEATE Science Processing System, the validation results are immediately available once the MODIS/VIIRS cloud products have been processed. This capability allows for efficient evaluation when changes are made to the MODIS/VIIRS cloud retrieval algorithms. An example of the collocated MODIS cloud top height retrievals compared to the CALIPSO cloud top heights for the months of August 2006 and February 2007 is presented below.

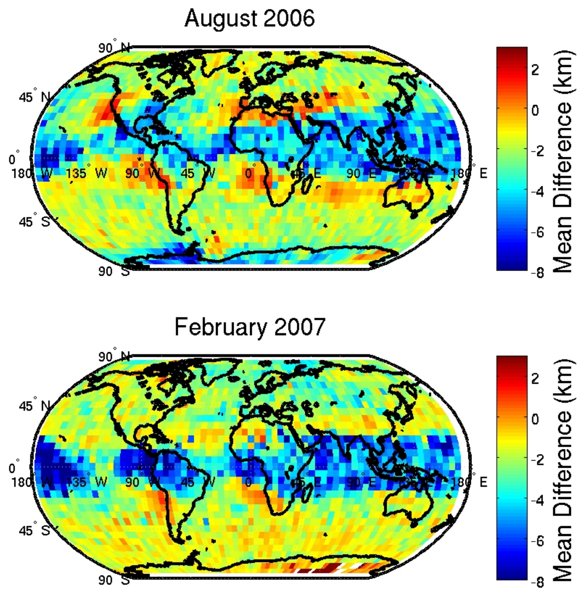

Figure 58 EDR Evaluation Example: Cloud Height (MODIS-CALIPSO)

Major milestones in the Atmosphere PEATE project include:

1. Completed Requirements, Preliminary Design, and Critical Design Reviews;
2. Processed and evaluated twelve months of global Aqua MODIS proxy data using MODIS, MODIS VIIRS-like, and VIIRS OPS cloud mask algorithms;
3. Ported VIIRS Cloud Mask, Cloud Optical Properties, Cloud Top Properties, and Aerosol Optical Thickness algorithms to Linux;
4. Demonstrated global evaluation of VIIRS Cloud Mask, Cloud Top Height, and Cloud Optical Depth using MODIS proxy data collocated with CALIPSO lidar; and
5. Demonstrated evaluation of VIIRS SDR using Aqua MODIS data as proxy for VIIRS and Aqua AIRS hyperspectral data as proxy for CrIS.

Publications

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STAR High Performance Computing System

CIMSS Personnel: Liam Gumley (PI/PM), Scott Nolin, Jesse Stroik, John Lalande, Endre Doeringsfeld, Paul Czerniak, Allen Lenzen, Jason Otkin, Jim Jung, Brad Pierce
Federal Collaborators: Sid Boukabara, Eve-Marie Devaliere, Aaron Pratt
Funded by: NOAA/NESDIS/STAR

CIMSS/SSEC has procured and installed a high performance computing (HPC) system with 3072 CPU cores, 8 TB of memory, 40 Gbps Infiniband connectivity, and 456 TB of disk space. The system is to be named “Supercomputer for Satellite Simulations and Data Assimilation Studies”, or S4. The S4 system will support data assimilation and OSSEs in support of NESDIS/STAR’s efforts to enhance the accuracy of weather prediction systems through improved use of satellite data within the U.S. Operational data assimilation and forecast systems. S4 is hosted within the SSEC Data Center, and utilizes SSEC infrastructure for cooling and UPS power. The SSEC Technical Computing (TC) Group provided system design, procurement, and installation, and will provide system administration and user training services for the system. NESDIS/STAR provides guidance on S4 resource allocation and selection of users, and is responsible for porting the NCEP operational NWP systems (GSI, GFS) to S4. The system is designed to be easy to use, and flexible enough to handle multiple simultaneous NWP jobs.

CIMSS/SSEC submitted a proposal draft to NESDIS/STAR in August 2010, and the final proposal in October 2010. A grant for $1.0M was awarded at the end of March, 2011. By mid-April, all of the hardware for the system has been ordered from Dell. Installation of the S4 hardware took place in May 2011 in the SSEC Data Center (room 649). SSEC TC worked for 6 months to gather information on the system requirements, create a system design, and review the design with HPC experts from Dell Corp. The final design is extremely cost effective, and the hardware was priced between 20-40% lower than GSA pricing available to federal agencies. SSEC TC worked with internal and UW-Madison campus infrastructure support services to ensure that the necessary power, cooling, and space infrastructure was available in time for S4 installation. The entire system is powered by UPS in order to ensure reliability and allow graceful shutdown in the event of extended power outages.

As of June 20, 2011, all hardware has been installed and unit tested. TC is working with Dell HPC to replace two compute servers that failed to meet specifications. The ROCKS cluster distribution for Linux (64-bit) has been installed, and the Grid Enginer cluster job manager has been installed and tested. Fast scratch space directories (64 TB each) have been created (built on the Lustre filesystem) for each of the four operational job queues. Shared data storage space (based on the GlusterFS filesystem) is available for longer term storage (200 TB). All required compilers and libraries have been installed, and preliminary system testing with LINPACK and WRF has commenced. Documentation for users and administrators has been developed. A one-month beta user test period has commenced, prior to the start of S4 operations for NESDIS/STAR users in late July, 2011.

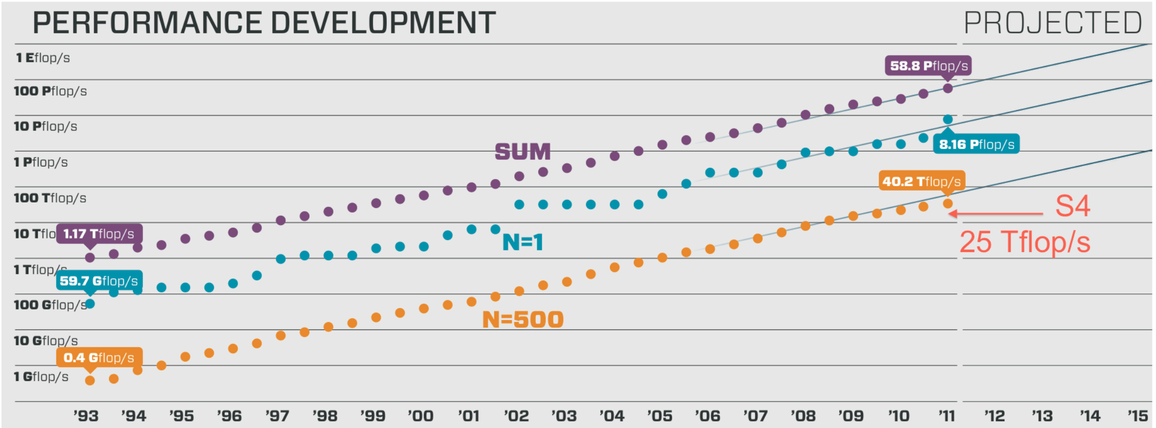

Figure 59 Top 500 HPC Performance in Tflops/s from 1993 to 2011 (S4 performance indicated on right)

Figure 60 S4 system racks in SSEC Data Center

Activities with the Real-time Air Quality Modeling System (RAQMS) for Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) Data Analysis

CIMSS Personnel: Todd Schaack, Allen Lenzen
Federal Collaborator: R. Bradley Pierce
Funded by: NASA

Project Description
This project focuses on utilization of the Real-time Air Quality Modeling System (RAQMS) [Pierce et al., 2003, 2007] at the University of Wisconsin-Madison Space Science and Engineering Center (SSEC) in support of post mission Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) science studies conducted in collaboration with NASA Langley Research Center and NASA Jet Propulsion Laboratory scientists. This research is aimed at understanding the production and loss mechanisms of Arctic ozone using ozone and carbon monoxide observations from the Tropospheric Emission Spectrometer (TES) [Beer, 2006] in conjunction with RAQMS chemical and aerosol analyses studies and Lagrangian photochemical analysis tools.

Two manuscripts have been published and two manuscripts are under review in the POLARCAT (Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models, of Climate, Chemistry, Aerosols, and Transport) special issue of Atmospheric Chemistry and Physics (ACP). RAQMS chemical and aerosol analyses contribute to these studies by providing global scale chemical analyses which are used for lateral boundary conditions for regional chemical modeling studies [Huang et al., 2010a,b], provide estimates of the influence of Asian wild fires on observed chemistry [Dupont et al., 2010] and radiative forcing [Natarajan et al., 2011] during ARCTAS.

Analysis shows that Kazakhstan wild fires are responsible for increases of O_3 and CO mixing ratios up to 6.4 ppbv and 38 ppbv in the lower troposphere (height of 2 to 6 km), and Thailand wildfires are responsible for increases of O_3 and CO mixing ratios up to 11 ppbv and 71 ppbv in the upper troposphere (height of 8 to12 km). For clear sky conditions, the monthly averaged top of atmosphere (TOA) radiative forcing due to the Asian wildfires is mostly negative with peak values less than -12 W/m^2 occurring near the fire regions. This negative forcing is mainly due to scattering of shortwave radiation by the increased aerosol loading. At high latitudes, the radiative forcing is positive with peak values of about 6 W/m^2. This warming effect is caused by the presence of absorbing aerosols over regions of high surface albedo. The monthly averaged radiative forcing at the surface (SRF) is mostly negative with peak values of less than -30 W/m^2 near the fire regions.

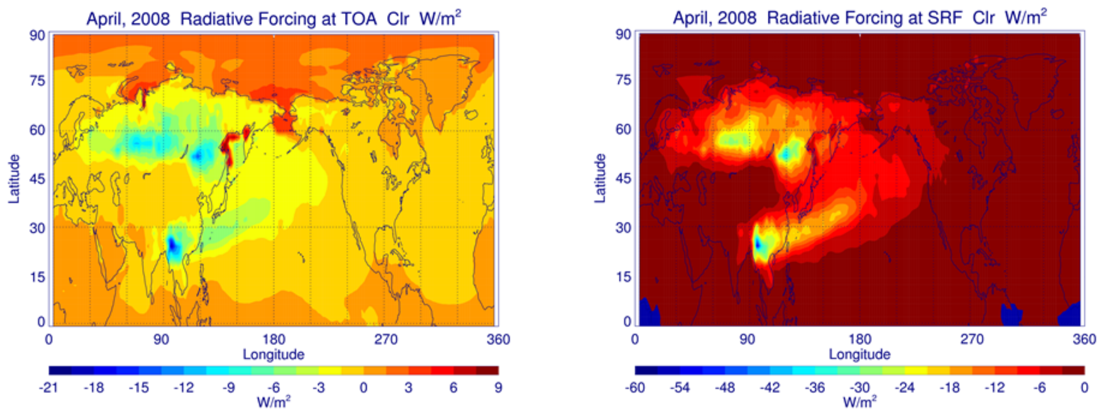

Figure 61 Calculated distribution of Clear Sky TOA (left) and Surface (right, note the different color scale) radiative forcing (W/m^2) due to changes in tropospheric ozone, and aerosols from Asian Wildfires for April, 2008.

Publications/Conference Presentations

M. Natarajan, R. B. Pierce, T. K. Schaack, A. J. Lenzen, J. A. Al-Saadi, A. J. Soja, T. P. Charlock, F. G. Rose, D. M. Winker, and J. R. Worden, 2011: Radiative forcing due to enhancements in tropospheric ozone and carbonaceous aerosols caused by Asian fires during Spring 2008. Submitted to *Atmos. Chem. Phys. Discuss.*, June 2011.

R. Dupont, B. Pierce, J. Worden, J. Hair, M. Fenn, P. Hamer, M. Natarajan, T. Schaack, A. Lenzen, E. Apel, J. Dibb, G. Diskin, G. Huey, A. Weinheimer, and D. Knapp, 2010: Reconstructing ozone chemistry from Asian wild fires using models, satellite and aircraft measurements during the ARCTAS campaign. *Atmos. Chem. Phys. Discuss.*, 10, 26751-26812.

M. Huang, G. R. Carmichael, S. N. Spak, B. Adhikary, S. Kulkarni, Y. F. Cheng, C. Wei, Y. Tang, A. D'Allura, P. O. Wennberg, G. L. Huey, J. E. Dibb, J. L. Jimenez, M. J. Cubison, A. J. Weinheimer, A. Kaduwela, C. Cai, M. Wong, R. B. Pierce, J. A. Al-Saadi, D. G. Streets, and Q. Zhang, 2010: Multi-scale modeling study of the source contributions to near-surface ozone and sulfur oxides levels over California during the ARCTAS-CARB period. *Atmos. Chem. Phys. Discuss.*, **10**, 27777-27823.

M. Huang, G. R. Carmichael, B. Adhikary, S. N. Spak, S. Kulkarni, Y. Cheng, C. Wei, Y. Tang, D. D. Parrish, S. J. Oltmans, A. D'Allura, A. Kaduwela, C. Cai, A. J. Weinheimer, M. Wong, R. B. Pierce, J. A. Al-Saadi, D. G. Streets, and Q. Zhang, 2010: Impacts of transported background ozone on California air quality during the ARCTAS-CARB period – a multi-scale modeling study. *Atmos. Chem. Phys. Discuss.*, **10**, 12079-12131.

A Product Development Team for Snow and Ice Climate Data Records

CIMSS Personnel: Yinghui Liu and Xuanji Wang
Federal Collaborator: Jeff Key
Funded by: NOAA

Project Description

The Cryosphere Product Development Team formed under this project is coordinating the generation, validation, and archival of fundamental and thematic snow and ice climate data records. CIMSS scientists are focusing on ice products from optical imagers. Our colleagues at the University of Colorado and NASA are addressing other products. We are extending, evaluate and document existing FCDRs and creating new products as necessary. A time series of FCDRs covering the period 1982-2011 is being developed from AVHRR and MODIS satellite data. The following CDRs are being generated:

- Ice/snow surface temperature,
- Ice/snow surface broadband albedo,
- Sea ice motion,
- Sea ice concentration and extent,
- Sea ice age, and
- Surface shortwave and longwave radiation.

During the first two project years (of a three-year project) we have revised the extended AVHRR Polar Pathfinder (APP-x) code to implement consistent cloud detection and calibrations and began APP-x reprocessing, updated sea ice concentration/extent, ice thickness and age algorithms for AVHRR/MODIS, held a public forum at the State of the Arctic Conference in Miami (March 2010), completed APP reprocessing, including metadata and documentation. We have also evaluated the applicability of our AVHRR and MODIS algorithms for NPP/JPSS. Examples of the surface temperature, surface broadband albedo, cloud amount, surface radiative flux, and ice thickness products are given in Figure 62.

A number of papers have been published on the use of the APP-x snow and ice CDR products for climate studies. The major findings are:

- A thermodynamic model can be used to estimate sea and lake ice thickness using optical (visible, near-infrared, and infrared) satellite data with relatively high accuracy. A climatology of ice thickness has been generated through the application of the thermodynamic model using the AVHRR record.
- Changes in sea ice concentration and cloud cover played major roles in the magnitude of recent Arctic surface temperature trends. Significant surface warming associated with sea ice loss accounts for most of the observed warming trend. In winter, cloud cover trends explain most of the surface temperature cooling in the central Arctic Ocean.
- The APP-x product was used in a study of controls on snow albedo feedback (SAF), which is important for assessing the validity of feedbacks in global climate models.

Publications/Conference Presentations

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

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

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

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

Liu Yinghui, Key R. Jeffrey, Liu Zhengyu, Vavrus Steven, Wang Xuanji, Feedback of Arctic Cloud-Sea Ice from Observations, (talk), 11th Conference on Polar Meteorology and Oceanography, 2-5 May, 2011, Boston, MA.

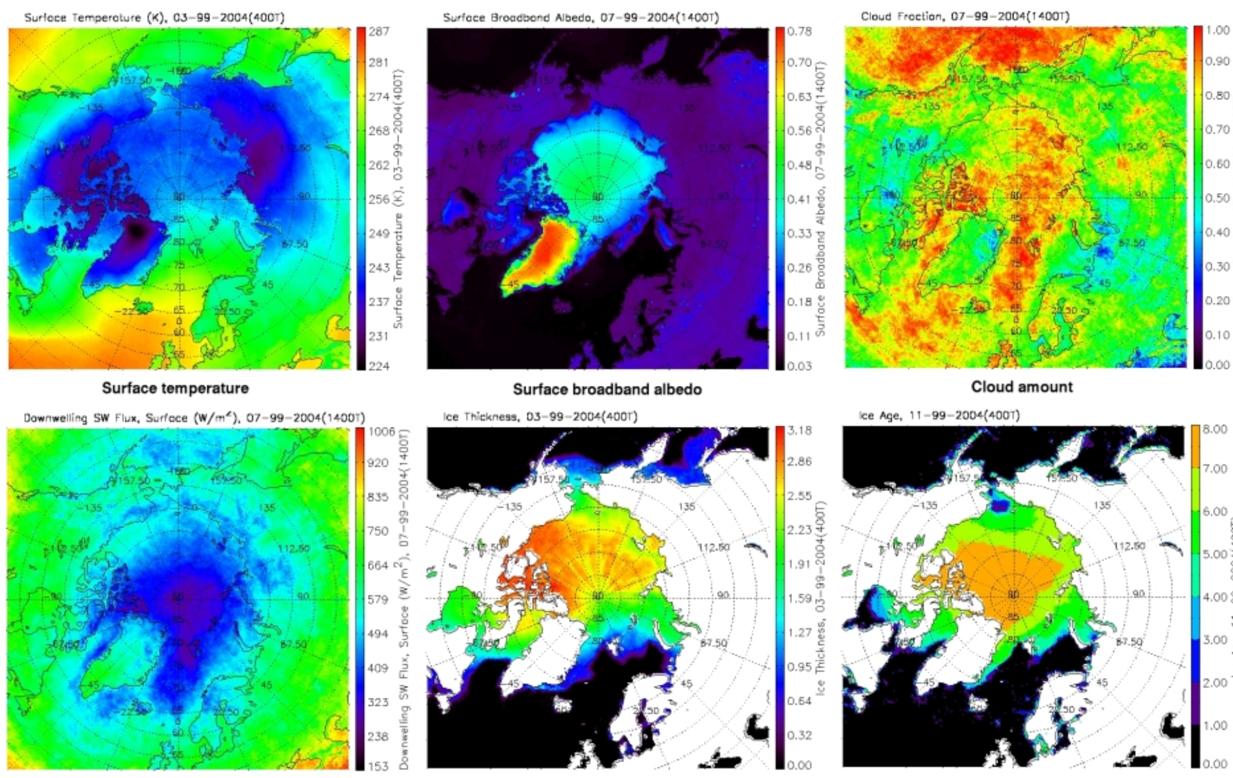


Figure 62 Examples of APP-x products. Clockwise from upper left: surface temperature (March, 2004), surface albedo (July, 2004), cloud fraction (July, 2004), sea ice age (0 open water, 1 new ice, 2 grey ice, 3 grey-white ice, 4 thin first-year ice, 5 median first-year ice, 6 thick first-year ice, 7 old ice) (March, 2004), sea ice thickness from AVHRR (March, 2004), and surface downward shortwave flux (July, 2004).

A Blended Polar Winds Product using Atmospheric Motion Vectors from MODIS Imager and AIRS Moisture Retrieval Data

CIMSS Personnel: Dave Santek, Chris Velden, Sharon Nebuda, Steve Wanzong
Federal Collaborator: Jeff Key
Funded by: NASA ROSES

The generation of polar winds from the Moderate Resolution Imaging Spectroradiometer (MODIS) imagery was pioneered at the University of Wisconsin by NOAA and CIMSS in the early 2000s. The MODIS polar winds product is composed of both infrared window (IR-W) and water vapor (WV) tracked features, resulting in atmospheric motion vectors (AMVs). The WV AMVs are only attainable at mid- and upper- tropospheric levels due to the MODIS WV atmospheric contribution function, while IR-W images also provide cloud tracers for vectors at lower levels. However, the WV AMVs yield a better spatial distribution than the IR-W since both cloud and clear-sky features can be tracked in the WV images.

As the next generation polar satellite era approaches, it is recognized that there is currently no WV channel planned on the Visible/Infrared Imager/Radiometer Suite (VIIRS), potentially resulting in a data gap with only IR-W derived AMVs possible. We have begun to investigate using Single Field of View (SFOV) Atmospheric Infrared Sounder (AIRS) moisture retrievals from consecutive overlapping polar passes to extract atmospheric motion from clear-sky regions on constant pressure surfaces (Figure); i.e., estimating winds in retrieval space rather than radiance space. Perhaps most significantly, this method has the potential to provide vertical wind profiles, as opposed to the current MODIS-derived single-level AMVs.

We are applying our existing polar AMV methodology to AIRS retrieved fields of relative humidity on constant pressure surfaces. This will generate a 3-dimensional tropospheric wind data set covering both polar regions, poleward of approximately 70 degrees latitude. The data set will be used to investigate model analysis and forecast impacts with experiments using the GMAO's Goddard Earth Observing System version 5 (GEOS-5). Given the positive impact of the AMVs on polar and extratropical forecasts that has been demonstrated using MODIS, we believe that satellite-derived polar winds will continue to be useful in operational numerical weather prediction systems in the foreseeable future. However, without a replacement for the MODIS clear sky water vapor AMVs, the impact may be significantly reduced in the post-Aqua era. Therefore, this effort to derive AMVs from AIRS and blending with MODIS, will provide a pathway for similar combinations of AMVs from the Infrared Atmospheric Sounding Interferometer (IASI) with AVHRR (on Metop), and the Cross-Track Infrared Sounder (CrIS) with VIIRS (on the upcoming NPOESS Preparatory Project (NPP) and Joint Polar Satellite System (JPSS) satellites).

Figure 63 is a pre-proposal example of tracking water vapor features from the AIRS retrievals, as this project has just begun in the second quarter of 2011.

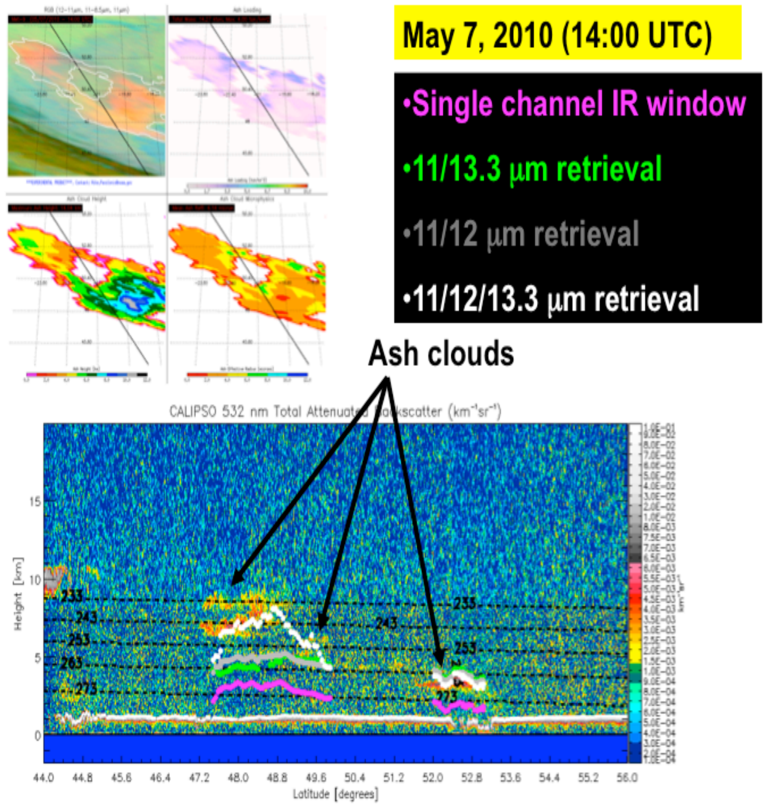


Figure 63 Demonstration of AMVs (before quality control) obtained from tracking water vapor features from SFOV AIRS retrieval moisture fields (400 hPa surface). The cyan dots represent identified features (targets) in the middle field (image) of a sequence of three successive overpasses. The yellow barbs are AMVs successfully tracked in the 3-image sequence. Data is from 6 September 2002.

The International MODIS/AIRS Processing Package (IMAPP)

CIMSS Personnel: Allen Huang, Liam Gumley, Elisabeth Weisz, James Davies, Kathleen Strabala
Federal Collaborators: Jeff Key, Brad Pierce
Funded by: NASA

To promote broad as well as optimal use of Terra and Aqua, NASA funded the initial development of the International MODIS/AIRS Processing Package (IMAPP) in 2000. This freely available software package provides the necessary tools for any ground station capable of receiving DB data from Terra or Aqua to produce calibrated and geolocated radiances (Level 1), along with a select group of science products (Level 2). IMAPP is derived from the operational processing software developed by the NASA MODIS and AIRS Science Teams, and is modified to be compatible with direct broadcast data.

IMAPP has successfully provided government policy and decision makers the capability to observe and monitor the environment using MODIS, AIRS, AMSU and AMSR-E instruments through software support of X-band receiving stations in near-real time. The IMAPP real-time products created from data received by the CIMSS/SSEC/UW-Madison antenna support a wide variety of applications and users. These include providing data and products to 48 US National Weather Service (NWS) field offices in support of short-term weather-forecasting, MODIS/AIRS/AMSR-E products used by the NASA Short-term Prediction Research and Transition Center (SPoRT) to support real-time use of the data, MODIS products supplied to the Bonneville Power Administration (part of the Department of Energy (DOE)), and MODIS true color and Aerosol Optical Depth products to support air-quality monitoring and forecasts in the US.

In the decade that IMAPP has been funded, CIMSS/SSEC/UW-Madison has released 42 separate software packages for MODIS, AIRS and AMSR-E including everything from a synergistic MODIS/AIRS utility package, to a globally configurable NWP model that assimilates MODIS cloud and moisture products, to a package that grids, composites and tiles 16 days of MODIS data to create a Bidirectional Reflectance Distribution Function (BRDF) product at 500 m and 1 km resolution centered on the user antenna location. These culminated in 2010, with a release of an entire direct broadcast Aqua and Terra processing system (Level 0 to Level 2 products plus quicklooks) in the form of a Virtual Appliance which can be installed and executed on Windows, Linux and Apple operating systems.

IMAPP has also supported 9 workshops focusing on Aqua and Terra direct broadcast applications on 5 continents. This not only promotes the use of the data, but also fosters the next generation of remotes sensing scientists.

Globally, more than 900 registered IMAPP users located in 64 countries have downloaded IMAPP Terra and Aqua software to support their own local real- and near-real-time applications. The IMAPP project has become one of the most successful NASA funded programs that enables and promotes the use of both Terra and Aqua data.

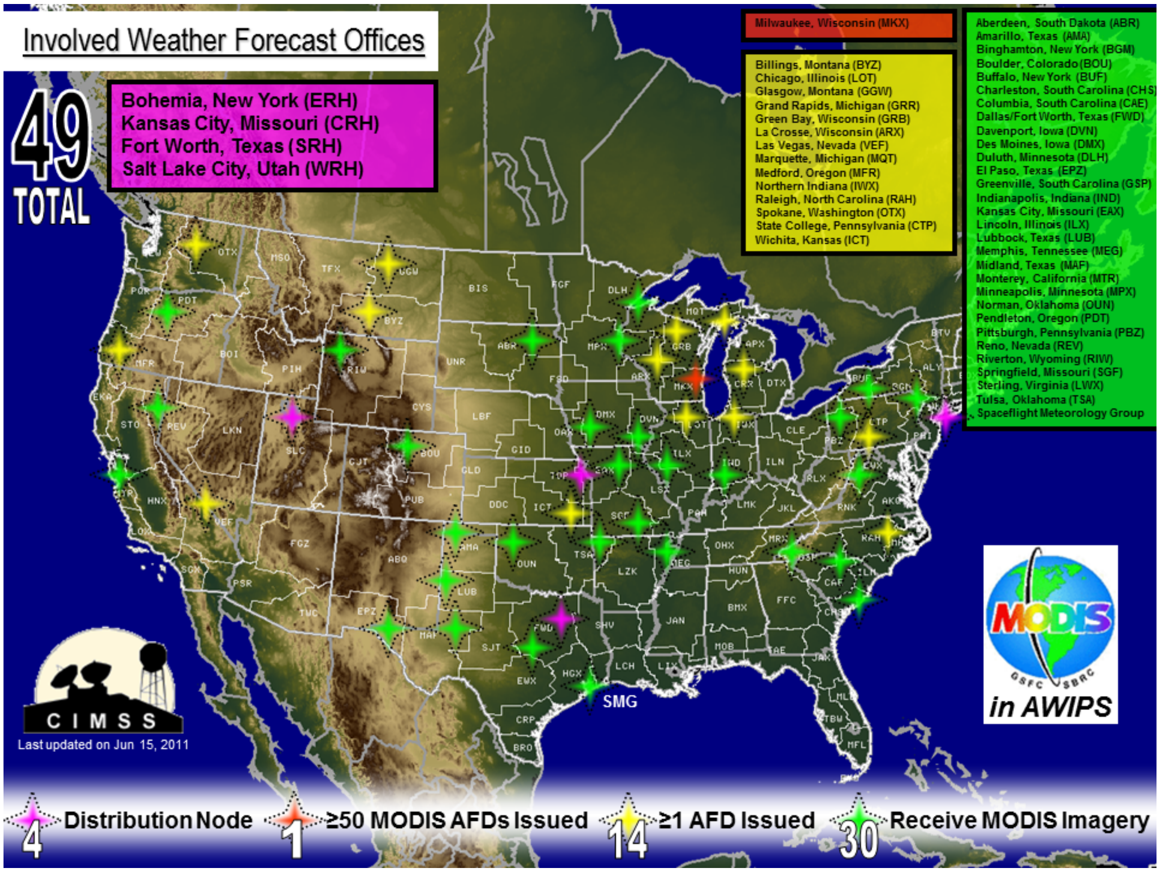


Figure 64 The location of NWS forecast offices receiving MODIS products in real-time as supplied by CIMSS/SSEC/UW-Madison. These products have been referenced in NWS Area Forecast Discussions more than 200 times as a tool in forecast decision making since distribution began in mid-2006.

Peer Reviewed Publications

Zhang, Hong, Huang, Hung-Lung, Lim, Agnes, Holz, Robert, Dutcher, Steve, Nagle, Fred, Gumley, Liam, Wang, Jinnian, Shi, Runhe, and Gao, Wei: 2010. Analysis and characterization of the synergistic AIRS and MODIS cloud-cleared radiances, Frontiers of Earth Science in China, Vol. 4, No. 3, pp. 363-373.

E. Weisz, W. P. Menzel, R. Frey, E. Borbas, 2010: An approach for Merging high Spectral Resolution Sounder Data with Spatial Resolution Imager Data to infer Cloud Cover Properties. Submitted to the *Journal of Applied Meteorology and Climatology*.

Conference/Invited Presentations

Kathleen Strabala gave a talk at the MODIS/VIIRS Science Team Meeting Plenary Session, held in Washington, DC, January 2010, entitled: The Global Impact of MODIS Direct Broadcast Atmosphere Products.

Elisabeth Weisz gave a talk at the International TOVS Study Conference 17 in Monterey, CA in April entitled: Updates to the IMAPP AIRS Utility Software.

Liam Gumley gave a talk at the 15th Australasian Remote Sensing and Photogrammetry Conference (ARSPC-15), held in Darwin, Australia, 20 September, 2010, entitled: The IMAPP Virtual Appliance.

Investigating Cirrus Optical Depth Biases Between CALIOP and MODIS

CIMSS Personnel: Robert Holz, Ralph Kuehn, Steven Ackerman
Federal Collaborator: Mark Vaughan (NASA Langley)
Funded by: NASA

Project Description
A preliminary comparison between these retrievals finds significant systematic differences for single layer thin ice clouds (visible optical depth < 3) as presented in Figure 65. Explanations for these differences are many, ranging from algorithm implementation to differences resulting from the physical assumption built into the MODIS and CALIOP optical thickness (OT) retrieval methods. A factor of two difference in cirrus OT has a significant impact on the characterization of the net cloud forcing for both the solar and IR, especially at low optical thickness (OT<1).

