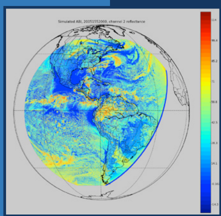

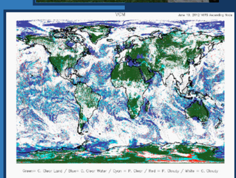

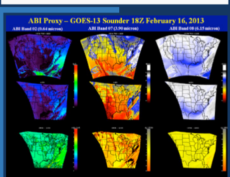

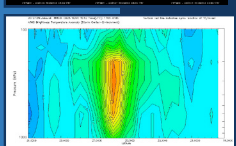

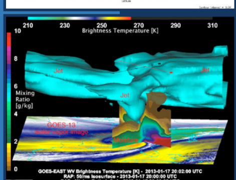

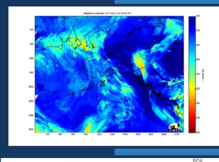

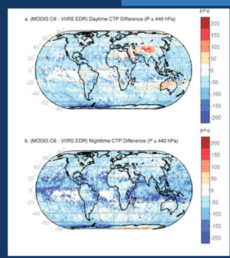

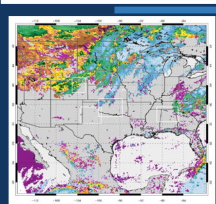

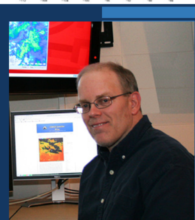

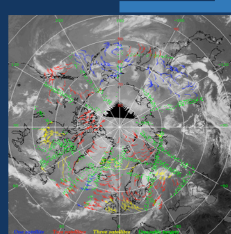

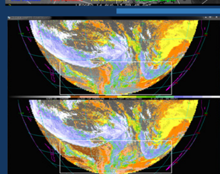

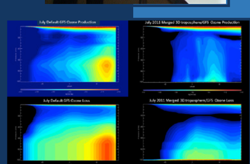

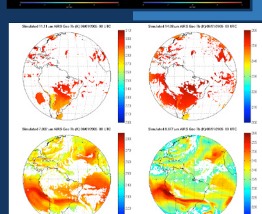

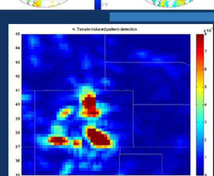

CIMSS

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

CIMSS Five-Year Review: 2013 Report

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

Meeting our Mission's Goals

...collaborating with NOAA,

...serving as a center of excellence in weather and climate studies,

...training the scientists and engineers of today and tomorrow...

18 September 2013

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1. CIMSS Overview

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin–Madison (UW–Madison) was established between NOAA/NESDIS and the University in 1980 to foster collaborative research in atmospheric and earth system science using satellite technology. A group of NOAA/NESDIS employees has been collocated at UW–Madison since 1977. The primary purpose of establishing the Institute was to create a mechanism to bring together the resources of a research-oriented university with NESDIS and other line offices of NOAA to develop a center of expertise in research related to satellite meteorology. Collocation with a major university research center provides access to outstanding university researchers and visiting scientists from throughout the world and promotes the sharing of state-of-the-art equipment and satellite facilities. Pooling these resources provides a multidisciplinary setting for addressing the complex research vital to the mission of NOAA and the Department of Commerce. Because of the scope and complexity of the atmospheric sciences, the need for collaborative research with a research university is substantial and enduring. CIMSS brings a formalized focus to a number of research programs that couple opportunities for collaborative investigations.

CIMSS underwent a 5-year review in 2004 and was re-competed in 2009. It was selected in 2010 to 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 research investigations increase our understanding of remote sensing and its application to weather and near-casting, clouds and radiation, the global hydrological cycle, environmental trends, and climate. CIMSS scientists are engaged in a broad array of research activities ranging from using real-time Geostationary Operational Environmental Satellite (GOES) observations to derive atmospheric stability indices in support of severe weather forecasting to designing analysis methods for the next generation GOES instrument. These diverse research activities may appear independent of one another, yet each project is integral to the process that enables CIMSS to achieve its goals. Our research process is represented in Figure 1. Analysis methods, or algorithms, are developed and applied to remote sensing *data* to yield *information* about our Earth system. We apply this information to gain *knowledge* about the Earth system, knowledge that can be utilized in decision-making processes. As we rely on this knowledge to take *action,* we close our process loop by realizing the need for better observations, and work with our partners, particularly the scientists and engineers of the UW-Madison Space Science and Engineering Center (SSEC), in designing and testing improved instrumentation. At the center of this research process is education and training: of students, ourselves, and the outside community of users. Before addressing the review panel questions, it is useful to provide an overview of how these activities are linked to create an ongoing, successful research program.

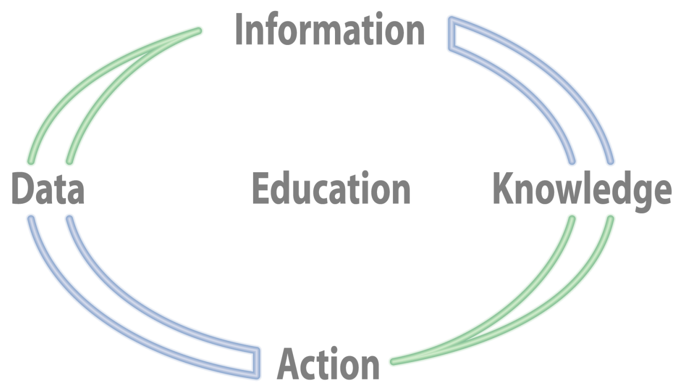


Figure 1. This schematic loop provides a framework to view the wide variety of activities conducted at CIMSS that engage researchers and students in a broad array of research and education endeavors.

A large variety of data are collected and organized for research studies at the UW–Madison. These data include a broad array of observations from geostationary and low-earth orbiting satellites to ground-based measurements from a mobile laboratory and the rooftop of our building. To achieve its goals, CIMSS uses observations from NOAA's operational satellites and data collected from ground-based and aircraft platforms through participation in a variety of field programs. We have developed algorithms that transform these observations into information about the Earth's atmosphere and its underlying surface. As an example, CIMSS has pioneered the estimation of tropospheric winds by tracking cloud and moisture features from sequences of satellite images. These satellite-derived winds are now a stable operational product and are assimilated into weather prediction models. CIMSS also leads the way in developing atmospheric sounding algorithms using observations from both geostationary and polar satellites. Global cloud properties are derived from a variety of instruments, and climate data records from 30+ years of polar orbiting satellites are being produced. New algorithms are continually being developed to generate new and improved products that contain information about the environment. Many research projects originating in CIMSS have led to computationally efficient algorithms utilized operationally by NOAA.

Coupling these observations with scientific hypotheses about how the atmosphere works leads to new knowledge about the atmosphere. We support and develop hypotheses with theoretical analysis and tools such as model simulations. By interpreting observations within this theoretical framework the information contained in observations becomes knowledge about how the Earth system behaves. A side-by-side examination of observations and model simulations establishes differences and similarities that lead to a better understanding of how physical processes are represented in weather models, and which processes are important in the maintenance of circulation patterns.

With a better understanding of the processes that govern the environment, focused research studies help to identify needed observations that further advance our understanding of the complex interactions that drive our weather and climate. Sometimes these observations are obtained by combining measurements from different instruments. With this approach we can mitigate the weaknesses of one measurement system with the strengths of another. Often new measurements are required and new instruments developed that provide unique data sets providing further information about our world and ultimately enabling improved predictions.

Throughout its 33-year history, CIMSS scientists have worked to develop methods of collecting and transforming data into knowledge about the atmosphere. We have achieved our goals through partnerships with NOAA, NASA, ONR, NSF, the UW-Madison Space Science and Engineering Center (SSEC), and the UW-Madison Department of Atmospheric and Oceanic Sciences (AOS). The research environment at CIMSS has proven to be effective in developing, demonstrating, and implementing data processing techniques for operational and research remote sensing instruments. CIMSS is housed in the same building as SSEC and AOS. The relationship between CIMSS, SSEC, and AOS can be viewed as a Venn diagram (Figure 2). CIMSS is an institute within SSEC, which is an interdisciplinary research center within the UW–Madison Graduate School. SSEC has demonstrated expertise in hardware and software system development for unique applications of satellite data. SSEC continues to be active in developing advanced meteorological instrumentation, most recently participating in the design of the NASA Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission.

AOS is an academic department within the UW-Madison College of Letters and Sciences. Thus, SSEC/CIMSS and AOS are administered by different entities within the UW–Madison. AOS consists of 13 faculty and approximately 70 graduate students and 40 undergraduate majors. The department provides excellent education and research programs, with research by the faculty covering a broad range of atmospheric and oceanic topics. The department is particularly strong in the areas of climate dynamics and satellite remote sensing. AOS faculty serve as academic advisors to 16 graduate students supported by CIMSS Principal Investigator (PI) grants. AOS faculty also collaborate with CIMSS PIs.

Eight NESDIS scientists are located at CIMSS, including seven with the Advanced Satellite Products Branch (ASPB) and one with the National Climate Data Center (NCDC). One employee with the National Severe Storms Laboratory (NSSL) also visits frequently. All NESDIS scientists work closely with CIMSS PIs, and can also advise students and serve as adjunct professors in AOS. This collaboration between CIMSS and ASPB meets NOAA's interest in partnering with academic institutions to explore new concepts and applications through robust weather and water research. CIMSS provides NOAA with a strong link to the university research environment. The NOAA ASPB located at CIMSS provides continuous communication of issues important to NOAA. This association enables CIMSS to provide input into the NOAA research planning process and for CIMSS to quickly react to NOAA's changing needs.

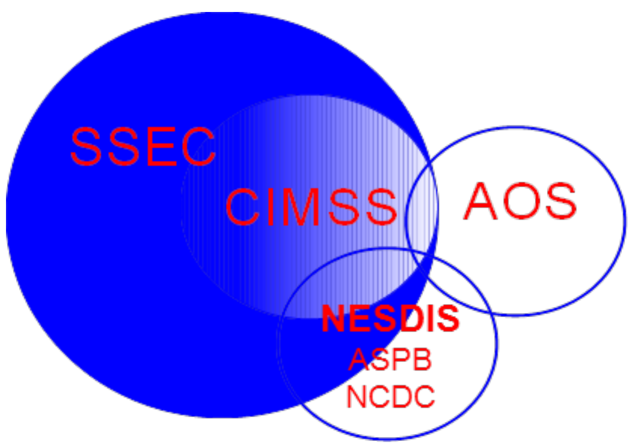


Figure 2. This Venn diagram is one way to represent the relationship between CIMSS, SSEC and AOS. CIMSS is a research institute within SSEC, which is part of the UW–Madison Graduate School. While some activities within CIMSS and SSEC are distinct, there are many collaborations, indicated in the blending between the CIMSS and SSEC circles. AOS is a department within the College of Letters and Sciences; thus CIMSS and AOS are administered by separate entities within the UW–Madison. Students provide the strong link between CIMSS and AOS, with AOS faculty serving as teachers, research advisors, and collaborators. NESDIS scientists collaborate with others in the building and advise students.

2. Strategic Plan

A. What is the scientific vision of the Institute?

CIMSS is part of SSEC. The SSEC scientific vision states, "… SSEC will strive to advance our technical excellence in the areas of:

- **Observational Science** (instrumentation, spacecraft system/mission design, field programs, and space flight instrument fabrication);
- **Analytical Science** (satellite and conventional data analysis, technique development, and modeling);
- **Computational and Visualization Science** (hardware and software systems for information generation, data management, and communication);
- **Campus Science Support** (Physics, Astronomy, Botany, Geology); and
- **Education and Public Outreach** (UW-Madison undergraduate and graduate programs, K–12 collaborations, science engagement with the general public)."

The SSEC/CIMSS scientific vision was developed as part of its Strategic Plan. The SSEC and CIMSS Directors and the CIMSS Executive Director were key authors of the SSEC Strategic Plan, with input requested from all SSEC staff. The SSEC Strategic Plan follows the themes of the UW–Madison Strategic Plan in promoting research and learning, building collaborations, locally to internationally, and supporting professional growth.

The CIMSS scientific vision is to conduct interdisciplinary research in the atmospheric sciences, focusing on using satellite observations and mathematical models to better understand the behavior of the Earth system. Referring to Figure 1 above, the continuous loop of CIMSS research activities is an excellent representation of how our science fulfills the SSEC/CIMSS vision statement. The CIMSS analytical, computational, and visualization science activities provide the means to flow from *data* acquisition through *information* processing to *knowledge* and discovery and finally to *action*.

To meet this scientific vision, CIMSS' mission is to develop, advance, and promote satellite meteorology. This is achieved through activities that:

- Support NOAA's global leadership role towards advancing environmental satellite applications;
- Promote and advance the use of satellite data in weather analysis and forecasting;
- Effectively exploit satellite observations in response to the challenges posed by climate change; and
- Develop a workforce knowledgeable in satellite meteorology and remote sensing.

The pathway to success is for CIMSS to:

- Foster collaborative research among NOAA, other federal agencies and the University in those aspects of atmospheric and earth system science that exploit the use of environmental satellite technology;
- Serve as a center at which atmospheric scientists and instrument/sensor engineers can work together on problems of mutual interest to focus on satellite-related research in atmospheric and earth system science; and
- Stimulate the training of scientists and engineers in the disciplines involved with remote sensing of the atmosphere.

The outcomes we desire are achieved through various activities and directions discussed throughout this report. Many of these activities are collaborative efforts with NOAA partners, particularly NESDIS' ASPB and NCDC.

B. How is the CIMSS mission related to the NOAA Strategic Plan?

The NOAA strategic plan contains four goals: Climate Adaptation and Mitigation, Weather-Ready Nation, Healthy Oceans, and Resilient Coastal Communities and Economies. Each goal has objectives as well as measures of success. (see: http://www.ppi.noaa.gov/goals/)

The NOAA strategic goals of Climate Adaptation and Mitigation and Weather-Ready Nation align with the research and education activities of CIMSS. Using satellite, aircraft, and surface-based observations of the atmosphere, water and land, CIMSS develops and applies algorithms to the observations, transforming them into information and knowledge, activities that are closely aligned with NOAA's Strategies in Weather and Climate. CIMSS research directly contributes to NOAA Performance Objectives for these Goals. For example, in support of the climate strategic goal, the 30+ year record of NOAA HIRS-derived global cloud cover and the 30+ year record of Pathfinder Atmospheres Extended (PATMOS-x) Advanced Very High Resolution (AVHRR) are unique data sets that provide important satellite-based climate studies. The PATMOS-x is a NOAA/NESDIS climate dataset generated in partnership with CIMSS. Designed initially for the AVHRR, PATMOS-x has been modified to generate products from the MODerate-resolution Imaging Spectroradiometer (MODIS), GOES and the Visible/Infrared Imager and Radiometer Suite (VIIRS) sensor. High-resolution Infrared Radiation Sounder (HIRS) data from NOAA-6 onwards have been re-processed using the original HIRS algorithm software with adjustments suggested by MODIS experience and spectral shifts suggested using the HIRS on the Meteorological Operational satellite (MetOp) as a reference. UW-Madison scientists delivered to NCDC software for converting HIRS Level 1b and higher level data files to NetCDF-4 along with the HIRS cloud algorithm software. A project that combines the advantages of the AVHRR product with the HIRS sounding capability is underway.

CIMSS scientists are actively involved in collaborative partnerships with NOAA to expand these satellite-based climate data records, as well as develop the next generation of records derived from EOS, Suomi National Polar-orbiting Partnership (NPP) and the future Joint Polar Satellite System (JPSS) missions. These activities fully support NOAA's climate-related objectives of "Improved scientific understanding of the changing climate system and its impacts" and "Assessments of current and future states of the climate system."

CIMSS as an institute is also involved in education and outreach efforts that address the NOAA objective "A climate-literate public that understands its vulnerabilities to a changing climate and makes informed decisions." The Climate Ambassador program of CIMSS directly addresses this objective through various training activities. CIMSS and AOS recently collaborated with the Madison Area Technical College (MATC) to develop an on-line course on climate change. This course has been completed and offered for a few semesters at MATC and will be offered through UW-Madison in the spring of 2014.

The NOAA Weather-Ready Nation Goal seeks to improve the accuracy of weather forecasts, and CIMSS scientists are actively engaged in helping to achieve this goal. For example, improvements in hurricane forecast accuracy are being tested through advancements in the assimilation of enhanced satellite datasets into numerical models. CIMSS researchers have developed the real time Satellite Data Assimilation for sTorm forecasts (SDAT) system (http://cimss.ssec.wisc.edu/sdat), which uses the Weather Research and Forecasting (WRF) model and the community Gridpoint Statistical Interpolation (GSI) data assimilation system, and is able to assimilate both GOES-R proxy products and JPSS sounder data (Cross-track Infrared/Microwave Sounding Suite (CrIMSS) soundings or radiances). SDAT has been used in experiments seeking to improve Hurricane Sandy forecasts using the NOAA/NESDIS/STAR S4 supercomputer located at SSEC. Results have shown that assimilating MODIS observations as a proxy for GOES-R moisture information and NPP CrIMSS sounding products produced more accurate track and intensity forecasts than the operational models (Global Forecast System (GFS) and Hurricane WRF (HWRF)).

The CIMSS NearCasting research effort has the overall objective of providing data driven tools to help National Weather Service (NWS) forecasters expand their use of GOES moisture and temperature soundings by 1) enhancing and expanding existing observations using clear-air variables that GOES observes and 2) adding new products to forecast the near-future state (0-6 hr) of the pre-storm environment. The NearCast model (http://cimss.ssec.wisc.edu/model/nrc/) is used to enhance the impact of the satellite products in short-range forecasts and to provide forecasters a more complete picture of the total atmospheric moisture and convective available potential energy observed by GOES in clear skies and its adiabatic transport into areas of interest. The basic version of the NearCasting system has been successfully tested at the Storm Prediction Center (SPC), Aviation Weather Center (AWC), and the European Severe Storms Laboratory (ESSL) (using Spinning Environmental Visible and InfraRed Instrument (SEVIRI) data as a surrogate for the GOES-R Advanced Baseline Imager (ABI)), and will be tested at the Weather Prediction Center (WPC) and Ocean Prediction Center (OPC) in 2014. Other good examples related to supporting NOAA's weather-ready nation objectives are: direct broadcast packages (International ATOVS Processing Package (IAPP)/International MODIS/AIRS Processing Package (IMAPP)/Community Satellite Processing Package (CSPP)) for real-time satellite products, GOES real-time research products (http://cimss.ssec.wisc.edu/goes/rt/) that are also made available in the Advanced Weather Interactive Processing System (AWIPS-2), and real-time tropical cyclone products via the CIMSS Web page (http://tropic.ssec.wisc.edu/).