Using cloudy radiative closure to characterize the optical depth bias
To investigate this bias, we will use a radiative closure technique that we have recently implemented into the Atmosphere Product Evaluation And Test Element (PEATE) processing system at SSEC. The approach uses a cloud resolving forward radiative transfer model LBLDIS (ref) to calculate the Top Of Atmosphere (TOA) infrared (IR) radiance given the cloud properties provided by the collocated MODIS and CALIOP observations. The cloud boundaries are provided by CALIOP with the atmospheric thermodynamic profile and surface temperature provided by a model re-analysis (GDAS or ECMWF). The cloud effective radius is provided by MODIS. The only dependent variable is the cloud OT. The TOA radiances are then calculate for each collocated MODIS pixel for both the CALIOP and MODIS retrieved OT. The high spectral resolution radiances are then convolved to the MODIS 11 um window channel using the MODIS spectral response function.

An obvious question is which retrieval (MODIS or CALIOP) is correct or do both have biases? The goal of the this research is to find closure between the CALIOP and MODIS ice cloud optical depth. Possible hypothesis that we will explore are:

- Uncertainties in the single scatter calculations used as part of the MODIS retrieval of cloud optical depth and effective radius and
- An incorrectly accounting for multiple scattering in the CALIOP retrieval of optical depth.

For MODIS, we are investigating Look Up Tables (LUT) using a modified interpretation of existing single scatter calculations while also exploring LUT based on the results of our investigation of the global prevalence of orientation. Using the new LUT we will reprocess the cloud optical properties retrievals leveraging the Atmospheric PEATE. The radiative closure calculations are then re-computed using the new MODIS OT and effective radius retrievals. We are conducting a similar investigation using CALIOP working closely with Mark Vaughan and Ralph Kuehn at NASA Langley. As discussed above, there are unresolved questions regarding the implementation of the multiple scatter correction for the CALIOP OT retrievals. There are also significant uncertainties regarding the correct magnitude of the correction. The radiative closure will provide a method of validation as the multiple scatter correction is investigated.

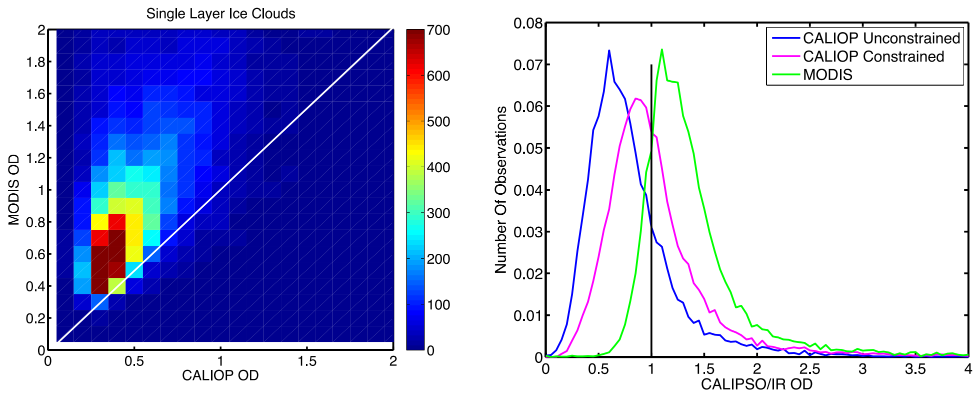


Figure 65 presents the comparison between the MODIS and CALIOP single layer cirrus optical depth retrievals for the month of February 2007. The left figure presents the direct comparison between MODIS and CALIOP. The right figure presents the fractional difference relative to the IR optical depth.

Publications/Conference Presentations

Borg, Lori A.; Holz, Robert E. and Turner, David D., 2011: Investigating cloud radar sensitivity of optically thin cirrus using collocated Raman lidar observations. *Geophysical Research Letters*, **Volume 38**, doi:10.1029/2010GL046365.

Holz, Robert E; Kuehn, Ralph, Ackerman, Steven, 2010: Investigating differences between cirrus optical depth retrievals between V3 CALIOP and MODIS observations. The NASA A-Train symposium, New Orleans LA, October 26 – 28 2010.

High Impact Weather Studies with Advanced Infrared Soundings

CIMSS Personnel: Jun Li, Jinlong Li, Jing Zheng, and Elisabeth Weisz
Federal Collaborators: Tim Schmit, Chris Barnet
NCAR Collaborator: Hui Liu
Funded by: NOAA, Navy

Project Description

Although the Hyperspectral Environmental Suite (HES) was removed from the GOES-R/S series, an advanced geostationary high-spectral resolution sensor is needed to meet validated user requirements. The hyperspectral IR sounders such as the Atmospheric InfraRed Sounder (AIRS), the Infrared Atmospheric Sounding Interferometer (IASI), and the Cross-track Infrared Sounder (CrIS) onboard Joint Polar-orbiting Satellite System (JPSS) can be used together with the high temporal and spatial resolution GOES-R Advanced Baseline Imager (ABI) (Schmit et al., 2005) to enhance the high impact weather (convective storms, tropical cyclones, etc.) nowcast and short-range forecast. In addition, an advanced infrared (IR) sounder in geostationary orbit will provide high temporal resolution of the three-dimensional fields of moisture, temperature, and wind with much greater vertical resolving power than either the broad-band legacy sounders on the current GOES series or other potential missions (Schmit et al., 2009). This breakthrough information on the temporal evolution of atmospheric horizontal and vertical water vapor, temperature and wind structures will lead to substantial improvements in monitoring the mesoscale environment for severe weather forecasting and other applications. The EUMETSAT (EUropean organization for the exploitation of METeorological SATellites) will fly a high spectral resolution sounder called InfraRed Sounder (IRS) on the geosynchronous Meteosat Third Generation (MTG) in 2018, other international communities (e.g., China) are also planning to fly advanced IR sounders in geostationary orbit in the 2015 time frame; thus it is essential to study the use of geostationary advanced IR sounding data for high impact weather warning, nowcasting and short-range forecasting.

In addition, CIMSS sounding team is conducting studies on JPSS sounding product evaluation through regional data assimilation and forecast systems. Assimilation of JPSS soundings in numerical weather prediction (NWP) models provides a supplementary and powerful evaluation technique, especially through assimilating soundings in a mesoscale forecast model. Key advantages of using regional assimilation techniques for sounding evaluation are: (1) spatial/temporal information can be evaluated through impact study; (2) sounding performance over ocean can be evaluated; and (3) it will help understand the applications of JPSS soundings on short range mesoscale forecasts.

The AIRS single field-of-view (SFOV) soundings are developed at CIMSS and are used in regional numerical weather prediction (NWP) model through assimilation. Typhoon Sinlaku (2008) track and intensity (central sea level pressure) analysis with and without AIRS soundings through WRF/DART (Weather Research and Forecasting Model/Data Assimilation Research Testbed) are compared with the observations. The control (CTL) run contains the radiosondes, satellite cloud winds, aircraft measurements, surface pressure, JTWC (Joint Typhoon Warning Center) advisory tropical cyclone (TC) position and other conventional observations. 6-hourly cycle is used in the analysis. The assimilation cycle started 08 September 2008. 9 km moving nest grid with feedback to 27 km grid in the WRF forecasts is used when TC is presented. The following experiments are conducted through WRF/DART:

- Control (CTL): RAOBs, satellite winds, aircraft measurements, surface pressure, TC position etc.
- CIMSS-T: Add AIRS T soundings from CIMSS algorithm.
- CIMSS-Q: Add AIRS Q soundings from CIMSS algorithm.
- CIMSS-TQ: Add both AIRS T and Q soundings from CIMSS algorithm.

Figure 66 shows the track (upper panel) and sea level pressure (lower right panel) analysis from CTL, CIMSS-T, CIMSS-Q, and CIMSS-TQ along with the observation. The track errors are shown in the lower left panel. From upper and lower left panels it can be seen that the combined temperature and moisture soundings provide the best analysis than either the temperature soundings alone or the moisture soundings alone. Either temperature soundings alone or moisture soundings alone performs better than the control run. The temperature soundings play more important role than the moisture soundings in track analysis for this particular case. For sea level pressure analysis (lower right panel), the temperature soundings alone, the moisture soundings alone and the combination of temperature and moisture soundings all improve the control run in general, however, the moisture soundings alone provide the best sea level pressure analysis in this particular case. The reason why the moisture soundings alone perform better than the combined temperature and moisture soundings is still under investigation. This is a collaborative work between CIMSS and NCAR (Dr. Hui Liu). This study demonstrates the positive impact of AIRS SFOV soundings on the hurricane track and intensity analysis. The next step is to evaluate the operational AIRS soundings.

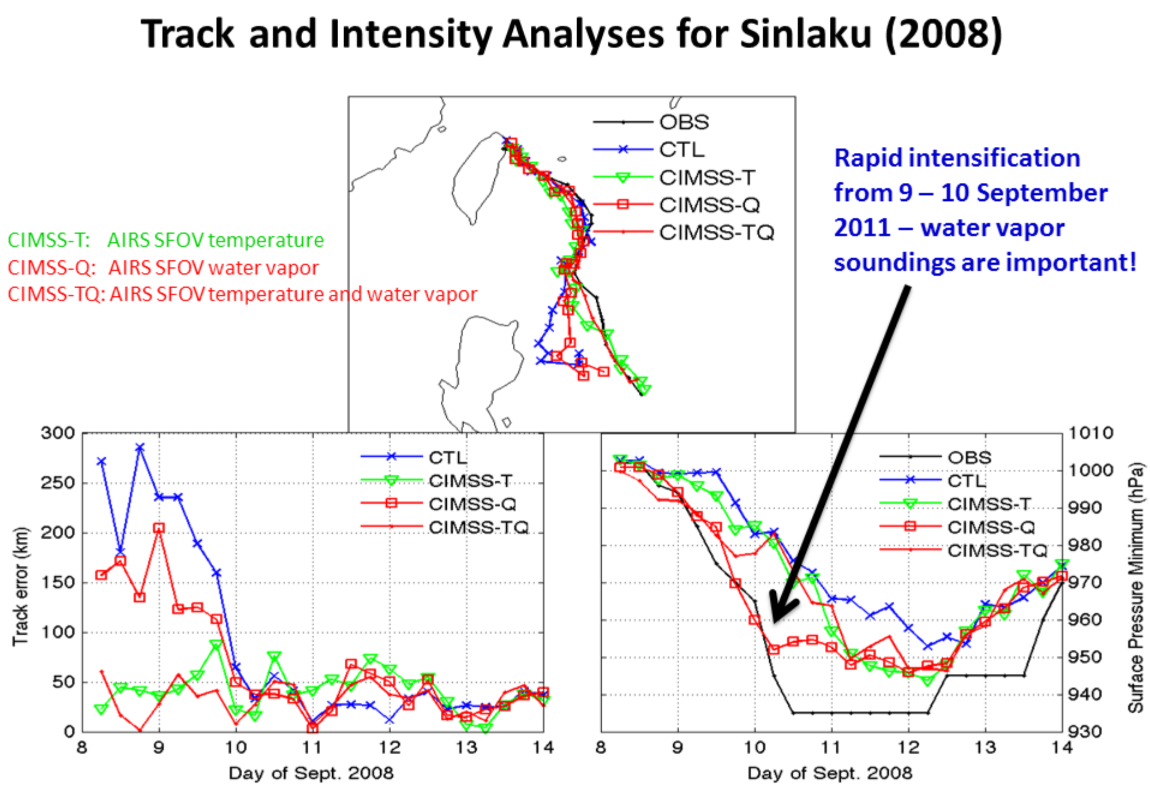


Figure 66 The track (upper panel) and sea level pressure (lower right panel) analysis from CTL, CIMSS-T, CIMSS-Q, CIMSS-TQ along with the observation, and the track errors from analysis (lower right panel).

CIMSS scientists has also implemented the WRF/3DVAR for assimilation studies, Hurricane Ike (2008) is used for assimilation experiments, AIRS SFOV soundings are used in the WRF/3DVAR assimilation and forecast system. Three AIRS granules (g066/067/068) at 06 UTC on 06 September 2008 are used in the experiment WRF/3DVAR experiment, the control (CTRL) run includes radiosondes, satellite winds, pilot report, GPS, ship, profiler, surface observations etc., and starts at 06 UTC on 06 September 2008; the AIRS (Control + AIRS) run uses the above observations (in CTRL) and the SFOV soundings in clear skies from three AIRS granules. Results show that the AIRS SFOV temperature and moisture soundings improve the 48-hour track forecasts, which is consistent with that from the WRF/DART assimilation and forecast system (Li and Liu 2009; Liu and Li 2010).

Publications/Conference Presentations

Li, J., 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, 2010: An improved in forecasting rapid intensification of Typhoon Sinlaku (2008) using clear-sky full spatial resolution advanced IR soundings. *J. Appl. Meteorol. and Cli.*, **49**, 821 - 827.

Li, J., H. Liu, and T. Schmit, 2010: Advanced Infrared Water Vapor Measurements Improve Hurricane Forecasts. SPIE, 012337/FAE9473B/000053. (published, not refereed)

Support for NOAA Cloud Climate Data Records

CIMSS Personnel: Michael Foster, William Straka III
Federal Collaborator: Andrew Heidinger
Funded by: NCDC

Project Description
The Pathfinder Atmospheres Extended (PATMOS-x) is a NOAA/NESDIS climate dataset generated in partnership with CIMSS. Until recently, PATMOS-x dealt exclusively with data from the Advanced Very High Resolution Radiometer (AVHRR) with instruments on the POES and METOP series of polar orbiting spacecraft. PATMOS-x has been modified to generate products from MODIS, GOES and the VIIRS sensor.

In 2010, PATMOS-x was selected as one of the first three Climate Data Records (CDR) to become operational CDRs at the National Climatic Data Center (NCDC). The version of PATMOS-x chosen for this delivery was the AVHRR-only version. NCDC's main goal was to host the PATMOS-x solar reflectance sensor data records (SDRs), which included the 0.63, 0.86 and 1.63 µm reflectances. The deadline for the initial operational CDRs was the end of the 3rd quarter, or 1 October 2010. The work this proposal is centered on is conducting the required dataset generation, documentation and delivery.

Accomplishments
- Generate PATMOS-x SDRs using AVHRR measurements with a spatial resolution of 0.1° (11 km) spanning 1978 to 2009.
- Verify the integrity of the data set, identifying corrupt/missing files, and format naming conventions and metadata to NCDC specifications.
- Document all code thoroughly and generate a processing flow chart with run instructions.
- Deliver compressed SDRs with checksums along with source code to NCDC for archival and distribution as operational CDRs.

This project was a collaborative effort with NCDC. Each of these milestones was met, and this data is available as an operational CDR from NCDC's site (http://www.ncdc.noaa.gov/sds/operationalcdrs.html). The SDR generation component was accomplished using the Atmospheric Product Evaluation And Test Element (PEATE) processing system at CIMSS. The AVHRR instrument records processed included those flown on TIROS-N, NOAA-7, -9, -11, -12, -14, -15, -16, -18, -19 and MetOp-A. Figure 67 shows an example false-color image of the three channels used to generate the SDRs.

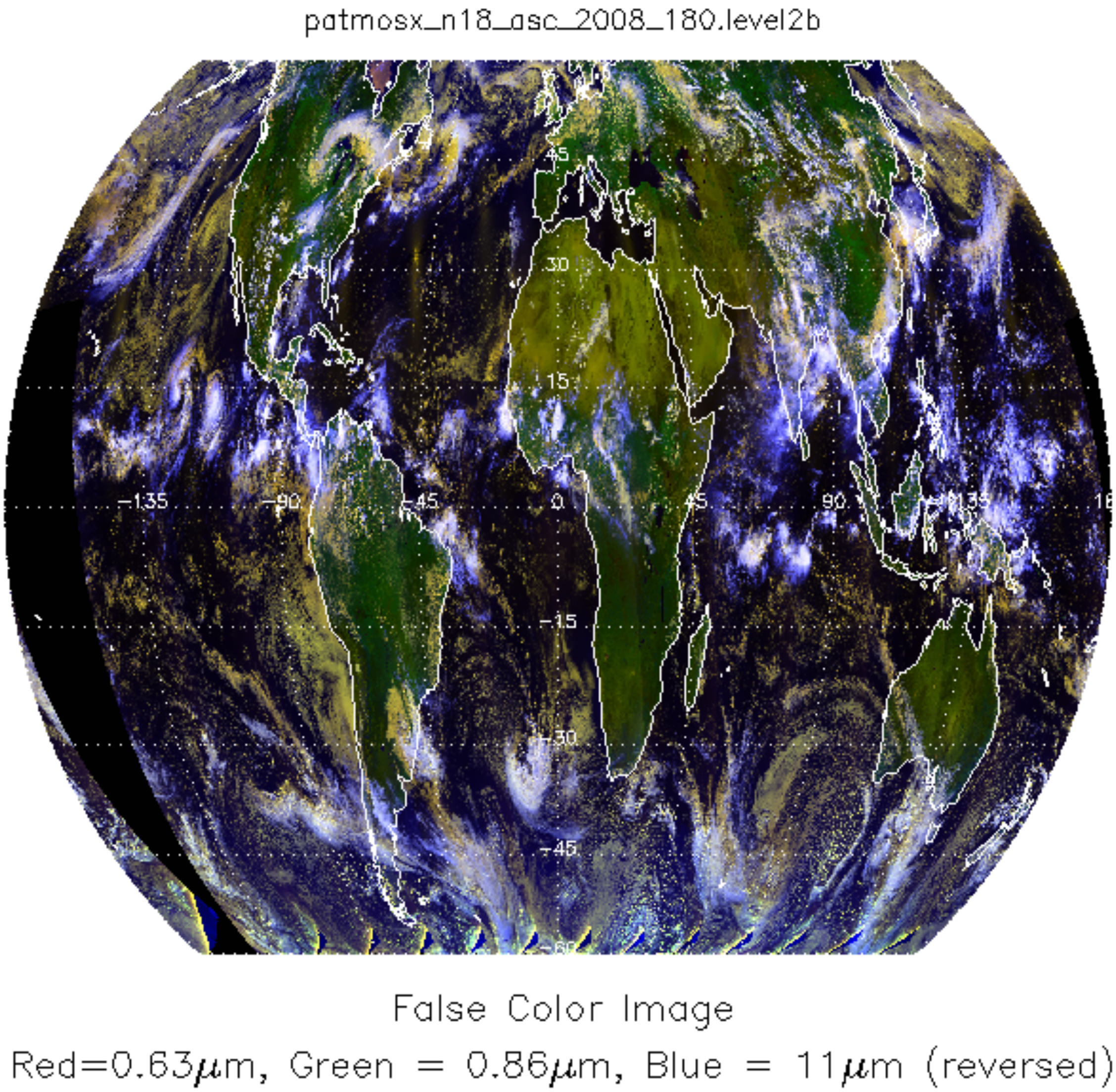


Figure 67 Example of PATMOS-x SDR values displayed as a false color image. The resolution of the PATMOS-x level-2b data is 0.1 degree in latitude and longitude. The NCDC delivery provided twice-daily data separated by orbital node for all AVHRR data from 1978 to 2009.

Publications/Conference Presentations

Heidinger, A. K., M. J. Foster and A. T. Evan 2011: A CALIPSO derived Naïve Bayesian Cloud Detection Scheme for the Pathfinder Atmospheres Extended (PATMOS-x) data set. *submitted to JAMC*.

Heidinger, Andrew K. and M. J. Foster, 2010: Towards a Consensus AVHRR Reflectance Calibration. ARC/SDS meeting, Asheville, North Carolina, September 2010.

Scientific Support for Derivation of Cloud Properties from Satellite Data

CIMSS Personnel: Patrick Heck
Federal Collaborators: Patrick Minnis (NASA), Andy Heidinger (NOAA)
Funded by: NASA Langley Research Center

Project Description

This project focuses on scientific and developmental analyses in support of GOES-R, CERES. ARM, NASA ASAP, CALIPSO and related programs by improving and enhancing algorithms and software used to derive cloud properties from satellite data. Additionally, personnel participate in collaborative synergistic studies between CIMSS and NASA Langley cloud/radiation groups to produce new methods and implement upgraded processing techniques for operational analyses of satellite data, including the development of GOES-R capabilities.

Accomplishments

For GOES-R nighttime cloud properties, a modified version of the NASA Langley Solar-infrared Infrared Split-window Technique (SIST) has been integrated into GEOCAT and the GOES-R Algorithm Integration Team (AIT) framework. This technique, the Nighttime Cloud Optical and Microphysical Properties (NCOMP) algorithm, derives cloud optical depth, cloud particle size and liquid/ice water path. NCOMP utilizes products from upstream GOES-R cloud algorithms, namely cloud temperature and cloud type, which are determined in algorithms developed by other NOAA and CIMSS researchers.

Validation studies of GOES-R NCOMP results from its application to SEVIRI as ABI proxy data compared to independent data sets, including CALIPSO, CloudSat and AMSR-E were a primary focus of the past year's work. As an example, results from comparing AMSR-E LWP to NCOMP LWP are presented in Figure 68.

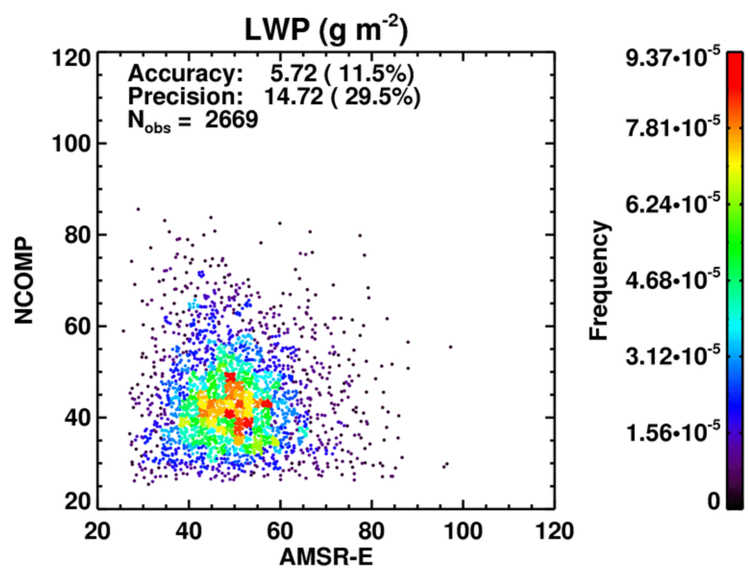


Figure 68 Comparison of derived LWP.

The accuracy and precision noted in Figure 68 easily meet the GOES-R F&PS requirements of 25.0 g/m^2 or 15%, whichever is greater, for accuracy and the greater of 25.0 g/m^2 or 40% for precision. This comparison was done for a subset of the 4-month period chosen for validation of all GOES-R cloud products.

Additional routine and deep-dive tools are being developed to validate all four NCOMP products, including comparisons to CALIPSO/CloudSat, surface-based MicroWave Radiometers (MWR), aicraft-based measurements and other satellite-derived products.

Publications/Conference Presentations

Publications

Minnis, P. and P. W. Heck, 2011: Nighttime Cloud and Optical Properties “GOES-R Algorithm Theoretical Basis Document”, NOAA, 100% delivery.

Minnis, P., S. Sun-Mack, Y. Chen, M. M. Khaiyer, Y. Yi, J. K. Ayers, R. R. Brown, X Dong, S. C. Gibson, P. W. Heck, B. Lin, M. L. Nordeen, L. Nguyen, R. Palikonda, W. L. Smith, Jr., D. A. Spangenberg, Q. Z. Trepte, B. Xi, 2010: CERES Edition 2 cloud property retrievals using TRMM VIRS and Terra and Aqua MODIS data: Part II: Examples of average results and comparisons with other data. *IEEE Trans. Geosci. Remote Sens.*, **49**, *11*, doi: 10.1109/TGRS.2011.2144602, in press.

Minnis, P., S. Sun-Mack, D. F. Young, P. W. Heck, D. P. Garber, Y. Chen, D. A. Spangenberg, R. F. Arduini, Q. Z. Trepte, W. L.Smith, Jr., J. K. Ayers, S. C. Gibson, W. F. Miller, V. Chakrapani, Y. Takano, K.-N. Liou, and Y. Xie, 2011: CERES Edition 2 cloud property retrievals using TRMM VIRS and Terra and Aqua MODIS data: Part I: Algorithms. *IEEE Trans. Geosci. Remote Sens.*, **49**, *11*, doi: 10.1109/TGRS.2011.2144601, in press.

Conferences

Heck, P. W., P. Minnis, S. T. Bedka, R. Palikonda, Y. Yi, M. M. Khaiyer, F. Chang, J. K, Ayers, 2010: Cloud property retrievals from satellite data using thermal wavelengths in daytime and nighttime. Proc. 13th AMS Conference on Atmospheric Radiation, Portland, OR, June 28-July 2.

CALIPSO Boundary Layer Studies

CIMSS Personnel: Ralph Kuehn, Bob Holz, Steve Ackerman
Federal Collaborators: NASA LaRC CALIOP Team
Funded by: NASA

This research focuses on the development and application of a planetary boundary layer height detection algorithm for CALIOP, the lidar on board the CALIPSO satellite. Accurate measurements of the Planetary Boundary Layer (PBL) height constitute a valuable data set for understanding boundary layer processes as well as to validate global weather forecast models. So far this project has concentrated on the development of a PBL height detection algorithm with a focus on the Great Lakes region and developing the validation methodology.

Our current approach uses a wavelet covariance transform analysis technique to find the top of the convective boundary layer from profiles of attenuated scattering ratio from the lidar. We use the methodology similar to that found in Davis et. al. 2000, and Brooks 2003, with several improvements that were necessary in order be successful with the low SNR data from CALIOP. Figure 69 shows our retrieval for the boundary layer top for October 9, 2010 overlaid on an image of CALIOP attenuated backscatter. The PBL height retrieved in this interval are approximately 1.76 km, the mixed layer height retrieved from AMDAR (Aircraft Meteorological DAta Relay) measurements at Chicago O'Hare (ORD) near the time of the CALIPSO overpass indicate a top in the range between 1.5 and 1.8 km.

References

Davis et. al. 2000: An Objective Method for Deriving Atmospheric Structure from Airborne Lidar Observations. *J. Atmos. Oceanic Technol.*

Brooks 2003: Finding Boundary Layer Top: Application of a Wavelet Covariance Transform to Lidar Backscatter Profiles, *J. Atmos. Oceanic Technol.*

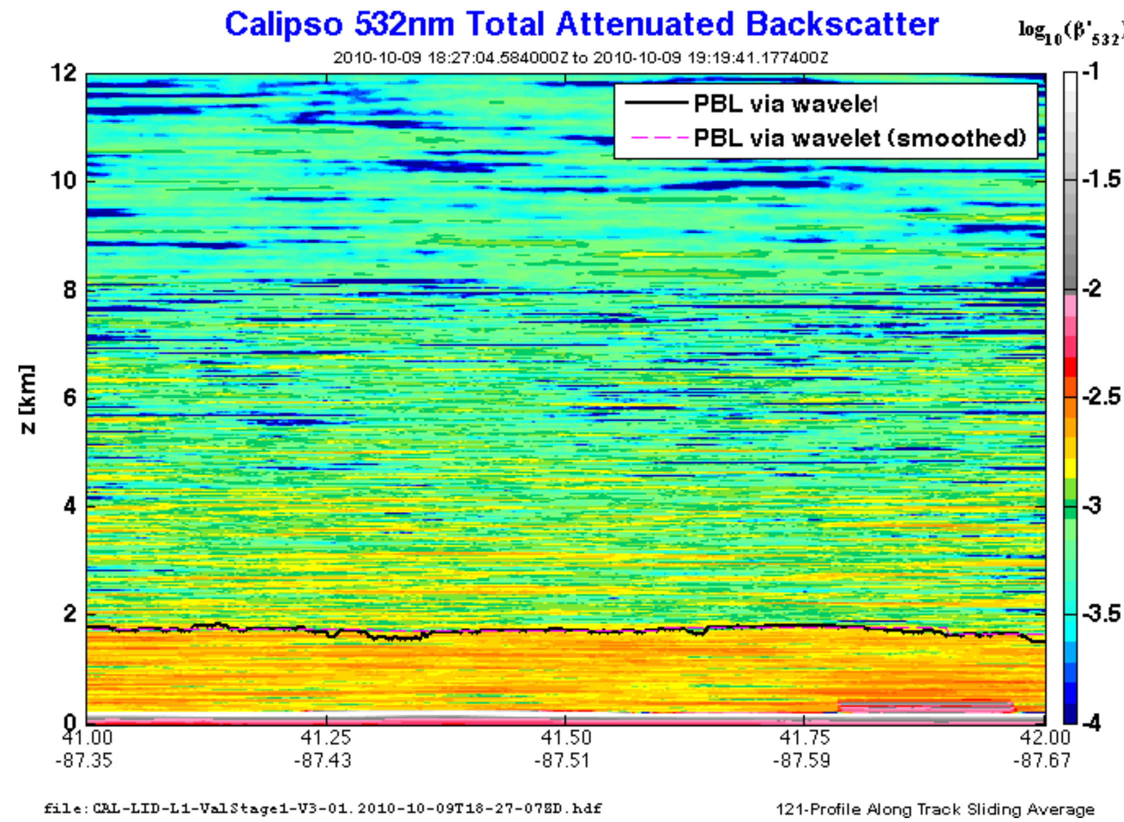


Figure 69 Attenuated backscatter image from CALIOP on 2010-10-09 near 19z between 41-42 Lat. The solid line indicates the retrieved boundary layer height from the PBL height algorithm, the mean retrieved height is 1.76 km over this region. The mixed layer height retrieved from AMDAR measurements near ORD indicate a boundary layer top in the range 1.5 to 1.8 km.

Publications/Conference Presentations

Presentation titled "Boundary Layer Heights from CALIOP" at the CALIPSO/CloudSat Science Team meeting, June 15-17, 2011. Montreal, Canada.

Reprocessing the HIRS Data to Study Cloud Property Trends

CIMSS Personnel: Paul Menzel, Erik Olson, Utkan Kolat
Federal Collaborator: John Bates
Funded by: NCDC

Project Description
HIRS data reprocessing is underway to mitigate several known issues affecting sensor to sensor radiance calibration and calculation of clear sky radiances. Comparison of broad band HIRS with the high spectral resolution Infrared Atmospheric Sounding Interferometer – IASI on METOP-A has established this HIRS as a reference sensor and inter-calibration with earlier HIRS using simultaneous nadir overpasses has helped to create a consistent sensor to sensor calibration record (Cao and Goldberg, 2009). In addition clear sky radiance calculations have been improved to mitigate calculated versus measured differences. We show that with these improvements, the HIRS observations of decadal changes in cloud cover can be mapped more accurately.

Sensor to sensor calibration differences have been difficult to overcome; however IASI provides a reliable calibration reference for HIRS. Based on the approach of Tobin et al. (2006), IASI measurements were convolved to the HIRS spectral response functions and compared with collocated (within 10 minutes and 10 km) HIRS measurements. Differences were noted between HIRS and IASI on METOP in clear and cloudy scenes for CO_2 sensitive spectral bands 4 (704 cm^{-1}, 14.2 μm), 5 (715 cm^{-1}, 14.0 μm), 6 (732 cm^{-1},13.7 μm), and 7 (750 cm^{-1}, 13.3 μm); mitigation was accomplished with a modest shift of the HIRS spectral bands. Then simultaneous nadir overpasses of the METOP HIRS an earlier HIRS on NOAA-19 back through NOAA-9 were used to suggest spectral shifts for those sensors.

Improvements in clear sky radiance calculations have been made by (1) implementing a 101–level radiative transfer model (Pressure Layer Fast Algorithm for Atmospheric Transmittances – PFAAST; Hannon et al., 1996; Strow et al., 2006) in the data reduction, (2) adjusting the ozone profile between 10 and 100 hPa to NCEP/NCAR Reanalysis (Kalnay et al., 1996) values (so that CO_2 radiances influenced by O_3 profiles are calculated more accurately), and (3) using a sinusoidal varying CO_2 concentration that increases 1.5 ppm per year from 337.5 in January 1980 to 381 ppm in January 2009 with a seasonal amplitude change of ± 3 ppm. These adjustments helped to reduce the magnitude of the radiance bias (observed minus calculated radiances) in the CO2 spectral bands by more than 50%.

Several additional adjustments to the cloud algorithm presented in Wylie et al. (2005) have been implemented after they were studied using the Moderate resolution Imaging Spectro-radiometer (MODIS) and the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) as a test bed (Menzel et al., 2008; Holz et al., 2008). These include (a) using CO_2 slicing for all ice and mixed phase clouds and infrared window determinations for all water clouds where cloud phase is indicated by split window considerations suggested by Heidinger and Pavolonis (2009), (b) modifying the CO_2 algorithm for top down application where the most opaque spectral band pair seeing the cloud determines the cloud top pressure (CTP), (c) lowering the "cloud signal" thresholds in CO_2 bands (change in radiance due to presence of cloud) from 1.0 to 0.5 mw/m2/ster/cm-1 to force more CO_2 slicing solutions for high thin clouds, (d) declaring clouds with small thermal contrast from clear skies as uncertain (e) restricting CO_2 band pair solutions to the appropriate portion of troposphere (as suggested by their weighting functions: 4/5 <440 hPa, 5/6 <560 hPa, and 6/7 < 680 hPa), (f) identifying stratospheric clouds when an opaque band (carbon dioxide vapor sensitive band 5 at 14.0 μm) is warmer than a less opaque band (carbon dioxide sensitive band 7 at 13.3 μm). All the improvements to the heritage cloud algorithm were tested on MODIS data where comparisons with CALIOP verified that the cloud product was improved.

Cloud observations from NOAA-6 onwards were processed from 60˚N to 60˚S, including both ascending and descending orbits (see Figure below). HIRS view angles less than 32˚ from nadir were considered to mitigate cloud edge effects. The cloud mask was based on spatial and temporal variances of the IR window plus CO_2 screening of thin cirrus. Clear radiances were derived from forward radiance calculations with bias corrections interpolated from neighboring fields of view using the NCEP/NCAR Reanalysis.

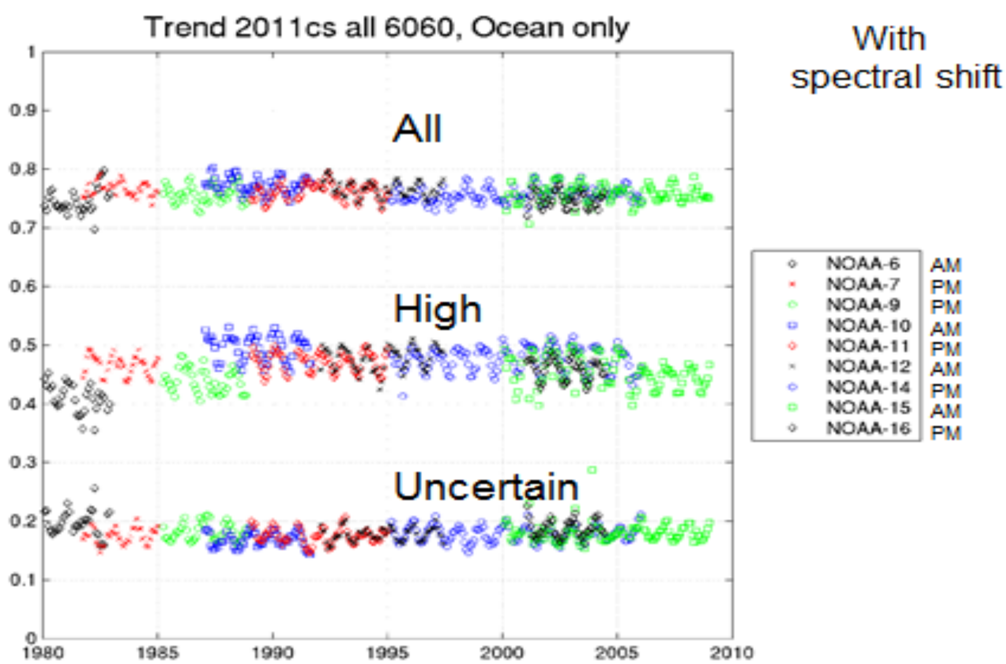


Figure 70 reprocessed cloud trends for NOAA -6 to -17 (after spectral adjustment and algorithm changes) for the percentage of HIRS observations where a cloud is detected, where a high cloud (cloud top pressure less than 440 hPa) is detected (this relies on spectral bands 4 at 14.2 µm and 5 at 14.0 µm), and where it is uncertain whether or not a cloud has been detected.

Figure 70 shows the reprocessed cloud trends for NOAA -6 to -17 (after spectral adjustment and algorithm changes) for the percentage of HIRS observations where a cloud is detected, where a high cloud (cloud top pressure less than 440 hPa) is detected (this relies on spectral bands 4 at 14.2 µm and 5 at 14.0 µm), and where it is uncertain whether or not a cloud has been detected. The uncertain category arises from situations where the thermal contrast of clear and cloudy is small and includes low clouds (1) where the cloud top pressure was estimated to be greater than 950 hPa, (2) where the cloud top temperature was estimated to be within 3 C of the sea surface temperature (or 5 C of the land surface temperature), and (3) where a low cloud (cloud top pressure greater than 680 hPa) was suspected over non-vegetated land.

Publications/Conference Presentations
Results were presented the 17th Conference on Satellite Meteorology and Oceanography, held in Annapolis, MD 27-30 September 2010

Five Year Insolation Climatology from GOES using SASRAB

CIMSS Personnel: Christine Molling, William Straka III
Federal Collaborator: Andrew Heidinger
Funded by: Nation Renewable Energy Laboratory

Project Description
Using funding provided through the Nation Renewable Energy Laboratory, CIMSS personnel are creating a 5-year climate data set of solar insolation and associated cloud products. This data set will allow users in the solar power industry to evaluate potential sites for photovoltaic and concentrated solar thermal plants. Others will use these data to investigate agricultural productivity, coral reef health, hydrology, and more. Files will be available every 30 min from Jan 1, 2005 through Dec 31, 2009. Files for 2009 have already been produced.

Solar power is an attractive, clean alternative to fossil fuel and nuclear power. When considering whether to place a solar power plant in any location, several questions must be answered: How much sunlight reaches the ground here on average? How variable is the sunlight over the course of a day, a week, and a year? Would it make more sense to use photovoltaics, which have a lower efficiency, but can operate on cloudy days, or concentrated solar thermal, which has a higher efficiency but only works on sunny days?

These questions can be answered in part by taking advantage of the long record of geostationary satellite imagery. An algorithm called SASRAB was developed several years ago and has been used by NESDIS in their GOES Surface & Insolation Products (GSIP). This algorithm uses GOES imager data to determine how much sunlight, both diffuse and direct beam, reaches the surface of the earth, along with information on clouds, surface temperatures, and other portions of the Earth's radiation budget. GSIP is available to the public only since 2009 at a 1/8 degree resolution.

CIMSS recently received funding to use the SASRAB algorithm to produce insolation and related products at a higher resolution, and for a full five years. SASRAB was inserted into the PATMOS-x satellite data processing system and now produces insolation, surface, and cloud products from GOES at the thermal pixel resolution (about 4km at the equator). Because it is embedded in PATMOS-x, a greater number of surface, cloud, and atmospheric properties are now available with the insolation variables.

For each day processed, 48 files are available for each of the two GOES over North America. A single file contains 50 different variables derived from the GOES imager visible and thermal channels. Acquired every 30 min, the images and the derived data produced from them in SASRAB and PATMOS-x cover either the Northern Hemisphere extended area (40/day) or the full disk (8/day).

One year of the data set, 2009, has been completed recently. The entire 5 year set will be complete by October, 2011, with an approximate size of 8.5 Tb. Analyses are currently underway to validate insolation, surface temperature, and cloudiness from SASRAB with in-situ data at seven locations in the United States. These will also be available as quality indicators to aid users of the data set.

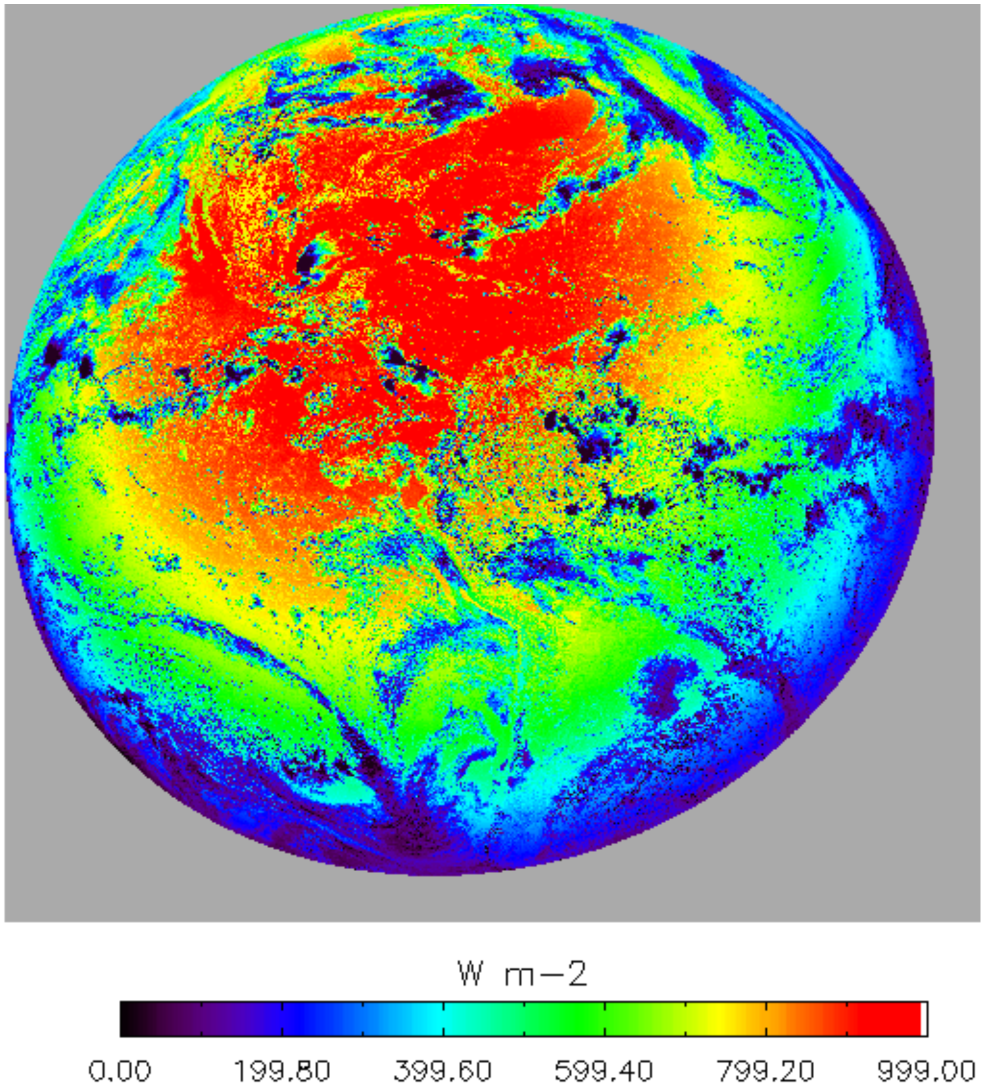


Figure 71 Total downwelling shortwave flux at the surface derived from the GOES-12 imager. Figure represents the total amount of sunlight reaching the ground on June 1, 2009 at 1745 UTC. The outlines of the southern part of North America, Central America, and the northern and western South America are visible among the blue and green cloudy areas.

Optimizing the Assimilation and Impact of Satellite Data in Hurricane Models

CIMSS Personnel: Chris Velden, Howard Berger, Will Lewis, Brett Hoover
Federal Collaborators: Rolf Langland and Carolyn Reynolds (NRL)
Other Outside Collaborators: Prof. Sharan Majumdar (U. Miami), Hui Liu (NCAR)
Funded by: ONR and NOPP

Project Description

Two complimentary studies are underway that aim to optimize the assimilation of high-resolution satellite data into numerical models to achieve improved tropical cyclone forecasts. One is focused on global model impacts, and the other is a pioneering study with novel mesoscale data assimilation and high-resolution models. The long term goal of each investigation is the development of successful real-time strategies to optimally assimilate data from satellites that will ultimately lead to the provision of improved initial and boundary conditions for numerical prognoses of tropical cyclones.

The "Advanced Satellite-Derived Wind Observations, Assimilation, and Targeting Strategies during TCS-08 for Developing Improved Operational Analysis and Prediction of Western Pacific Tropical Cyclones" project primary research goal is to evaluate and diagnose the impact of assimilating the advanced satellite wind observations on global Navy model forecasts, and high-resolution forecasts of structure change. The aim is to better understand how to utilize the satellite wind data in the context of numerical model assimilation and forecast impact. Optimizing the assimilation of the experimental satellite winds will involve a continued investigation of the satellite data impacts with respect to objective targeting of analysis-sensitive regions, and utilizing 4DVAR approaches.

During the field phase of the Tropical Cyclone 2008 (TCS-08) field program, experimental satellite-derived wind observations were produced by UW-CIMSS using state-of-the-art automated methods. Hourly datasets were routinely derived from operational images provided from the Japan Meteorological Agency (JMA) MTSAT geostationary satellite. In addition, special rapid-scan (r/s) images from MTSAT-2 were provided by JMA for extended periods (24-48hrs) over specific regions, and including parts of selected typhoon life cycles. UW-CIMSS also processed these images into wind fields (higher resolution). These special satellite-derived wind observations provide unique time-continuous environmental data in locations that were deemed important to tropical cyclone formation and development.

The project uses the latest versions of the NRL Atmospheric Variational Data Assimilation System – Accelerated Representer (NAVDAS-AR) and NOGAPS, the Navy's current operational data assimilation and global forecast model systems, so that the research results may be easily transitioned to improve the Navy's operational predictions. The hourly MTSAT AMV datasets were first assimilated in NAVDAS-AR for the two- month TCS-08 period. The hourly AMVs allow for more consistent temporal coverage of the evolving atmospheric flow. This baseline analysis also includes all conventional and special T-PARC observations except for dropwindsondes and rapid-scan AMVs, and is referred to as the control (CTL). Two additional experiments were produced: (i) "No-AMV" which is CTL with the CIMSS hourly winds removed, and (ii) "Rapid-Scan" which is CTL but with the rapid-scan AMVs included. For NOGAPS forecasts of length exceeding 3 days, the average error of the tropical cyclone track forecasts is reduced considerably due to the assimilation of the hourly AMVs (Table). The same forecasts were also improved further by the inclusion of rapid-scan winds. For example, for 4-day forecasts, the average track error was reduced by ~30% when hourly winds were included, and by ~45% when both hourly and rapid-scan winds were included.

Fcst (hrs)	0	12	24	36	48	60	72	84	96	108	120
CTL w/ AMV	22	39	70	93	114	151	213	195	167	248	317
No-AMV	22	40	67	91	108	154	227	248	245	365	450
Rapid-Scan	25	45	78	111	122	158	210	174	135	215	250
# cases	22	20	18	16	14	13	12	11	9	8	7

TABLE. NOGAPS track forecast errors (in nm) for the three NAVDAS/NOGAPS numerical experiments, over all tropical cyclone cases during TCS-08.

The "Achieving Superior Tropical Cyclone Intensity Forecasts by Improving the Assimilation of High-Resolution Satellite Data into Mesoscale Prediction Models" project is newly underway. CIMSS AMV providers are partnering with experts in the data assimilation field to pioneer approaches to optimize full resolution multivariate satellite observations into mesoscale analyses and forecast models. A comprehensive database of full-resolution observations from multiple satellite platforms for selected TC case studies has been prepared for provision to the Navy, NOAA and NCAR collaborators in this study. We aim to quantify how best to utilize the multiple satellite datasets in applications to TC structure/intensity prediction, using advanced data assimilation and high-resolution forecast models, and ultimately to provide a pathway towards advanced satellite data assimilation in the emerging operational TC forecast models (i.e., HWRF, COAMPS-TC).

Our approach is to first investigate and optimize the assimilation of the satellite data in the WRF ensemble-based assimilation system. The COAMPS-TC system will also be employed in later efforts. In the evaluation phase, the investigators are analyzing the parallel model forecasts that assimilate and do not assimilate the satellite data. In this manner, the utility of the various satellite data in improving TC intensity predictions is being assessed. The main science focus is on investigating and understanding how the assimilation of the satellite data modifies the model analyses and forecasts of TC structure. Moreover, the improvement in model representation of important synoptic features such as adjacent trough interactions, outflow channels, and available environmental moisture is expected to benefit the numerical forecasts of TC intensities. The effects of assimilating data from multiple satellite platforms will be investigated for each individual platform, and for combinations of platforms. Typhoon Sinlaku and Hurricane Ike, both from 2008, are being targeted as first-look cases, but other TCs during our study period that undergo rapid intensity change will become candidates for further investigations. A preliminary promising result of the AMV impacts for the Ike case is shown in Figure 72.

Publications/Conference Presentations

Berger, H., R. Langland, C. Velden, C. Reynolds and P. Pauley, 2011: Impact of Enhanced Satellite-Derived Atmospheric Motion Vector Observations on Numerical Tropical Cyclone Track Forecasts in the Western North Pacific during TPARC/TCS-08. J. Appl. Meteor and Clim.

Liu, H., C. Velden, J. Anderson, S. Majumdar, and C. Snyder, 2011: Improved Analyses and Forecasts of Rapidly Intensifying Tropical Cyclones by Assimilation of Rapid Scan Satellite Winds Using an Ensemble Filter. 15th Symposium on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans and Land Surface (IOAS-AOLS).

Wu, Ting-Chi, H. Liu, C. Velden, S. Majumdar, and J. Anderson, 2011: Improving the Assimilation of High-Resolution Satellite Wind Data into Mesoscale Prediction Models. 65th Interdepartmental Hurricane Conference.

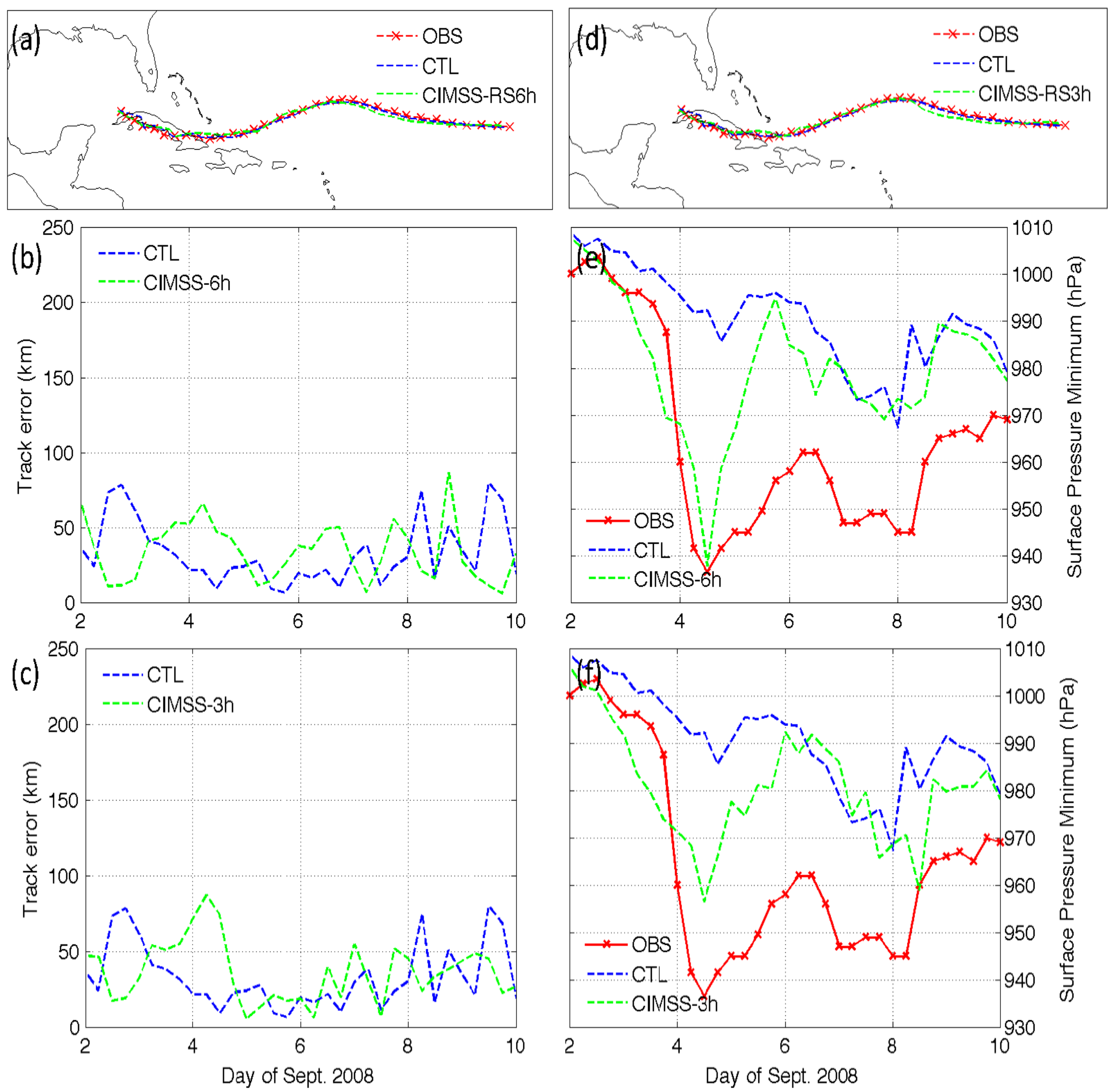


Figure 72 Analyses for Hurricane Ike, for (a-c) 6-hour intervals and (d-f) 3-hour intervals. The graphs represent analysis differences (not forecasts) at these intervals for 8 days of the experiment. NHC Best Track data is used in the validation

Support and Research for PREDICT (PRE-Depression Investigation of Cloud Systems in the Tropics)

CIMSS Personnel: Chris Velden, Derrick Herndon, Dave Stettner, John Sears, Sarah Monette
Other Collaborator: Prof Lance Bosart (SUNY-A)
Funded by: NSF

Project Description
The proposed PRE-Depression Investigation of Cloud-systems in the Tropics (PREDICT) was a focused observational field campaign conducted in the Atlantic in 2010 to investigate both the structure and evolution of tropospheric wave-like disturbances in the tropics and sub-tropics and the subsynoptic- and mesoscale processes operating within the waves that contribute to the formation of tropical depressions. The formation of tropical cyclones remains one of the great, unsolved problems in meteorology. It inherently requires study of multiple scales of atmospheric motion from cloud particles to synoptic-scale waves. PREDICT is distinguished from previous efforts related to tropical cyclone formation by (a) new dynamical hypotheses to be tested; (b) nearly continuous aircraft observations; (c) the region of study; (d) advanced sensors and facilities. Its intellectual merit is that it will test hypotheses concerning tropical cyclone genesis using this unique data set. The contribution by the CIMSS team of investigators is to provide timely and unique satellite-based products that will help investigators define environmental parameters associated with tropical cyclone genesis.

Broader Impacts: While there is evidence that tropical cyclone forecasts have improved in recent years, deterministic genesis prediction is still a very difficult problem. As prediction is required on longer time scales for emergency management and short-term mitigation, prediction of genesis becomes more important. Mechanisms of genesis are crucial to understand in order that processes leading to simulated genesis in weather and climate models can be adequately evaluated. PREDICT will improve our ability to anticipate genesis, by arming forecasters with conceptual tools regarding the process.

The PREDICT field campaign phase was successfully completed last fall, and the CIMSS PREDICT team was instrumental in supporting mission planning and flight operations support. Tailored satellite-based products were used by analysts and forecast teams in the daily operations. PI Velden was in St Croix for three weeks to provide decision-making and analysis support for missions of interest to PREDICT goals. All satellite data and products processed by the UW-CIMSS team were made available in real time, including special experimental diagnostics. These data and products were also made available to the PREDICT data management team for archival purposes. Since the field program ended, a post-analysis phase of the data and case studies has begun. The CIMSS team is collaborating on a paper submission to the AMS Bulletin (BAMS).

We continue to investigate two principles threads of research with the PREDICT data. The first involves an exploration of the upper-level antecedent conditions prior to TC genesis. Case studies have been identified, and locally-produced 3-D analyses have been assembled to begin our investigations. Code was written to deduce horizontal mass flux, integrated available kinetic energy, and eddy flux convergence diagnostics. These parameters will be viewed independently and in combination to isolate potential signatures of favorable upper-level conditions for TC genesis. A CIMSS student is working on his MS and making good progress. Expected completion date is December, 2011. His topic is on analyzing both satellite and aircraft upper-level data for possible leads to TC genesis conditions. Preliminary findings from composite analyses and case study TC Karl are encouraging (see Figure 73).

The second project involves an investigation of the vertical hot tower (VHT) frequency distributions and behavior prior to genesis, to assess the prognostic potential as expressed by a probability function. The proxy for VHTs are overshooting cloud tops as diagnosed by a local algorithm developed at CIMSS that operates on GOES IR satellite imagery. A Master of Science degree was awarded to one of the students working on this project. Her thesis was a direct result of analysis of satellite data during the PREDICT field phase. Results show promise towards predicting TC genesis. A journal article will derive from the MS and is currently being written.

Publications/Conference Presentations

Monette, S., 2011: Tropical Applications of a Satellite-Based Objective Overshooting Top Detection Algorithm. Univ. Wisconsin M.S. Thesis.

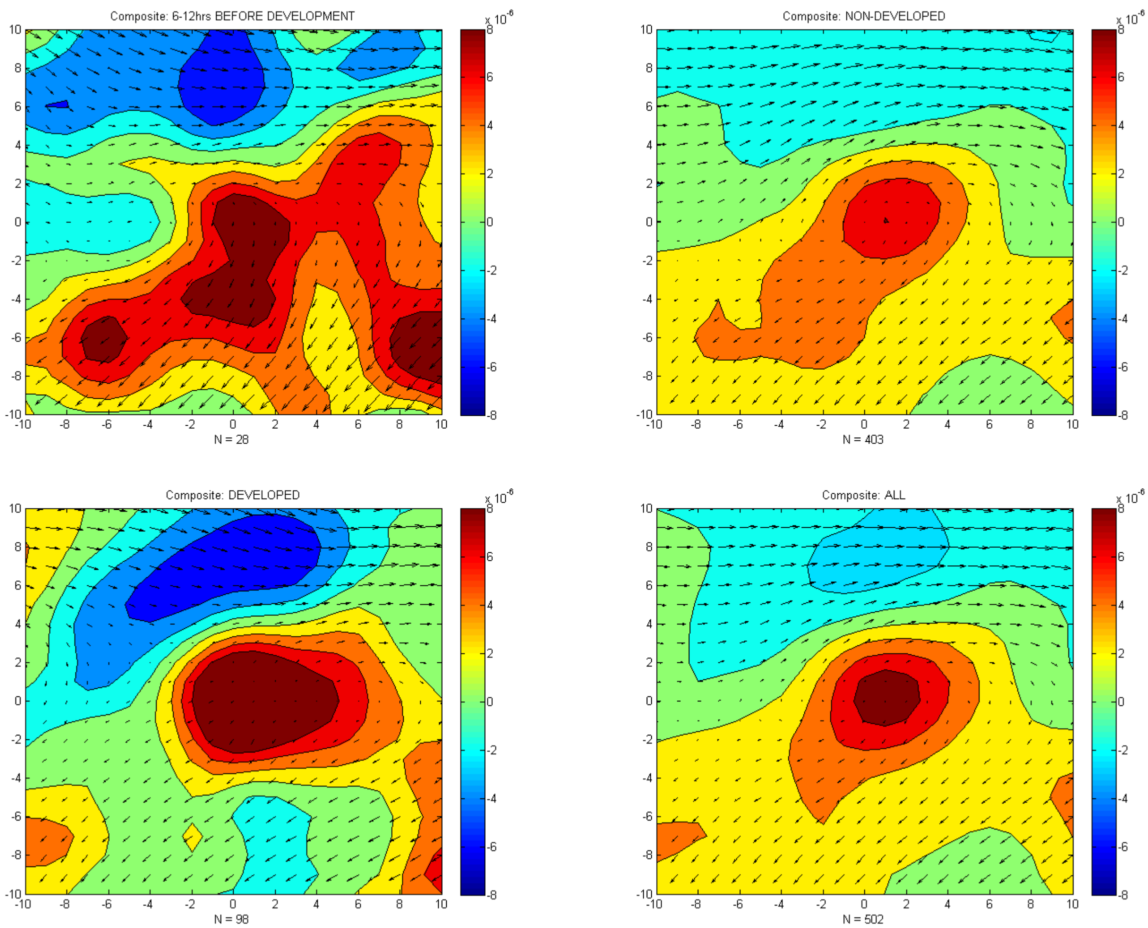


Figure 73 Composite analyses of divergence based on 502 disturbance-centered CIMSS analyses in the tropical Atlantic from 2010. Shown is composited 200hPa Divergence (red is strong) for all cases (u/l), pre-developing only (u/r), non-developing (l/l), and already developed systems (l/r). 200hPa composited wind vectors are also plotted. The pre-developing analyses reflect 6-12 hrs before genesis (from NHC Best Tracks). ***The pre-dev composite indicates much stronger divergence relative to the non-dev composite, and also suggests outflow channels.***

University of Wisconsin Space Science and Engineering Center (SSEC) FY10 GEO-CAPE Science Working Group Activities

CIMSS Personnel: Todd Schaack, Allen Lenzen
Federal Collaborator: R. Bradley Pierce
Funded by: NASA

Project Description
This effort supports the NASA Geostationary Coastal and Air Pollution Events (GEO-CAPE) Atmospheric Variability Science Working Group (SWG). The SWGs are responsible for preparation for the GEO-CAPE Mission. High resolution WRF-CHEM simulations are used to statistically characterize the spatial variability of targeted atmospheric constituents over the spatial scales relevant to GEO-CAPE, and to investigate the sensitivity of model simulated atmospheric variability to horizontal resolution. Results from these analyses provide the GEO-CAPE Science Team with information useful for establishing measurement requirements for GEO-CAPE.

The variogram analysis developed by Jim Crawford (NASA/LaRC) has been adapted for applications to generalized gridded model output. Variogram analyses were completed for WRF-CHEM CO, O3, NO2, SO2, and cloud optical thicknesses and were compared to TEXAQS aircraft variograms by Crawford. Results show that column CO and O3 distributions show relatively small (1-2%) normalized differences, column NO2 and SO2 distributions show larger normalized differences (10-12%), and cloud optical thicknesses (COT) show the largest normalized differences (60-65%) at 4km. These model results were validated by utilizing special observing strategies during the NOAA GOES-15 Science Test to collect high spatial (1km) and temporal (5 minutes) measurements for conducting cloud optical thickness variogram analysis. GOES-15 COT retrievals were performed for each of the 5 minute scans using the Daytime Cloud Optical and Microphysical Properties (DCOMP) algorithm and 0.6 and 3.9 micron radiances. The DCOMP algorithm was developed under the GOES-R Advanced Baseline Imager (ABI) Cloud Algorithm Working Group led by Andrew Heidinger (NOAA/NESDIS/STAR).

Variogram analysis showed that the majority of the GOES-15 COT distribution (both lower 50th and upper 50th percentiles) show variation (as measured by normalized differences) of 5 times the mean value at 1km and 15 times the mean value at 4km which is significantly higher then the WRF-CHEM estimates of cloud variability. These studies show that going from 4km to 1km pixel reduces normalized variation by a factor of 3 for GOES-15 COT retrievals and suggests that cloud clearing requirements will drive the GEO-CAPE minimum pixel size.