The NOAA Strategic objective "Improved transportation efficiency and safety," under the Weather-Ready Nation Goal, contain elements of the CIMSS research objectives. CIMSS collaboration with NOAA on satellite-based detection of fog provides important information for the transportation industry, both for highway and for waterway transportation. CIMSS is also conducting research on hazardous weather to aviation, including fog, turbulence and volcanic ash. For example, the volcanic ash research at CIMSS/ASPB encompasses multiple projects supporting multiple sensors. Originally the volcanic ash research group was assembled to support the GOES-R Algorithm Working Group (AWG) volcanic ash requirement of retrieving the volcanic ash cloud-top height and column mass loading (algorithms that have been completed and delivered to the program office). The JPSS Risk Reduction program recently denoted volcanic ash detection and physical retrievals as a missing component of the VIIRS product suite and therefore funded the CIMSS/ASPB group to modify the GOES-R volcanic ash detection and retrieval algorithms for use with VIIRS data. Figure 3 provides an example of an automated alert report and imagery generated for the eruption of the Popocatepetl volcano in Mexico on 17 June 2013 that was distributed on the Web and automatically sent to users (e.g., volcanic ash alert center forecasters).

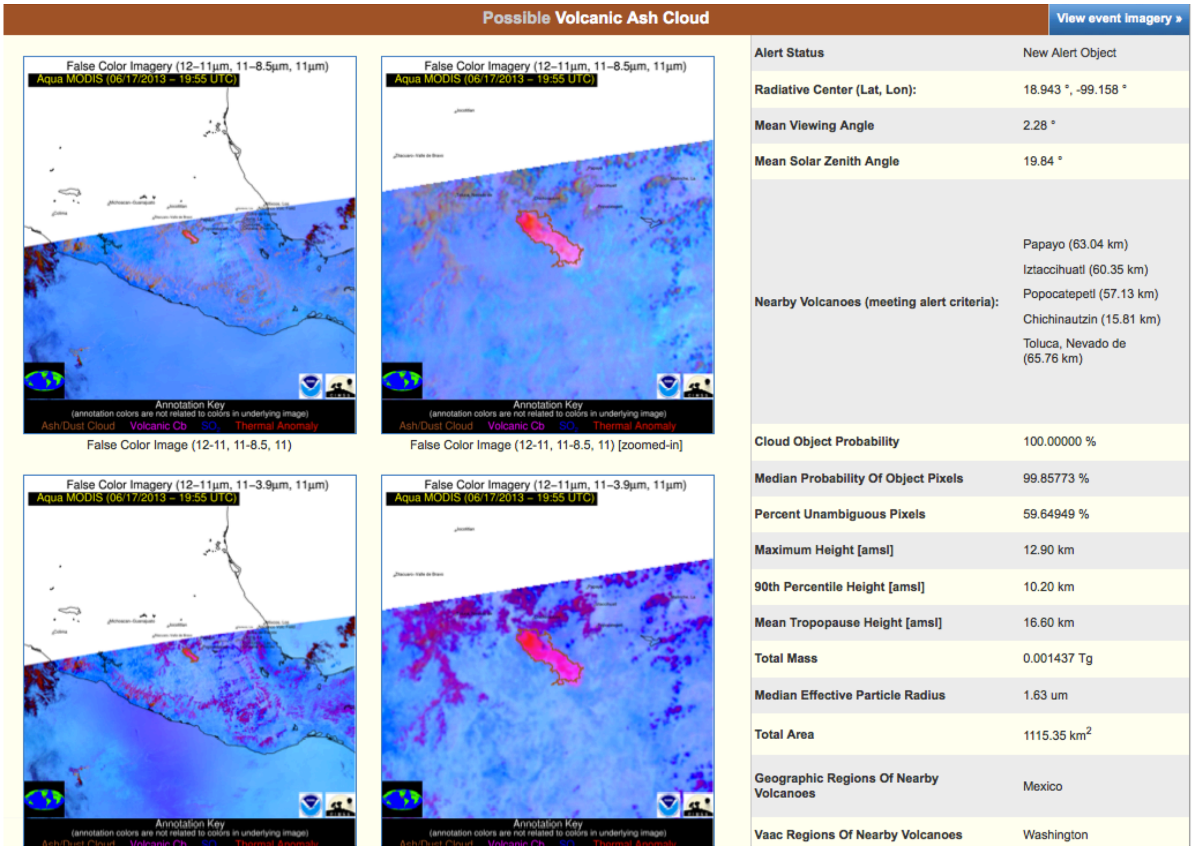


Figure 3. Example of an automatically generated volcanic ash cloud alert and associated imagery. A user will receive notification of the alert, including a link to the above URL. This example is an ash cloud from the Popocatepetl volcano near Mexico City, Mexico on 17 June 2013. This ash cloud has a spectral signature consistent with volcanic ash and is the pink/magenta region bounded by a brown outline. The satellite observations are from MODIS Aqua, which has spectral channels similar to GOES-R ABI. On the left are preview images that can be clicked for full-resolution imagery and on the right is alert information (e.g., ash cloud height, total column mass, Volcanic Ash Advisory Center responsibility, etc.). (Figure provided by M. Pavolonis)

CIMSS has been heavily involved in GOES calibration as well as product generation since its inception. The effort and expertise developed at CIMSS on current GOES has been extended to include the GOES-R ABI. Over half of the NOAA operational ABI product algorithms are being developed at CIMSS.

Working closely with ASPB, CIMSS scientists assist in the check-out of GOES instruments. Three recent examples are:

- CIMSS/ASPB played many roles in the check-out and assessments of the GOES-13, -14 and -15 imagers and sounders. For example, CIMSS/ASPB was actively involved in addressing an anomaly in GOES-13 that started at 03:40 UTC on 22 May 2013, and ending at 04:29 UTC. This effort spanned the time before, during and after the outage and included image analysis, interfacing with the Office of Satellite and Product Operations (OSPO), comparing observations versus calculations, the impact on satellite derived products (especially the sounder products) and display within AWIPS. Figure 4 shows successive images from just before the anomaly at nominal times of 03:15 UTC and 03:32 UTC. There is a large navigation offset (~200 km) apparent at 03:32 UTC, the last scanned image from GOES-13 before the major anomaly.

- On December 6, 2011, GOES-15 began operational use as GOES-West, replacing GOES-11. Before this change occurred, CIMSS provided OSPO updated versions of operational software packages for clear sky brightness temperature, imager and sounder cloud products, temperature/moisture retrievals, and atmospheric motion vector algorithms. CIMSS was a key contributor to the NOAA science technical report for GOES-15, providing figures and analysis to the report on noise analysis, image generation, and product validation.
- As requested by OSPO, CIMSS provided coverage examples of the Atlantic region from GOES-15/14/13/12 and SEVIRI. In addition, CIMSS/ASPB worked with the NWS to determine if GOES-12 could augment coverage over Puerto Rico. With the temporary loss of GOES-13 *(GOES-East)*, the GOES-15 *(GOES-West)* satellite has been placed into Full Disk scan mode, which only provides imagery over CONUS every 30 minutes. Much of this was also posted on the CIMSS satellite blog, with data provided via the SSEC Data Center.

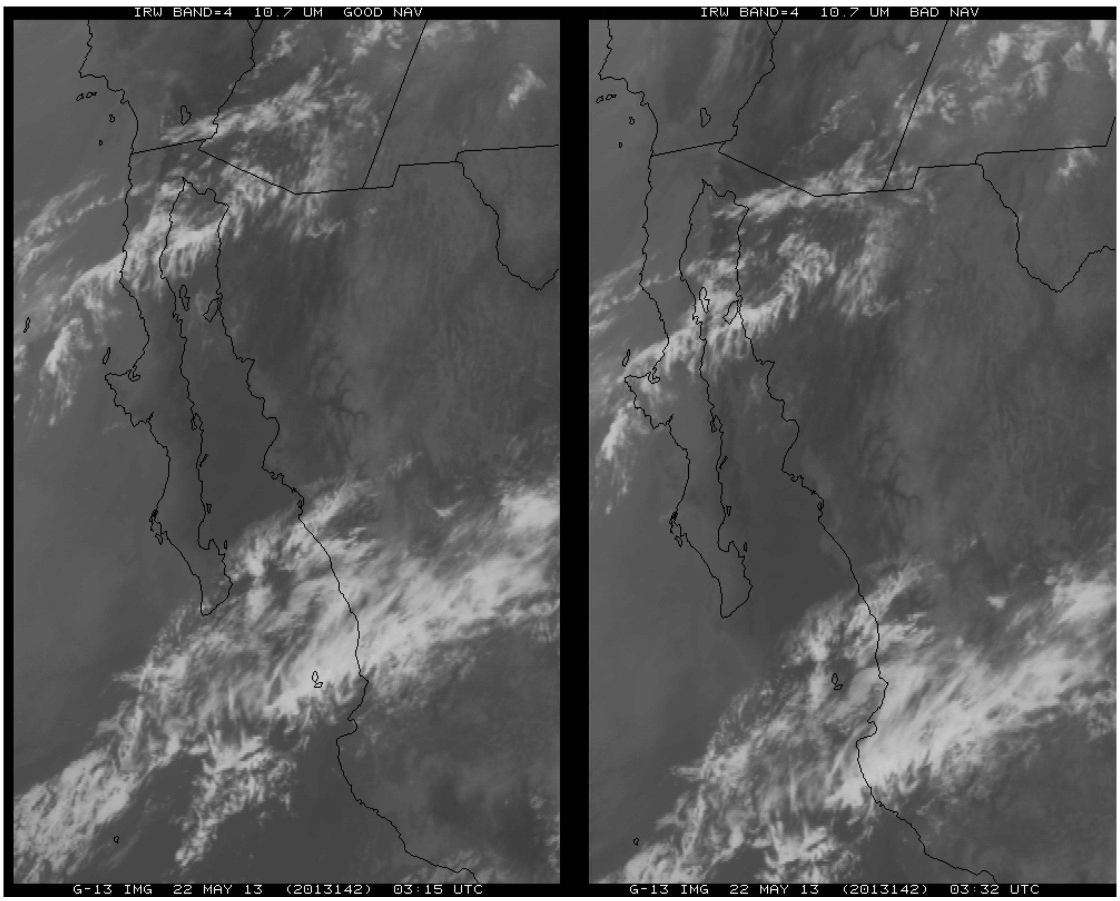


Figure 4. Last GOES-13 10.7 µm images before outage on May 22, 2013. (Figure provided by S. Bachmeier)

Another NOAA goal is the "Delivery of critical high-performance computing capabilities for evolving environmental modeling requirements." In support of NOAA modeling efforts, the S4 super computer system was installed at UW-Madison to assist research efforts to enhance existing data assimilation techniques with the goal of improving the U.S operational forecast models. CIMSS scientists routinely collaborate with NOAA and JCSDA scientists to exchange ideas and gain knowledge on porting the operational software to S4, running benchmark tests to assess the consistency of model output, and demonstrating that the S4 system can be used as an experimental surrogate for the National Centers for

Environmental Prediction (NCEP) operational system. For example, to support hurricane modeling and assimilation studies, the 2012 version of the operational HWRF model was obtained from the Developmental Testbed Center and ported to S4 with the help of CIMSS.

C. What are the goals of CIMSS?

The CIMSS mission, as stated in the Memorandum of Agreement (See Appendix A) and the Cooperative Agreement, consists of three goals:

- To foster collaborative research among NOAA, other federal agencies, and the University in those aspects of atmospheric and earth system science that exploit the use of satellite technology.
- To serve as a center at which scientists and engineers working on problems of mutual interest can focus on satellite-related research in atmospheric and earth system science.
- To stimulate the training of scientists and engineers in the disciplines involved in atmospheric and earth sciences.

To achieve these mission goals CIMSS works closely with the ASPB to maintain research collaborations with NESDIS and foster new collaborations with NOAA. We encourage and nurture leadership among staff, enabling scientists to fulfill their full potential by providing infrastructure for their development and one-on-one guidance in such activities as proposal preparation and writing journal articles. We host and support visiting scientists, as well as work with AOS in student recruitment. We host national and international workshops in research areas where we excel. For example, since 2010 CIMSS has hosted about 40 workshops and meetings (Appendix L).

With regard to training of scientists, in addition to working with graduate and undergraduate students at UW–Madison and at other institutions, we have participated in many education workshops, including those on satellite remote sensing in Italy for the EUropean organization for the exploitation of METeorological SATellites (EUMETSAT). We have held satellite infrared and microwave remote sensing 'bootcamps' for the GOES-R satellite liaisons. We have also conducted on-line professional training sessions for NWS forecasters on satellite meteorology through the VISITView (Virtual Institute for Satellite Integration Training) and Satellite Hydrology and Meteorology Course (SHyMet) programs and have a strong relationship with our local NWS office at Sullivan, WI.

D. What criteria are used internally to measure progress in accomplishing the CIMSS mission?

Traditional methods that measure success in a research center are proposal submission success and publications in refereed journals. These metrics are discussed in the CIMSS yearly staff evaluations, as well as other measures of success such as conference presentations, seminars, public service (outreach), scientific breakthroughs, transition of successful research to NOAA operations, student degrees with AOS, and scientific recognition awards.

The CIMSS mission statements, identified above, are used as one framework to measure CIMSS' progress in reaching its goals. The success of our goal of "fostering collaboration research" between CIMSS and its MOA partners, can be judged by noting the number of research algorithms developed at CIMSS that have been transferred to NOAA for use in its operational mission. The NOAA OSPO manages and directs the operation of the central ground facilities which ingest, process, and distribute environmental satellite data and derived products to domestic and foreign users. Their data products page (e.g., http://www.ospo.noaa.gov/Products/atmosphere/index.html) lists several products in which CIMSS was involved, often with our ASPB colleagues, and include sounder cloud top pressure, Automated Biomass Burning Algorithm (ABBA), GOES Total Ozone, sounding products, and the Clouds from

AVHRR Extended (CLAVR-x). A major goal of the CIMSS partnership with NOAA is to develop techniques and algorithms that apply satellite observations to produce geophysical information to support the NOAA operational mission. One way to achieve that goal is to routinely produce data sets from satellites from our algorithms and to test them in a real-time mode. To this end, CIMSS maintains GOES real-time products on the Web, which can be found at http://cimss.ssec.wisc.edu/goes/rt/.

The CIMSS vision extends to its strong partnership with NOAA in future satellite initiatives. One good example is the GOES-R program. CIMSS and NESDIS scientists work together in teams on many GOES-R activities. These include the GOES-R Proving Ground, the Algorithm Integration Team (AIT), the GOES-R Analysis Facility Instrument for Impacts on Requirements (GRAFIIR) team, and the AWG for Soundings, Winds, Clouds, Aviation, and Imagery/Visualization. CIMSS helps to derive proxy ABI datasets for testing and evaluating AWG team algorithms, supplying data in response to instrument waivers put forth by the GOES-R instrument vendors, and providing data to help train operational weather forecasters on the coming capabilities of ABI observations. CIMSS also assists NOAA in their response to proposed changes in ABI instrument specifications by assessing the potential impacts of the ABI waiver request on product performance and accuracy. The primary diagnostic tool, called Glance, has been provided to the AWG's AIT. The GRAFIIR team continues to consult with the Integrated Modeling Working Group (IMWG) on behalf of the AWG. **Table 1** lists the GOES-R algorithms being developed by the NESDIS/STAR (Center for Satellite Applications and Research) and CIMSS scientific partnership that lay the groundwork for continued collaborations with NOAA.

Helping NOAA offices achieve their objectives is another metric of success. To support national and international collaborators, SSEC/CIMSS developed the CSPP that assists the Direct Broadcast (DB) meteorological and environmental satellite community by packaging and distributing open source science software. CSPP supports DB users of both polar orbiting and geostationary satellite data processing and regional real-time applications through distribution of free open source software, and through training in local product applications. As an example, CIMSS and SSEC leveraged its experience with the CSPP and IMAPP projects, and with operating direct broadcast ground stations, to manage the installation of a satellite data reception system for the National Weather Service in Honolulu, HI to enable real-time acquisition and processing of data from polar orbiting satellites. Satellite imagery from the system is now used routinely in AWIPS by the NWS Forecast Office in Honolulu, HI. For example, during the approach of Hurricane Flossie in July 2013, VIIRS Day/Night Band (DNB) imagery was used by the NWS to alter the forecast track because it allowed the storm center to be better located. The forecast discussion is included below:

> TROPICAL STORM FLOSSIE DISCUSSION NUMBER 19
> NWS CENTRAL PACIFIC HURRICANE CENTER HONOLULU HI EP062013
> 500 AM HST MON JUL 29 2013
> **THE CENTER OF FLOSSIE WAS HIDDEN BY HIGH CLOUDS MOST OF THE NIGHT BEFORE VIRS NIGHTTIME VISUAL SATELLITE IMAGERY REVEALED AN EXPOSED LOW LEVEL CIRCULATION CENTER FARTHER NORTH THAN EXPECTED.** WE RE-BESTED THE 0600 UTC POSITION BASED ON THE VISIBLE DATA. SUBJECTIVE DVORAK ANALYSES CONTINUED SHOW CURRENT INTENSITIES OF 3.0 BUT SATELLITE LOOPS SUGGEST A RAPID WEAKENING TREND WITH THE LOW LEVEL CENTER PULLING AWAY FROM A SMALL AREA OF CONVECTION SOUTHEAST OF THE CENTER. IT IS LIKELY THAT CONTINUED NORTHWEST SHEAR WILL MAINTAIN THIS WEAKENING TREND.
> THE TRACK HAS BEEN SHIFTED NORTH TO REFLECT THE RE-LOCATED CENTER. THE TRACK GUIDANCE SHIFTED FOLLOWING THE TRACK CHANGE AND WAS CONSISTENT WITH A NEW TRACK FARTHER TO THE NORTH. THE TRACK NOW SHOWS FLOSSIE PASSING OVER MAUI TODAY...OVER OAHU TONIGHT...THEN PASSING SOUTH OF KAUAI EARLY TUESDAY MORNING. WE EXPECT FLOSSIE TO WEAKEN STEADILY AS IT TRACKS WEST NORTHWEST AND DISSIPATE WITHIN 96 HOURS.