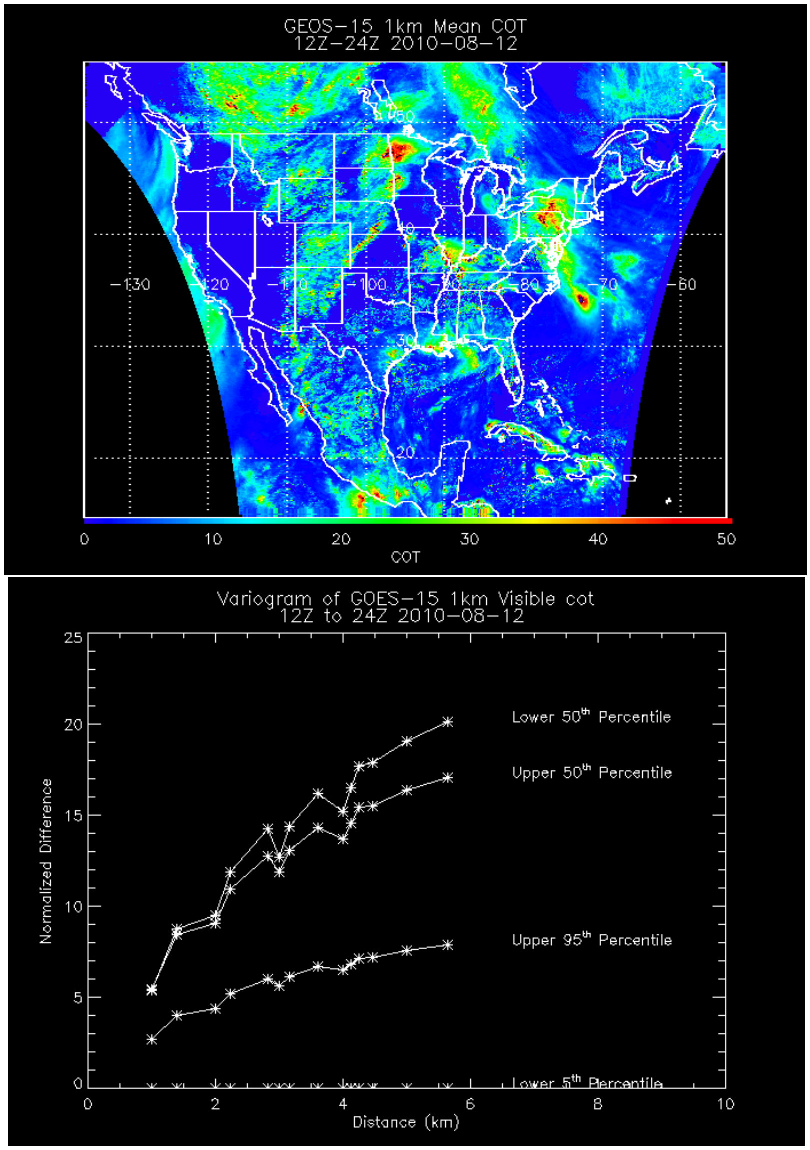


Figure 74 Mean GOES-15 1x1km Cloud Optical Thickness (COT) distribution from 12Z to 24Z on 08/12/2010 (upper) and normalized differences vs. distance (km) (lower) for upper 95%, upper 50%, lower 50%, and lower 5% of mean COT distribution.

Publications/Conference Presentations

A Geostationary Satellite Constellation for Observing Global Air Quality: An International Path Forward, Prepared by the CEOS Atmospheric Composition Constellation, Draft Version 4.0, April 12, 2011 (http://www.ceos.org/images/ACC/AC_Geo_Position_Paper_v4.pdf)

University of Wisconsin Space Science and Engineering Center (SSEC), FY10 GEO-CAPE Science Working Group Activities , SSAI Task Order 1-013, Subcontract Agreement 2616-08-062, Final Report

A New Secondary Eyewall Formation Index, Transition to Operations and Quantification of Associated Intensity and Structure Changes

Personnel: James Kossin (NOAA), Matthew Sitkowski (CIMSS/AOS), Chris Rozoff (CIMSS)
Funding Agency: NOAA

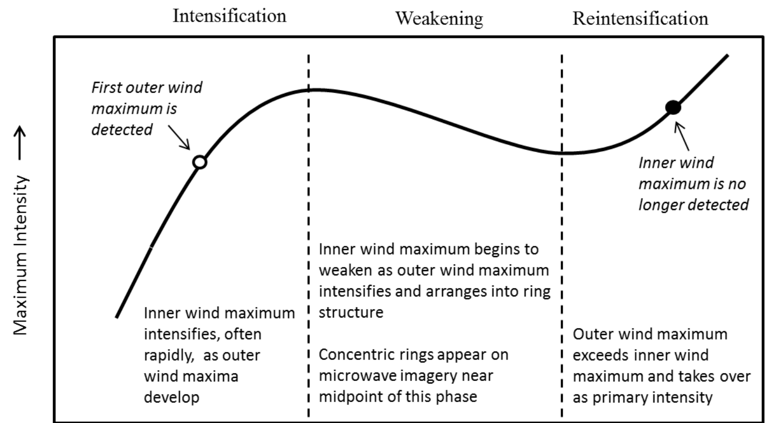
Project Description / Milestones:
Work under this project has been successfully continuing. The Probability of Eyewall Replacement Cycle (PERC) model was incorporated into National Hurricane Center (NHC) operations and is now in its 2nd year of testing. A decision regarding the permanent acceptance into NHC operations will be made after the conclusion of the 2011 season. The PERC model determines the likelihood of a hurricane undergoing eyewall replacement over the next 2 days, every 6 hours in conjunction with NHC forecasts. The model was utilized and mentioned in some of official NHC discussions during the 2010 hurricane season and appears to be getting attention by hurricane specialists. Model performance for the first year of testing, along with validation from previous in-house forecasts appear below in Figure 75. Overall, the PERC-model has been performing as expected based on cross-validated testing when the model was developed.

Operational Brier Skill Scores

Year	N (ERC)	00−12 hr	12−24 hr	24−36 hr	36−48 hr
2010	9	+27%	+20%	+0%	−3%
2009	3	−6%	−9%	−2%	+3%
2008	4	+14%	+11%	−9%	+1%
2008−2010	16	+17%	+12%	−3%	−1%

Figure 75 Operational Brier skill scores for the PERC-model. Each forecast assigns probabilities of an ERC during the next 12h, 12-24hr, 24-36hr, and 36-48hr periods.

While the PERC-model assists forecasters with the timing of eyewall replacement, it does not yet provide information on how structure and intensity forecasts should be adjusted. As a first step to adding this guidance to complement the PERC-model, a flight-level aircraft database was constructed to develop a climatology of structure and intensity changes during eyewall replacement cycles. The eyewall replacement cycle (ERC) paradigm first developed by Willoughby et al. (1982) was further refined as a result of this research project, dividing an ERC into 3 distinct phases: intensification, weakening, and reintensification (Figure 76). In addition, microwave imagery was compared with the flight-level data to provide a sense of convective structure during the three phases of an ERC. It was found that well-defined convective rings appear well into an ERC, about half way through the weakening phase. Additional results and detailed information on the methodology used to produce the ERC climatology are available at the link below.



Time (hr)		9		16		11	
r_1 (km)	35		28		27		24
r_2 (km)	106		91		63		51
v_1 (m s^{-1})	52		59		49		41
v_2 (m s^{-1})	35		39		49		51

Figure 76 Schematic of the intensity and structure evolution during the 3 phases of an ERC. The inner (outer) eyewall intensity is represented by v_1 (v_2). The average amount of time to complete each phase, along with the average values of the location (distance from storm center) of the inner and outer eyewalls, r_1 and r_2, respectively, are listed for the start, end, and transition periods of the ERC.

Publications/Conference Presentations

Sitkowski, M., J. P. Kossin, and C. M. Rozoff, 2011: Intensity and structure changes duringhurricane eyewall replacement cycles. *Mon. Wea. Rev.*, in press. Early online release available at http://journals.ametsoc.org/doi/abs/10.1175/MWR-D-11-00034.1

Kossin, J., M. Sitkowski, and C. Rozoff, 2011: A New Secondary Eyewall Formation Index: Transition to Operations and Quantification of Associated Hurricane Intensity and Structure Changes. 65th Interdepartmental Hurricane Conference, Miami, FL, 28 Feb-3 March 2011.

References

Willoughby, H. E., J. A. Clos, and M. G. Shoreibah, 1982: Concentric eyewalls, secondary wind maxima, and the evolution of the hurricane vortex. *J. Atmos. Sci.*, **39**, 395-411.

CIMSS Support of STAR Calibration/Validation Activities: Retrospective Analysis of GSICS Inter-calibration Method using AIRS

CIMSS Personnel: Mat Gunshor, Scott Lindstrom
Federal Collaborator: Tim Schmit
Funded by: NOAA/NESDIS

Project Description
CIMSS has been heavily involved in GOES calibration projects since the inception of the GOES project. The GOES/POES intercalibration project at CIMSS has consistently been a cornerstone of that work. The methods developed at CIMSS laid the groundwork for an international effort to monitor the calibration of geostationary imagers world-wide.

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

In this project, CIMSS performs retrospective analysis using the GSICS method for NOAA. The operational GSICS team at performs intercalibration daily for their host of geostationary imagers and includes the United States (NOAA/NESDIS), Japan, China, and Europe. CIMSS is doing a retrospective analysis of all of the instruments being done operationally, as well as several instruments no longer in operations. Using AIRS to compare to the Imagers using the official GSICS algorithm, CIMSS began with retrospective processing of all GOES Imagers using AIRS. This effort will be expanded in future years to include international instruments such as MTSAT, METEOSAT, FY-2 and possibly others.

The GSICS code was provided to CIMSS by NOAA/NESDIS/STAR. CIMSS implemented the code locally and leveraged another project (PEATE) to obtain the AIRS data. The Space Science and Engineering Center (SSEC) datacenter has the GOES archive available for CIMSS scientists at a small cost to individual projects.

The GOES/AIRS GSICS code was tested extensively to be sure that it was implemented at CIMSS properly. Once the code installation was verified, back-processing of GOES-10 Imager began. Some issues with the local AIRS database have slowed down the retrospective processing somewhat. So far CIMSS has generated the GSICS output files for GOES-10/AIRS (2003-2007), GOES-11 (2006-2007), andGOES-12/AIRS (2004-2007). This retrospective analysis will continue while CIMSS also will be developing the capability to do GOES/IASI comparisons, with focus on maintaining identical functionality with NESDIS and the GSICS algorithm.

Publications/Conference Presentations
Gunshor, Mathew M.; Tobin, D.; Schmit, T. J. and Menzel, W. P., 2010: Intercalibration activities at CIMSS in preparation for the GOES-R era. Annual Symposium on Future National Operational Environmental Satellite Systems - NPOESS and GOES-R, 6th, Atlanta, GA, 17-

21 January 2010. Proceedings. American Meteorological Society, Boston, MA, 2010, (Poster)

Gunshor, Mathew M., Lindstrom, S., Schmit, T. J., Tobin, D. and Menzel, P., 2011: Intercalibration activities at CIMSS in preparation for the GOES-R era. Annual Symposium on Future Operational Environmental Satellite Systems, 7th, Seattle, WA, 23-27 January 2011. American Meteorological Society (AMS), Boston, MA, 2011. (Poster)

Goldberg, Mitch; Weng, F.; Wu, X.; Yu, F.; Wang, L.; Tobin, D. C. and Gunshor, M. M.. The Global Space-based InterCalibration System (GSICS) for GOES-R and JPSS. Annual Symposium on Future Operational Environmental Satellite Systems, 7th, Seattle, WA, 23-27 January 2011. American Meteorological Society (AMS), Boston, MA, 2011. (Poster)

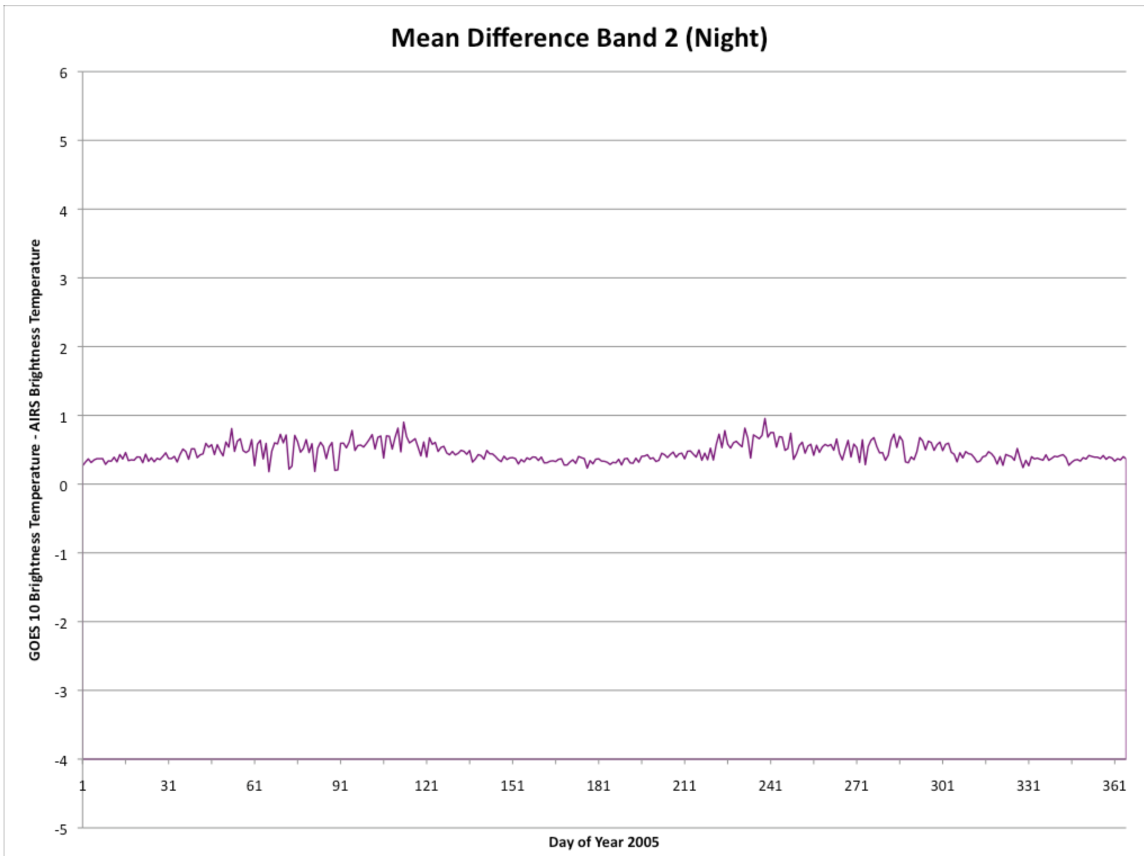


Figure 77 GSICS Intercalibration results for band 2 (3.9 micrometer) of the GOES-10 Imager compared to AIRS; GOES is slightly warmer than AIRS by approximately 0.5 K. Only night-time results are shown since reflected solar radiation during the day creates difficulties for comparisons in this shortwave band. The results shown are just for the year 2005.

GFS/GSI AIRS Retrieval Assimilation Studies

CIMSS Personnel: Allen Lenzen, Ralph Petersen
Federal Collaborator: R. Bradley Pierce
Funded by: SSEC internal funding

Project Description
Under internal funding SSEC has begun developing capabilities to conduct AIRS temperature retrieval assimilation experiments using the NOAA National Centers for Environmental Prediction (NCEP) global assimilation and forecast system (GDAS) which includes the Global Forecasting System and Gridpoint Statistical Interpolation (GFS/GSI) analysis system. Currently, GDAS AIRS radiance assimilation is done only over oceans for clear sky scenes due to limitations in forward modeling of clouds and land surface emissivity. Assimilation of AIRS (and future IASI) temperature and water vapor retrievals provides a means of incorporating the AIRS data over land and above clouds to complement radiance assimilation. The use of the NCEP assimilation and forecast models will foster ready transition into future operations. This work is being coordinated with JCSDA, NCEP, GOES-R Sounding AWG, NESDIS and the AIRS retrieval programs.

GFS/GSI T382 Control and AIRS temperature retrieval assimilation experiments were conducted during Nov 18-Dec 31, 2009 with Nov 18-30, 2009 being treated as a spin-up period. These experiments were conducted on the “Jet” super computer at NOAA Earth Systems Research Laboratory (ESRL) through collaboration with Stan Benjamin at ESRL’s Global Systems Division. Assimilation Quality (Quality=0) AIRS V5 AIRX2SUP (100level AIRS & AMSU) temperature retrievals were assimilated below 10mb since initial experiments using all the assimilation quality retrievals resulted in large adjustments in the upper stratosphere due to the large background errors in the upper stratosphere. Further filtering of the AIRS retrievals was necessary due to memory constraints on Jet. The assimilation experiments only consider the upper 50% of the assimilation quality AIRS retrievals within each AIRS granule. The upper 50% of the AIRS retrievals for each granule are determined based on the vertically averaged retrieval error below 70mb.

Validation of the 6hr GFS Control and AIRS assimilation forecasts was done using all radiosondes and also for a subset of radiosondes with strong (>4K) temperature inversions below 740mb. CONUS radiosonde validation of 6hr forecasts from Control and AIRS retrieval assimilation experiments shows reduced free tropospheric biases and increased low level biases with significant reduction in mean high biases below 400mb. . Increased low level biases in the AIRS assimilation experiment are associated with difficulties in retrieval of low level inversions and demonstrates need to account for the AIRS verticality in the GSI observation operator.

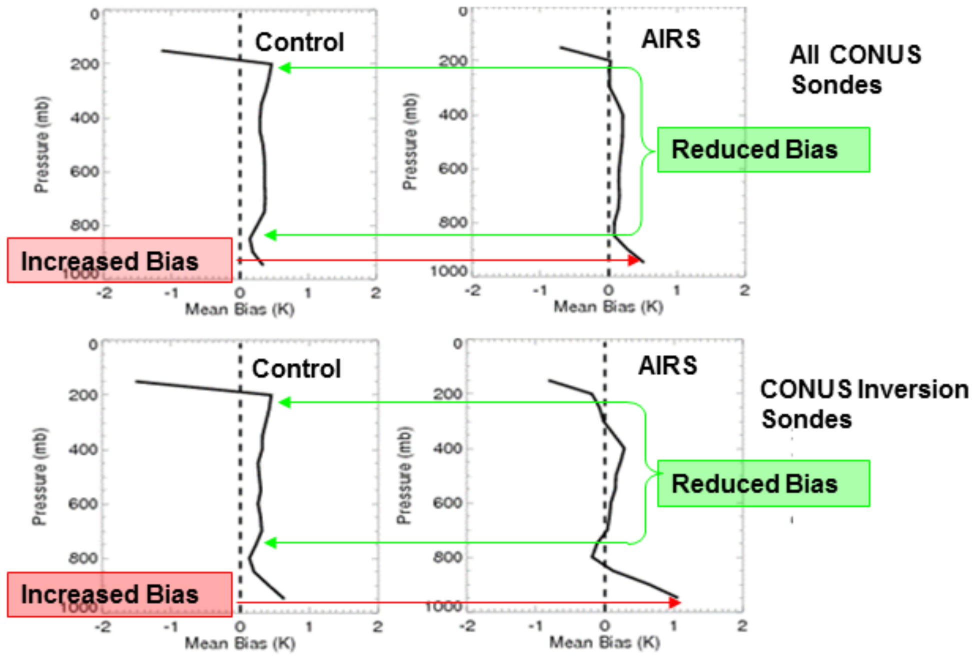


Figure 78 Radiosonde validation of 6hr GFS forecasts initialized with Control (left) and AIRS assimilation (right over the continental US (CONUS) for all sondes (upper panels) and for radiosondes with strong low-level temperature inversions (lower panels) during December 2009.

Assessment and Implementation Strategies for the WVSS-II Aircraft Borne Water Vapor Sensing System

CIMSS Personnel: Ralph Petersen, Wayne Feltz, Erik Olson, Lee Cronce
Federal Collaborator: David Helms (NWS)
Funded by: NOAA-NWS

Project Description
Inter-comparisons were made between co-located rawinsonde and automated aircraft observations using the WVSS-II instrument during evenings in fall 2009 and spring and summer 2010 at Rockford IL (RFD). The goal of this effort was to define the accuracy and error characteristics of WVSS-II data. Rawinsonde observations were made by CIMSS at approximately 3-hourly intervals, immediately before, after and between periods when UPS-757 aircraft equipped with the WVSS-II instruments landed and departed. Subjective comparisons using both ascent and descent aircraft reports showed very similar vertical structures to the rawinsonde data, especially true in the lowest 300hPa of the atmosphere where all aircraft were flying essentially along the same paths and close to the rawinsonde launch site. The agreement between successive (and independent) WVSS-II soundings provides confidence in the accuracy of and consistency between the individual WVSS-II observations.

Overall, the ascent data exhibit a small positive Specific Humidity (SH) Bias, with a Standard Deviation (StDev) of 0.91 g/kg. In middle/lower moisture ranges, the Bias increases slightly, while the StDev decreases to .56 g/kg. Descending report show a slightly smaller Bias, but higher StDev (0.85 g/kg). The fact that multiple aircraft showed these same behaviors shows both good consistency between the aircraft reports and the possibility that the rawinsonde data taken at 3 hourly intervals may not have been fully representative of the small-scale moisture structures observed by the WVSS-II aircraft. The WVSS-II and rawinsonde SH profiles displayed consistent structure across the full range of rawinsonde RH observations.

Summary statistics were calculated over the entire test period comparing all aircraft observations (ascent and descent) using additional criteria to limit the temporal difference in Relative Humidity (RH) between successive Raob reports and between adjacent vertical levels in individual reports. This was done to eliminate both the effects of scattered clouds that could have been encountered along the rawinsonde trajectory and to eliminate cases where shallow banks of moisture and fronts were moving vertical during the test period.

Profiles of SH differences (the variable reported by the WVSS-II instrument) are shown in Figure 79. These results also show positive Biases at all levels, ranging from 0.1 to 0.3 g/kg. This systematic behavior of the instrument can readily be removed and modified over time if the instrument performance is monitored against a calibrated standard on a regular basis. More importantly, however, the random difference between the WVSS-II and rawinsonde moisture observations ranges between 0.2 and 0.7 g/kg at the majority of levels. Increases aloft occur where the number of inter-comparisons and average time/space separation between the 2 observing systems increases. This performance is well with WMO standards for both global and mesoscale applications.

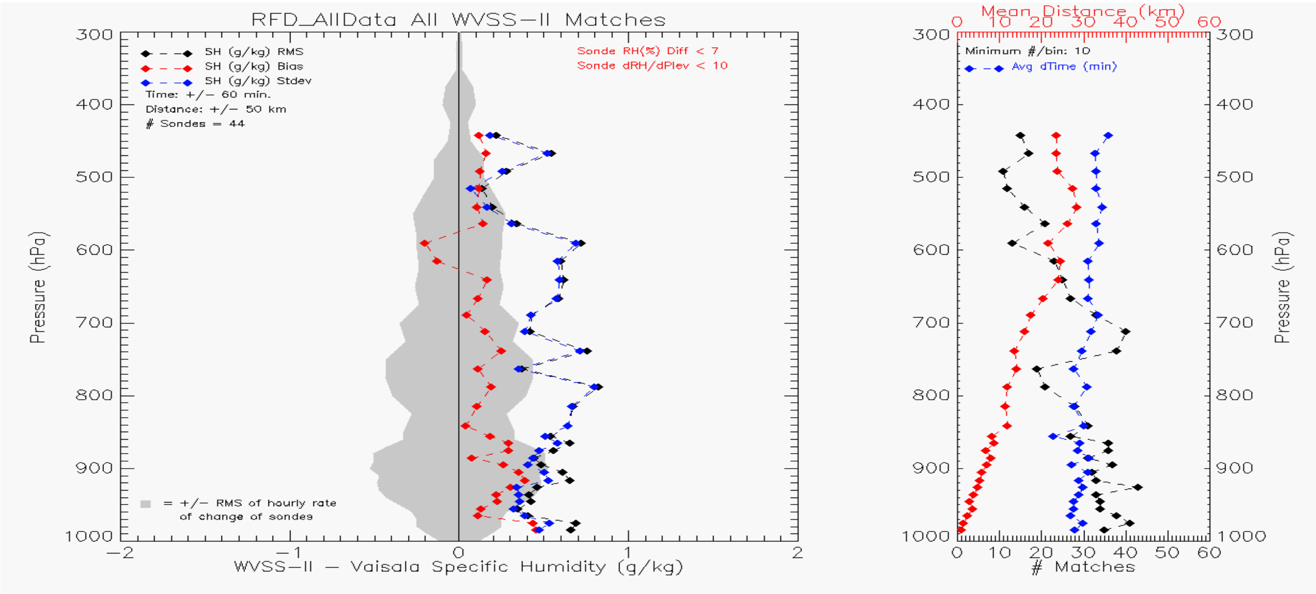


Figure 79 Left - Plots of SH comparison statistics between co-located observations from WVSS-II and rawinsonde data taken for all 2009-2010 inter-comparison periods at Rockford, IL (Bias, °C - red; RMS, °C - black; StDev, °C - blue). Right - Number of observations inter-comparisons used (black, mean distance between reports (km, red) and mean time difference between reports (Min., blue). Shading area indicates ± 1 RMS of variations (scaled to 1 hour time interval) observed between all approximately 3-hourly rawinsonde pairs used.

As another measure of the robustness of the WVSS-II observation, inter-comparisons were computed between WVSS-II observation pairs made within specific time, height and spatial limits. Results indicate both that the variability increases systematically with both time and space separation and, more importantly, that WVSS-II observations taken within 15 minutes, 20 km and 55 m altitude of each other agreed to within better than 0.2 g/kg. The fact that the agreement is much better than that obtained in the rawinsonde-to-WVSS-II comparisons indicates that a substantial portion of the difference detected in the multiple instrument inter-comparisons may have been due to errors in the rawinsonde reports.

Overall, the WVSS-II SH observations match the rawinsonde data very closely, with random differences ranging from 0.2 to 0.7 g/kg, well within WMO recommendations. Although the aircraft data show a slight moist Bias (ranging from 0.1 to 0.3 g/kg), the Bias should be correctable in post-processing if the WVSS-II data are monitored regularly. Inter-comparison within the WVSS-II data set observations made within 15 minutes, 60 km distance and 55 m altitude showed variability of less than 0.2 g/kg, exceeding the performance of most other operational moisture observations.

Publications/Conference Presentations

Petersen, R., L. Cronce, W. Feltz, E. Olson, D. Helms, September 2010: WVSS-II moisture observations: A tool for validating and monitoring satellite moisture data. Proceedings of the EUMETSAT Users Conference, Cordoba, Spain.

Petersen, R., October 2010: WVSS-II INTERCOMPARISON STUDIES. Report of the WMO AMDAR Panel, Geneva.

Wildfire Automated Biomass Burning Algorithm Development and Applications

CIMSS Personnel: Christopher Schmidt, Elaine Prins (Consultant), Jason Brunner, Jay Hoffman
Funded by: NOAA, NASA, Navy

Project Description
The Wildfire Automated Biomass Burning Algorithm (WF_ABBA) produces fire detection and characterization from data from a variety of geostationary satellites, from the current GOES series to Meteosat Second Generation, MTSAT, and the next generation GOES-R with upcoming support for India's INSAT 3-D and Korea's COMS. WF_ABBA data is produced in near realtime at CIMSS and at NOAA and used by a variety of users, including air quality modelers and monitors, researchers in land use change, wildland fire managers, and even pilots who want up-to-the minute information on where smoke will likely be. The Navy has a keen interest in monitoring fire activity globally as they manage their assets worldwide, and as a result has been a long-time supporter of algorithm development and production of data. The WF_ABBA has been a NOAA Operational product for almost a decade, with CIMSS providing updates and support. The algorithm's success led to its inclusion as a baseline product for the GOES-R Advanced Baseline Imager. The algorithm development for ABI has reached the 100% level and the reference code and ATBD have been delivered to NOAA for implementation.

Recent updates to the WF_ABBA enhanced its functionality, adding a metadata mask that tells users about each pixel in the satellite image, its category if it was classified as a fire, a flag indicating why it was not determined to be a fire due to, for example, clouds, unusable surface types like water or rock, and solar reflectance areas, or a fire-free pixel. As additional satellites become available, the WF_ABBA is becoming a truly global, cross-platform algorithm. Those updates were applied to a reprocessing of GOES data dating from 1995 to the present day, producing a consistent 16 year data base. Validation of the WF_ABBA has advanced in collaboration with Wilfrid Schroeder from CICS at UMD and Ivan Czisar of NOAA, developing the use of high resolution data from instruments such as ASTER and Landsat ETM+, as well as airborne sensors, to provide fire locations and in some cases fire characterizations.

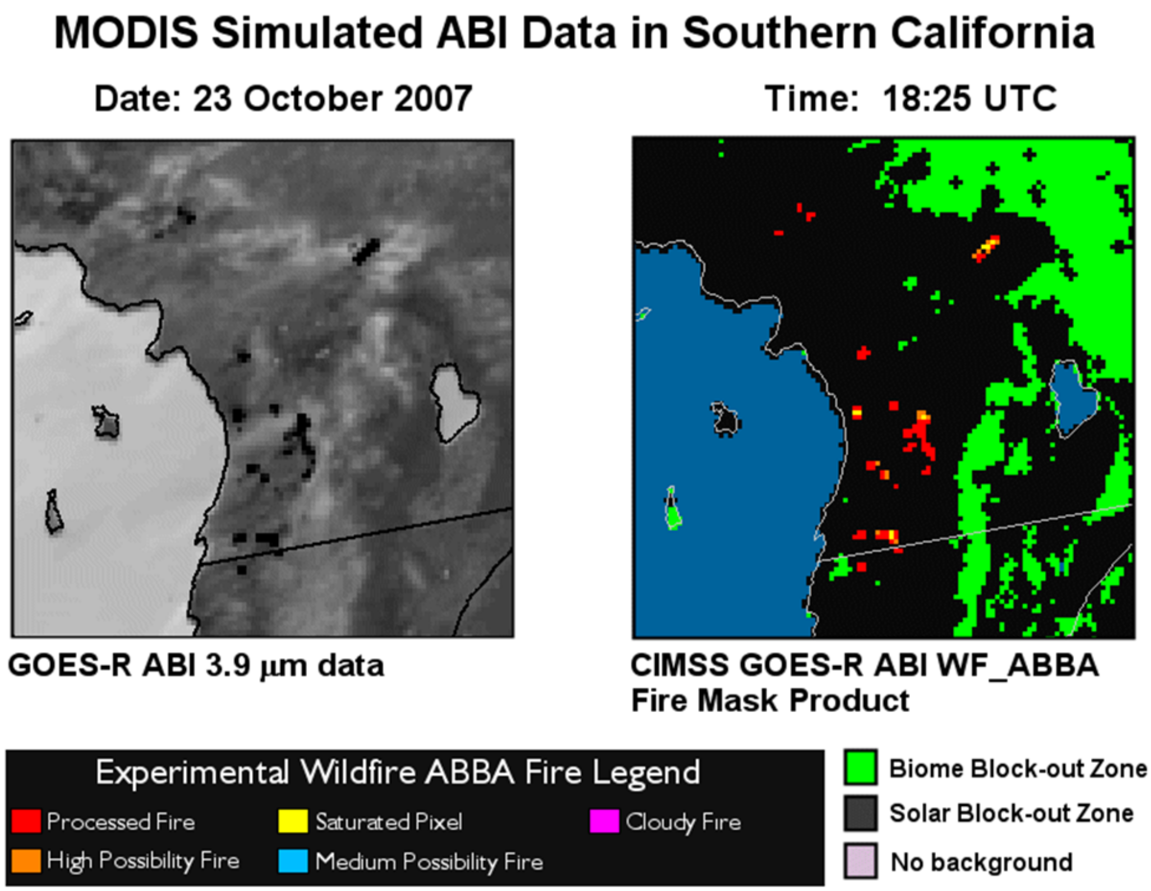


Figure 80 WF_ABBA fire detections from ABI proxy data generated with a model developed at CIRA for 18:25 UTC on 23 October 2007. Creating proxy data for ABI algorithm development represents a substantial area of new research to accurately model instrument effects such as the point spread function, electronic crosstalk, and other technical details.

Publications/Conference Presentations

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Reid, Jeffrey S.; Hyer, Edward J.; Prins, Elaine M.; Westphal, Douglas L.; Zhang, Jianglong; Wang, Jun; Christopher Sundar A.; urtis, Cynthia A.; Schmidt, Christopher C.; Eleuterio, Daniel P.; Richardson, Kim A. and Hoffman, Jay P.. Global monitoring and forecasting of biomass-burning smoke: Description of and lessons from the Fire Locating and Modeling of Burning

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Provision of RTTOV Interface for Land Surface Infrared Emissivity

Personnel: Eva Borbas, Benjamin Ruston (NRL, Monterey, Ca) Roger Saunders (UK Met Office, UK)
Funded by: EUMETSAT/NWP_SAF

Project Description
The RTTOV fast radiative transfer model is a key EUMETSAT NWP SAF (satellite applications facility on numerical weather prediction) deliverable. Providing improved techniques for simulating infrared radiances over land using RTTOV is an important goal, which this work will help to realize. The current calculations of upwelling infrared radiances over land with RTTOV v9 are reliant on a single emissivity value, assumed to be 0.97. The objective of this project is to provide a user interface which can be used with RTTOV (v9 onwards) and provide emissivity estimates for input to RTTOV and their associated error covariance for data assimilation applications. This should help in the assimilation of infrared radiances over land. This was a one-year long project through 2009-2010.

Objectives
To provide an improved estimate and associated error of land surface emissivity for infrared radiometers for input to RTTOV (Version 9 and later).

Recent Accomplishments

- *The UWiremis module has been developed from the UW-Madison Infrared High Spectral Resolution (HSR) Emissivity Database/Algorithm* for the RTTOV forward model to help improve estimates of the IR surface emissivity for meteorological applications, which require brightness temperature simulations, e.g., data assimilation or retrievals.
- *In January 2011 a new version of the fast radiative transfer model, called as RTTOV-10, which includes this new module has been officially released by the EUMETSAT/NWP-SAF*.

In this study, the new UWiremis module has been developed and its evaluation with SEVIRI and IASI observations and its test in assimilation mode have been performed and published (Borbas and Ruston, 2010). Calculated brightness temperatures with the default RTTOV emissivity (0.98) and the new UWiremis module have been compared to the observations for four selected days representing the four seasons separately day and night. The evaluation on both the broad band SEVIRI instrument on the geostationary MSG and the high spectral resolution IASI instrument on the polar orbiting METOP-A agreed that the use of the UWiremis shows positive impact over the default value generally everywhere on the globe both day and night. The bias between the observed and calculated BT was reduced by 1.5 - 3.5 K at the 4 and 8.7 μm regions and by 0.5 – 2 K between 9.5 and 13.2 μm globally. The most significant impact occurs over very dry (sand), e.g., the Sahara region (Figure 81 and Figure 82). The bias was reduced 5 - 12 K at the 4 and 8.7 μm regions. During the day the systematic bias across all surface sensitive channels can be attributed to bias error in the land surface temperature model. In addition, the error in the SW region during the day is caused by the uncertainty in the solar radiation component in the RTM. Looking at the evaluation for the four days, the biases have been significantly reduced for each time across all seasons by using the UWiremis RTTOV module. The assimilation tests were not significant at the 95% confidence level, and show that though the bias corrected innovation was spatially coherent and had a smooth transition from land to ocean, it did not correspond to an increase in forecast skill. The standard deviations of the non-bias corrected innovations show that possibly assimilating just the highest peaking channels over land is possible, and that for the mid- to lower-tropospheric channels further tuning of the observation error and revised quality control are necessary for the land and sea-ice conditions. Certain deficiencies were identified by the research team, but overall the current version of the UWiremis module is adequate for a baseline to disseminate to the larger community where we can receive other insights and ideas for improvements..

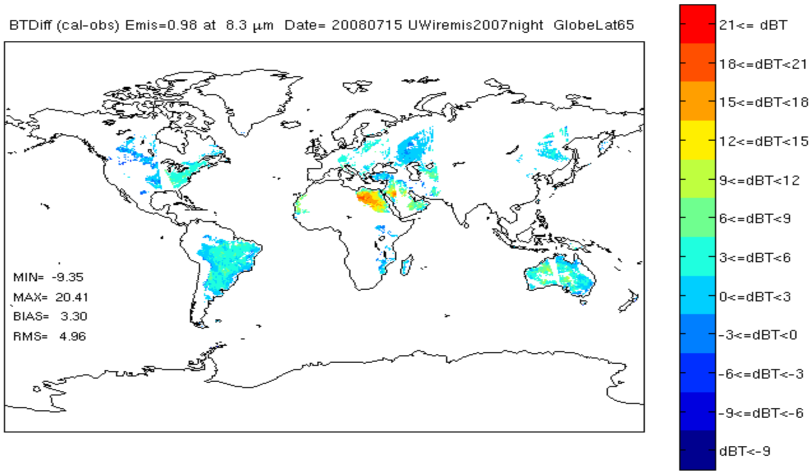

Figure 81 Brightness temperature differences for 8.3 μm between IASI observations and calculated values from ECWMF analyses using the default RTTOV emissivity, on July 15, 2008 night time.

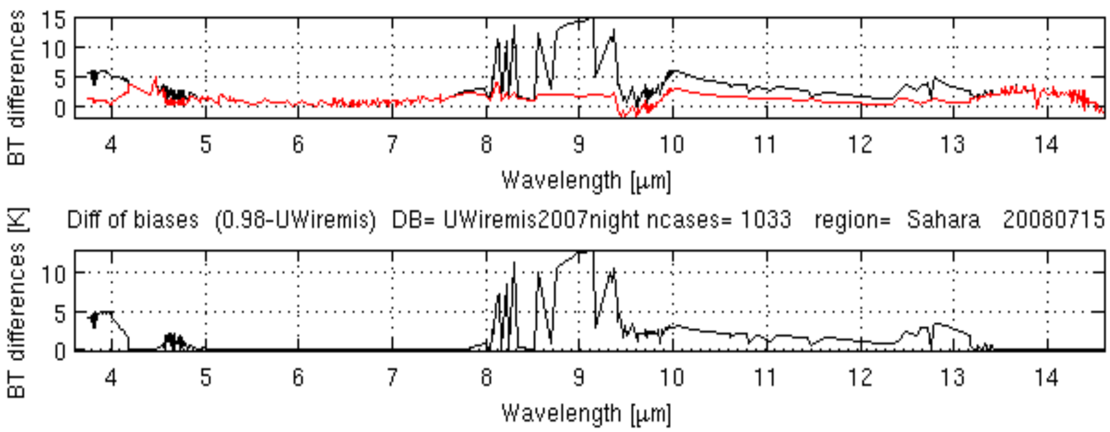

Figure 82 IASI brightness temperature biases (calc-obs) for July 15, 2008 when RTTOV default (black) and RTTOV UWiremis module (red) were used in the calculations. The statistics were calculated over the Sahara Desert region, nighttime only. (bottom) The differences of the two curves in the top panels are shown. The positive values represent positive impact by using the new RTTOV UWiremis module.

References/Presentations

Borbas E.E., B. Ruston, R. Saunders, A. Collard, R. Knuteson, J. Hocking and A. Huang, 2010: Application of the UW/CIMSS High Spectral Resolution Global IR Land Surface Emissivity Database into the RTTOV Model. Presented at the International TOVS Study Conference, Monterey, CA, USA, April 14-20, 2010. http://cimss.ssec.wisc.edu/itwg/itsc/itsc17/session5/5.1_borbas.pdf

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MODIS MOD07 Atmospheric Profile Retrievals

CIMSS Personnel: Eva Borbas and Paul Menzel
Funded by: NASA

Project Description
The operational algorithm for retrieving temperature and moisture profiles and total column ozone from infrared (IR) radiances observed by the National Aeronautics and Space Administration/Earth Observing System (NASA/EOS) Moderate Resolution Imaging Spectroradiometer (MODIS) instrument is a clear sky synthetic regression retrieval algorithm called MOD07 (Seemann et al., 2003, 2006, 2008). The MOD07 retrieval algorithm uses clear-sky radiances over land and ocean for both day and night from eleven MODIS infrared channels (25, 27-36). The operational algorithm employs a statistical retrieval. Atmospheric retrieval algorithms such as MOD07 require a global set of profiles and corresponding surface data (surface emissivity, surface skin temperature, and surface pressure) to train the synthetic regression. Radiance calculations for each training profile and surface values are made using a transmittance model, and the calculated radiance/atmospheric profile pairs are then used to derive the regression relationship.

Objectives
To develop, maintain, evaluate, and document the MODIS MOD07 algorithm.

Recent Accomplishments
In April the new Collection 006 version of MOD07 algorithm was delivered and in November 2010 it was implemented at NASA/LAADS. The major updates are:

- The radiative transfer model has been updated to CRTM v1.2;
- The TPW based bias adjustment has been removed in the final product;
- The code has been updated to make the separate algorithms for Aqua and Terra satellites uniform (the main different of the two versions was the IR surface emissivity data used in the regression coefficients files), and now for both satellites, the latest version of UW-Madison/CIMSS Global Land Surface IR emissivity database has been used;
- The definition of TPW low and TPW high have been modified to enable calculation of 3 layer water vapor means; the new layers are: (Low) sfc-680 and (high) 440-Top (10hPa); and
- The content and format of the output files have been also updated according to the users' comments/requests.

The new products were tested over the SGP ARM cart site with MWR and GOES, over Budapest, Hungary with Brewer and TOMS/OMI measurements, and globally in some select days with TOMS and AIRS data. See below in more detail the evaluation results of TPW over the SGP cart site and of the TOZ over Central Europe.

A validation study was performed to investigate the impact of the Aqua/MODIS Band 27, 28, 34, 35 and 36 spectral shifts suggested by Tobin et al. (2006, JGR) on the MOD07 TPW products for 317 clear sky cases over the ARM SGP site. Adding the spectral shifts to the H_2O/CO_2 bands has shown significant TPW improvement particularly for the wet cases (TPW >= 15mm) where the RMS error was improved by 1.9 mm and the bias was reduced by 2.3 mm. RMS error for both Terra and Aqua MODIS TPW, compared to the MWR TPW is 3.0 mm, with an overall bias near zero (0.1-0.3 mm).

The Collection 6 MOD07 “total_ozone” amount (TOZ) has also been evaluated for the whole 2007 year over Central Europe with OMI total ozone data and the surface Brewer measurements as the most accurate measurements of the vertically integrated ozone values. The Brewer TOZ data were measured in Budapest and provided by the Hungarian Meteorological Service. The new MOD07 collection 6 algorithm with the Aqua H2O/CO2 channel spectral shifts applied results in the best correlation (the lowest standard deviation) with the Brewer measurements among the MODIS Col 5 and Col 6 with and without the shifts applied. The correlation (and stdev) for Terra/MODIS TOZ is also improved by the new algorithm. The year-long time series of TOZ observations in Figure 83 shows smaller Aqua scattering and indicates that the MOD07 TOZ follows nicely the annual trend by OMI, the ECMWF ERA40, and Brewer TOZ values.

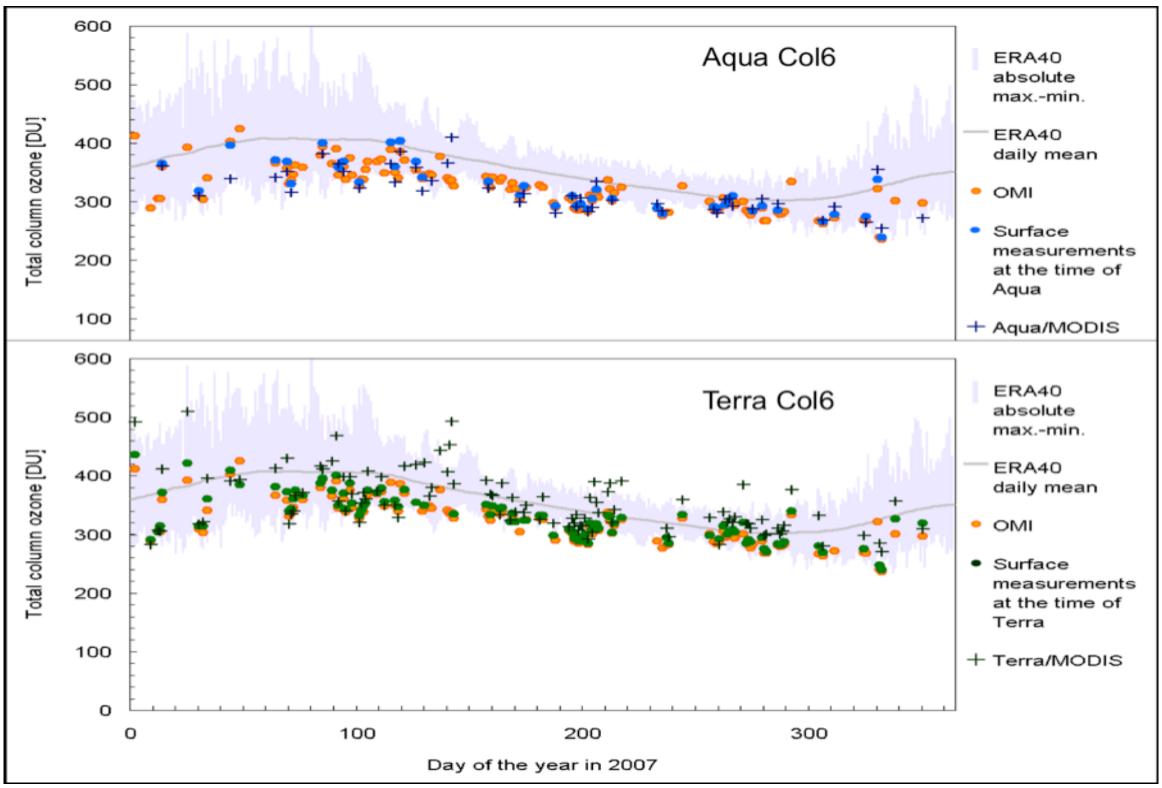

Figure 83 Time series of Total Ozone observations (+ stands for MODIS, orange dots are OMI and green dots are the surface Brewer Measurements) for the year 2007 over Budapest, Hungary separated by Aqua (top) and Terra (bottom) overpass times. The ECMWF ERA40 daily mean and absolute maximum and minimum TPW for the year 2007 are also plotted in grey.

References/Presentations:

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http://modis-atmos.gsfc.nasa.gov/_docs/MOD07:MYD07_ATDB_C006.pdf

MODIS Algorithm (MxD35 and MxD06)

CIMSS Personnel: Steve Ackerman, Paul Menzel, Bryan Baum, Richard Frey, Eva Borbas, Chris Moeller
Federal Collaborators: Steve Platnick and MODIS Atmosphere team, NASA GSFC
Funded by: NASA

Project Description
The goal of this work is to maintain, validate and refine four Terra and Aqua MODIS algorithms: cloud mask (MOD35) and associated clear sky composite maps, atmospheric profiles (MOD07), cloud top properties (CTP) including cloud-top pressure, temperature, and phase (part of MOD06). Maintenance requires (a) monitoring changes in calibration and associated adjustment of cloud detection thresholds, (b) considering replacement channels when primary channels exhibit calibration problems, and (c) continuing validation through comparisons with products from other satellite based algorithms, ground-based observations and focused field experiments.

The team is focused towards delivery of Collection 6 code, which fully integrates advances made possible through intercomparison of passive (MODIS) and active (CALIPSO; Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) sensors. More specifically, we use data from the CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) on the CALIPSO platform. While cloud top properties have been provided historically through Collection 5 at 5-km resolution, Collection 6 will provide CTP at both 1-km and 5-km resolution.

Atmospheric retrievals from MODIS have been compared with those from other observing systems to evaluate the various algorithms (e.g., Menzel et al., 2006; Holz et al., 2006; and Ackerman et al., 2008). We also focused research efforts on creating high spatial resolution cloud statistics. Figure 84 shows the mean seasonal cloud amounts over Wisconsin at ~1.2 km resolution. At this resolution the statistics are nearly resampled at the native granule resolution. This allows for analysis of the variability in the cloud field at extremely high resolutions. We can clearly see the increases in cloud amounts in the winter over northern Wisconsin. This is consistent with surface observations. If the summer map we can see the increases in cloud amount over urban areas like metro and suburban Milwaukee (Southeastern Wisconsin). This may be either an artifact in the data set or could be an increase in cloud amount due to surface heating of urban areas(urban heat island affect). This is an area in need of further research.

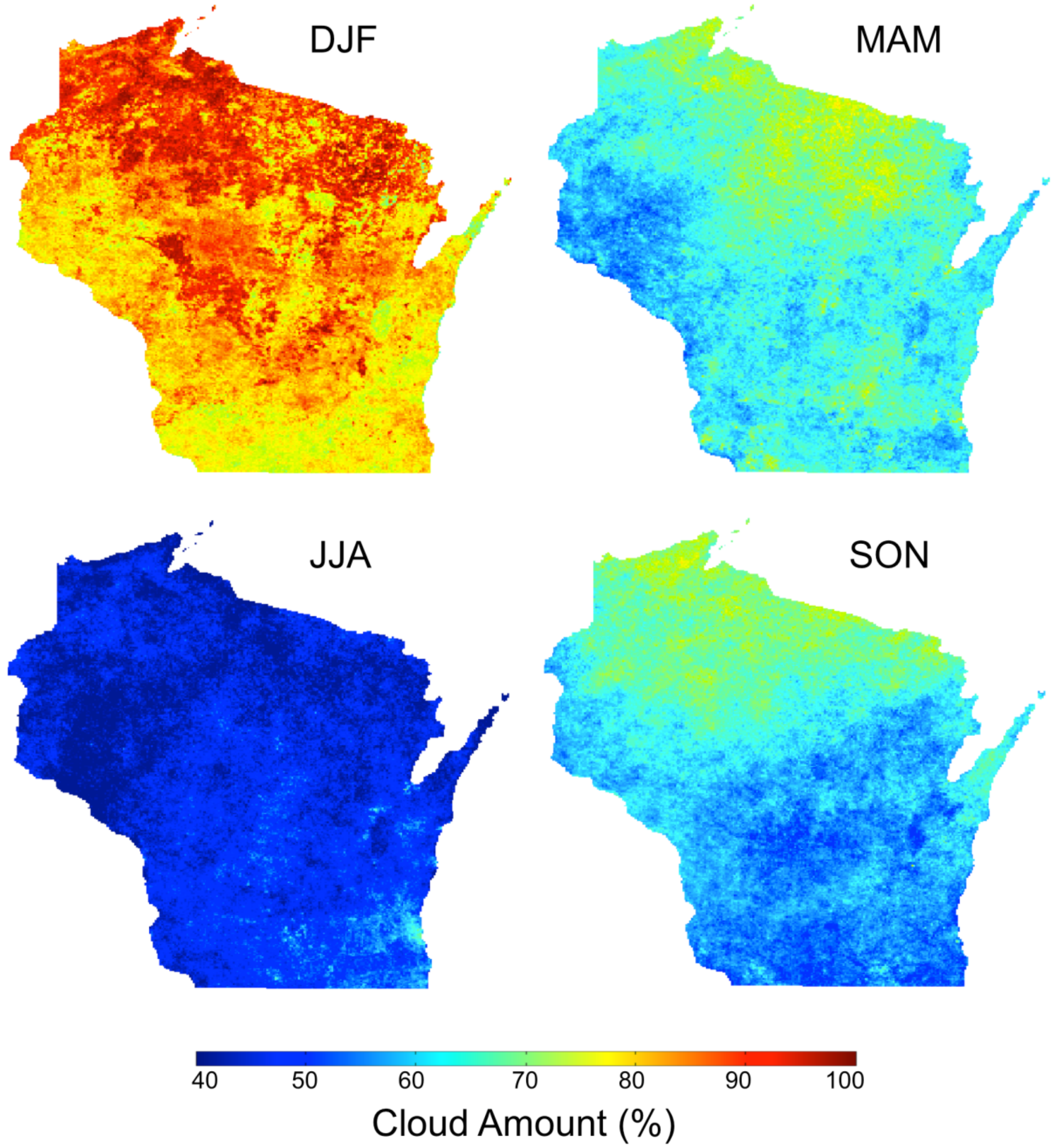

Figure 84 The seasonal mean daytime cloud amount over Wisconsin is shown.

Publications/Conference Presentations:

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Platnick, S. E. Z. Zhang; B.C. Maddux; S.A. Ackerman, 2010: Observed Differences in Spectral Microphysical Retrievals from MODIS, AGU Fall meeting, San Francisco, CA, 13-17 December.

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Mission 3

Stimulate the training of scientists and engineers in the disciplines involved in the atmospheric and earth sciences.

Satellite Hydro-Meteorology (SHyMet) Course

CIMSS Personnel: Steve Ackerman, Scott Bachmeier, Scott Lindstrom
Funded by: NOAA

Project Description
The Satellite and Hydro-Meteorology (SHyMet) training course is a collaborative effort between CIMSS and CIRA to develop and deliver distance learning material to prepare NWS forecasters to better understand and utilize the increased observing capabilities of current (GOES, MODIS, AIRS) and future (GOES-R+, NPOESS) geostationary and polar orbit satellites.

The goals of the SHyMet course are to:

- Expand the current library of distance learning modules with new satellite and hydrology topics; and
- Evaluate student feedback from course surveys and comments, and modify the instructional material as appropriate.

Accomplishments (May 2010-May 2011)

- The lessons "Water Vapor Channels" and "Interpreting Satellite Signatures" were incorporated into the "SHyMet for Forecasters" course curriculum.
- The lessons "Objective Satellite-Based Overshooting Tops and Enhanced-V Anvil Thermal Couplet Signature Detection" and "The UW Convective Initiation Product" were incorporated into the "SHyMet: Severe Thunderstorm Forecasting" course curriculum.
- Attended the NPOESS/GOES-R Training Resources Development Workshops held at COMET in Boulder, Colorado (May 2010, May 2011), to identify the training needs of the community that can be addressed by the SHyMet program.

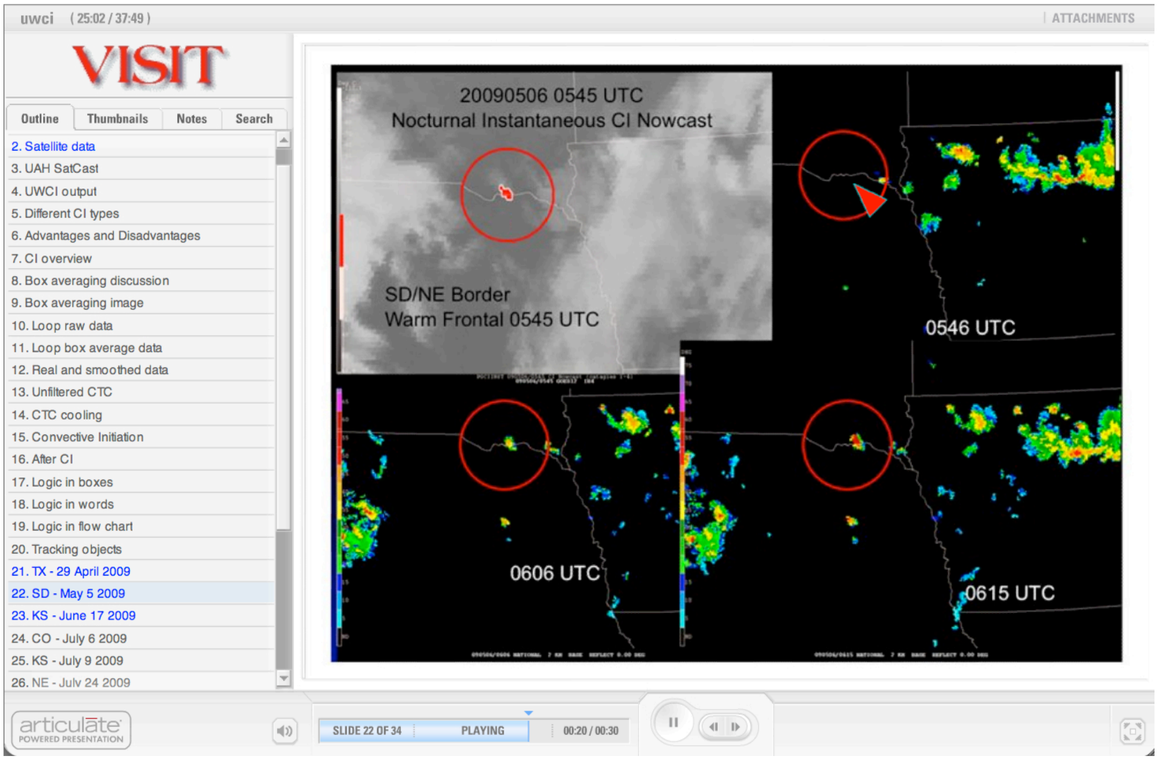


Figure 85 Example of a slide from "The UW Convective Initiation" lesson that is a part of the SHyMet Severe Thunderstorm Forecasting course

Virtual Institute for Satellite Integration Training (VISIT)

CIMSS Personnel: Scott Bachmeier, Scott Lindstrom, Tom Whittaker
Funded by: NOAA/NESDIS

Project Description
The VISIT (Virtual Institute for Satellite Integration Training) program performs pioneering research in the use of tools, data, and techniques for supporting distance learning activities in the atmospheric sciences. The U.S. National Weather Service, the World Meteorological Organization, and weather services in other countries have made use of the VISITview software and VISIT lesson material to support their needs for decentralizing training activities to their respective constituents.

The goals of the VISIT program are to:
- Develop distance learning material that integrates satellite data into forecast operations,
- Continue to improve the functionality of VISITview software,
- Update existing VISIT lesson content with new material, and
- Explore new distance learning techniques.

The following instructor-led VISIT lessons were offered in 2010-2011:
1. CRAS Forecast Imagery in AWIPS
2. TROWAL Identification
3. Mesoscale Convective Vortices
4. Interpreting Satellite Signatures
5. Basic Satellite Principles
6. The UW NearCasting Product
7. The UW Convective Initiation Product
8. POES and AVHRR Satellite Imagery in AWIPS
9. Morphed TPW Detection (MIMIC)
10. Objective Satellite-Based Overshooting Top and Enhanced-V Anvil Thermal Couplet Signature Detection

Accomplishments (May 2010-April 2011)
- 52 live instructor-led VISIT sessions conducted, with 130 NWS offices participating (cumulative forecast office tally);
- New “POES and AVHRR Satellite Products in AWIPS” lesson developed;
- New “The University of Wisconsin Convective Initiation Product” lesson developed;
- New “The University of Wisconsin NearCasting Product” lesson developed;
- New “Objective Satellite-Based Overshooting Top and Enhanced-V Anvil Thermal Couplet Signature Detection” lesson developed;
- New “Morphed Total Precipitable Water Detection (MIMIC)” lesson developed;
- Contributed to lesson content on the “Volcanoes and Volcanic Ash”, “Aviation Hazards”, and “Water Vapor Imagery Analysis for Severe Weather” lessons that were developed at CIRA;
- 165 posts were added to the CIMSS Satellite Blog (URL: http://cimss.ssec.wisc.edu/goes/blog/), covering categories ranging from Air Quality to Winter Weather. This blog has become an important “just-in-time” training tool to

supplement the longer and more detailed lesson modules being developed for the VISIT program.

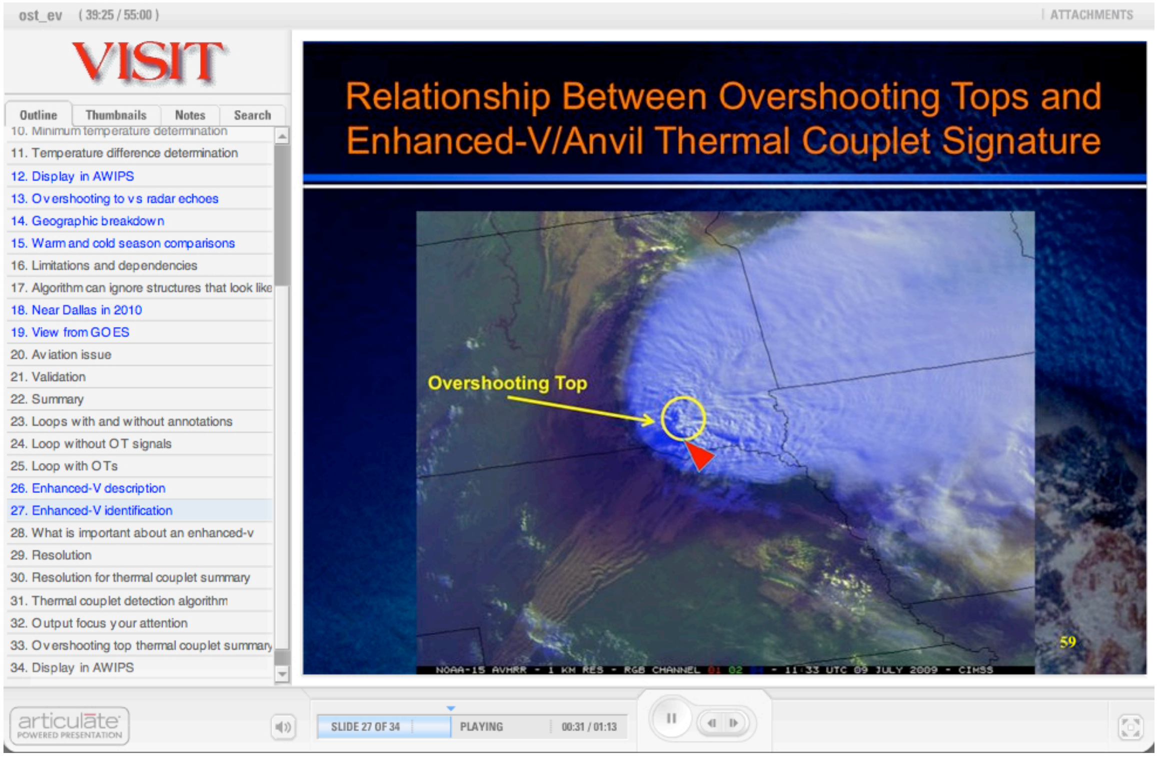


Figure 86 Slide from the “Objective Satellite-Based Overshooting Top and Enhanced-V Anvil Thermal Couplet Signature Detection” VISIT lesson.