Table 1. CIMSS research algorithms for future GOES-R Advanced Baseline Imager that are being transitioned into future NOAA operational algorithms and function in unified software input environment developed at CIMSS called the GEOstationary Cloud Algorithm Test-bed (GEOCAT).

NOAA GOES-R ABI Product List

CIMSS/UW-Madison is responsible for 34 products (in Cyan & Yellow)

1 Aerosol Detection (including Smoke & Dust)	4 Probability of Rainfall	3 Surface Albedo
3 Aerosol Particle Size	4 Rainfall Potential	3 Surface Emissivity
1 Suspended Matter / Optical Depth	2 Rainfall Rate / QPE	4 Vegetation Fraction: Green
2 Volcanic Ash: Detection and Height	1 Legacy Vertical Moisture Profile	4 Vegetation Index
4 Aircraft Icing Threat	1 Legacy Vertical Temperature Profile	4 Currents
1 Cloud & Moisture Imagery (KPPs)	2 Derived Stability Indices (5)	4 Currents: Offshore
3 Cloud Layers / Heights & Thickness	1 Total Precipitable Water	4 Sea & Lake Ice: Age
3 Cloud Ice Water Path*	1 Clear Sky Masks	4 Sea & Lake Ice: Concentration
3 Cloud Liquid Water*	3 Absorbed Shortwave Radiation: Surface	4 Sea & Lake Ice: Motion
1 Cloud Optical Depth*	3 Downward Longwave Radiation: Surface	2 Snow Cover
1 Cloud Particle Size Distribution*	2 Downward Solar Insolation: Surface	4 Ice Cover / Landlocked: Hemispheric
1 Cloud Top Phase	2 Reflected Solar Insolation: TOA	4 Snow Depth (Over Plains)
1 Cloud Top Pressure	3 Upward Longwave Radiation: Surface	2 Sea Surface Temps
1 Cloud Top Temperature	3 Upward Longwave Radiation: TOA	
3 Cloud Type	3 Ozone Total	
3 Convective Initiation	3 SO_2 Detection	
4 Enhanced "V" / Overshooting Top Detection	2 Derived Motion Winds	
2 Hurricane Intensity	2 Fire / Hot Spot Characterization	
3 Low Cloud & Fog	4 Flood / Standing Water	
3 Turbulence	2 Land Surface (Skin) Temperature	
4 Visibility		

*Day and Night are separate algorithms

In GEOCAT	Non-CIMSS algorithms in GEOCAT	Near-term plans for GEOCAT
29	1	5

Of the 34 of 56 ABI products (level 1 or 2) at CIMSS,29 of the products are in GEOCAT
As of July/17/2013

The success of CIMSS Mission Statement #2, to serve as a center of excellence on problems of mutual interest in satellite-related research, is demonstrated through CIMSS publications and conference presentations. The CIMSS publication information for the years 1995–2013 is shown in Figure 5; a list of these publications is given in Appendix M.

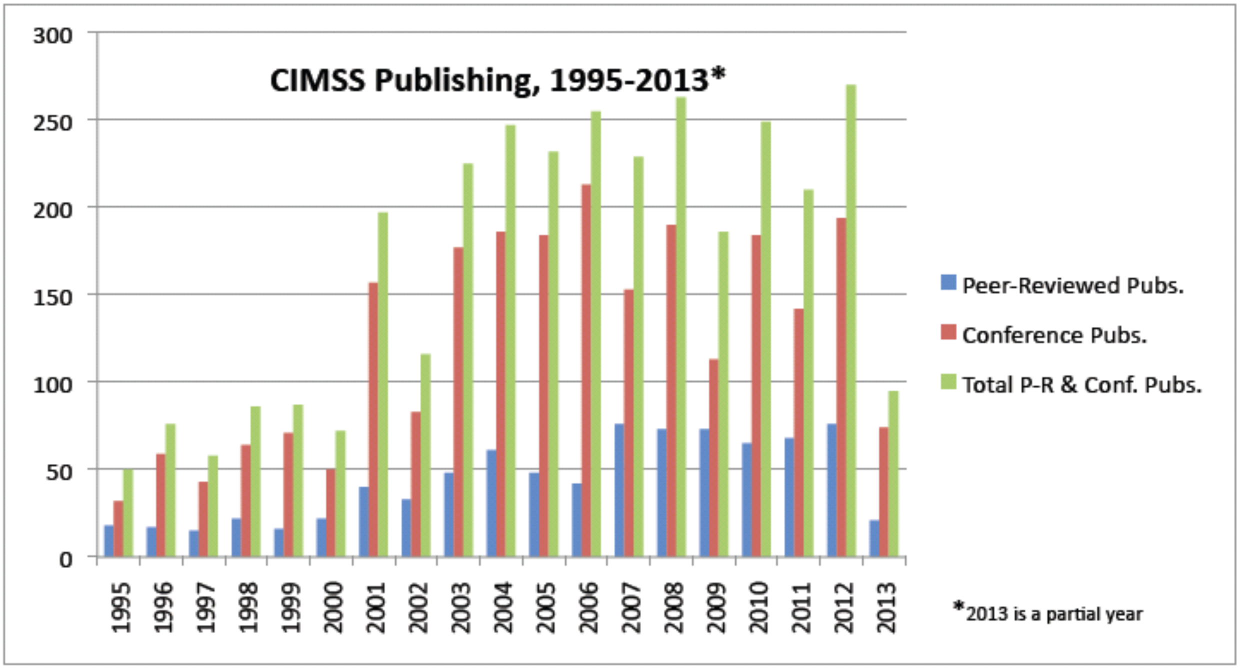


Figure 5. CIMSS annual publication totals for 1995-present. Publishing totals reflect the output of most CIMSS scientists; however, there may be a few whose publications are not represented. Note – information for 2013 is incomplete. (Data provided by J. Phillips)

Approximately 30% of the CIMSS publications are peer-reviewed and of the 254 journal articles published during the period 2010-2013, 43% included a NOAA scientist (ASPB or other NOAA) as co-author, which reflects positively on achieving our first mission goal of collaborating with NOAA.

Another measure of success for CIMSS is the establishment of international collaborations and the recognition of our work in the international community. Figure 6 shows some of the locations where CIMSS has international partnerships and active ongoing collaborations. CIMSS has especially strong ties with research and operational centers in Asia and Europe, and has maintained ongoing scientist exchange programs with several research partners. CIMSS and NOAA fostered the creation and growth of the International TOVS Working Group (ITWG) after the inception of the NOAA series of operational polar orbiting satellites in 1978. This group has grown to include members from dozens of countries, and with strong support from the World Meteorological Organization (WMO) and satellite providers the ITWG continues to be a resource for international collaboration, education and training.

The success of the CIMSS goal to train scientists and engineers can be evaluated by the number of CIMSS students who have obtained degrees, and also by the breadth of the CIMSS visiting scientist program. Figure 7 shows the number of CIMSS graduate students over its history. The significant number of CIMSS graduated students working with and for NOAA, NASA, and also at CIMSS (see Appendix F) demonstrates that the research training students receive at CIMSS while pursuing their degrees prepares them well for weather and climate related careers in government and government-sponsored research.

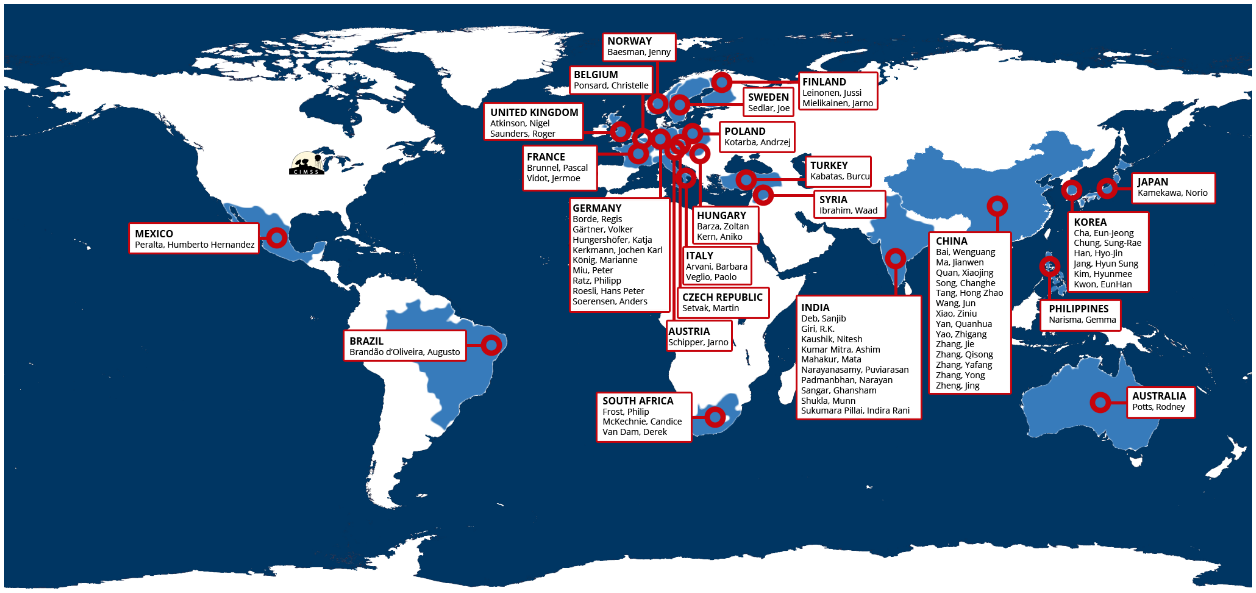


Figure 6. CIMSS has strong ties with research and operational centers in Asia, Australia and Europe and has maintained ongoing scientist exchange programs with most of those research partners. (Figure provided by P. Rowley)

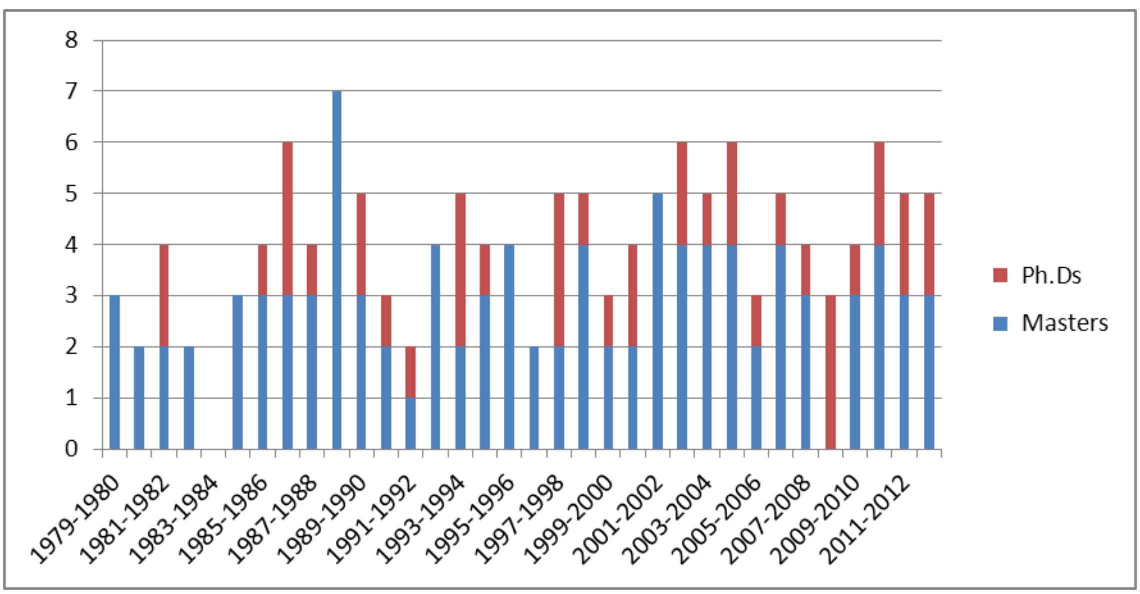


Figure 7. Graduate student research contributes significantly to the goals of individual proposals and grants. CIMSS actively conducts research partnerships with graduate students in AOS.

Another way to meet the goals of education, training and outreach is through participating in professional training focused on meteorological satellites and their applications. The CIMSS GOES-R Proving Ground activities familiarize operational forecasters with novel products and their potential applications. As discussed earlier, CIMSS scientists are working closely with various NWS offices as we approach the launch of GOES-R. The objective is to help forecasters understand the value of these emerging observations prior to their availability. For example, as part of the NOAA Hazardous Weather Testbed (HWT) Spring Experiment, the Center for the Analysis and Prediction of Storms (CAPS) at the University of Oklahoma has produced high-resolution ensemble model forecasts in real-time over the CONUS since 2007. By utilizing national supercomputing resources, sophisticated forward radiative transfer models were used to generate synthetic infrared brightness temperatures at hourly intervals for several ensemble members during the 2012 and 2013 HWT Spring Experiments. Since the ensemble members employed different cloud microphysical and planetary boundary layer (PBL) parameterization schemes, an evaluation of the radiative transfer model and parameterization schemes was also possible. The synthetic satellite imagery was made available to the HWT as part of the CIMSS GOES-R Proving Ground Activities. We also work with our numerical modeling colleagues, such as the Joint Center for Satellite Data Assimilation (JCSDA), to promote and ready them for the coming capabilities of GOES-R. CIMSS scientists also conduct international training activities. For example, CIMSS conducted two China Meteorological Administration (CMA)/WMO international McIDAS training in Beijing in 2011 and 2012 as well as a 10 day remote sensing summer school in Bracciano, Italy for EUMETSAT in the summers of 2011, 2012 and 2013.

E. What are the major CIMSS scientific themes?

The major scientific themes were set forth in the 2009 recompetition for the CIMSS. These themes and some example activities are:

Theme: Satellite Meteorology Research and Applications

- Develop new methods of using GOES to support weather analysis and forecasting through participation in programs like the GOES Improved Measurements and Product Assurance Plan (GIMPAP) and GOES-R Risk Reduction;
- Transition research to NOAA operations through participation in activities such as the Product Systems Development and Implementation (PSDI) and GOES-R AWG;
- Develop climate datasets from geostationary and polar orbiting weather and environmental satellites;
- Develop improved methods of characterizing the atmosphere using satellite observations, in particular, continue advancement of atmospheric profiling, atmospheric motion vectors, tropical cyclone analysis, fire detection, cloud properties, and ozone retrievals;
- Produce new and advanced analysis products by integrating measurements from geostationary and polar satellites with aircraft and ground-based observations to better detect aviation weather hazards; and
- Advance synergistic algorithms for atmospheric and environmental products from multiple sensors from single platforms and multiple platforms.

Theme: Satellite Sensors and Techniques

- Conduct instrument trade studies and sensor performance analysis to support NOAA's future satellite needs;
- Contribute expertise and algorithms to the international efforts to intercalibrate the Global Observing System (GOS) for geostationary and polar orbiting imagers and sounders;
- Participate in post-launch test efforts for the GOES and NPOESS (National Polar-orbiting Operational Environmental Satellite System) Preparatory Project (NPP)/Joint Polar Satellite System (JPSS) series of satellites;
- Further develop software modules (such as the HYperspectral-viewer for Development of Research Applications (HYDRA) and McIDAS-V (Man computer Interactive Data Assimilation System)) that enable visualization, quantitative interrogation, and comparison of remote sensing data and derived products; and

- Continue to maintain and develop direct broadcast processing packages to provide the NWS with products to aid in real time forecast and fire management, air quality monitoring and to support international direct broadcast users.

Theme: Environmental Models and Data Assimilation

- Develop and improve existing data assimilation techniques;
- Develop real time experimental satellite data assimilation system within regional numerical weather prediction (NWP) models, to improve data assimilation research, the application of satellite measurements and to accelerate the transition from research to NOAA operations;
- Improve radiance assimilation techniques through efforts to improve the community radiative transfer model (CRTM);
- Continue collaboration with NOAA to quantify and improve the information obtained from existing and future satellites; and
- Continue participation in Observing System Experiments (OSE) and Observing System Simulation Experiments (OSSE) that help guide NESDIS planning for the future and improve utilization of the present remote sensing assets.

Theme: Outreach and Education

- Continue education of students in NOAA-related fields in order to provide a suitable workforce for the future;
- Continue research training for undergraduate and graduate students through collaborations with the Department of Atmospheric and Oceanic Sciences;
- Participate in the Cooperative Research Program (CoRP) Science Symposium;
- Provide professional training on the use of satellite observations in weather forecasting through programs such as GOES-R Proving Ground, SHyMet and VISIT;
- Continue to work with the NWS in bringing appropriate satellite images and derived products to the forecasting offices;
- Conduct outreach to the public through participation in activities such as Science On a Sphere (SOS), radio call in shows, and the American Meteorological Society's (AMS) WeatherFest;
- Train high school teachers on the uses of environmental satellite data through workshops, online training activities and our Satellite Meteorology for Grades 7-12 CD and Web site;
- Continue to offer week-long remote sensing classes to national and international communities;
- Support DB users of both polar orbiting and geostationary satellite data processing and regional real-time applications through distribution of free open source software, and through training in local product applications;
- Extend education collaborations with other STAR Cooperative Institutes (CIs) and NOAA's Cooperative Remote Sensing Science and Technology Center (CREST); and
- Training through the CIMSS satellite blog (http://cimss.ssec.wisc.edu/goes/blog/).

The above activities, conducted in collaboration with NOAA scientists, are aimed at helping NOAA deliver weather and water information that serves society's needs and at providing mission support. Three additional functions that CIMSS performs to achieve the same ends are:

- Hosting ASPB and providing the infrastructure for them to continue their work. Beyond addressing space needs, UW-Madison provides technical support, library facilities, and Data Center access;
- Organizing and hosting NOAA-sponsored conferences, symposiums and workshops; such as the GOES-R AWG annual review meetings and GOES User's Conference; and
- Supporting NCDC by maintaining the SSEC's Data Center holdings, including over 30 years of GOES data, nearly a decade of non-GOES geostationary satellite data, and archiving satellite data that NOAA does not receive (e.g., GOES-10, China's FY-2, India's Kalpana).

i. How were these themes identified?