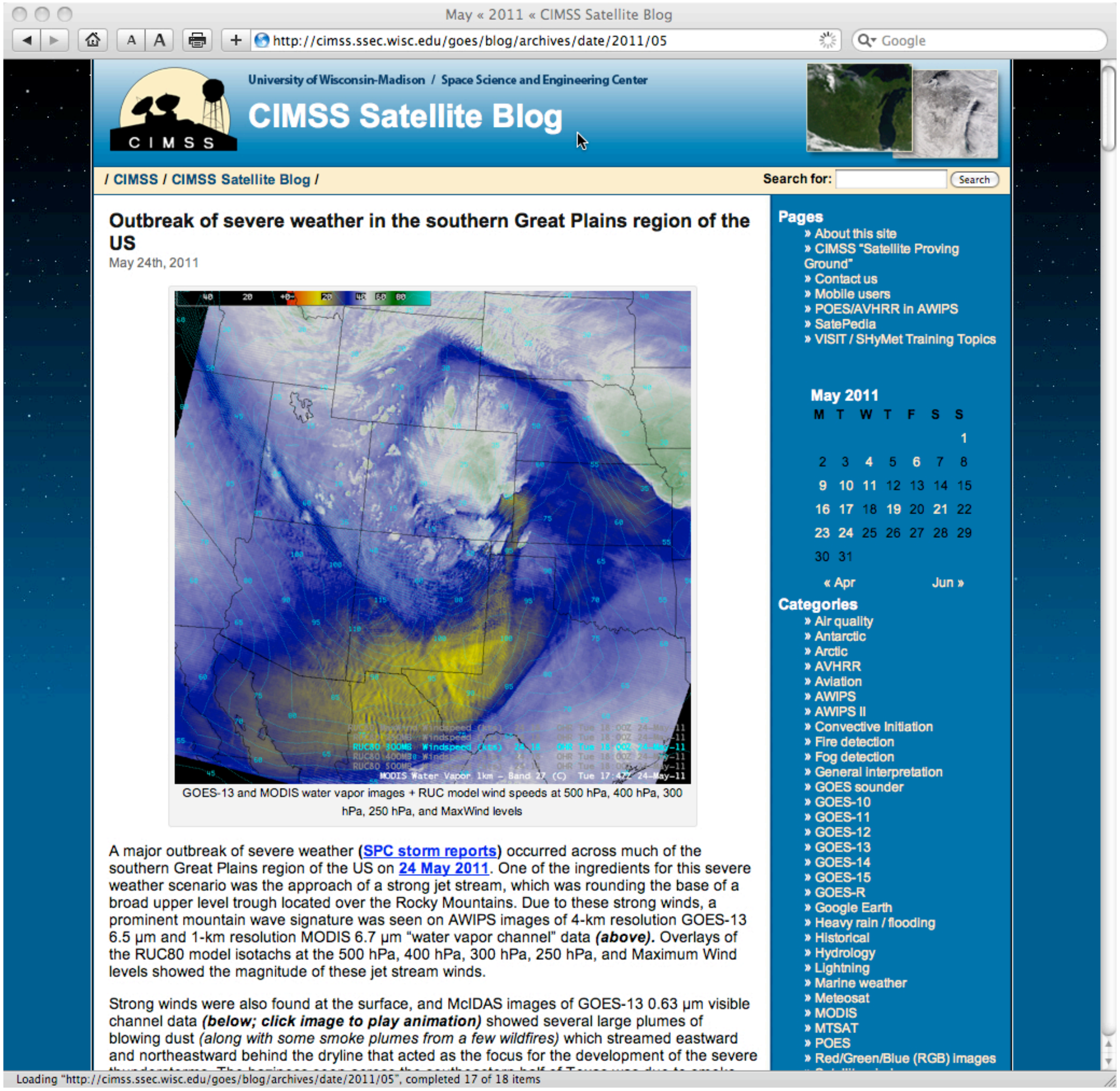


Figure 87 An example of a post on the CIMSS Satellite Blog (URL: http://cimss.ssec.wisc.edu/goes/blog).

Advanced Weather Information Processing System (AWIPS Infusion)

Personnel: Scott Bachmeier, Jordan Gerth, Scott Lindstrom, Kathy Strabala, Russ Dengel, Steve Wanzong, Jerrold Robaidek, Robert Aune
Funded by: NOAA

Project Description
A real-time Advanced Weather Information Processing System (AWIPS) workstation capability is now fully functional at CIMSS. AWIPS is the primary warning and forecast tool utilized at all National Weather Service forecast offices, and this permits CIMSS researchers to test and evaluate new satellite products in an environment similar to that used by operational NWS forecasters. The real-time AWIPS capability also allows CIMSS staff to monitor current weather events and select cases for later use in VISIT and SHyMet satellite training modules.

The goals of the AWIPS Infusion program are to:
- Function as a satellite test-bed for new CIMSS products; and
- Provide real-time data and imagery for use in VISIT and SHyMet training modules.

Accomplishments (May 2010-April 2011)
- Added a number of new MODIS, POES AVHRR, and GOES products to AWIPS, and maintained their distribution to the NWS Central, Southern, Western, and Eastern Region headquarters AWIPS servers.
- Conducted numerous site visits to the NWS forecast office at Milwaukee/Sullivan to discuss the new satellite products in AWIPS with NWS staff.
- Maintained the CIMSS Satellite Blog to serve as a diverse online library of cases that showcase the utility of many of the CIMSS satellite products in AWIPS.

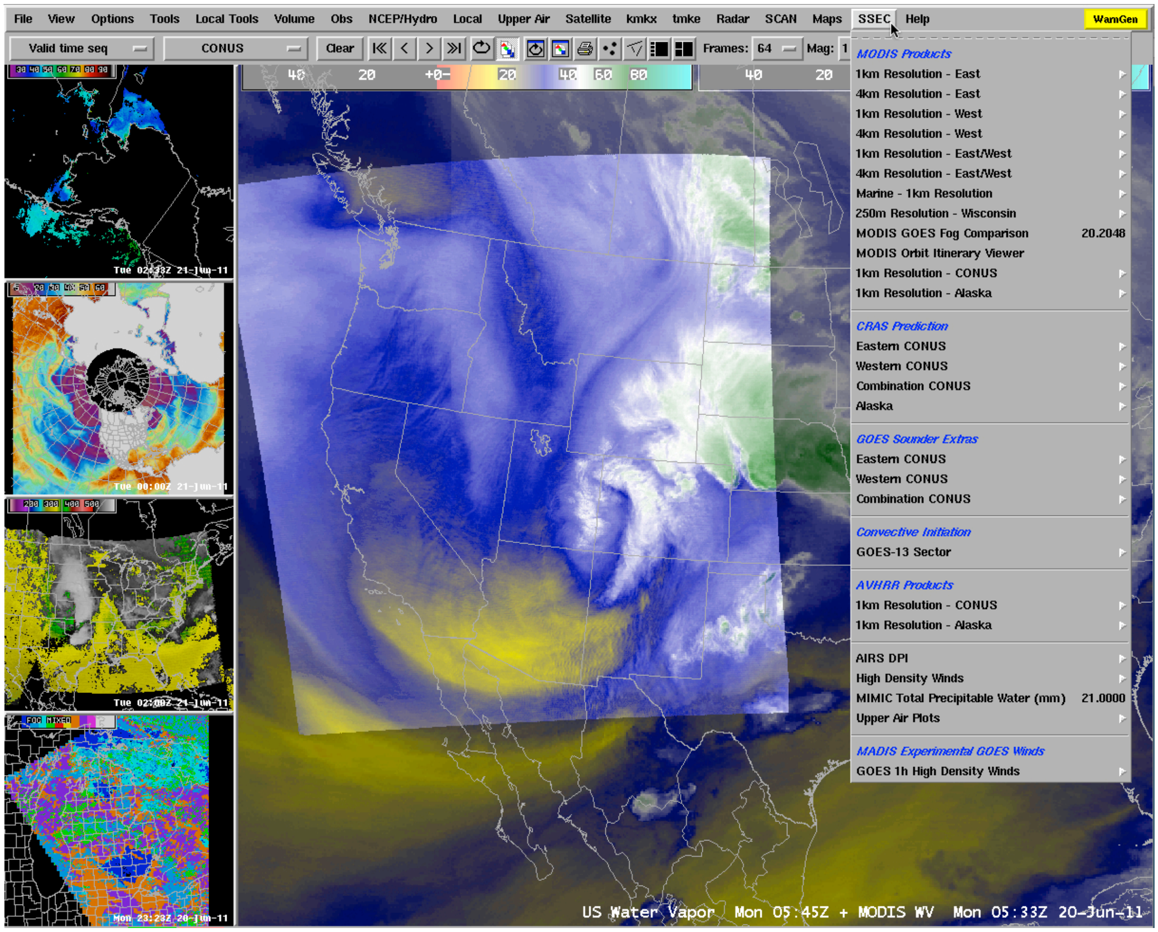


Figure 88 AWIPS screen capture showing a few examples of the types of CIMSS satellite products being offered in AWIPS for NWS forecast office use. The main panel is a combination of a 4-km resolution GOES water vapor image with a swath of the corresponding 1-km resolution MODIS water vapor image that was available over the western US. Images in the smaller panels along the left, from top to bottom, are: AVHRR Sea Surface Temperature product over the Alaska region; the MIMIC Total Precipitable Water product over the northern Hemisphere; the GOES sounder Total Column Ozone product over the continental US; and the POES AVHRR Cloud Type product over the Great Lakes region.

Suomi-Simpson Fellowship

CIMSS Personnel: Steve Ackerman, Brent Maddux
Federal Collaborator: Steve Platnick, NASA GSFC
Funded by: NASA

Project Description
Research has focused on producing local, regional, global cloud statistics for the purposes of assessing trends, monitoring cloud processes and characterizing the error and uncertainty in the cloud data records. The production and use of cloud statistics at varying spatiotemporal scales allows us to fully characterize the MODIS cloud data records.

Globally the MODIS cloud amount has remained very constant. With a10-year MODIS cloud record we have observed only small ENSO events and no major volcanic eruptions. Even with nearly an 11-year solar cycle being captured no statistically significant trends are observed in the global or near global cloud field. Figure 89 shows the trend in cloud amount for all observations inside of 60°N and 60°S latitude of only ~.35%/decade. This time series contains the deseasonalized monthly mean daytime cloud amount as observed by MODIS on Terra (blue) and Aqua (red line). This trend would have to be over 1.4%/decade to be significant just based on the monthly variability.

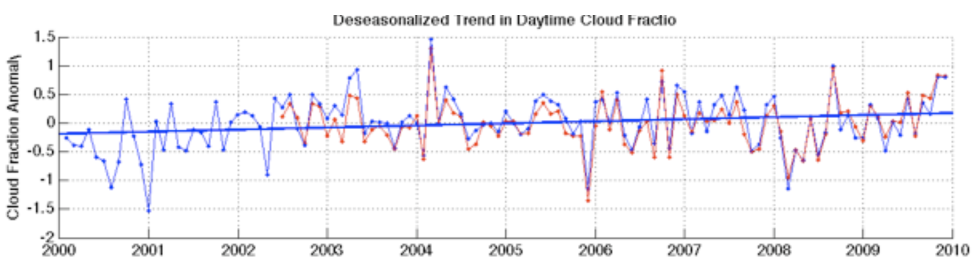


Figure 89 This time series contains the de-seasonalized monthly mean daytime cloud amount as observed by MODIS on Terra (blue) and Aqua (red line).

We also used MODIS Level-3 statistics to study cloud properties at regional scales to better assess the uncertainty within the data records. Figure 90 shows the effect of view geometry for marine stratocumulus clouds in the south east Pacific Ocean. The cloud amount is dependent on satellite view geometry; this relationship is in turn also dependent on cloud type. For stratocumulus clouds the annual cycle is dampened at high view angles. This reduction is not constant throughout the year, ranging between 12% in the January - May time period and 5-7% in the July – December time period.

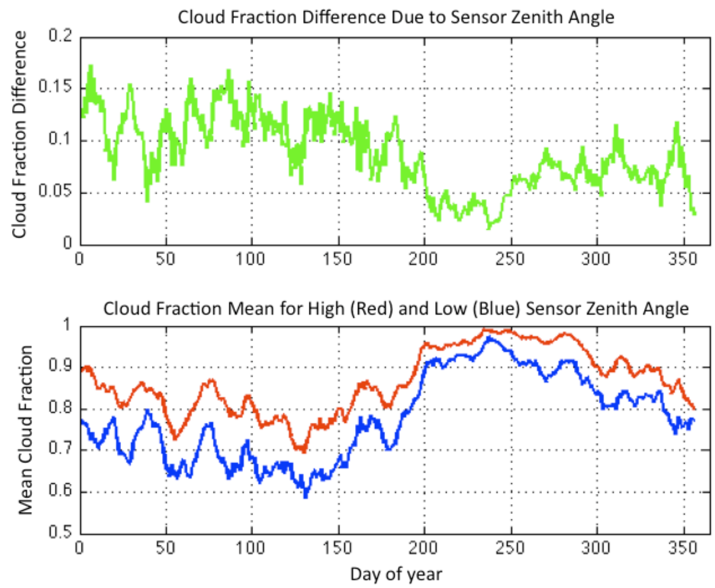


Figure 90 The annual cycle of cloud amount over the SE Pacific marine stratocumulus region is dampened by the satellite view geometry. The green line is the difference between the high view geometry observations (red) and near nadir observations (blue).

Publications/Conference Presentations

Foster, M.J., S.A. Ackerman, A.K. Heidinger, and B.C. Maddux, 2011: Global Cloudiness [in "State of the Climate in 2010"]. *Bull. Amer. Meteor. Soc.*, in Press.

Maddux, B.C., S.A. Ackerman, and S. Platnick, 2010: View Geometry Dependencies in MODIS Cloud Products, *J. of Atmos. Ocean. Tech.*, **25**, 1073-1086.

Liu, Yinghui, S.A. Ackerman, B.C. Maddux, J.R. Key, R.A. Frey, 2010: Errors in Cloud Detection over the Arctic Using a Satellite Imager and Implications for Observing Feedback Mechanisms. *J. Climate*, **23**, 1894-1907 doi: 10.1175/2009JCLI3386.1

Foster, M.J., S.A. Ackerman, A.K. Heidinger, and B.C. Maddux, 2010: Global Cloudiness [in "State of the Climate in 2009"]. *Bull. Amer. Meteor. Soc.*, **91**, S34-S35.

Maddux, Brent C., S. A. Ackerman, P. Menzel, and S. Platnick. Variability and interpretation of satellite derived cloud properties from MODIS. The 17th Conference on Satellite Meteorology and Oceanography, September, 26 - 30 September 2010, Annapolis, MD.

Maddux, Brent C., S. Platnick, S. A. Ackerman, and P. Menzel. 10 Years of MODIS Cloud Products, poster. The 17th Conference on Satellite Meteorology and Oceanography, September, 26 - 30 September 2010, Annapolis, MD.

Maddux, Brent C., Steven A. Ackerman, W. Paul Menzel, Steve Platnick, and Richard Frey. MODIS Level-3 Cloud Properties, Poster. A-Train Symposium, October 25-28, 2010, New Orleans.

Maddux, Brent C., et al., 2010: 10-Years of MODIS Cloud Properties, Poster, NOAA/NESDIS Cooperative Research Program (CoRP) 7th Annual Science Symposium, August 10-11, 2010, Fort Collins, Colorado. *2nd Student Poster Presentation Award.

Maddux, Brent C., et al.,2010: Regional and Global Cloud Variability, NOAA/NESDIS Cooperative Research Program (CoRP) 7th Annual Science Symposium, August 10-11, 2010, Fort Collins, Colorado.

Maddux, Brent C., Steven A. Ackerman, and W. Paul Menzel. MODIS Cloud Climatology: State and Variability of the Global Cloud Field. GEWEX Cloud Assessment Meeting, June 22-25, 2010, Berlin, Germany.

Collaboration with California Air Resources Board (ARB) and NOAA/ESRL Chemical Sciences Division (CSD) during the 2010 CalNex Field Mission

CIMSS Personnel: Todd Schaack and Allen Lenzen
Federal Collaborator: R. Bradley Pierce
Funded by: GOES-R Visiting Scientist Program

Project Description
The objectives of the GOES-R Visiting Scientist activities during CalNex (May-June, 2010) were to engage the NOAA Oceanic and Atmospheric Research (OAR) Earth System Research Lab (ESRL) field mission program in joint science activities involving multiple observational platforms, initiate GOES-R satellite validation activities using existing satellite instruments as test cases, and engage the California Air Resources Board (ARB) in the use of existing satellite retrievals for providing lateral boundary conditions and assessment of the fidelity of air quality modeling to support regulatory programs.

CIMSS and ASPB scientists collaborated with ARB regional chemical and aerosol modelers on the incorporation of Real-time Air Quality Modeling System (RAQMS) (http://raqms-ops.ssec.wisc.edu/index.php) Lateral Boundary Conditions (LBC) into ARB's CalNex Community Multi-scale Air Quality (CMAQ) model forecasts. Automated transfers of RAQMS subsetted forecasts to ARB supported the NOAA CalNex and Department of Energy (DOE) Carbonaceous Aerosol and Radiative Effects Study (CARES) Field Campaigns. Automated transfers of RAQMS forecasts were sent to ESRL and NCEP for real-time LBC for CalNex WRF-chem forecasts (Georg Grell, NOAA/ESRL) and a developmental version of the NAM-CMAQ (Youhua Tang, NOAA/NCEP).

CIMSS and ASBP scientists supported the CalNex Meteorological Working Group by providing daily forecasts of long-range chemical and aerosol transport patterns during CalNex and CARES. These forecasts were based on RAQMS global chemical and aerosol predictions initialized with OMI cloud cleared total column ozone and MLS ozone profiles from the NASA Aura satellite and MODIS aerosol optical depth from the NASA Terra and Aqua satellites. Observation System Experiments (OSE) were conducted to determine the impact of assimilating MODIS AOD measurements on lower tropospheric aerosol predictions. Results of these OSE studies showed that assimilation of AOD retrievals results in significant improvements in black and organic carbon (BC+OC) and dust forecast skill based on large-scale Anomaly Correlation statistics.

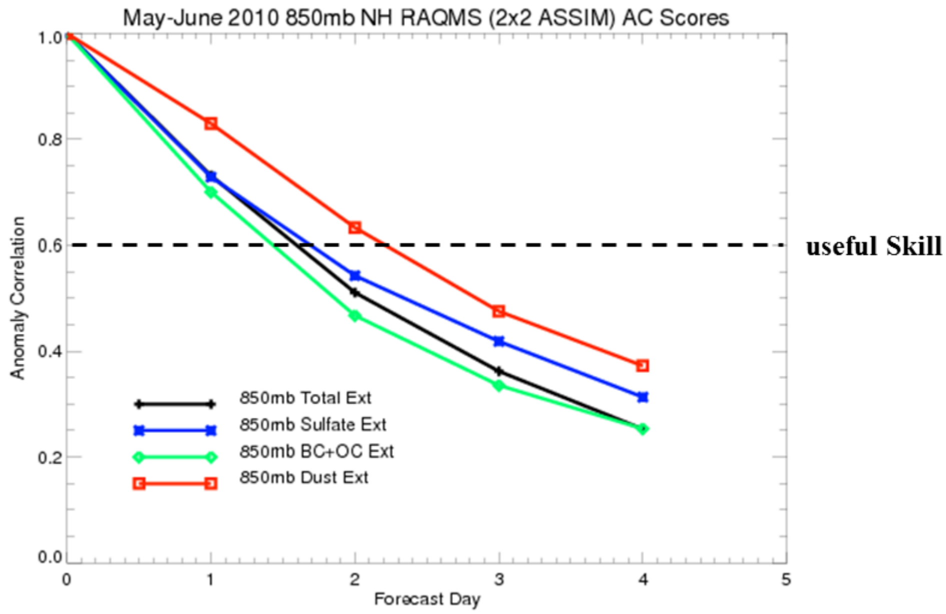


Figure 91 Northern Hemisphere 850mb May-June 2010 Anomaly Correlations (AC) for total (black), Sulfate (blue), Carbon (green), and Dust (red) aerosol extinction with MODIS Assimilation.

Publications/Conference Presentations

Pierce, R. B., et al., 2010: Real-time Air Quality Modeling System aerosol and ozone assimilation and forecasting experiments using A-Train measurements during the NOAA CalNex field mission, NASA A-Train Symposium, Oct 25-28, 2010, New Orleans, LA.

Pierce, R. B. et al., 2011: Chemical and Aerosol Data Assimilation Activities during CalNex, Seventh Annual NOAA Crest Symposium, April 27-28, 2011, Hampton, VA.

Pierce, R. B. et al., 2011: The Use of Current and Future Hyperspectral Trace Gas Retrievals in Atmospheric Chemistry Research at NOAA, NOAA, NASA, EUMETSAT Satellite Hyperspectral Sensor Workshop, March 29-31, 2011, Miami, FL.

Pierce, R. B. et al., 2011: Chemical and Aerosol Data Assimilation Activities during CalNex, CalNex Data Analysis Workshop - May 16-19, 2011, Sacramento, CA.

Climate Literacy Ambassadors

CIMSS Personnel: Steve Ackerman and Margaret Mooney
Federal Collaborators: Lin Chambers and Takmeng Wong
Funded by: NASA GCCE

Project Description
CIMSS is conducting a three-year program to train G6-12 teachers to be Ambassadors of Climate Literacy in their local schools and communities. The complete training involves participation at a teacher workshop combined with an eight week distance learning course culminating in a technology-supported virtual community of climate change educators. Participating teachers will also have the option to develop a capstone project engaging students in climate research utilizing NASA data.

The first workshop was held on May 8th, 2010 at CIMSS in Madison Wisconsin. The second Climate Literacy Ambassadors workshop was held at the Federation of Earth Science Information Partners (ESIP) July 2010 meeting in Knoxville Tennessee. The 3rd and 4th workshops were held at CIMSS in Madison Wisconsin in January 2011. A total of 67 educators have attended these workshops thus far. Six educators took the on-line course in the summer of 2010 and twenty teachers enrolled for credit with the UW-Madison 2011 spring semester. The next workshop will be held at the ESIP meeting in July 2011.

Accomplishments
2010 Climate Literacy Ambassadors produced twenty-nine (29) climate-related lesson plans which have been posted as a resource for all educators. 2011 ambassadors have produced 50 additional lesson plans. One ambassador, Chuck Tennessean from Dodgeville Wisconsin developed a district-wide action plan detailing opportunities and incentives for students to investigate the size of their individual and/or household carbon footprints and identify actions to reduce carbon pollution. This event was coordinated with 350.org and the 10-10-10 global work party; over eight hundred (800!) students participated. The action plan and lesson plans are available via the Global and Regional Climate Change on-line course Web page:
http://cimss.ssec.wisc.edu/climatechange/

Figure 92 Climate Literacy Ambassador Workshop Participants

CIMSS Facebook Page

CIMSS Personnel: Margaret Mooney
Funded by: NOAA

Project Description
CIMSS launched a Facebook page in 2010 to increase exposure via social media. The page is accessible at http://www.facebook.com/pages/CIMSS/277457832219. The majority of posts feature CIMSS satellite imagery and projects.

Accomplishments
New images and stories are posted several times a week to 175 fans (to date), with an average number of 500 impressions per post, where impressions are defined as the "raw number of times this story has been seen on your wall and in the news feed of your fans". According to the stats available from Facebook, the majority of fans hail from the United States (145) with 1 or more from the following countries: Canada, Puerto Rico, Hong Kong, Mongolia, Egypt, Democratic Republic of Congo, Australia, Sri Lanka, Brazil, India, Iceland, Mexico, Netherlands, Pakistan, Malaysia, Romania, Poland, Portugal and Hungary.

Below is a screen shot from two January 2011 posts, note that both had over 900 impressions:

Satellite Applications in Geoscience Education (SAGE)

CIMSS Personnel: Margaret Mooney, Tom Whitaker and Justin Sieglaff
Federal Collaborator: Nina Jackson
Funded by: NOAA/NESDIS

Project Description
Satellite Applications in Geoscience Education (SAGE) is a distance-learning course for G6-16 educators that seeks to leverage satellite observations with teachers' connection to students to raise awareness of Earth's dynamic air and water systems. Originally funded by the National Science Foundation, SAGE debuted in the fall of 2007 from a collaborative effort between oceanographers from the University of Washington and University of Wisconsin meteorologists and geologists. In 2010 course refinements and aviation-related updates were funded by the National Oceanic and Atmospheric Administration.

Accomplishments
CIMSS recently completed incorporating feedback from teachers which was collected when the course was offered for credit at the UW-Madison in 2007. In addition, a new aviation lesson was developed and added to the unit on meteorology, including an applet based on the identification of aviation hazards. Content and imagery for the new applet was provided from the CIMSS SNAPP team. (satellite-based nowcasting and aviation application program) The new applet is available on-line at http://cimss.ssec.wisc.edu/sage/meteorology/lesson6/aviation.html.

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

Publications/Conference Presentations:

Mooney, Margaret., Ackerman, S., Jackson, N., and Whittaker, T., 2011: Infusing satellite data into earth science education with SAGE, ESIP and SNAPP. American Meteorological Society 20th Symposium on Education, January 2011.

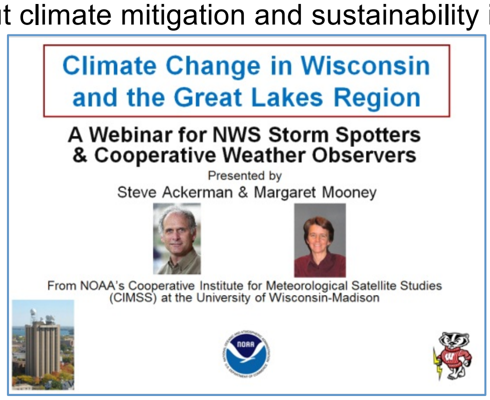
Climate Change Web Seminars for NWS Storm Spotters – a Pilot Project through the NOAA Climate Stewards Education Program

CIMSS Personnel: Margaret Mooney and Steve Ackerman
Federal Collaborators: Rusty Kapela, Peg Steffen and Bruce Moravchik
Funded by: NOAA

Project Description
In support of NOAA's 2010 first class of Climate Stewards, CIMSS agreed to distribute mini-grants to certified stewards under the direction of the Climate Stewards Education Program (CSEP) leadership team. CSEP is a national network of formal and informal educators created to align with NOAA's education goals in their 2009-2029 Strategic Plan. Once certified, Climate Stewards are eligible for a mini-grant to execute action plans ranging from community projects, opportunities for service learning, classroom projects and curriculum infusion.

CIMSS EPO Director, Margaret Mooney, participated in this flagship class of Climate Stewards and applied a mini-grant to an existing concept to engage NOAA's National Weather Service (NWS) storm spotters in climate mitigation and environmental stewardship. Mooney, a former National Weather Service employee, collaborated with Rusty Kapela from NWSFO MKX to invite storm spotters in southern Wisconsin to a Web seminar scheduled for May 10th co-presented with CIMSS director Steve Ackerman. The 1-hour Webinar featured information from two recent publications: the 2009 U.S. Global Change Research Program and the 2011 Wisconsin Initiative on Climate Change Impacts (WICCI). Along with educating storm spotters on climate change topics, the presenters suggested mitigation and stewardship activities and promoted CIMSS/SSEC efforts to engage mobile phone users by demonstrating how to access real-time weather and climate data.

Accomplishments
Nineteen storm spotters participated and eleven provided feedback via a follow-up survey. A third of the respondents took action to minimize their carbon footprint, a large majority (90%) indicated their likelihood to take action in the near future and more than two-thirds said they would like to learn more about climate mitigation and sustainability in the Great Lakes Region.



Presentations
The Webinar is available for viewing at http://vimeo.com/23571211.

Student Workshop on Atmospheric and Earth Science

CIMSS Personnel: Jordan Gerth, Maria Vasys, Margaret Mooney & Patrick Rowley
Federal Collaborator: Gary Wade
Funded by: Participant fees and NOAA

Project Description
The CIMSS student workshop on Atmospheric and Earth Science is an exciting five-day science camp featuring a full agenda of meteorology, land remote sensing, geology and astronomy. Participating students stay on the UW-Madison campus in lakeside dorms and experience science education, research and technology through hands-on activities working directly with scientists, graduate students and professors.

Accomplishments
Since 1991, the CIMSS high school student workshop has shepherded 100s of students into Earth science college majors and future science careers. This time-tested summer workshop for high school students has become a legacy in the educational community. The 2011 workshop is scheduled for June 26th through the 30th with ten students coming from Wisconsin, Illinois, Minnesota and Connecticut. For more information, agendas and photo galleries, please visit http://cimss.ssec.wisc.edu/studentworkshop/.

Figure 93 CIMSS Summer Workshop

Publications/Conference Presentations:

Mooney, Margaret, Wade, Gary, Smith, W. L, Achtor, T., Ackerman, S, Avila, L., Brunner, J, and Pertzborn, R., 2007: The history and sustainability of the CIMSS student workshop on

atmospheric, earth, and space science at the University of Wisconsin in Madison, AMS 16th Symposium on Education, January 2007.

Investigations in Earth System

CIMSS Personnel: Steve Ackerman, Tom Whittaker, Tommy Jasmin
Federal Collaborator: Lin Chambers, NASA LaRC
Other Collaborator: Catherine Lange, Buffalo State College
Funded by: NASA

Project Description
Students and Teachers Using Data from Investigations in Earth Systems (STUDIES) will integrate and modify currently existing NASA Earth system science datasets, interactive models, simulations and educational resources, especially the MY NASA DATA Web site (http://mynasadata.larc.nasa.gov), for use in a wide range of middle and high school standards-based classrooms. Using the idea of unifying concepts from the National Science Education Standards, interdisciplinary curriculum materials will be developed focusing on three areas: Earth Motions, Weather, and Mapping. With focus toward an efficient interface between the cutting edge work of NASA scientists and K-12 science pedagogy, we will increase understanding about Earth's complex systems and appreciation of NASA's high-quality and important data records and Earth observations. The project includes a comprehensive, systematic implementation and testing process to assure its success and sustainability.

The team from the University of Wisconsin-Madison team is developing applets that provide visual meaning, assist in the translation of complex science datasets to understandable forms that teachers and students can utilize. To address misconceptions regarding the cause of the seasons, we developed the ‘Seasons Applet’. For reference, the URL is:
<http://www.ssec.wisc.edu/~tomw/test/seasons.html>

We demonstrated a version of the "Seasons applet" (Figure 94) on a touch-screen kiosk at the Grand Opening of the new Wisconsin Institutes for Discovery:
<http://www.discovery.wisc.edu/home/discovery/events/grand-opening-events/grand-opening-events-home.cmsx>

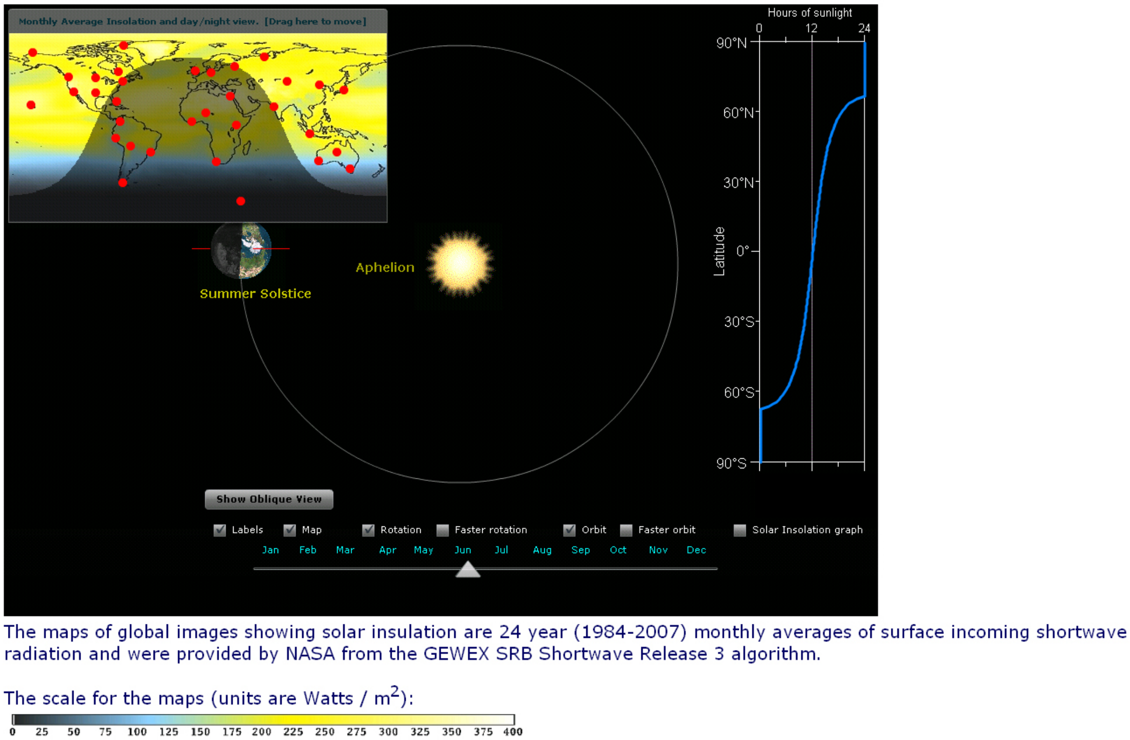


Figure 94 Screen capture of the applet that helps to explain the causes of the seasons by overcoming some common misconceptions.

The majority of the people passing by the station stopped and looked at the applet. A few commented on the relationship between the Earth spinning and orbiting and the day-night view on the map. We found, however, that the widgets as currently rendered are too small for use on the kiosk where fingers are the pointing and tapping device. While few people asked any questions, the fact that many stopped and watched for a while means there was some attraction to the display: the motions and the coordination between the spinning, orbiting, and map displays.

In July, we participate in a teacher workshop in Buffalo to test the applet and assess its potential as a learning tool.

Interpretation of Real-Time Weather and Climate Data for Spherical Displays (EarthNow)

CIMSS Personnel: Steve Ackerman, Rick Kohrs, Margaret Mooney, Patrick Rowley
Federal Collaborator: Dan Pisut, NOAA Environmental Visualization Lab / IMSG
Other Collaborators: Phil Arkin, CICS; Jeff Hayward, Evaluator
Funded by: NOAA OED/ELG

Project Description
Following the recommendations of the Science On a Sphere® (SOS) Collaborative Network, the EarthNow project attempts to satisfy the desire for meaningful real-time datasets related to weather and climate that connect to the audience, along with the need for interpretation of those datasets. Through a blog-like Web site, timely weather-climate relationship stories are published along with accompanying datasets and dataset interpretation. SOS facilitators at more than 70 institutions worldwide can then access these stories, allowing for more accessible data interpretation, resulting in more compelling presentations to the public. Stories so far have included monthly climate reports, droughts and wild fires, flooding, the Grímsvötn volcano eruption, and Hurricane Adrian. What makes these stories different from many other reports is the focus on some level of attribution for the events. By its very nature, spherical displays allow for global system discussions. This, however, also presents the challenge of discussing smaller-scale events that currently have the public's attention. Hurricane Adrian is a good example. Many times, storms like this are presented as an individual beast, rather than the product of Earth's systems working together. Instead, the EarthNow blog entry uses not only real-time IR cloud data, but also real-time sea surface temperature and tropical cyclone heat potential datasets. After a project team meeting in Madison on 26 May, our evaluator began the front-end evaluation process, testing questions with Chicago's Museum of Science and Industry and the Ocean Explorium in New Bedford, Massachusetts. Following those initial conversations, the front-end evaluation will continue with museums which the team deemed as "SOS Power Institutions," or those which already have a history of working with real-time data and giving facilitator-led SOS presentations. The goal of this front-end evaluation will be to help shape how we communicate the weather-climate stories to the network as the project moves forward.

Science On a Sphere exhibit at Chicago's Museum of Science and Industry. There are now over 70 SOS installations worldwide.

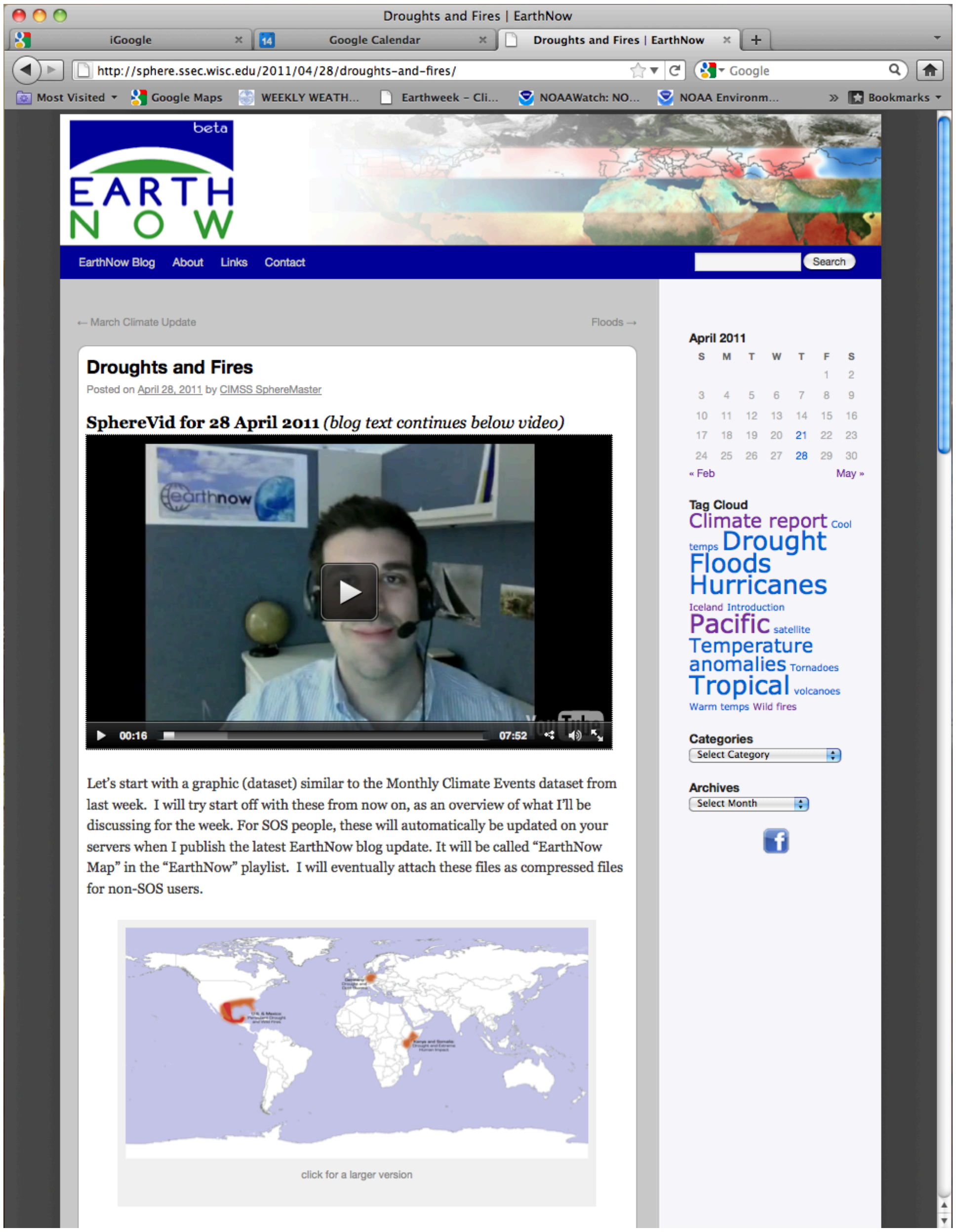


Figure 95 Excerpt from an April 2011 EarthNow blog entry. Many entries also include a "SphereVid" in which datasets and imagery are explained in more depth. EarthNow Web site: http://sphere.ssec.wisc.edu

Publications/Conference Presentations:

Ackerman, Steve and Pisut, Dan, 2011: *A Global Perspective of Scientific Visualization: Developing Meaningful Imagery to Engage Audiences.* International Symposium on Remote Sensing of the Environment, Sydney, Australia, April 2011.

Pisut, Dan, 2011: Real-time Data Interpretation Panel. Science On a Sphere Collaborative Network Meeting, Chicago, IL, May 2011.

Rowley, Patrick, 2011: *EarthNow: Real-Time Data Interpretation and Training*. Science On a Sphere Collaborative Network Meeting, Chicago, IL, May 2011.

Mooney, Margaret; Pisut, Dan; Rowley, Patrick, 2011: *EarthNow Project Evaluation Expo.* Science On a Sphere Collaborative Network Meeting, Chicago, IL, May 2011.

Satellites See Wisconsin

CIMSS Personnel: Steve Ackerman, Leanne Avila, Sam Batzli, Bill Bellon, Britta Gjermo, Liam Gumley, Mark Hobson, Rick Kohrs, John Lalande, Daniel Pasowicz, Jean Phillips, Maria Vasys, and SSEC's Technical Computing and Library Staff
Federal Collaborators: NOAA (imagery source and NESDIS staff – Tim Schmit), NASA (imagery source)
Funded by: SSEC/CIMSS

Project Description
"Satellites See Wisconsin" is a public museum-like exhibit installed at the Dane County Regional Airport from Feb through September 2011. This project informs and stimulates public interest in satellite observations of Wisconsin. It enables the public to experience the excitement of learning and discovery that comes with images generated through environmental remote sensing.

Scientists and engineers have long been using satellite remote sensing to monitor and predict its evolution and changes of the Earth-atmosphere system. This generation of satellite remote sensing platforms is providing a wealth of advanced sensor observations for understanding ocean, land, and atmosphere processes. We wanted the public to appreciate how scientists use satellite observations to study Wisconsin and the surrounding region. The exhibition shows dramatic and visually captivating views of Wisconsin from a variety of NOAA and NASA instruments, including GOES, MODIS, ASTER, EO-1, SRTM, AIRS CALIPSO, Landsat, and CloudSat. To support UW-Madison's Wisconsin Idea, we engaged resources within and across institutions to build strong partnerships that included working closely with Tandem Press.

The exhibit consists of three large double-sided glass cases containing approximately 50 images. Two smaller four-sided cases are used for posters about satellites and the full-scale model of SSEC's Explorer 7 satellite. The educational sphere is deployed as part of the exhibit and displays imagery drawn from SSEC servers. SSEC hosts a Web site for the exhibit here: http://www.ssec.wisc.edu/airportexhibit/ A custom version of the SSEC OWL is included in the exhibit and can be viewed here: http://www.ssec.wisc.edu/airportexhibit/owl/

Significant Milestone
The exhibit has been very well received by the general public and professionals in the field. The following are a brief selection of typical comments collected through comment boxes at the exhibit.

"First class exhibit. Design, storytold--informative. A WI success story. …- I've seen earlier exhibits! I hope these continue."

"Outstanding exhibit! Please make it PERMANENT!"

"Simply awesome! Great Work!"

"Really cool! I like the history of satellites exhibit, and I've never seen an airport with a 3D exhibit before. I like it!"

"Terrific! The globe with weather currents, etc. is great, also. Love the connection with lake on all the photos. So impressive. Thank you!!!"

Figure 96 General view of the *Satellites See Wisconsin* exhibit during the opening reception February 11, 2011

Figure 97 Approval by the general public of the exhibit is in evidence every day.

CIMSS ADMINISTRATION

Personnel

- CIMSS Personnel (text and graphic)
- CIMSS Personnel History (graphic)
- CIMSS Graduate Student Degree Awards (graphic)
- CIMSS Current Graduate Student and Post Doctor Research Topics

Financial

- CIMSS Spending History (total - graphic)
- CIMSS Spending by Agency (past 12 months - graphic)
- CIMSS Spending History by Agency (graphic)

Publications

- CIMSS Publishing History (1995-2011 – table and graphic)
- CIMSS Review Publications (2010-2011)
- CIMSS Conference Presentations/Papers, Book Chapters, Reports (2010-2011)

CIMSS Personnel

CIMSS PERSONNEL SUMMARY: (128 Associates) June 2011

CIMSS ADMINISTRATION AND TECHNICAL SUPPORT (4):	Steve Ackerman	Director
	Tom Achtor	Executive Director
	Maria Vasys	University Services Associate
	Leanne Avila	Editor/Webmaster

UNIVERSITY PRINCIPAL INVESTIGATORS: (23)

(Steve Ackerman	Professor, AOS	Clouds / Aerosols)
(Tom Achtor	Researcher	McIDAS)
Bryan Baum	Associate Scientist	Cloud Microphysics
Ralf Bennartz	Professor, AOS	Microwave / Radiative Transfer
Wayne Feltz	Assistant Scientist	Aviation Weather
Mike Foster	Assistant Researcher	Cloud microphysical properties
Tom Greenwald	Associate Scientist	Microwave / Data Assimilation
Liam Gumley	Instrument Innovator	Direct Broadcast and Data Analysis
Bob Holz	Assistant Scientist	NPOESS / Lidar
Allen Huang	Distinguished Scientist	Retrieval Science / Hyperspectral
Bormin Huang	Assistant Scientist	Data Compression / Retrieval Science
Bob Knuteson	Associate Scientist	Hyperspectral Instruments / Data Analysis
Matthew Lazarra	Assistant Scientist	Antarctic Research
Jun Li	Senior Scientist	Retrieval Science / Hyperspectral
Colleen Mouw	Associate Researcher	Ocean and fresh water remote sensing
Paul Menzel	Senior Scientist	Clouds and Climate / Instrumentation
Ralph Petersen	Senior Scientist	NWP / Nowcasting
Grant Petty	Professor, AOS	Microwave / Rainfall
Elaine Prins	Contracting Scientist	Biomass Burning / Aerosols
Hank Revercomb	Senior Scientist	Hyperspectral Instruments/Data Analysis
Dave Santek	Assistant Scientist	Polar Winds / Data Assimilation
Chris Schmidt	Senior Researcher	Biomass Burning
Bill Smith Sr.	Senior Scientist	Hyperspectral Instruments/Data Analysis
Dave Tobin	Associate Scientist	Radiative Transfer
Chris Velden	Senior Scientist	Satellite Winds / Tropical Cyclones

NOAA SCIENTISTS: (9)	Jeff Key	ASPB Team Leader
	Robert Aune	ASPB
	Andrew Heidinger	ASPB
	Mike Pavolonis	ASPB
	Brad Pierce	ASPB
	Tim Schmit	ASPB
	Gary Wade	ASPB
	Jim Kossin	NCDC
	Robert Rabin	NSSL

UNIVERSITY SCIENTIFIC AND PROGRAMMING STAFF (63)	Paolo Antonelli	Researcher
	Scott Bachmeier	Researcher
	Kaba Bah	Assistant Researcher

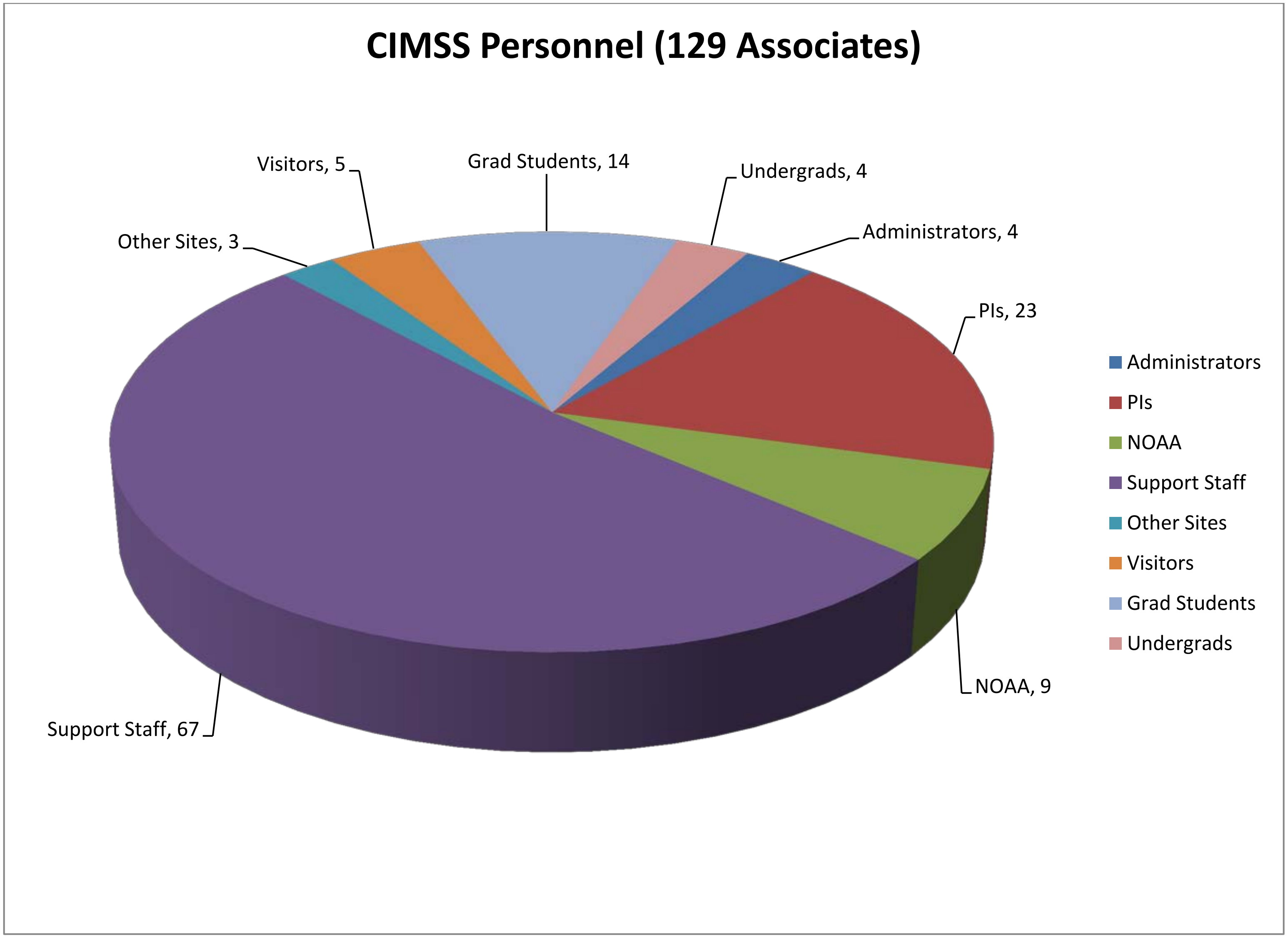
	Eva Borbas	Assistant Scientist
	Lori Borg	Assistant Researcher
	Jason Brunner	Associate Researcher
	Corey Calvert	Associate Researcher
	Lee Cronce	Assistant Researcher
UNIVERSITY SCIENTIFIC AND PROGRAMMING STAFF (continued)	Geoff Cureton	Asst. Instrument Innovator
	Jim Davies	Assistant Researcher
	Ralph Dedecker	Asst. Instrument Innovator
	Dan DeSlover	Researcher
	George Diak	Emeritus Scientist
	Rich Dworak	Assistant Researcher
	Joleen Feltz	Assistant Researcher
	Bruce Flynn	Instrument Technician
	Richard Frey	Researcher
	Ray Garcia	Instrument Innovator
	Mat Gunshor	Associate Researcher
	Dan Hartung	Associate Researcher
	Pat Heck	Researcher
	Derrick Herndon	Associate Researcher
	Jay Hoffman	Assistant Researcher
	Tommy Jasmin	Sr. Systems Programmer
	Joo Hyeon Kim	Associate Researcher
	Ralph Kuehn	Assistant Researcher
	Yong-Keun Lee	Assistant Researcher
	Allen Lenzen	Sr. Instrumentation Tech
	Jinlong Li	Associate Researcher
	Zhenglong Li	Associate Researcher
	Scott Lindstrom	Sr. Instrument Technician
	Yinghui Liu	Assistant Researcher
	Graeme Martin	Instrument Technician
	Szu-Chia Moeller	Assistant Researcher
	Chris Moeller	Researcher
	Christine Molling	Associate Researcher
	Sarah Monette	Research Intern
	Margaret Mooney	Sr. Outreach Specialist
	Fred Nagle	Researcher
	Jim Nelson	Researcher
	Sharon Nebuda	Research Intern
	Tim Olander	Researcher
	Erik Olson	Associate Researcher
	Min Oo	Assistant Research
	Chan Park	Research Intern
	Jason Otkin	Associate Researcher
	Youri Plokhenko	Researcher
	Greg Quinn	Instrument Technician
	Tom Rink	Senior Instrumentation Tech
	Patrick Rowley	Outreach Specialist
	Chris Rozoff	Assistant Researcher
	Todd Schaack	Researcher
	Eva Schiffer	Instrument Technician
	Tony Schreiner	Researcher

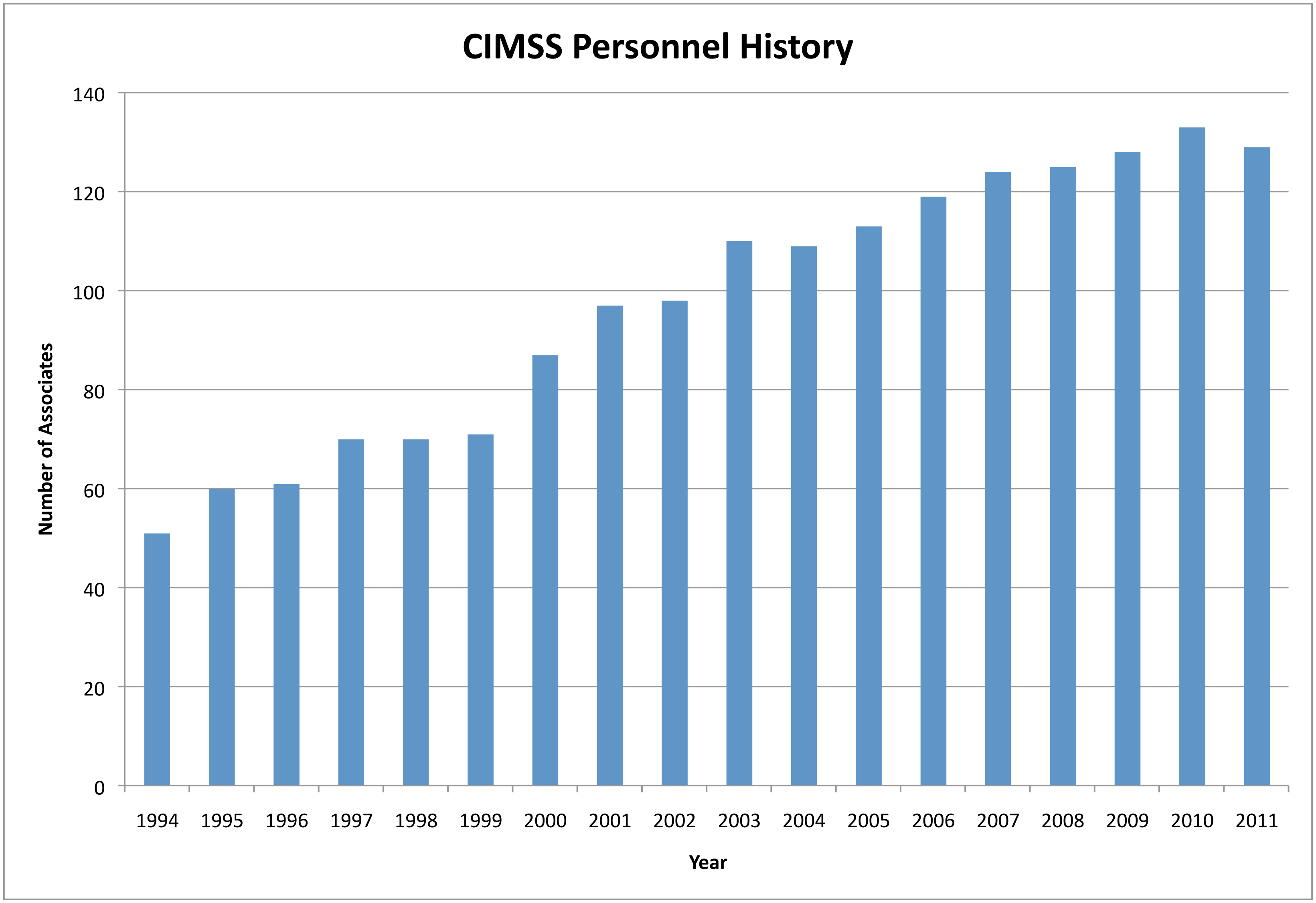
	Justin Sieglaff	Assistant Researcher
	Dave Stettner	Associate Researcher
	Kathy Strabala	Researcher
	William Straka	Assistant Researcher
	Xuanji Wang	Associate Researcher
	Steve Wanzong	Associate Researcher
	Elisabeth Weisz	Associate Researcher
	Tom Whittaker	Researcher
	Hong Zhang	Researcher
POST DOCTORS: (4)	Brett Hoover	Research Associate
	Mark Kulie	Research Associate
	Nadia Smith	Research Associate
	Tim Wagner	Research Associate
STAFF AT OTHER SITES: (3)	Howard Berger	Iowa/Associate Researcher
	Jim Jung	NCEP/Assistant Scientist
	Tony Wimmers	U.Calgary/Associate Researcher
VISITING SCIENTISTS (5)	Eun-Han Kwon	Korea
	Jarno Mielikainen	Finland
	HyunJong Oh	Korea
	Yong Zhang	China
	Jing Zheng	China

GRADUATE STUDENTS: (13)

Student	**Degree**	**Science Advisor**	**Academic Advisor**
Jordan Gerth	M.S.	Ackerman	Ackerman
Agnes Lim	Ph.D.	A. Huang	Ackerman
Brent Maddux	Ph.D.	Ackerman	Ackerman
Willem Marais	M.S.	Gumley	
Aronne Merrelli	M.S.	Turner	Ackerman
Kathryn Mozer	M.S.	Heidinger	Ackerman
(Michael Pavolonis	Ph.D.	Heidinger	Ackerman)
John Rausch	M.S.	Bennartz	Bennartz
Ilya Razenkov	M.S.	Eloranta	Ackerman
John Sears	M.S.	Velden	Ackerman
Matthew Sitkowski	Ph.D.	Kossin	Ackerman
Mark Smalley	Ph.D.	Holz	Ackerman
William Smith, Jr.	Ph.D.	Ackerman	Ackerman
Kenneth Vinson	M.S.	Ackerman	Ackerman

UNDERGRADUATE STUDENT EMPLOYEES (4)	Megan Evansen
	Elise Garms
	Britta Gjermo
	Jacola Roman


CIMSS Personnel (129 Associates)
Visitors, 5
Grad Students, 14
Undergrads, 4
Other Sites, 3
Administrators, 4
PIs, 23
NOAA, 9
Support Staff, 67
Administrators
PIs
NOAA
Support Staff
Other Sites
Visitors
Grad Students
Undergrads


CIMSS Personnel History
Number of Associates
0
20
40
60
80
100
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140
1994
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Graduation History of CIMSS Supported Graduate students

CIMSS scientists, as of summer 2011, have supported 90 M.S. and 37 PhD degrees.

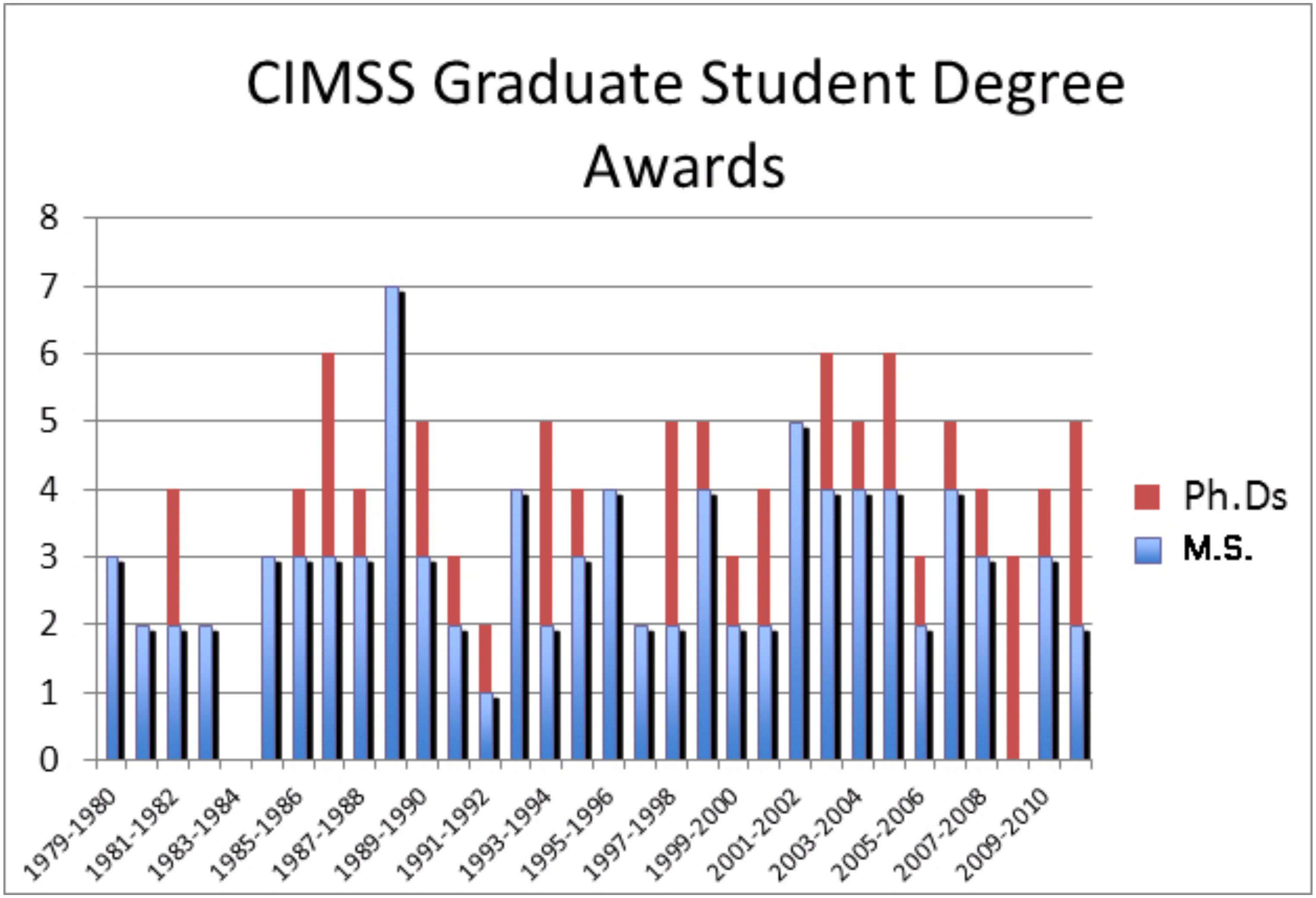


Figure 98 CIMSS related graduate student degrees.

2009-2010
Utkan Kolat MS (Turkey)
Ilya Razenkov MS (Returning for PhD)
Kathryn Mozer MS (NOAA Contractor)
Mark Kulie PhD (CIMSS/SSEC)

2010-2011
Chian-Yi Liu PhD (Taiwan)
Sarah Monette MS (CIMSS/SSEC)
Kenneth Vinson MS (CIMSS/SSEC)
Brent Maddux PhD (KNMI)
Timothy Wagner PhD (Creighton University)

Research Topics of Current CIMSS Graduate Students and Post-Doctors

NOAA FUNDED GRADUATE STUDENTS

Jordan Gerth
Research studies the impact of varied initial conditions and lateral forcings on numerical weather prediction forecasts, and works heavily on research to operations exercises supporting future National Weather Service use of the Geostationary Operational Environmental Satellite R-Series (GOES-R) as part of a proving ground effort.

Agnes Lim
PhD Thesis title: "Examining Atmospheric Variability within Convective System through Hyperspectral Infrared Satellite Data and Their Assimilation." Forecast skill on summer convective precipitation remains low. The aim of this study is to identify specific channels of a hyperspectral sensor (IASI) that can pick up the thermodynamics and dynamics characteristics of convective systems and incorporate this information into the initialization of NWP models through variational data assimilation to increase the forecast skill. Both clear sky and cloudy sky conditions will be tackled.

Sarah Monette
Current research examines operational uses for an objective overshooting top detection algorithm. Presently working on the employment of an objective overshooting top detection algorithm to various stages of a tropical cyclone, mainly genesis and intensification. In addition, the algorithm has been applied to the likelihood of an airplane experiencing turbulence, as well as detecting the climatological signal of the El Niño Southern Oscillation.