CIMSS has a planning process that allows us to identify evolving themes and research directions. The process is illustrated in Figure 8 and patterns itself after the strategic process followed by many on the UW-Madison campus. This process allows us to chart the broad course for the institution and identify themes that are emerging, transforming or becoming outdated. The blue boxes are important milestones that are set or revised during CIMSS assessment and planning. The blue arrows mark the flow of formal and informal processes that lead to setting goals, priorities and principles. The yellow boxes list some of the questions addressed during this process. This continuous evaluation allows planning that is sensitive to the evolving external needs and involves a variety of stakeholders along the way.

The CIMSS research program began in 1980 in support of the newly launched NOAA series of polar orbiting satellites. Its primary mission was to develop techniques and products from AVHRR and HIRS/ Microwave Sounding Unit (MSU) measurements. Soon after, CIMSS scientists became involved with the GOES Imager and Visible and Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS) toward developing quantitative applications from geostationary platform data. As CIMSS grew in the 1980s, the CIMSS and NOAA on-site science leadership identified areas of research related to remote sensing and earth systems science and proposed new ideas to NOAA, NASA, and other agencies that expanded CIMSS research activities. By 1995, when CIMSS wrote its first Cooperative Agreement (CA) proposal to NOAA, it had a diverse and robust research program. CIMSS underwent a successful review in 2004 and in 2010 CIMSS was successful in the NOAA sponsored re-competition. During the re-competition these themes were identified and are the CIMSS research themes for its CA with NOAA.

ii. How have these themes evolved over the last decade?

The major scientific themes of CIMSS are broad with specific research projects often spanning multiple themes. Therefore, the evolution of research themes often occurs at the research project level in addition to the process outlined above. Numerous programs that track one or more themes have emerged and evolved throughout CIMSS history. These projects evolve to meet NOAA needs, improved scientific understanding, and the new capabilities associated with advanced satellite observations. **Table 2** summarizes some example projects, their scientific themes and evolution.

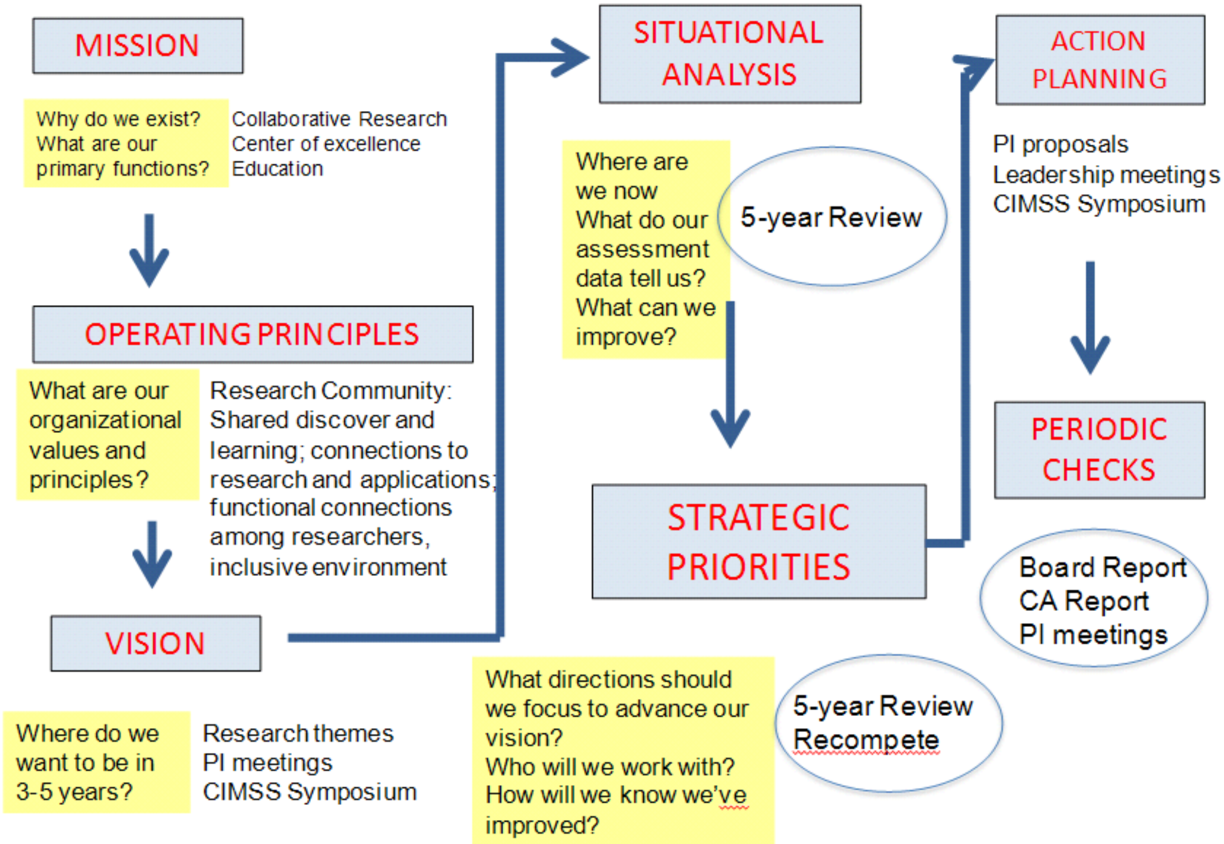


Figure 8. The overall process used by CIMSS to guide, plan and identify themes and directions for our institute.

Table 2. Example CIMSS research programs, including current research theme and because of their history, the previous theme in parentheses and evolution of the program.

Project	Themes	Evolution
Biomass Burning	Satellite Meteorology Research and Applications (Environmental Trends/Climate)	Started in the 1990s, the biomass burning projects focus on using GOES observations to characterize biomass burning and study trends. The GOES Wildfire Automated Biomass Burning Algorithm (WFABBA) has been an Operational product since 2001; currently providing fire detections and characterizations for the GOES satellites and the Meteosat and MTSAT series of satellites, as well as Korea's COMS.
Atmospheric Sounding	Environmental Models and Data Assimilation (Weather Nowcasting and Forecasting)	Began with algorithm development for VAS in the late 1970s. Algorithms also developed for polar orbiting satellites, including TOVS, MODIS and AIRS. These algorithms are distributed to a wide variety of users through the International TOVS Processing Package (ITPP), IAPP, IMAPP and CSPP. Algorithms are modified and transitioned to operations. Most currently operate on the contemporary series of NOAA satellites. Hyperspectral research applications are currently underway with Suomi NPP/JPSS CrIS, and MetOp IASI, and leading to future geostationary advanced IR sounder.
Derived Product Imagery (DPI)	Satellite Meteorology Research and Applications (Weather Nowcasting and Forecasting)	Grew out of a need to help users apply GOES sounding products. CIMSS continues to develop and distribute DPI from GOES products.
Tropical Cyclone Studies	Satellite Meteorology Research and Applications (Weather Nowcasting and Forecasting)	Began in the 1980s to use satellite observations to better understand tropical cyclone formation, development, and movement. Multiple products now used operationally by hurricane forecasters around the world. CIMSS tropical cyclones Web site was pioneering in the early 1990s and continues today as a lead TC Web page for real time and research satellite-derived products aimed at hurricane applications.
Cloud Properties	Satellite Meteorology Research and Applications (Climate/Clouds and Radiation)	A 30+ year climatology of cloud-top pressure from polar orbiting and geostationary platforms has been assembled using an internationally recognized approach to high cloud remote sensing. AVHRR climate records produced by CIMSS scientists under ASPB leadership are available through NCDC and UW-Madison. The data set accommodates the processing of AVHRR data from NOAA and MetOp platforms. These projects are now expanding into the Suomi NPP and JPSS era.

Satellite Derived Winds	Environmental Models and Data Assimilation/ Satellite Meteorology Research and Applications (Weather Nowcasting and Forecasting)	The tracking of persistent, identifiable cloud and water vapor features in sequential geostationary satellite imagery, as an estimation of the ambient wind flow was one of the original quantitative applications attempted with GOES data and has its heritage at SSEC/CIMSS. The algorithm was automated in the late 1980s and expanded to also derive polar winds. The algorithm was transitioned into NOAA/NESDIS operations in the early 1990s and now operationally run in support of data assimilation into NCEP and other numerical forecast models.
High-spectral resolution (HSR) infrared research	Satellite Meteorology Research and Applications (Weather Nowcasting and Forecasting)	This program began in the late 1970s. It is an area of research emphasis for CIMSS. Working with SSEC, CIMSS is internationally recognized for its work with HSR observations from satellite, aircraft and ground-based platforms.
Cryosphere studies	Satellite Meteorology Research and Applications (Climate)	There is a strong polar group at CIMSS, led by ASPB chief scientist J. Key. The team is now developing algorithms for GOES-R and JPSS and exploring how to measure ice properties on the Great Lakes. New projects include assessing the suitability of heritage snow algorithms, algorithm selection, implementation, testing and validation, and routine product generation with Advanced Microwave Scanning Radiometer (AMSR2) data.
Calibration and validation	Satellite Sensors and Techniques (Weather Nowcasting and Forecasting/Climate/)	CIMSS has long supported NOAA and NASA in satellite cal/val activities. These include ground-based and aircraft flown validation field programs as well as inter-satellite calibration studies. CIMSS has a representative at Calibration Working Group (CWG) monthly meetings (teleconferences), where presentations show how CIMSS scientists address issues with current GOES. CIMSS maintains a Web page for monitoring GOES Sounder calibration and product visualization.

iii. Which themes/sub themes are near completion?

The CIMSS Research Themes are very broad in scope. Advancement of our applications and understanding for topics like weather forecasting, the energy-hydrologic cycle or climate will continue far into the future. Within most current CIMSS research programs we continue to adapt techniques to new computer technologies and new instruments and re-direct the focus towards new research objectives. Thus, many programs are ongoing, making continuous progress as ideas and technologies advance and new challenges emerge.

iv. What are the emerging thematic areas? Why?

Long term satellite data sets are leading to more investigations using these long-term data. As a result, the development of climate data records from satellite observations is becoming a more prominent theme for

CIMSS as we work with NOAA and NASA scientists on projects to extend the time series from AVHRR in the 1980s, through the EOS era and into the Suomi NPP and JPSS polar orbiting programs. Emerging technologies can drive new science and applications, and this area is where CIMSS thrives.

The MODIS instrument provides multispectral observations for numerous new techniques, and the high-spectral resolution sounding instruments (Infrared Atmospheric Sounding Interferometer (IASI) and Cross-track Infrared Sounder (CrIS)) are providing the capability to greatly improve characterizations of the atmosphere, and offer significant advances in weather forecasting and severe storm warnings. Results from NASA funded EOS research programs are now being extended to NOAA interests. The launch of the Suomi NPP satellite in 2011 provides another advanced operational imager and sounder in polar orbit. CIMSS is working closely with NOAA and NASA to develop validation tools, conduct validation studies, and ensure maximum impact of the observations on weather analysis and forecasting. The launch of the European IASI instrument in 2006 and the CrIS on the Suomi NPP provide additional high-spectral resolution platforms in polar orbit. CIMSS is working closely with its partners on validation efforts and in aiding in the use of these observations in real-time applications.

CIMSS scientists are working with NOAA and NASA collaborators to extend the long-term NOAA data sets with current NASA EOS and Suomi NPP data sets and looking to the future with JPSS. For example, the CIMSS/ASPB HIRS cloud algorithm software has been adapted from MODIS and delivered to NCDC along with benchmark data and an Algorithm Theoretical Basis Document. These lay the ground work for a long-term, consistent cloud-top pressure retrieval from the CO_2 slicing method. CIMSS scientists are working with NASA and NOAA scientists to develop a consistent data set that extends MODIS era observations into the VIIRS era. This extension is challenging as the differences between pixel-level MODIS Level-2 cloud product and VIIRS Intermediate Products (IPs) and Environment Data Records (EDRs) are ultimately related to a combination of two primary factors: (1) differences between the MODIS and VIIRS instruments, and (2) differences in the geophysical algorithms, including radiative models, ancillary data sets, and quality assurance (QA) filtering of pixels.

The MODIS and VIIRS errors are also being extended to the past to match AVHRR observations using the ASPB PATMOS-x approach. Figure 9 shows the global map of the difference between the two analysis methods. White regions indicate both the VIIRS Cloud Mask (VCM) and PATMOS-x detect cloud, while green and blue regions are where both methods detect clear over land and water, respectively. Regions colored cyan indicate where the VCM detected clear while the PATMOS-x detected cloud; red pixels are where the VCM assigned cloudy and PATMOS-x clear. The two algorithms are applied to the same input data (VIIRS Science Data Records (SDRs)), so differences in the performance arise from the differences between the algorithms. There is generally good agreement between about 60S and 60N, with the VCM producing more clouds in the southern polar region, and less cloud to the north of 60N.

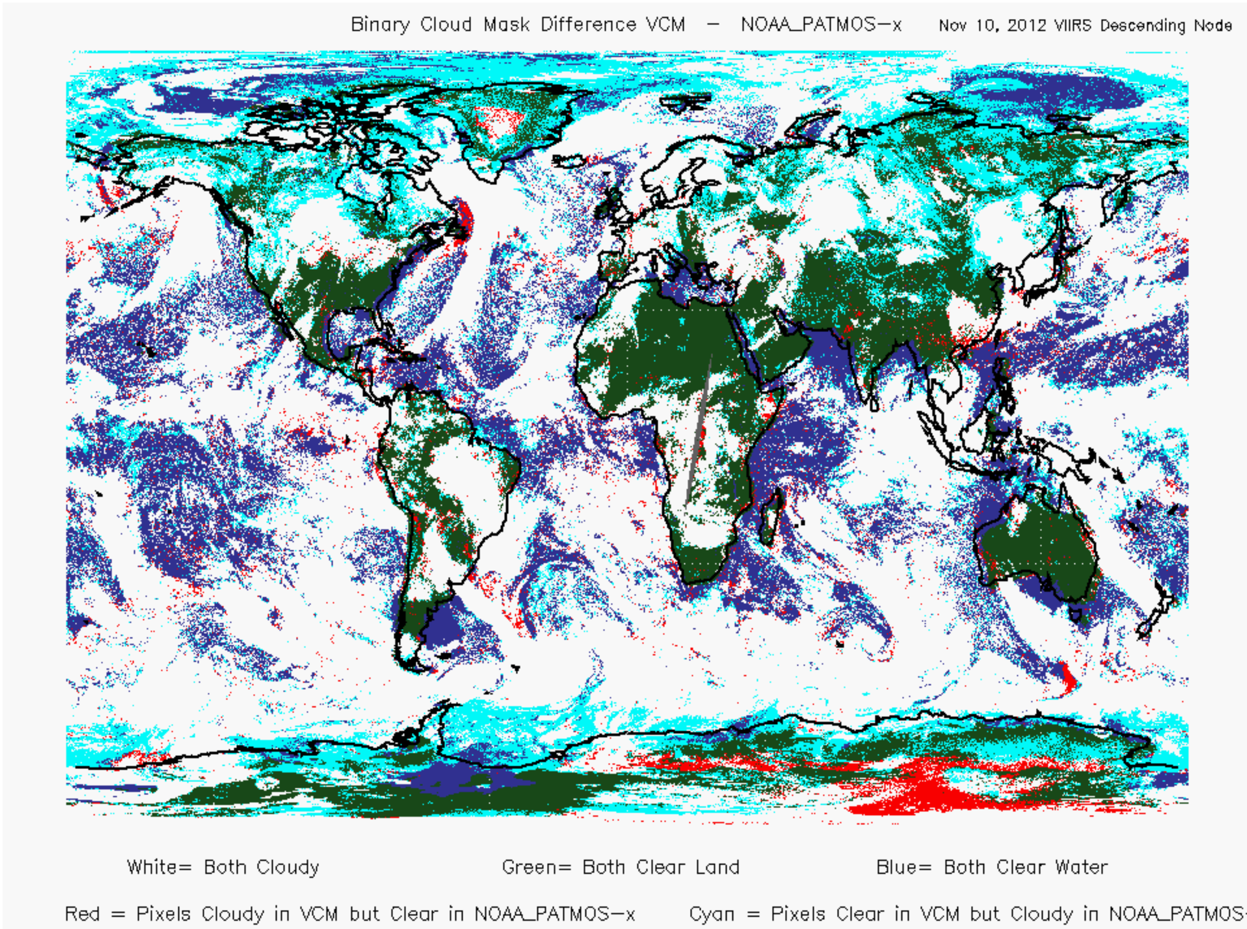


Figure 9. Difference between VCM and PATMOS-x cloud mask algorithms applied to VIIRS data collected in ascending orbit, 10 November 2012. Green and blue regions are where both methods detect clear over land and water, respectively. Cyan regions indicate where the VCM detected clear while the PATMOS-x detected cloud; red pixels are where the VCM assigned cloudy and PATMOS-x clear. (Figure supplied by A. Heidinger and D. Botambekov.)

CIMSS is seeking to extend its remote sensing expertise into regional change studies, such as the Great Lakes. Collaborations with scientists in the Center for Climatic Research (CCR) and the Sea Grant Institute at UW–Madison are avenues we are exploring. The PATMOS-x AVHRR 30+ year record developed by ASPB/CIMSS scientists is providing an excellent foundation to develop these opportunities. Figure 10 shows the trend in cloudiness over the Great Lakes region during the time period 1982-2012; the white stippling effect indicates areas where the linear trend could be considered statistically significant. This satellite data record is being used to assess climate model performance for this region of the world. In a separate study, improving observation and nowcasting of lake effect snow (LES) is being undertaken using a new GOES and NEXRAD data fusion method. LES bands commonly occur in the Great Lakes region and are prolific snowfall producers, yet the NEXRAD network often does not effectively observe LES since the lowest radar elevation angle can overshoot shallow LES structures. Satellite products are being used in an effort to mitigate these NEXRAD observational shortcomings and improve nowcasting and remotely sensed quantitative snowfall estimates for LES events. So an emerging theme is a study of the Great Lakes using satellite observations coupled with surface based measurements.

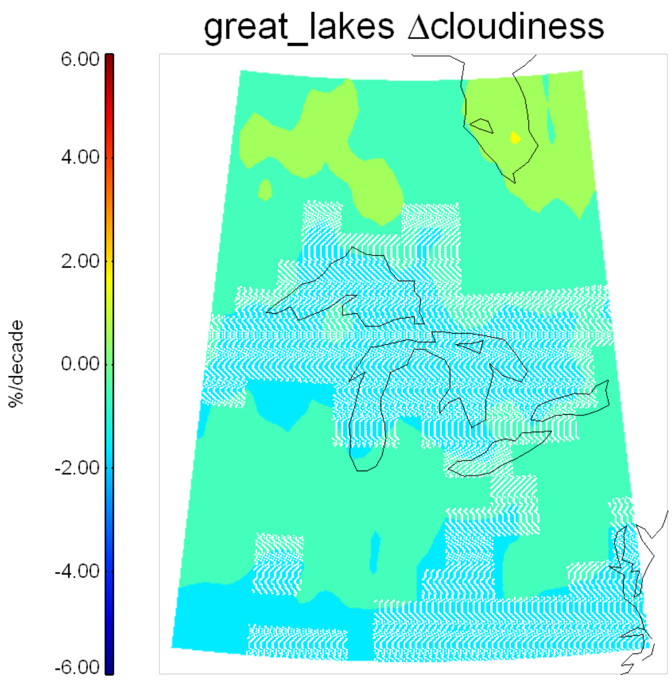


Figure 10. The change in cloudiness over the Great Lakes region during the period 1982-2012, as determined by PATMOS-x cloud analysis. White stippled regions indicate statistically significant trends. (Figure provided by M. Foster)

SSEC/CIMSS is a leader in developing software packages for the international community to receive DB data and apply scientific algorithms to create or enhance local weather analysis capabilities. ITPP/IAPP IMAPP are freely distributed software packages for DB users. CIMSS continues to provide the same resources for international users during the Suomi NPP era. The Suomi NPP/JPSS component of the CSPP for DB transforms VIIRS, CrIS, and Advanced Technology Microwave Sounder (ATMS) Raw Data Records (RDRs) to SDRs and selected EDRs, and is optimized for real-time processing and regional applications. CSPP has also released software packages supporting processing of IASI, AIRS, MODIS, and AVHRR data. While not listed as a theme, CIMSS will continue to collaborate with SSEC and its national and international partners in the distribution of satellite access and analysis software packages.

Modeling and data assimilation activities have recently expanded at CIMSS, often in collaboration with ASPB and other partners. For example, CIMSS/ASPB researchers are working toward improving ozone prediction in the GFS through inclusion of three-dimensional diurnally varying ozone production and loss tendencies. Several assimilation studies have also been performed to examine the impact of atmospheric motion vectors (AMVs) and temperature and water vapor sounding retrievals on reducing hurricane forecast track and intensity errors. OSSEs have been used to examine the potential impact of assimilating cloudy-sky infrared brightness temperatures from the GOES-R ABI sensor on forecasts of high-impact weather events. In collaboration with researchers at the NOAA NSSL, new studies are underway to explore optimal methods to simultaneously assimilate satellite and radar observations to improve model forecasts. In addition, we have led several efforts to use satellite observations to examine the accuracy of numerical model forecasts and to investigate the ability of various cloud microphysical and planetary boundary layer parameterization schemes to realistically represent the spatial characteristics of the observed cloud field. Finally, CIMSS is developing methodologies for simulating both current low Earth orbit (LEO) and future geostationary (GEO) advanced IR sounders from existing and future high resolution nature runs. CIMSS provides simulated data at temporal/spatial resolutions in conjunction with the Atlantic Oceanographic and Meteorological Laboratory (AOML) based on global OSSE design.

Education and Public Outreach (EPO) has always been an important activity in CIMSS. The CIMSS Director, scientists, and many staff have been personally involved in EPO activities for many years. CIMSS started a week-long Summer Workshop for high school teachers and students in 1992, and these have been held annually since then. Until recently, there has been a lack of national organization in EPO activities, but the importance of these programs has greatly increased in the past few years. CIMSS seeks to incorporate EPO activities into all its major research programs. To achieve this goal, CIMSS established its Office of Education and Outreach in 2012 to help coordinate education activities and to focus efforts in ways that support NOAA while ensuring that CIMSS programs support the Wisconsin Idea of building collaborations across the State and across the globe. These efforts are discussed later in this report.

F. Scientific partnerships

CIMSS hosts scientists from STAR and NCDC, both of NOAA/NESDIS, resulting in a strong partnership among all organizations. CIMSS has a number of other strong linkages to NOAA branches and laboratories, such as the NWS, the National Hurricane Center (NHC), the Environmental Modeling Center (EMC) of NCEP, and with JCSDA; and collaborates closely with other NOAA Cooperative Institutes. CIMSS/SSEC has strong international partnerships, particularly with EUMETSAT and the China Meteorological Administration.

In an effort to improve how the general population uses and interacts with weather forecasts and other environmental data, we are beginning to strengthen our connections to social scientists. For instance, a new CIMSS project is examining the ability of the GOES-based Evaporative Stress Index (ESI) to provide early warning of developing or intensifying drought conditions. Focus group studies will be held with various stakeholder groups, such as farmers/ranchers, natural resources managers, county extension agents, and insurance company representatives to better understand how they can use this data to enhance their management decisions. Results from these studies will be used to further enhance the utility of the drought monitoring products, such as preferred methods to distribute and display the information. We are also working with UW Sea Grant to try to establish collaborations with social scientists. The new director of the Sea Grant at UW, Dr. Jim Hurley, gave one of the invited talks at the CIMSS Science Symposium. An attempt to hire a post-doc in the social sciences temporarily stalled as she took a one year Presidential Fellowship in Washington DC. We are hiring a post-doc in the fall with expertise in Geographic Information Systems (GIS) and working with the Federal Emergency Management Agency (FEMA) to support the development of an application to integrate ASPB/CIMSS fog probability product with information such as road location.

i. What is your relationship to the OAR Laboratories and other NOAA entities?

The analysis of publications shows that we have a significant number (over 40%) of collaborative research projects with several NOAA CI and laboratories. As a NESDIS cooperative institute, we have our strongest relationship with scientists from the NESDIS laboratories. Appendix E shows cross cutting relationships across many Office of Oceanic and Atmospheric Research (OAR) and NESDIS CIs and laboratories. Here is an example of the interactions between CIMSS and NSSL/ Cooperative Institute for Mesoscale Meteorology Studies (CIMMS): model-derived synthetic satellite datasets generated at CIMSS were made available to NSSL collaborators to investigate the relationship between the spatial structure of visible and infrared satellite imagery and the model-simulated precipitation and cloud top height distributions. A dataset containing synthetic GOES-R ABI visible reflectances and infrared brightness temperatures was created using model output from a very high resolution WRF model simulation that tracked the evolution of severe thunderstorms across the Upper Midwest during 19-20 July 2006. Subsequent synthetic satellite datasets were generated using output from real-time NSSL-WRF model forecasts over the contiguous U.S. during 2012 and 2013. User support was provided for each of these datasets.

ii. What, if any, formal procedures do you have for cooperative planning?

CIMSS participates in both NOAA and NESDIS annual meetings of the Cooperative Institute directors, where a range of issues are discussed including inter-CI collaborative opportunities and challenges. The NESDIS CI Directors' meetings in particular provides an opportunity to initiate and coordinate the broad research and development activities associated with the CIs roles in the GOES-R and JPSS programs. At weekly meetings the CIMSS director, executive director and the head of ASPB discuss the current status of CIMSS/ASPB relationships. These interactions help to foster collaborations with other institutes.

For example, Figure 11 lists collaborations between CIMSS researchers and CIMMS at the University of Oklahoma.

UW CIMSS and OU CIMMS/NSSL Collaborations 2013

CIMSS Collaborators	*CIMMS/NSSL Collaborators*	*Research Topic*	*Resources*
Wayne Feltz	Greg Stumpf and Kristin Kuhlman	GOES-R PG HWT testbed 2008-present	GOES-R Proving Ground
Wayne Feltz, Michael Pavolonis, Justin Sieglaff, John Cintineo (OU-CIMMS student)	Valliappa Lakshmanan, Travis Smith	Satellite WDSS-II Object Tracking, Convective Nowcasting Fusion	Past GIMPAP funding, new GOES-R Risk Reduction LOI 2013
Jason Otkin and Becky Cintineo (OU CIMMS student)	Tom Jones, David Stensrud, Steve Koch, Jack Kain	GOES-R satellite NWP data assimilation	GOES-R 3, new GOES-R3 LOI 2013
Bill Line	Kristin Kuhlman/Bill Line	Newly hired UW-CIMSS graduate student as GOES-R HWT Satellite Liaison	GOES-R
Wayne Feltz and Brad Pierce	David Turner, Mike Coniglio, and Steve Koch	Uplooking remote sensing mobile facility deployments	GOES-R Cal/Val, LOIs submitted for NSF PECAN deployment
Steve Ackerman, Brad Pierce, and Wayne Feltz	Kimberly Klockow	Social science	TBD

Figure 11. Collaborations with CIMSS and CIMMS scientists, including cross CI recent hires.

CIMSS itself utilizes a number of methodologies for cooperative planning specific to our own research programs and objectives. Individual research teams routinely meet to discuss results and future research directions. Regular meetings, approximately once a month, of CIMSS PIs are convened to discuss CIMSS issues and to inform each other about opportunities, such as research collaborations. Annual all-hands meetings are convened where the Director provides an update on the status of CIMSS (one will follow this review). All PIs were involved in the writing of the CIMSS re-competition proposal.

In house CIMSS seminars are routinely held to exchange research ideas within the center and also with visitors. Twice a year we hold a CIMSS Science Symposium to share our science and explore visionary concepts; the next symposium will be held in late October. Each spring a half-day poster symposium is held for the entire AOS/SSEC/CIMSS/CCR enterprise where presentations of ongoing research are made and new opportunities discussed.

3. Science Review

A. What are the Institute's most recent scientific highlights and accomplishments?

CIMSS has had many accomplishments over the past three years as seen in the accompanying document "The Science of CIMSS." To appreciate the breadth and depth of science conducted at CIMSS it is useful to return to the research process loop presented in the introduction and discuss various research highlights in relation to that diagram (Figure 12). In this way programs can be better viewed in relation to one another and with respect to the CIMSS mission as a whole. We begin with a discussion of the various data used at CIMSS.

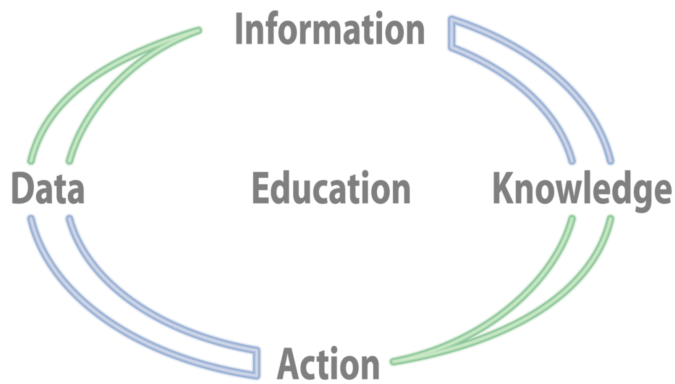


Figure 12. CIMSS researchers and students engage in a variety of endeavors. This loop provides a framework to view the research and education program conducted at CIMSS as a whole.

i. Collecting Data

SSEC/CIMSS receives geostationary and polar satellite data through 10 rooftop antennas, including a relatively new X/L-band antenna with Suomi JPSS direct broadcast capability. The data includes that from geostationary weather satellites GOES, Meteosat, Meteosat Second Generations (MSG) and the Geostationary Meteorological Satellite (GMS). SSEC/CIMSS also receives global NOAA polar orbiting operational weather satellite data through a NOAA relay to a commercial downlink. In addition, SSEC/CIMSS has direct broadcast reception facilities for the NOAA polar orbiting satellites and for the NASA EOS Terra/Aqua and Suomi JPSS satellites. The SSEC Data Center receives the NOAAPort feed, providing surface and radiosonde data, radar and numerical model output.

CIMSS also acquires data through its participation in field experiments, flying instruments such as the Scanning HIS (High-resolution Interferometer Sounder), NPOESS Atmospheric Sounder Testbed-Interferometer (NAST-I), and MODIS Airborne Simulator on the NASA ER-2, DC-8, Proteus, and Unmanned Airborne Vehicle (UAV) Global Hawk. These aircraft experiments have a variety of science objectives, and often one of these objectives is data collection to validate satellite measurements, both radiances and derived products. A new ground-based portable trailer named the SSEC Portable Atmospheric Research Center (SPARC) has been acquired by SSEC/CIMSS to replace the 1996 AERIbago truck to allow collection of up-looking active/passive remotely sensed atmospheric data from Lidar, Atmospheric Emitted Radiance Interferometer (AERI), Cimel sun photometer, Global Positioning System (GPS) antenna, and microwave radiometer instrumentation. This new asset will be deployed in future NOAA GOES-R/JPSS satellite validation and calibration activities.

Once data is collected, it must be calibrated and geo-located. CIMSS scientists, in collaboration with NASA and NOAA, are actively involved in calibrating infrared sensors on a variety of satellites, including the GOES Sounder and Imager, AVHRR, AIRS, MODIS, CrIS, and VIIRS.

CIMSS has been heavily involved in GOES calibration as well as product generation since its inception. CIMSS scientists assist the GOES-R CWG on matters of ABI calibration by consulting, through the monthly CWG telecons, with the group and, when appropriate, offering a tie-in to products to help quantify and understand calibration issues. This work will help ensure ABI L1b calibration and data quality. CIMSS scientists also assist the CWG with Japan Meteorological Agency (JMA)'s Advanced Himawari Imager (AHI) in understanding the calibration and navigation, which allows us to leverage all knowledge gained at JMA and will assist the CWG in preparation for the ABI. Very similar to ABI, the AHI is being constructed by the same vendor and is scheduled for launch in December 2013. In addition, CIMSS continues to monitor the current GOES Sounder calibration using the "calc versus obs" method developed for this project, in preparation for the GOES-R ABI.

Continuous monitoring of GOES radiances through inter-calibration techniques allows for quick diagnosis of instrument or software malfunctions. For instance on 22 May 2013, GOES-13 experienced a serious anomaly, now believed to be caused by a micro-meteorite striking the spacecraft, which caused the satellite to place itself in storage mode. CIMSS, SSEC, and ASPB colleagues provided support to the OSPO during the outage. On 30 May 2013 GOES-13 was sending data again. These data were received in real-time by the SSEC Data Center. The Sounder was put through outgassing at the request of T. Schmit (STAR/ASPB stationed in Madison, WI) for approximately 4 days in order to improve the signal-to-noise before returning to operations. The operational Sounder data were monitored for noise and showed an improvement in the shortwave bands, especially band 15 (4.5 micron). Another example shown within Figure 13, indicated the effects of a co-registration error are seen in this GOES-13 Imager cloud top pressure comparison from 11:15 UTC 15 May 2012. Co-registration is a problem where data from two or more satellite bands from the same instrument are not aligned properly on the Earth coordinate system.

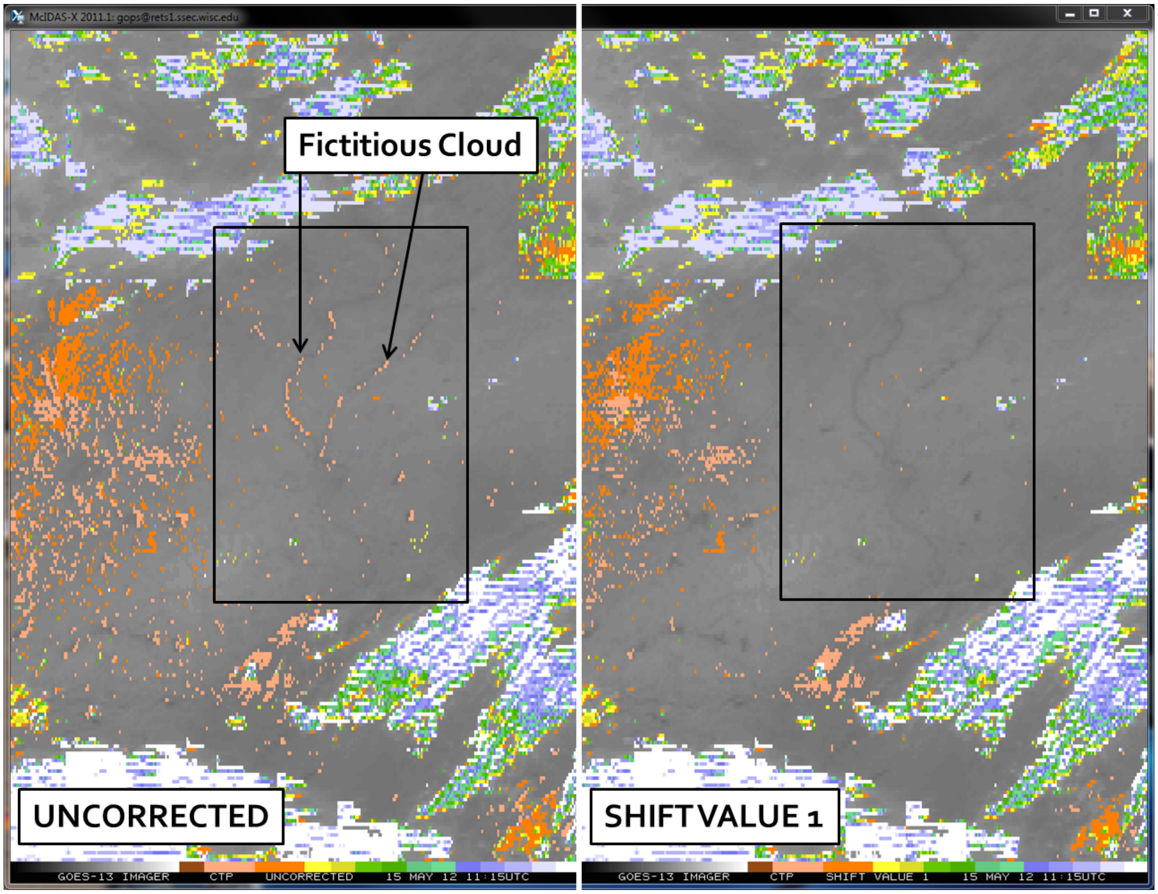


Figure 13. The effects of a co-registration error are seen in this GOES-13 Imager cloud top pressure comparison from 11:15 UTC 15 May 2012. Co-registration is a problem where data from two or more satellite bands from the same instrument are not aligned properly on the Earth coordinate system. Since cloud products, among others, rely on band differencing, errors can result. On the left, the uncorrected data show fictitious clouds along several river borders (e.g., Mississippi and Illinois Rivers) as well as along some small lakes. On the right is the cloud top pressure product after the data have been corrected; note that the fictitious clouds along rivers and lakes have been removed.