Kathryn Mozer (Graduated)
Research involves the PATMOS-x satellite dataset (1982-2009) created by Andrew Heidinger and comparing low cloud fraction (over the eastern South Pacific) from PATMOS-x, NCAR/CCSM3.0 (20th century and SRESa1b experiments),and GFDL/CM2.0 (20th century and SRESa1b experiments)to lower tropospheric static stability as described in Klein and Hartmann 1993, calculated from the models and NCEP Reanalysis data. The goal is to determine how well the models compare to the satellite and if LTS is indeed an appropriate diagnostic for low cloud in this region.

Matthew Sitkowski
Ph.D. Thesis title: "The Physical Processes and Prediction of Secondary Eyewall Formation." This study explores some of the physical processes that occur within the inner-core of a hurricane during the formation of a secondary eyewall. An environmental and GOES based algorithm is also developed to predict the likelihood of secondary eyewall formation. Flight-level aircraft data are being utilized to examine structure and intensity changes associated with eyewall replacement cycles.

NOAA FUNDED POST DOCS

Michael Foster
Currently working on a naive Bayesian cloud-masking algorithm as well as a technique for integrating HIRS measurements into the PATMOS-x processing framework. Other projects include studying 3D radiative transfer through broken cloud fields and the effects deep convective clouds have on stratospheric energy balance.

Zhenglong Li (recently hired into permanent position)
Ph.D. Thesis title: "Improvements and Applications of Atmospheric Soundings from Geostationary Platform." Now research focuses on two projects. The first one focuses on retrieving the surface properties, including the surface emissivity and the land surface temperature, from the SEVIRI instrument. The second one focuses on combining the GOES Sounder and AIRS in order to improve the current sounding products.

STUDENTS FUNDED ON OTHER PROJECTS THAN NOAA

Utkan Kolat (Graduated)
Thesis title: “Re-evaluation of HIRS Detection of High Clouds.” HIRS data are re-processed with two adjustments to the CO_2 slicing algorithm. (1) Stratospheric clouds are identified when more opaque CO_2 channels are warmer than less opaque CO_2 channels. (2) The cloud detection threshold (clear minus cloudy radiances required to indicate cloud presence in CO_2 bands) is lowered to force more CO_2 slicing solutions for high thin clouds. This work will study the resulting changes in high cloud detection.

Mark Kulie (Graduated)
Ph.D. Thesis title: "Combined active-passive microwave remote sensing of clouds and precipitation at higher latitudes." This work uses a combined active-passive microwave observation and modeling system to quantify simulated uncertainties due to the assumed ice particle model and particle size distribution (PSD) used to characterize frozen hydrometeors. A database of microwave optical properties using previously published ice particle models has been created to demonstrate both the potential uncertainties in multi-frequency microwave simulations of clouds and precipitation and to test what ice models produce the most realistic results when compared to observations. Sensitivity tests for space-borne dual-frequency radar applications will also be undertaken to highlight the large uncertainties due to common underlying assumptions of ice model and PSD.

Aronne Merrelli
Ph.D. Thesis title: "Information Content of High Resolution Far Infrared Spectra." Currently investigating information content of Far Infrared (FIR) spectra, using modeled satellite observations of clear-sky atmospheric profiles. Future work will extend the analysis to profiles with ice and mixed-phase layer clouds.

John Sears
Currently working to maximize the accuracy of the ADT, an automated hurricane strength estimating program. Goal is currently to use readily available information from the processing to improve the overall estimations. Future (thesis) work will focus on PREDICT, a project to understand early tropical cyclone development.

Mark Smalley
Master's research title: "An analysis of uncertainties in retrieved cloud top heights associated with CO2 Slicing." There are many uncertainties that can propagate through the CO2 slicing equation and into retrieved cloud top heights. This research focuses investigating the sensitivity of retrieved cloud top heights using CO2 slicing to differences in MODIS and HIRS instrument spectral response functions. HIRS and MODIS radiances are simulated with convolved AIRS radiances.

William Smith, Jr.
Ph. D. Thesis title: "Using Satellite Data to Improve the Representation of Clouds and their Effects in Numerical Weather Analyses and Forecasts." New cloud products derived from CloudSat and CALIPSO data form the basis for a technique developed to retrieve the vertical distribution of cloud water from passive satellite observations. The technique is applied to GOES data over North America and adjacent oceans and the cloud products ingested into the NOAA Rapid Update Cycle (RUC) assimilation system. The impact of the satellite data on RUC model analyses and forecasts is assessed.

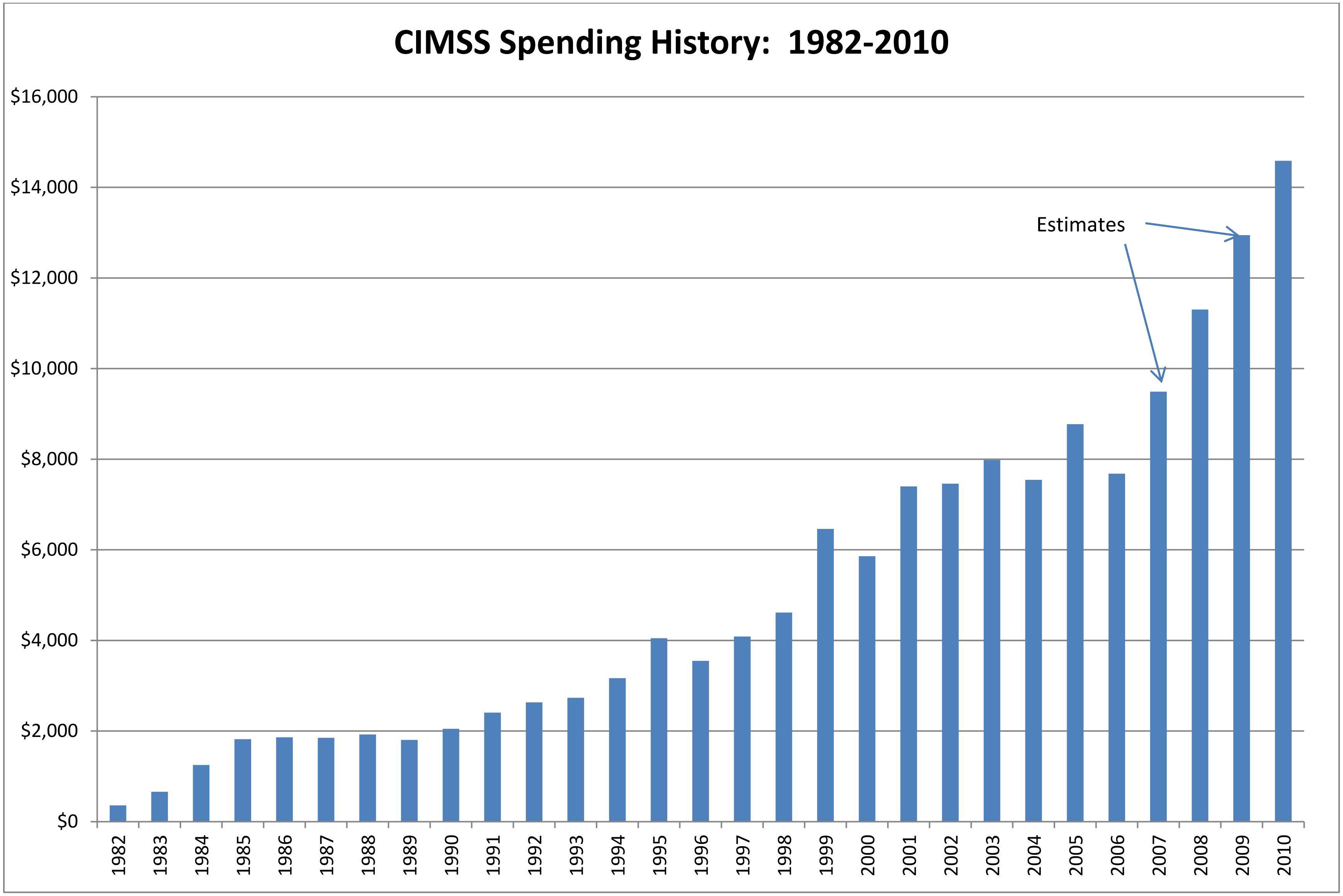
Kenneth Vinson (Graduated)
Master's Thesis title: "Constraining Predicted Trends in Arctic Methane Release using Satellite Observations." There is a great deal of methane stored in the Arctic, mainly in the form of underwater methane clathrate ices and in frozen peat bogs in areas with permafrost. Predicted 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.

Tim Wagner (Graduated)
The impact that cumulus clouds have on the environment is a function of the rate of entrainment of environmental air into the developing cloud. Typically observations of entrainment are obtained from aircraft-borne instruments, but we are developing an algorithm to remotely retrieve entrainment rate from ground-based profiling instruments. This will make it possible to evaluate cumulus parameterizations as well as generate climatologies of entrainment.

POST DOCTORS FUNDED ON OTHER PROJECTS THAN NOAA

Giuseppe Baldassarr
Ph.D. Thesis title: “A performance analysis of advanced MSG-SEVIRI fire detection algorithms (WF_ABBA and RST_FIRES) over Italy.” Research activities consist of comparing WF_ABBA (Wildfire Automated Biomass Burning Algorithm) and RST_FIRES (Robust Satellite Techniques Fires) fire products with the fire ground truth provided by the Italian State Forestry Department and see the performances of this two satellite techniques.

Colleen Mouw (recently hired into permanent position)
Ph.D. dissertation title (2009): "Bio-optical and remote sensing investigation of phytoplankton community size structure." Current research interests in refining and developing optical algorithms to improve the retrieval of biological and biogeochemical parameters from satellite imagery of the ocean, Great Lakes and small inland lakes of Wisconsin. Utilizes in situ data sets, various sources of satellite imagery to understand the physical drivers of biological variability in aquatic systems.


CIMSS Spending History: 1982-2010
$16,000
$14,000
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$0
Estimates
1982
1983
1984
1985
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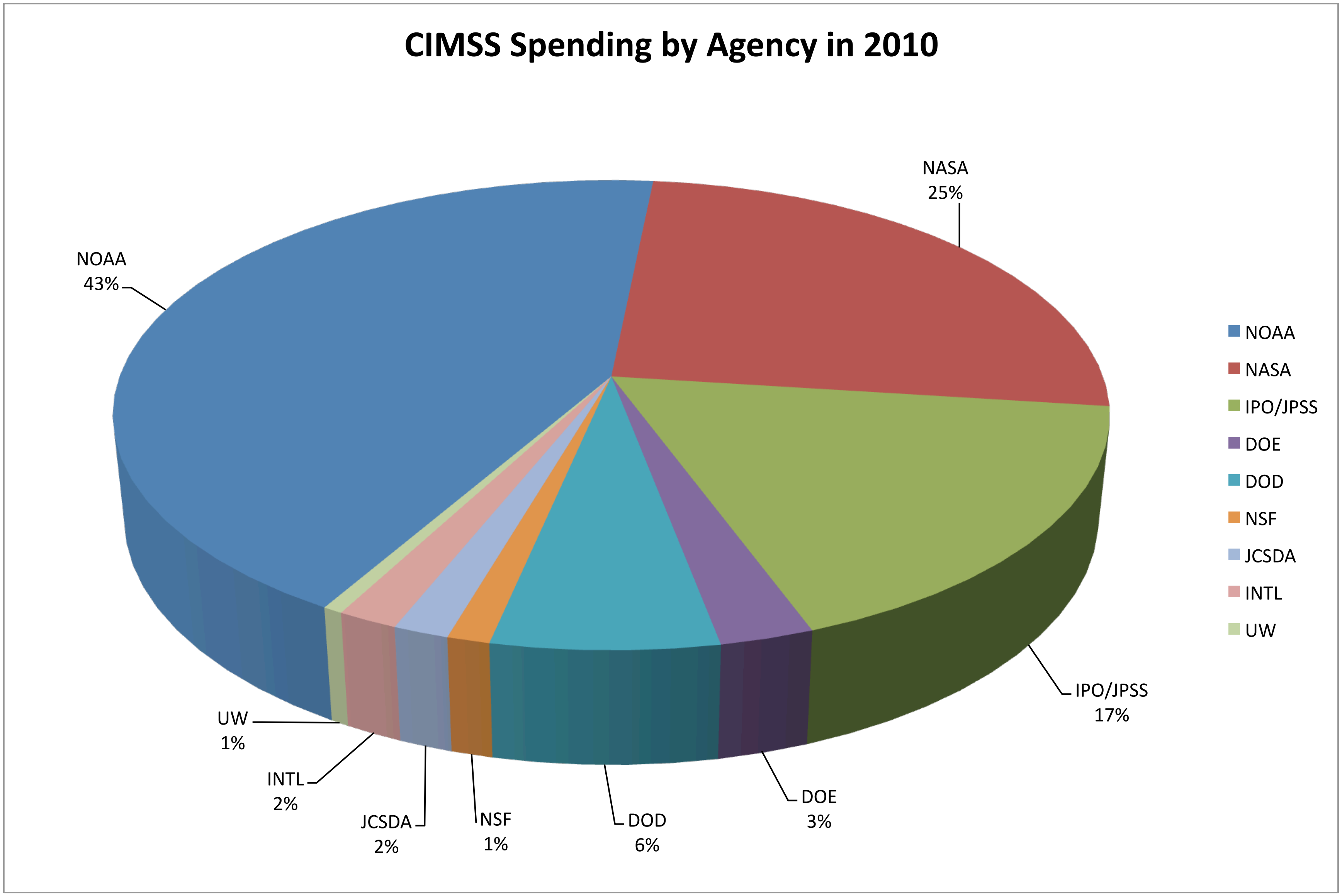
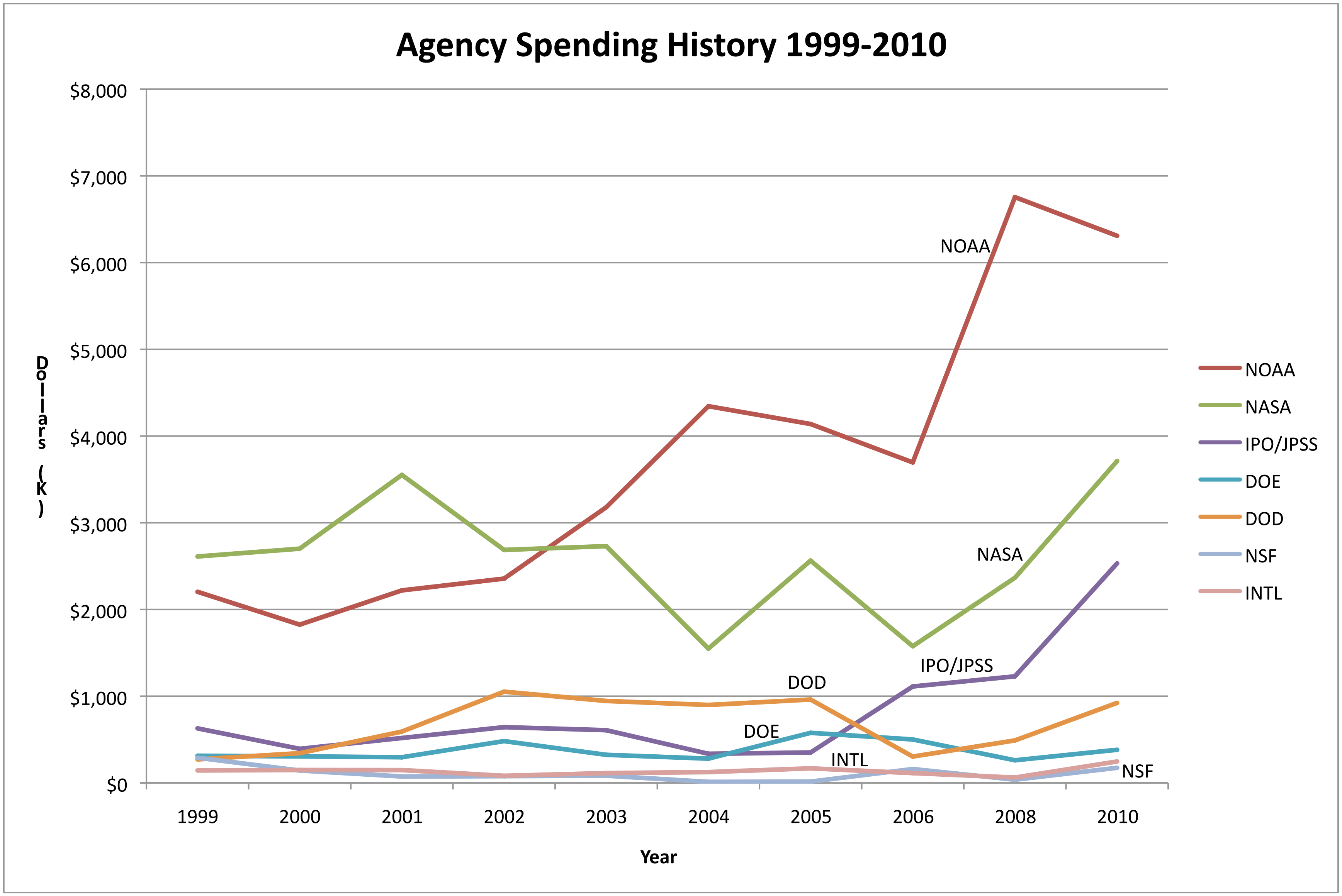

CIMSS Spending by Agency in 2010
NASA 25%
NOAA 43%
IPO/JPSS 17%
DOE 3%
DOD 6%
NSF 1%
JCSDA 2%
INTL 2%
UW 1%
NOAA
NASA
IPO/JPSS
DOE
DOD
NSF
JCSDA
INTL
UW


Agency Spending History 1999-2010
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Dollars (K)
1999
2000
2001
2002
2003
2004
2005
2006
2008
2010
Year
NOAA
NASA
IPO/JPSS
DOD
DOE
INTL
NSF
NOAA
NASA
IPO/JPSS
DOE
DOD
NSF
INTL

Summary of CIMSS Publications

The tables below show the number of papers on which CIMSS and ASPB scientists were first author (Table 1) or contributors (Table 2) to peer reviewed journal articles and non-reviewed articles. Note that data for 2011 is incomplete.

A separate listing of publications of the Advanced Satellite Products Lab (ASPB) is available at: http://library.ssec.wisc.edu/resources/aspb/aspb.php .

Table 1:

Peer Reviewed and Non Peer Reviewed journal articles having CIMSS and/or NOAA lead authors, 2009-2011.* Publications are categorized by Institute, NOAA and Other Lead Author.

	Institute Lead Author			NOAA Lead Author			Other Lead Author		
	2009	**2010**	**2011***	**2009**	**2010**	**2011***	**2009**	**2010**	**2011***
Peer Reviewed	16	19	9	7	8	1	44	31	10
Non Peer Reviewed	1	3	0	1	1	0	0	1	0

*2011 incomplete: does not include papers submitted for publication, accepted for publication, or those in review.

Table 2:

Peer Reviewed and Non Peer Reviewed journal articles having one or more CIMSS and/or NOAA Co-Authors, 2009-2011.

	Institute Co-Author			NOAA Co-Author		
	2009	**2010**	**2011***	**2009**	**2010**	**2011***
Peer Reviewed	52	42	19	20	19	6
Non Peer Reviewed	2	1	0	0	2	0

*2011 incomplete: does not include papers submitted for publication, accepted for publication, or those in review.

Table 3:

CIMSS Publishing History, showing peer reviewed and conference publications.

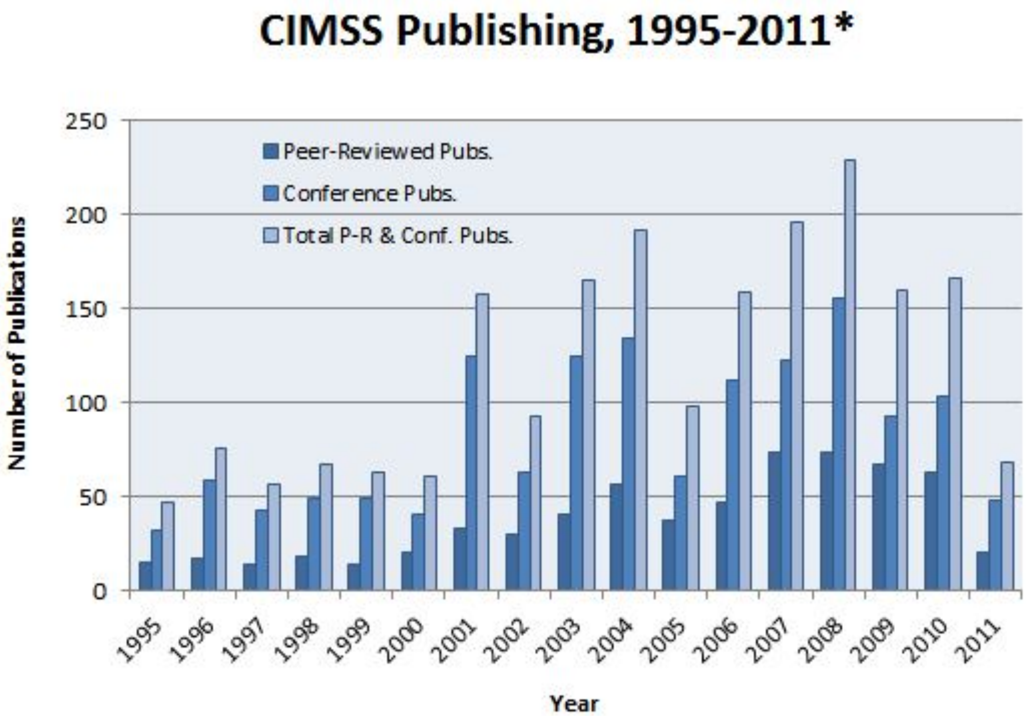


Figure 99 CIMSS Publishing, 1995-2011. (2011 is incomplete).

*2011 incomplete: does not include papers submitted for publication, accepted for publication, or those in review.

CIMSS Reviewed Publications, 2010-2011

2011
Baum, Bryan A.; Yang, Ping; Heymsfield, Andrew J.; Schmitt, Carl G.; Xie, Yu; Bansemer, Aaron; Hu, Yong-Xiang, and Zhang, Zhibo. Improvements in shortwave bulk scattering and absorption models for the remote sensing of ice clouds. Journal of Applied Meteorology and Climatology v.50, no.5, 2011, pp1037-1056.

Bennartz, Ralf; Fan, Jiwen; Rausch, John; Leung, L. Ruby, and Heidinger, Andrew K. Pollution from China increases cloud droplet number, suppresses rain over the East China Sea. Geophysical Research Letters v.38, no.2011, ppdoi:10.1029/2011GL047235.

Bi, Lei; Yang, Ping; Kattawar, George W.; Hu, Yongxiang, and Baum, Bryan A. Diffraction and external reflection by dielectric faceted particles. Journal of Quantitative Spectroscopy and Radiative Transfer v.112, no.2, 2011, pp163-173.

Bi, Lei; Yang, Ping; Kattawar, George W.; Hu, Yongxiang, and Baum, Bryan A. Scattering and absorption of light by ice particles: Solution by a new physical-geometric optics hybrid method. Journal of Quantitative Spectroscopy and Radiative Transfer v.112, no.9, 2011, pp1492-1508.

Borg, Lori A.; Holz, Robert E., and Turner, David D. Investigating cloud radar sensitivity of optically thin cirrus using collocated Raman lidar observations. Geophysical Research Letters v.38, no.2011, ppdoi:10.1029/2010GL046365.

Chen, Xiuhong; Wei, Heli; Yang, Ping; Jin, Zhonghai, and Baum, Bryan A. An efficient method for computing atmospheric radiances in clear-sky and cloudy conditions. Journal of Quantitative Spectroscopy and Radiative Transfer v.112, no.1, 2011, pp109-118.

Ding, Shouguo; Yang, Ping; Weng, Fuzhong; Liu, Quanhua; Han, Yong; van Delst, Paul ; Li, Jun, and Baum, Bryan. Validation of the community radiative transfer model. Journal of Quantitative Spectroscopy and Radiative Transfer v.112, no.2011, pp1050-1064.

Foster, Michael J.; Bennartz, Ralf, and Heidinger, Andrew. Estimation of liquid cloud properties that conserve total-scene reflectance using satellite measurements. Journal of Applied Meteorology and Climatology v.50, no.1, 2011, pp96-109.

Goldberg, M.; Ohring, G.; Butler, J.; Cao, C.; Datla, R.; Doelling, D.; Gartner, V.; Hewison, T.; Iacovazzi, B.; Kim, D.; Kurino, T.; Lafeuille, J.; Minnis, P.; Renaut, D.; Schmetz, J.; Tobin, D.; Wang, L.; Weng, F.; Wu, X.; Yu, F.; Zhang, P., and Zhu, T. The global space-based inter-calibration system. Bulletin of the American Meteorological Society v.92, no.4, 2011, pp469-475.

Hiley, Michael J.; Kulie, Mark S., and Bennartz, Ralf. Uncertainty analysis for CloudSat snowfall retrievals. Journal of Applied Meteorology and Climatology v.50, no.1, 2011, pp399-418.

Huang, Bormin; Mielikainen, Jarno; Oh, Hyunjong, and Huang, Hung-Lung Allen. Development of a GPU-based high-performance radiative transfer model for the Infrared Atmospheric Sounding Interferometer (IASI). Journal of Computational Physics v.230, no.6, 2011, pp2207-2221.

Lewis, John M.; Kaplan, Michael L.; Vellore, Ramech; Robin, Robert M.; Hallett, John, and Cohn, Stephe A. Dust storm over the Black Rock Desert: Larger-scale dynamic signatures. Journal of Geophysical Research v.116, no.2011, ppdoi:10.1029/2010JC014784.

Li, Jun; Li, Jinlong; Otkin, Jason; Schmit, Timothy J., and Liu, Chian-Yi. Warning information in a preconvection environment from the geostationary advanced infrared sounding system - a simulation study using the IHOP case.

Journal of Applied Meteorology and Climatology v.50, no.3, 2011, pp776-783.

Li, Jun; Li, Zhenglong; Jin, Xin; Schmit, Timothy J.; Zhou, Lihang, and Goldberg, Mitchell D. Land surface emissivity from high temporal resolution geostationary infrared imager radiances: Methodology and simulation studies. Journal of Geophysical Research v.116, no.2011, ppdoi:10.1029/2010JD014637.

Nasiri, Shaima Dang H. Van T.; Kauh, Brian H.; Fetzer, Eric J.; Manning, Evan M.; Schreier, Mathias M., and Frey, Richard A. Comparing MODIS and AIRS infrared-based cloud retrievals. Journal of Applied Meteorology and Climatology v.50, no.5, 2011, pp1057-1073.

Pandya, Rajul; Smith, David; Ackerman, Steven A.; Brahma, Priti P.; Charlevoix, Donna J.; Foster, Susan Q.; Gaertner, Karl Volker; Lee, Thomas F.; Hayes, Marianne J.; Mostek, Anthony; Murillo, Shirley T.; Murphy, Kathleen A.; Olsen, Lola; Stanitski, Diane M., and Whittaker, Thomas. A summary of the 18th AMS Symposium on Education. Bulletin of the American Meteorological Society v.92, no.1, 2011, pp61-64.

Sieglaff, Justin M.; Cronce, Lee M.; Feltz, Wayne F.; Bedka, Kristopher M.; Pavolonis, Michael J., and Heidinger, Andrew K. Nowcasting convective storm initiation using satellite-based box-averaged cloud-top cooling and cloud-type trends. Journal of Applied Meteorology and Climatology v.50, no.1, 2011, pp110-126.

Wimmers, Anthony J. and Velden, Christopher S. Seamless advective blending of total precipitable water retrievals from polar-orbiting satellites. Journal of Applied Meteorology and Climatology v.50, no.5, 2011, pp1024-1036.

Xie, Yu; Yang, Ping; Kattawar, George W.; Baum, Bryan A., and Hu, Yongxiang. Simulation of the optical properties of plate aggregates for application to the remote sensing of cirrus clouds. Applied Optics v.50, no.8, 2011, pp1065-1081.

Zhou, Daniel K.; Larar, Allen M.; Liu, Xu; Smith, William L.; Strow, L. Larrabee; Yang, Ping; Schlussel, Peter, and Calbet, Xavier. Global land surface emissivity retrieved from satellite ultraspectral IR measurements. IEEE Transactions on Geoscience and Remote Sensing v.49, no.4, 2011, pp1277-1290.

2010

Baum, Bryan A.; Yang, Ping; Hu, Yong-Ziang, and Feng, Qian. The impact of ice particle roughness on the scattering phase matrix. Journal of Quantitative Spectroscopy and Radiative Transfer v.111, no.17-18, 2010, pp2534-2549.

Bedka, Kristopher; Brunner, Jason; Dworak, Richard; Feltz, Wayne; Otkin, Jason, and Greenwald, Thomas. Objective satellite-based detection of overshooting tops using infrared window channel brightness temperature gradients. Journal of Applied Meteorology and Climatology v.49, no.2, 2010, pp181-202.

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

Bennartz, Ralf; Watts, Philip; Meirink, Jan Fokke, and Roebeling, Rob. Rainwater path in warm clouds derived from combined visible/near-infrared and microwave satellite observations. Journal of Geophysical Research v.115, no.2010, ppdoi:10.1029/2009JD013679.

Bi, Li; Jung, James A.; Morgan, Michael C., and Le Marshall, John G. A two-season impact study of the WindSat surface wind retrievals in the NCEP global data assimilation system. Weather and Forecasting v.25, no.3, 2010, pp931-949.

Cernak, Jan; Wild, Martin; Knutti, Reto; Mishchenko, Michael I., and Heidinger, Andrew K. Consistency of global satellite-derived aerosol and cloud data sets with recent brightening observations. Geophysical Research Letters v.37, no.2010, ppdoi:1029-2010GL044632.

Corfidi, Stephen F.; Weiss, Steven J.; Kain, Joh S.; Corfidi, Sarah J.; Rabin, Robert M., and Levit, Jason J. Revisiting the 3-4 April 1974 Super Outbreak of Tornadoes. Weather and Forecasting v.25, no.2, 2010, pp465-510.

Delamere, j. S.; Clough, S. A.; Payne, V. H.; Mlawer, E. J.; Turner, D. D., and Gamache, R. R. A far-infrared radiative closure study in the Arctic: Application to water vapor. Journal of Geophysical Research v.115, no.D17, 2010, ppdoi:10.1029/2009JD12968.

Dupont, R.; Pierce, B.; Worden, J.; Hair, J.; Fenn, M.; Hamer, P.; Natarajan, M.; Schaack, T.; Lenzen, A.; Apei, E.; Dibb, J.; Diskin, G.; Huey, G.; Weinheimer, A., and Knapp D. Reconstructing ozone chemistry from Asian wild fires using models, satellite and aircraft measurements during the ARCTAS campaign. Atmospheric Chemistry and Physics Discussions v.10, no.11, 2010, pp26751-26812.

Ebell, Kerstin; Lohnert, Ulrich; Crewell, Susanne, and Turner, David D. On characterizing the error in a remotely sensed liquid water content profile. Atmospheric Research v.98, no.1, 2010, pp57-68.

Felker, S. R.; Moody, J. L.; Wimmers, A. J.; Osterman, G., and Bowman, K. A Multi-sensor Upper Tropospheric Ozone Product (MUTOP) based on TES ozone and GOES water vapor: Derivation. Atmospheric Chemistry and Physics Discussions v.10, no.12, 2010, pp30055-30087.

Foster, M. J.; Ackerman, S. A.; Heidinger, A. K., and Maddux, B. C. State of the climate in 2009: Global cloudiness . Bulletin of the American Meteorological Society v.91, no.7, supplement, 2010, ppS34-S35.

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