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

The operational GSICS team performs intercalibration daily for their host of geostationary imagers and includes the United States, Japan, China, and Europe. CIMSS scientists conduct a retrospective analysis of all of the operational instruments, as well as several instruments no longer in operations. The AIRS instrument is used to intercalibrate the GOES, Meteosat, FY-2, and MTSAT Imagers using the NESDIS GSICS algorithm retrospectively for the entire period of data record overlap between AIRS and these geostationary imagers. When that is completed, the same would be done for the GOES Sounders. A summary of this satellite to satellite retrospective processing is shown in Figure 14. Fundamental to this research is the vast satellite database available due to the in house SSEC Data Center.

GEO-AIRS GSICS Back-processing

GOES Imager	GOES-08	GOES-09	GOES-10	GOES-11	GOES-12	GOES-13	GOES-14
Days	148	854	2,366	1,976	3,138	7	47
Date Ranges	2002244-2003090	2003113-2005321	2002244-2009334	2006152-2011340	2003016-2010364	2013151-2013157	2012228-2012274

	MET-07	MET-09	MTSAT-1R	MTSAT-2	FY2C
Days	1,035	1,644	933	913	911
Date Ranges	2007001-2009365	2007101-2011364	2007254-2012360	2010182-2012366	2005184-2007365

Figure 14. Over 38 years of satellite comparisons have been processed using the GSICS GEO-AIRS method. This fills in the NESDIS GEO-AIRS GSICS archive for the above instruments. Dates are general ranges of comparisons; the dates are typically not continuous since the GEOs are not continually operated during these dates.

To better accommodate climate change monitoring and improved weather forecasting, there is an established need for higher accuracy and more refined error characterization of radiance measurements from space and the corresponding geophysical products. This need has led to emphasizing direct tests of in-orbit performance with SI traceability and high accuracy. For the calibration validation process to be both accurate and repeatable, it is very important that the reference data instrument be extremely well characterized and understood, carefully maintained, and accurately calibrated. The UW-Madison S-HIS meets and exceeds these requirements and, along with other sensors, flew on the high altitude NASA ER-2 aircraft during the May 2013 Suomi NPP airborne calibration validation campaign. Continued participation in regularly scheduled aircraft campaigns for Suomi NPP and JPSS are anticipated. An intercomparison example is shown in Figure 15.

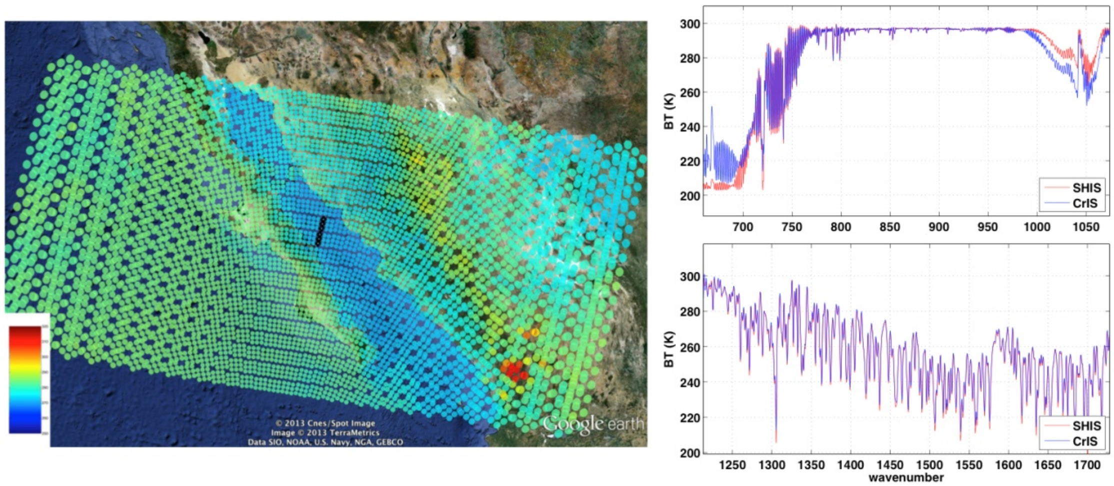


Figure 15. CrIS/S-HIS underflight comparison on 01 June 2013. The left hand image shows the CrIS brightness temperatures for each footprint and the nadir track over the Gulf of Mexico coincident with the ER-2 underflight. The right hand panels show comparisons of the mean CrIS and S-HIS brightness temperature spectra.

CIMSS, in conjunction with the Atmospheric Radiation Measurement (ARM) program field sites, provides another satellite validation opportunity through regular radiosonde launches. In this arrangement, radiosondes (purchased by NOAA) are launched from the ARM sites coincident with the satellite overpasses of the sites, and analysis is performed by UW-Madison personnel to compare the radiosonde and CrIMSS EDR products to assess the accuracy of the satellite products. Previously for AIRS and IASI, best estimates of the atmospheric state and surface properties at the satellite overpass times were produced via a similar collaborative effort between NASA and ARM. This work was a fundamental, integral, and cost-effective part of the EOS validation effort and provided critical accuracy assessments of the AIRS temperature and water vapor soundings. This effort is anticipated to be repeated throughout the NPP mission life into FY15.

CIMSS provided real-time mission and hazard-avoidance support for the Global Hawk drones flying in the Hurricane and Severe Storm Sentinel (HS3) field experiment, operating out of Wallops Island, Virginia during the summers for 2012 and 2013. Started in late August, and continued through late September, HS3 missions will investigate and overfly Atlantic hurricanes with both high-altitude dropsondes and remote sensing instruments. One of these instruments is SSEC's S-HIS. This year, CIMSS provided critical decision-making products derived from GOES, including cloud-top heights (CTH) and tropical overshooting tops (TOTs); an example is shown in Figure 16. Both of these products are being developed and demonstrated as part of the NOAA/NESDIS GOES-R Risk Reduction and Proving Ground programs and use the GOES-R CTH and OT algorithm methodologies using current GOES imager data. In addition, the GOES-14 special 1-minute rapid scanning operations (due to GOES-R Proving Ground activities) coincided with the first 10 days of HS3, and also benefited mission support when activated over targeted hurricanes. The HS3 Global Hawk aircraft was collecting S-HIS data that was transmitted in near real-time to the SSEC Data Center for temperature and moisture retrieval processing.

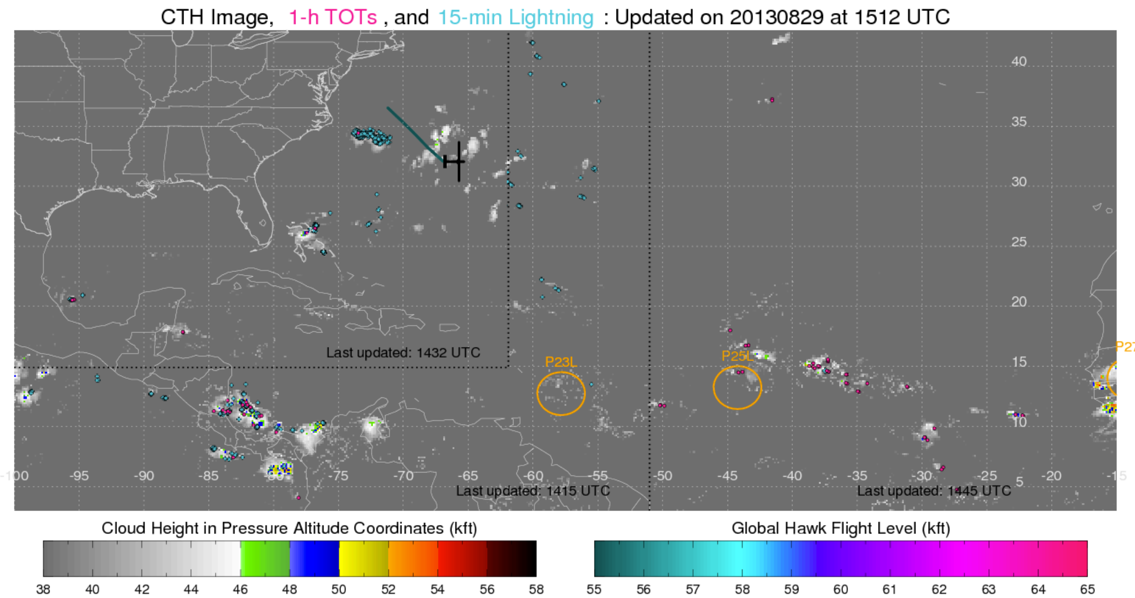


Figure 16. Quicklook image developed to assist NASA HS3 with NOAA GOES-R proxy derived cloud top heights and convective overshooting top detection along with lightning for Global Hawk aircraft guidance.

In addition to the aircraft field campaign support, ground-based field experiment data collection and validation are being conducted by CIMSS for GOES-R Cloud, Aerosol, Land and Sounding AWG team algorithm requirements. It also addresses the need for more extensive calibration and validation as just highlighted in the GOES-R Algorithm Development Board's baseline and option 2 response documents under Finding #1: "Insufficient Validation : Reporting of measurement validation lacked completeness and was rarely independent." During the first year of this project a Cimel sun photometer was added to the UW-Madison SSEC roof-top instrumentation suite and became a member of the Aerosol Robotic Network (AERONET) federation. A ground based GPS instrument was also acquired and has become part of the Suominet GPS network (http://www.suominet.ucar.edu/pw_plots.html?site=SSEC).

The observational value of high-spectral resolution infrared measurements has been demonstrated by CIMSS/SSEC for many years. It is important to get the data in the hands of scientists and to provide them with tools to manipulate the measurements. CIMSS scientists are, therefore, developing freely available tools for scientists to view and analyze hyperspectral data from a variety of instruments. There is a keen interest in the global community for such a toolkit. Having to work with data provided in a variety of formats is very challenging—especially HDF. The global community cannot afford expensive commercial runtime licenses; hence, this toolkit, known as HYDRA, is being developed in Java and Python and is based on the freely available VisAD library. In addition, there is an emphasis on rapid remote access to only the required data sets, setting the stage for being able to cope with very large data sets. Recent workshops in Ravello, Italy, and Nanjing, China made extensive use of HYDRA in training students to use hyperspectral satellite data. Early comments from experienced scientists are very encouraging; one said, "I thought I knew everything about my data, until I started using HYDRA...now, I realize just how much I don't know about it ..."

ii. Algorithms: From Observations to Information

CIMSS has a long history of developing algorithms using observations from aircraft, ground-based and satellite platforms to characterize the atmosphere and surface. Many of these algorithms now support

NOAA operations and objectives. The web page of the Office of Satellite and Product Operations (OSPO) (http://www.ospo.noaa.gov/Products/atmosphere/index.html) provides environmental data from remote platforms using NESDIS satellites, and many of their web page products have links to CIMSS research. Table 3 lists some of the historical products that CIMSS developed that are now routinely available from GOES satellites. This section further discusses some of the many algorithms developed by CIMSS researchers that turn observations into information about our environment.

Table 3. List of some of the CIMSS satellite-based meteorological algorithms transitioned from research to operations.

Imager	**Sounder**
Derived Product Images	Derived Product Images
Water Vapor	Water Vapor
CAPE	CAPE
Lifted Index	Lifted Index
Skin Temperature	Skin Temperature
Winds from multiple satellites	Winds
High density infrared	7.0 micrometers
High density water vapor	7.5 micrometers
High density visible	
High density 3.9 μm	
Derived wind fields (shear, divergence, etc)	
Hurricanes	
Objective Dvorak technique	
Intensity estimates	
	Clouds
	Site-specific Cloud Product
Biomass Burning	Single FOV product DPI
	Cloud Top Height
	Retrievals
	Temperature/moisture profiles
	Total/Layer Precipitable Water
Clear-sky Brightness Temperature	

The experience developed at CIMSS on the current GOES sounder technology has been extended to include the GOES-R ABI. Over half (34) of the ABI product algorithms are being developed at CIMSS. The capability of generating products, comparing product outputs, product analysis and validation has a long history at CIMSS and is an asset to the GOES-R AWG. For example, CIMSS scientists have developed methods of deriving temperature and moisture profiles from the current GOES sounder instruments. They are now developing the legacy atmospheric profile (LAP) algorithm for the next generation GOES-R ABI product generation. Since the Hyperspectral Environmental Suite (HES) has been removed from GOES-R, the ABI is used to continue the current GOES Sounder products. The algorithm has not only been developed and delivered for operational implementation, but it has also been adapted to process SEVIRI and MODIS.

In preparation for the launch of GOES-R, the CIMSS winds team is actively engaged with the GOES-R AWG winds team developing AMV derivation algorithms and using them in demonstration studies. The AMV algorithm development has reached a mature stage and the project is now in a validation mode. The software is being tested in a near real-time demonstration using Meteosat-9 SEVIRI data as ABI proxy imagery, with the resultant AMVs validated against "truth" data sets. Hourly AMVs from Meteosat-9 will be produced in near real-time and validated against the GFS analysis wind fields. The primary activity involves the analysis of AMV height assignments using the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation satellite (CALIPSO) observations as a benchmark comparison dataset. AMV-CALIPSO collocations provide a novel way to look into the validity of the AMV height assignment within the GOES-R nested-tracking software.

Atmospheric Profiles

CIMSS is heavily engaged in development of the GOES-R LAP algorithm. The algorithm retrieves GOES-R baseline atmospheric temperature and moisture profiles and the derived products including total precipitable water (TPW), layer precipitable water (PW), lifted index (LI), convective available potential energy (CAPE), total totals index (TT), Showalter index (SI), and the K-index (KI) from the clear sky infrared (IR) radiances within a 5 by 5 ABI field-of-view (FOV) box area. This project requires CIMSS scientists to develop the GOES-R LAP algorithm to be able to process high temporal and spatial resolution ABI data efficiently. This project provides science codes to the GOES-R AIT for algorithm integration and helps the system provider to implement the algorithm and codes into the GOES-R ground system. CIMSS scientists also validate the GOES-R LAP algorithm to assure that the GOES-R atmospheric temperature and moisture profiles, TPW, LI, CAPE, TT, SI and KI products meet the science requirements and applications. An example of quantitative validation comparisons between the circa pre-2013 algorithm, the new operational upgrade at NOAA NESDIS, and the future GOES-R algorithm is shown in Figure 17.

CIMSS also has a rich history in the development of infrared hyperspectral retrieval theory which is being applied to current high spectral resolution polar data including AIRS, CrIS, and IASI infrared high spectral resolution sensors. Accurate retrievals from hyperspectral sounder radiance measurements under both clear and cloudy sky conditions are valuable sources of mesoscale information and have the potential to greatly enhance regional weather prediction capabilities. To encourage the operational use of hyperspectral retrieval data in NWS forecasting offices, retrieval products from AIRS, IASI and CrIS are prepared for near real-time viewing and analysis in close collaboration with Alaska Region researchers and forecasters. This is the second year of a three-year JPSS PGRR (Proving Ground and Risk Reduction) project, previously titled "Atmospheric Soundings from Suomi NPP/Aqua and MetOp-A/MetOp-B Sounding Pairs." Examples of CrIS retrievals of relative humidity at 400 hPa, cloud top height, and cloud optical thickness are shown in Figure 18. Much of the knowledge obtained from the polar orbiting hyperspectral resolution data will be applied to future geostationary high resolution infrared measurements from focal plane arrays expected to be launched internationally within the next decade.

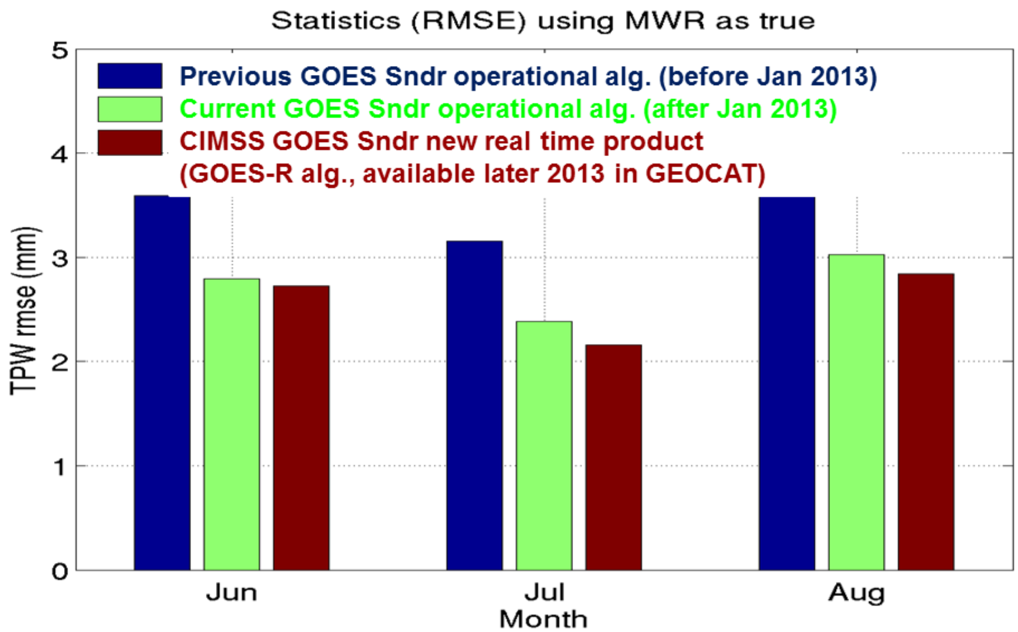


Figure 17. RMSE of TPW from the GOES-13 Sounder with the LAP retrieval algorithm, the previous operational GOES Sounder algorithm (operational before Jan 2013), and the current operational GOES Sounder algorithm (operational after Jan 2013). The reference data is MWR measured TPW at the ARM CART site and the comparisons are between Jun. 1, 2012 and Aug. 30, 2012.

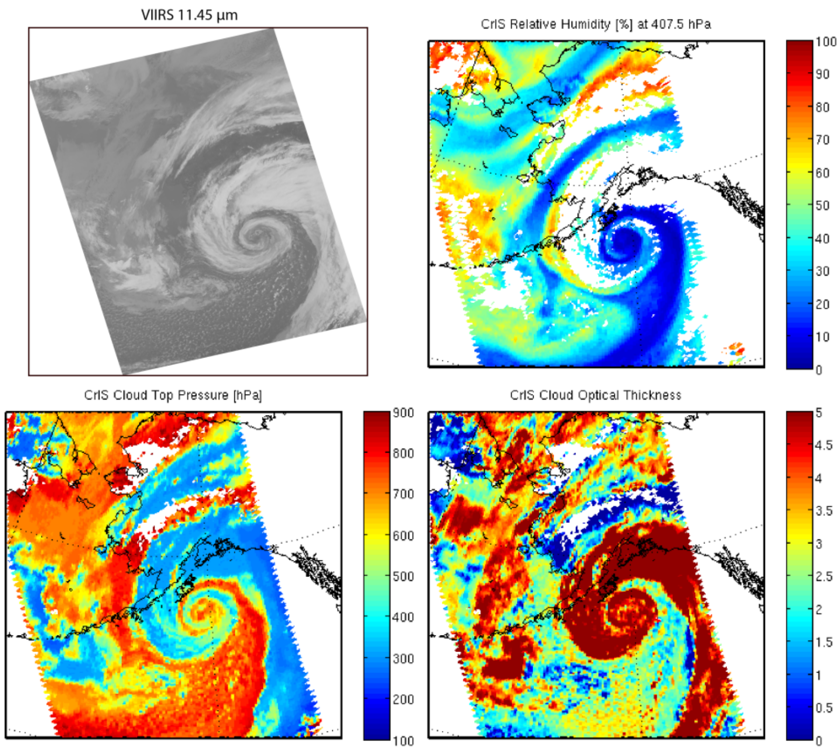


Figure 18. VIIRS 11 μm (I5) band, CrIS retrievals of relative humidity (at 400 hPa), cloud top pressure and cloud optical thickness for 26 Sept 2012.

Clouds and Aerosol Properties

In addition to retrieving the thermodynamic atmospheric state, it is essential to know location and properties of clouds to make accurate retrievals and for data assimilation. The GOES-R and JPSS cloud property algorithms are currently under development at CIMSS. NESDIS/STAR and CIMSS have been developing a suite of products that will offer advanced cloud detection and retrievals of cloud properties utilizing the GOES-R ABI instrument. The Cloud AWG has developed five algorithms that generate fourteen independent cloud products. These include the clear sky mask, cloud type and phase, cloud top height, cloud top pressure, cloud top temperature, and both day and nighttime cloud microphysical properties. This project has been ongoing for five years. The GOES-R AWG cloud algorithms have been modified for and are running on current GOES data. CIMSS validation indicates that these data are high quality and the results approach the expected GOES-R performance for many scenarios.

Lessons learned from improved cloud property retrieval techniques from GOES-R are being applied to the data from the Suomi NPP VIIRS. Specifically, the implementation of the ABI cloud mask (ACM), the ABI Cloud Height Algorithm (ACHA) and the Daytime Cloud Optical and Microphysical Properties (DCOMP) Algorithm on Suomi JPSS VIIRS radiances is underway. Implementation support is also provided for the Nighttime Cloud Optical and Microphysical Properties (NCOMP) Algorithm. In all, this research covers using VIIRS to generate the following cloud products: clear-sky mask, top height, temperature and pressure, optical depth, particle size, water/ice path and base height. The motivation for this project is to demonstrate efficient processing of VIIRS data with NOAA and to generate a set of products from VIIRS that is physically consistent with those from GOES-R (Figure 19).

One component of the current cloud retrieval scheme at CIMSS is the daytime cloud optical and microphysical properties (DCOMP) algorithm, which generates estimates of cloud optical thickness, cloud effective radius and ice/water path during daylight conditions [Walther and Heidinger, 2012]. Research is underway to use the new VIIRS Day-Night Band (DNB) within a feasibility study to see if DCOMP is extendable to nighttime products by moonlight reflectance measurements. We will add a nighttime component to DCOMP using a lunar spectral irradiance model developed by Miller and Turner (2009). The lunar reflectance retrieval developed by Steven Miller of CIRA could be implemented in the CLAVR-x framework. Solar to lunar reflection comparisons in clear-sky cases over deserts in South America have proved that daytime and nighttime visible reflectance are consistent to the first order. These nighttime visible reflection values can be used for cloud properties and cloud mask retrievals.

Over the high latitude regions, image morphing/compositing for polar orbiter imagery has reached a mature state for application to the cloud products imagery. CIMSS has currently demonstrated the morphing/compositing algorithm on AVHRR 11μm data at sufficient accuracy and processing speed for operations. The algorithm employs Large-Displacement Optical Flow algorithms to intelligently constrain the image morphing process to matching features between sequential images from each contributing polar orbiting platform: MetOp-A, B, NOAA-15, 16, 18 and 19. The end product is a 30-minute resolution composite of the NOAA Grid 207 domain (Alaska and its surroundings; see below Figure 20) with minimal artifacts between satellite swaths. Routine gaps of more than four hours between satellites are filled with morphed imagery that accounts for advection of cloud patterns.

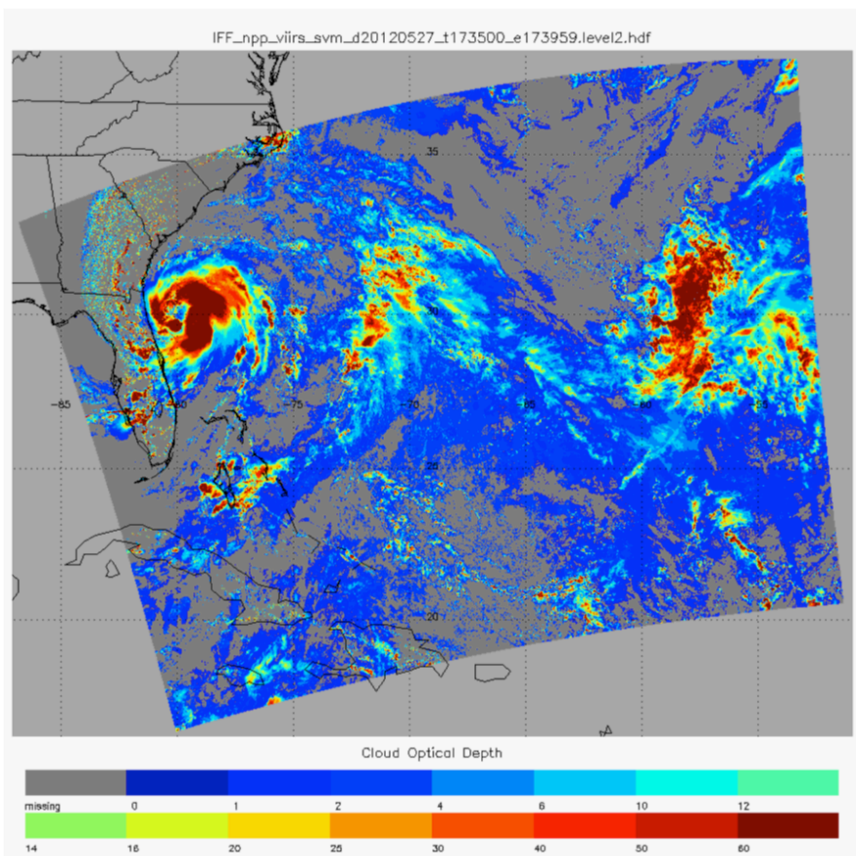


Figure 19. Cloud Optical Thickness from VIIRS/NPP on May 27 2012 17:35 UTC.

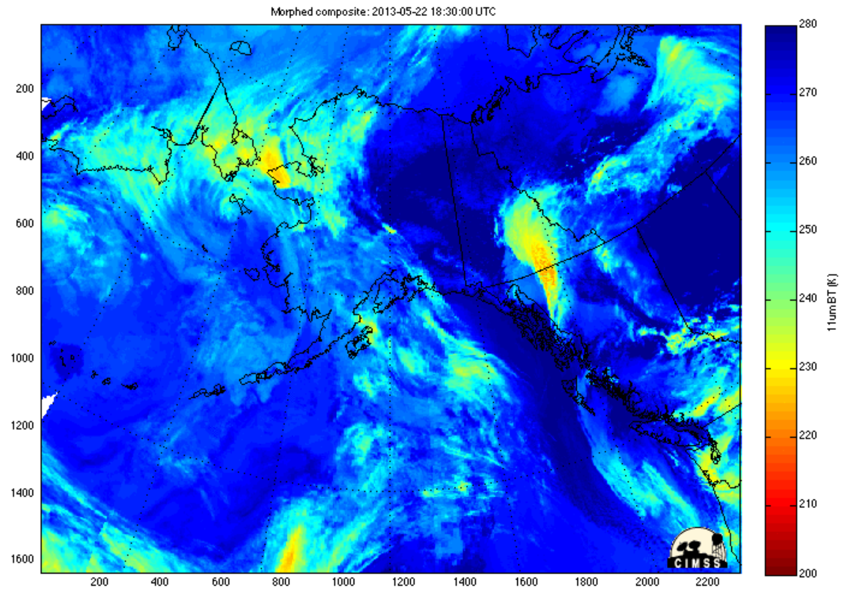


Figure 20. Morphed composite of AVHRR 11 µm scans from MetOp A, B, NOAA-15, 16, 18 and 19 for 2013-05-22 1830 UTC.

Aviation Decision Support Algorithms

Within the last decade, CIMSS has developed new GOES-R Aviation decision support requirement algorithm methodologies to support Federal Aviation Administration (FAA), NWS, and commercial airlines flight planning and in route situational awareness. Specifically, the NOAA-funded GOES-R Aviation AWG was formed in November 2006 to assess satisfying aviation related GOES-R science requirements as defined in the GOES-R Mission Requirements Document. A suite of aviation decision support related algorithms were developed and are being evaluated to assess meteorological hazards to aircraft derived from the current generation of GOES and European SEVIRI imager data in preparation for the GOES-R launch. CIMSS addressed needs for satellite-based aviation decision support products such as convective initiation, overshooting-top/enhanced-V, turbulence, and volcanic ash/SO2 hazards. These new methodologies have relevance to the GOES imager and SEVIRI today, and product utility has been improved through satellite Proving Ground activities at the AWC and SPC. In the coming years satellite-based decision support for aviation in order to improve future air transportation route planning and warning (Joint Agency NextGen activities) for the general public with an emphasis on successfully bridging research to operations will also be discussed.

One example of an aviation requirement leading to volcanic ash research at CIMSS encompasses multiple projects and supports multiple sensors. Originally the volcanic ash research group was assembled to support the GOES-R Aviation AWG volcanic ash requirement of retrieving the volcanic ash cloud-top height and column mass loading. The GOES-R AWG work resulted in a two-step approach for meeting these requirements—the first algorithm is designed to detect volcanic ash while the second algorithm performs the physical retrievals to determine the cloud-top height, column mass loading, and effective particle size using a 1-DVAR approach. The algorithms have been completed and delivered to the GOES-R Program Office. The GOES-R AWG volcanic ash group continues to support the AWG by participating in technical interchange meetings and answering questions related to the algorithm theoretical basis document (ATBD).

More recently, GOES-R Risk Reduction (GOES-RRR) determined that the AWG volcanic ash requirements would underutilize the GOES-R capabilities (e.g., the AWG products are not designed (or required) to issue alerts to forecasters when an ash cloud was identified, which is necessary to fully utilize the 5-minute refresh rate expected from GOES-R ABI to support the 5-minute volcanic cloud warning criteria established by the international aviation community). As a result, GOES-RRR funding was awarded for the development of a fully automated volcanic cloud alert system for GOES-R. Specifically, the goal is to identify volcanic clouds with skill comparable to a well-trained human analyst in a computationally efficient manner, with very low false alarm rates, and have the ability for multiple methods of product dissemination.

Most recently, the JPSS Risk Reduction program identified volcanic ash detection and physical retrievals as a missing component to the suite of VIIRS products. The VIIRS instrument has fewer spectral channels than the GOES-R ABI (e.g., missing the 13.3 μm channel used by GOES-R volcanic ash retrieval algorithm), but does contain an 8.5 μm channel—which is critical for volcanic ash detection. The JPSS Risk Reduction program awarded funding to modify the GOES-R volcanic ash detection and retrieval algorithms for optimal performance with the available VIIRS spectral channels.

As noted earlier, an automated volcanic ash alert system has been running in real-time at CIMSS for nearly a year, processing imagers aboard the GOES-EAST, GOES-WEST, MODIS, Meteosat, and MTSAT satellites. Operational personnel at the Anchorage and Washington DC Volcanic Ash Advisory Centers, as well as Alaska Volcano Observatory and United States Geological Survey scientists, are evaluating the alerts. These partnerships and evaluation of the automated alert system will continue and grow during the remainder of 2013.

CIMSS has also been conducting research into satellite-based detection of areas where the possibility of atmospheric turbulence is enhanced due to convection, tropopause folds, and/or mountain waves. We have been collaborating with the National Center for Atmospheric Research (NCAR) turbulence team, which is responsible for the NOAA AWC Graphical Turbulence Guidance (GTG) nowcast product to identify possible areas in which satellite-based turbulence interest fields would provide value added information.

iii. From Information to Knowledge

Algorithms are used to transform satellite radiance measurements into information about our environment. This information needs to be placed in a scientific context to gain a better understanding of Earth's natural systems. This section provides a few specific examples of activities at CIMSS that have contributed to improving our understanding of weather phenomena, environmental modeling, and long-term monitoring that contribute to the CIMSS mission by transforming information into knowledge.

Satellite observations play an important role in modern forecast systems. Observations in the visible, infrared, and microwave spectrum provide vital information on the atmosphere states; however it is expensive to build and maintain these new observation systems. To assess the potential impact of these measurements on weather forecasting, scientists design OSSEs and CIMSS researchers are no exception. These experiments help to assess how the information embedded in the observations improve our knowledge of the atmospheric structure. For example, CIMSS is collaborating with AOML and JCSDA to study the unique value of a geostationary advanced infrared (IR) sounder for severe weather warning and short-range forecasting, and to develop methodologies for simulating the geostationary advanced IR sounder data from nature runs for OSSE. As part of the OSSE project, CIMSS is responsible for generating the simulated radiance/brightness temperature (Tb) from future instruments.

CIMSS scientists help familiarize operational forecasters, numerical modelers and physical scientists with the capabilities of GOES-R. For example, as part of the NOAA Hazardous Weather Testbed (HWT) Spring Experiment, the Center for the Analysis and Prediction of Storms (CAPS) at the University of Oklahoma has produced high-resolution ensemble model forecasts in real-time over the CONUS since 2007. By utilizing national supercomputing resources, sophisticated forward radiative transfer models were used to generate synthetic infrared brightness temperatures at hourly intervals for several ensemble members during the 2012 and 2013 HWT Spring Experiments. Since the ensemble members employed different cloud microphysical and planetary boundary layer (PBL) parameterization schemes, an evaluation of the radiative transfer model and parameterization schemes was also possible. The synthetic satellite imagery was made available to the HWT as part of the CIMSS GOES-R Proving Ground activities. Figure 21 shows a representative example of synthetic GOES-13 10.7 micron imagery from four of the CAPS ensemble members at 22 UTC on 22 May 2012. The ensemble members had identical configurations except for using different cloud parameterization schemes. Inspection of the synthetic imagery shows that the deep convection across the central U.S. was very sensitive to the assumptions made by each microphysics scheme. Synthetic GOES-13 infrared brightness temperatures generated during the 2012 HWT were compared to real satellite observations to assess the ability of various microphysics and PBL parameterization schemes in the WRF model to accurately simulate the spatial and temporal characteristics of the cloud field.

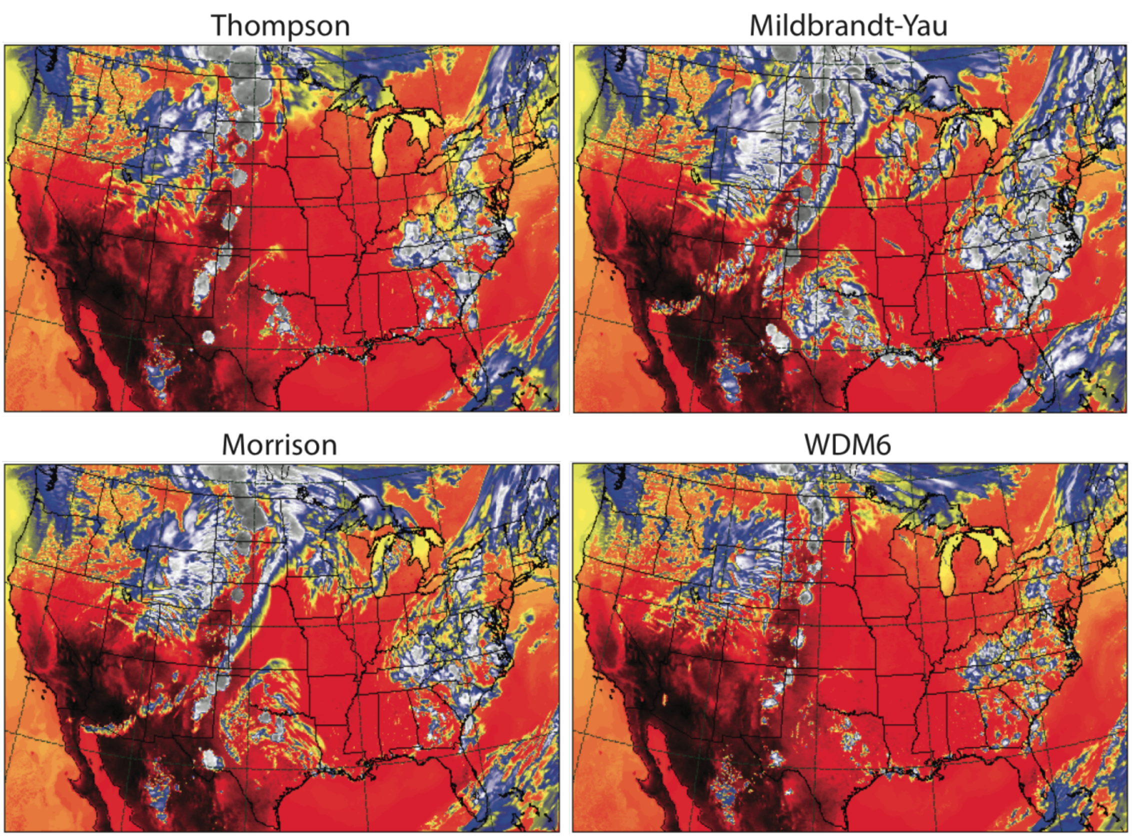


Figure 21. Simulated GOES-13 10.7 micron brightness temperatures (K) valid at 2200 UTC on 22 May 2012 for four of the CAPS ensemble members differing only in their use of microphysics parameterization schemes.

CIMSS researchers have designed and implemented a software system that will allow investigators to quantitatively assess the value of an atmospheric observing system to operational mesoscale numerical forecasts. The system uses the construct of the Observing System Experiment (OSE), which allows for the objective assessment and comparison of existing operational observing systems in a controlled software environment. Observations that represent the characteristics of the observing system being tested are synthesized from forecasts generated by a sophisticated numerical prediction model that is independent of the operational assimilation system being used. These forecasts are referred to as the "true," or "nature" atmosphere. The forecast model used to produce the "nature" atmosphere must have a known performance history, and must be calibrated against reality. The observations that are synthesized from the "nature" atmosphere must mimic, as close as possible, those observations from the real observing system that is being assessed. The OSE system described here is unique in that it attempts to measure the impact of a designated observing system over a limited area. Previous applications of the OSE construct have been performed using global prediction models, which are not influenced by pre-specified lateral boundary conditions. Every attempt was made to isolate the assimilating forecast model from the influence of pre-specified lateral boundaries.

The software system described above can be extended to include proposed, next-generation, observing systems. These assessments are also performed using OSSEs. Observations for these experiments are simulated using projected instrument characteristics. In this context future-observing systems can be compared to existing systems to determine if there is value added in the form of improved forecast skill.

CIMSS scientists are studying how to best combine the advanced imaging products from GOES-R and the advanced sounder data from polar-orbiting satellites to support high impact weather warning, nowcasting and short range forecast applications. Severe weather warning, monitoring and forecasting requires nearly continuous monitoring of the vertical temperature and moisture structure of the atmosphere on various spatial scales, the value of combining the high spatial and temporal resolution GOES-R Advanced Baseline Imager (ABI) and the advanced IR sounder observations for high impact weather (convective storms, tropical cyclones, etc.) warning, nowcasting and short-range forecasting are studied and demonstrated using AIRS, CrIS, MODIS, and the current GOES Sounder observations. The group has designed and developed a demonstration system for tropical cyclone forecasts with combined GOES-R water vapor and JPSS sounder data. Observations of atmospheric temperature and moisture information in the environment region are very important to predict the genesis, intensification, motion, rainfall potential, and landfall impacts of TCs such as Sandy through numerical weather prediction (NWP) models.

CIMSS is working with CIRA scientists on a project to improve the prediction of downslope wind events at select western U.S. locations using a combination of GOES imagery and output from numerical models. A statistical method was previously developed at CIRA to predict downslope windstorm events in Ft. Collins, CO using model output such as midtropospheric directional shear and thermal stability. The collaboration extends that work by adding GOES predictors that are not well resolved in numerical models (such as evidence of orographically-forced mesoscale vertical motion), as well as to create similar models for other locations that are prone to severe downslope winds. GOES Water Vapor (WV) imagery was collected for about 1250 events to examine potential predictors for Ft. Collins high wind events. A set of 9 potential predictors was tested using a logistical regression method, and several of the predictors showed great promise in improving the forecasts for downslope winds. The "Terrain Pattern Score" is a derived product that indicates the amount of alignment between the patterns in WV brightness temperatures and the terrain underneath, which serves to identify downslope wind conditions such as drying patterns and updraft-induced cloud banks. Figure 22 is from 4 January 2006 at the time of an observed downslope windstorm in Ft. Collins.

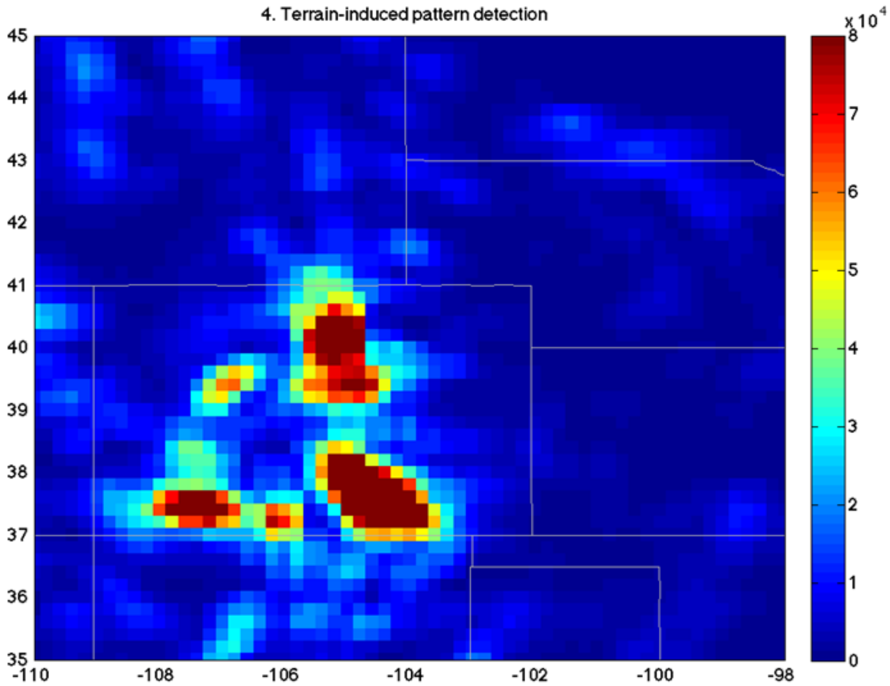


Figure 22. GOES water vapor-derived Terrain Pattern Score over Colorado valid at 0015 UTC on 4 January 2006, at the same time as an ongoing downslope windstorm in Ft. Collins, CO.

iv. Applying Knowledge

CIMSS recognizes the value of getting access to data and algorithms to transform data into information that, when interpreted correctly, leads to improved knowledge about our world, which leads to better decisions. Sometimes the lack of access to information hinders this decision-making process. Thus, CIMSS develops software packages for international distribution that allows any ground station capable of receiving NASA EOS Terra and Aqua and Suomi NPP direct broadcast imaging and sounding data to produce a suite of geophysical products in real time for multidisciplinary applications.

Accurate retrievals from hyperspectral sounder radiance measurements under both clear and cloudy sky conditions are valuable sources of mesoscale information and have the potential to greatly enhance regional weather prediction capabilities. To encourage the operational use of hyperspectral retrieval data in NWS forecasting offices, retrieval products from AIRS (Atmospheric Infrared Sounder), IASI (Infrared Atmospheric Sounding Interferometer) and CrIS (Cross-Track Infrared Sounder) are prepared for near real-time viewing and analysis in close collaboration with Alaska Region researchers and forecasters. With a fast, multi-instrument sounding retrieval algorithm now available (the dual-regression retrieval algorithm was released in November 2012 under the CSPP), real-time information from multiple sounders can be examined for the first time. It is anticipated that this newly available information source, if used together with traditional NWP data sources, will help forecasters to prepare more timely and accurate forecasts and severe weather warnings. In high latitudes, such as the Alaskan region, overpasses by the polar-orbiting satellites (Aqua, Suomi NPP, MetOp-A and MetOp-B) are frequent enough to provide sufficient temporal and spatial coverage to allow the study of atmospheric dynamics.

CIMSS tropical cyclone (TC) research also supports applications in weather forecasting. CIMSS is internationally known for its tropical cyclone research. The development of the tropical cyclone satellite research and applications program at CIMSS goes back to the 1980s. This research and applications program examines new approaches for analyzing TCs using satellite sensor technologies, computer-based methods, and display capabilities, with the goal of increasing our knowledge about tropical storms and improving forecasts. Example activities that CIMSS scientists are engaged in:

- Estimating TC intensity from multispectral sources (infrared and microwave) and satellites (GEO and LEO),
- Correlating satellite observations with TC behavior in order to gain a better understanding of the processes affecting TC intensity and track changes,
- Optimizing satellite winds impact on NWP in TC events through collaborations with the data assimilation community, and
- Developing new satellite-based TC products and diagnostic fields to aid in prediction and research by working closely with TC forecasters and analysts.

This information extracted from satellite observations is extremely valuable to hurricane forecasters. A good example of this research is the application of the new JPSS ATMS microwave instrument to monitor the intensity of Super Typhoon Jelewat in Figure 23.

The formation of a secondary outer concentric eyewall in a hurricane usually precedes large intensity and wind structure changes. These changes are particularly difficult to forecast because they are not captured well by the standard numerical and statistical guidance. Consequently, when the formation of a secondary eyewall is observed or predicted in an operational setting, forecasters must rely on expert judgment based on past experience to subjectively modify the objective intensity forecasts provided by the available guidance. CIMSS scientists are providing objective models on the probability of secondary eyewall formation and the associated intensity and structure changes at various forecast lead times. These models will be transitioned into operational testing at the National Hurricane Center.

Satellite imagery of the poles has gained value as a tool for forecasters as they apply their knowledge to the forecasting problem. For over 20 years, the Antarctic Meteorological Research Center (AMRC) has been making Antarctic satellite composite imagery using observations from both geostationary and polar orbiting satellite platforms. These satellite composites have inspired the development of an Arctic satellite composite, developed and demonstrated with funding from the National Science Foundation during the International Polar Year. As a result of this demonstration effort, the OPC formally filed a request to have these composites made routinely by NOAA to support their increasing forecast efforts and transportation in an increasingly ice-free Arctic. Other groups within NOAA have requested to make use of the composites including the Weather Prediction Center (formerly the Hydrometeorological Prediction Center), the NWS Alaska, and the National Ice Center. The composite is also provided to the Satellite Proving Ground for Marine, Precipitation, and Hazardous Weather Applications program. The AMRC is creating 4-kilometer nominal resolution composites on an hourly basis in 5 different spectral channels centered over the entire Arctic basin and adjacent continental regions. The five bands include the infrared window channel, visible channel, water vapor channel, shortwave and longwave infrared channel. All available geostationary and polar orbiting satellite observations are used in the composite. Composite imagery resulting from this project and imagery from prior test versions are being provided to end users for evaluation. Imagery can be found on the Web at http://arctic.ssec.wisc.edu.

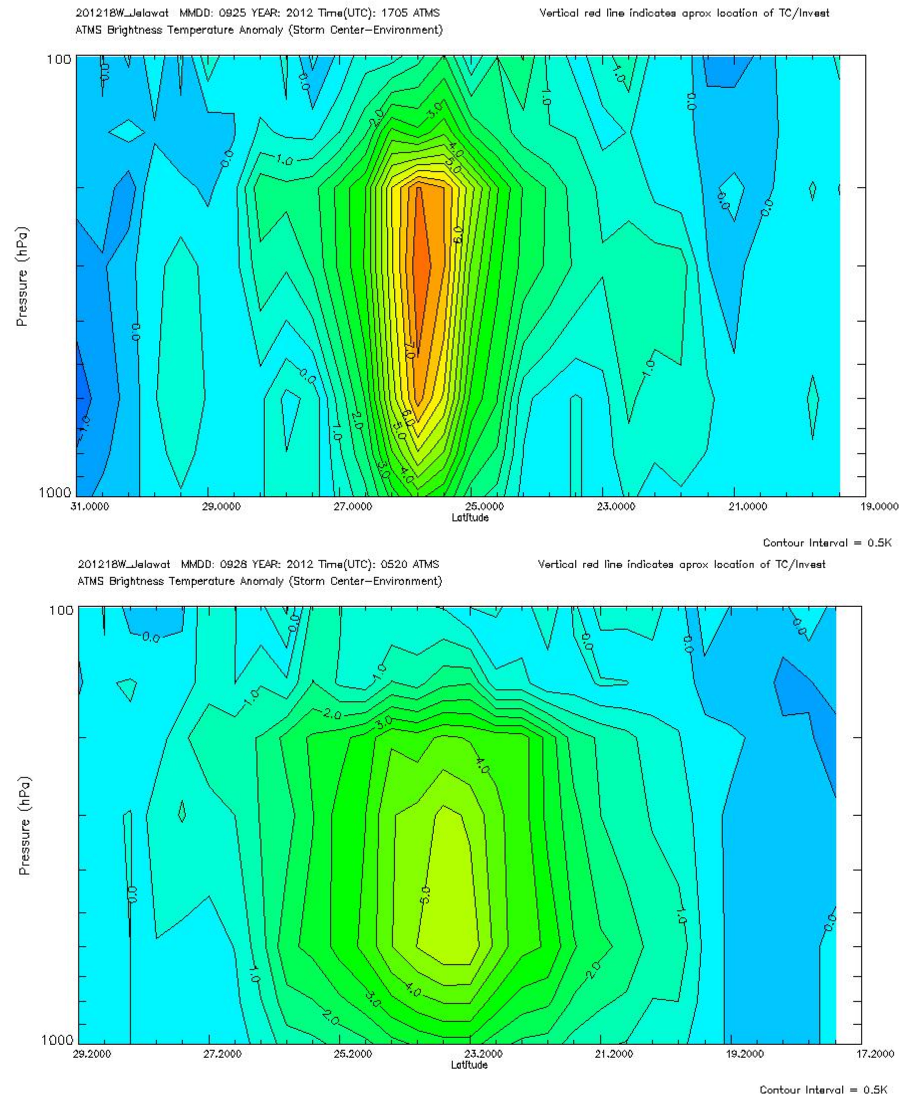


Figure 23. ATMS brightness temperature anomaly cross section for Super Typhoon Jelewat on September 25, 2012 (top) and September 28, 2012 (bottom). By the 28th, the Tb anomaly is reduced in magnitude while also expanding horizontally as the system underwent weakening.

v. Defining New Capabilities

Knowledge gains often clarify observational needs. This is particularly true in the Earth sciences where observations play a key role in advancing the sciences. CIMSS is actively involved in exploring future needs for satellite remote sensing of the environment. CIMSS has a long history of working with what were once considered future satellite systems (e.g., VISSR, VAS, GOES-I, GOES-R, Terra/Aqua, and Suomi NPP) and those in the planning stages (e.g., GOES-R and JPSS). As part of SSEC, CIMSS is an ideal partner for NOAA and NASA engineers and scientists in preparing for the next generation satellite instruments.

vi. Education

The next section addresses our education and outreach programs. Here we note the value of the NOAA proving ground and test-bed activities. In these collaborations, forecasters get to experience the latest research and the researchers are exposed to the forecasters' challenges and needs. This work supports crossing the 'valley of death' as we work to transition research to operations. There is no question that CIMSS researchers excel in basic research, but we are dedicated to finding ways to apply that knowledge.

4. Education/Outreach

A. What types of educational activities/opportunities (K–12, undergraduate and graduate students) does the Institute offer on an ongoing basis?

CIMSS is committed to the development of a weather-ready, science literate society. CIMSS's location within SSEC at the UW-Madison is ideal for engaging and educating students of all ages. CIMSS scientists and educators participate in numerous education and public outreach activities on the topics of weather, climate and satellite remote sensing. On-going activities range from sponsoring a time-honored STEM science camp for high school students to teacher workshops on and off campus, outreach programs using NOAA's Science On a Sphere (SOS), developing and distributing online education activities, engaging undergraduate and graduate students in research projects, and training professionals through workshops, on-line curricula, blogs and webinars. Due to the steady expansion of education and outreach programming at CIMSS, the CIMSS Director formally established the **CIMSS Education and Public Outreach Office** in 2012. CIMSS EPO promotes satellite meteorology resources to advance weather and climate literacy, often in collaboration with national and international partners.

i. Formal Education - Graduate Students at CIMSS

CIMSS is currently supporting 16 Graduate students studying for their Master's or Ph.D. degrees in AOS at the UW-Madison. Research activities range from exploring new methods of remote sensing to studying media and climate change to data assimilation. This research contributes to the goals of individual CIMSS grants and contracts. Graduate students at CIMSS have an academic advisor in AOS and a science advisor in CIMSS. Graduate students work directly with CIMSS research teams, giving the student valuable experience for their future careers. Refer back to Figure 7 to see the number of CIMSS graduate students receiving Master's or Ph.D. degrees over time.

CIMSS also participates in annual CoRP gatherings and recently hosted the 2013 symposium on "Toward a Weather-Ready Nation and Resilient Coastal Communities." (http://cimss.ssec.wisc.edu/corp/2013/) CoRP symposia highlight research by graduate students and early-career scientists from NESDIS cooperative institutes. They give young scientists the chance to practice their communication skills while connecting with peers. The 2013 agenda included several panels, a poster session and a luncheon with a UW-Madison speaker discussing networking and career planning.

Figure 24. The 2013 CoRP Symposium at CIMSS.

ii. Formal Education - Undergraduate students at CIMSS

CIMSS normally employs 2-4 undergraduate students each year who are majoring in Atmospheric Science or a related field and have expressed interest in pursuing advanced degrees. By providing hands-on experiences for undergraduates, CIMSS plays a valuable role in integrating research and education at UW-Madison. By working with CIMSS scientists, these students experience collaborative thinking and become engaged with other scientists in research activities and the research environment. They frequently work in the outreach activities that CIMSS conducts, such as open houses, workshops and science camps. The majority of these students have gone on to get their masters or PhD and later work in science-related careers.

For example, Britta Gjermo is a senior at UW-Madison majoring in Atmospheric Science. She is in the Air Force ROTC and will be commissioned as a Weather Officer in the Air Force when she graduates from college. After winning a Suomi Scholarship (see below), Britta started working at CIMSS/SSEC her freshman year, where she contributed to *Satellites See Wisconsin*, a public display of satellite imagery at the Dane County Regional Airport in Madison, as well as to various conferences, plus the annual CIMSS Student Workshop. In addition to giving building tours and acting as the Student Workshop camp counselor, Britta recently started contributing to the CIMSS PyroCB blog (https://pyrocb.ssec.wisc.edu/archives/198).

The Suomi Scholarship Awards from CIMSS are given to several UW System incoming freshmen each year who are interested in careers in the physical sciences. Award winners are given $1000 each. A few past award recipients (for example, Jordan Gerth and Jason Brunner) have gone on to become graduate students working with CIMSS researchers.

iii. Formal Education – K-12 teachers and students

CIMSS welcomes students of all ages but focuses outreach on grades six and higher for both students and teachers. CIMSS' flagship outreach event is the Student Workshop on Atmospheric, Satellite, and Earth Sciences (http://cimss.ssec.wisc.edu/studentworkshop/) established in 1991. One of the first STEM (science, technology, engineering and math) camps in the country, the CIMSS Student Workshop has introduced hundreds of students to the wonders of science. Participating students experience Earth science education, research, and technology firsthand, with visits to nearby venues such as a TV studio to meet with a TV meteorologist, the local National Weather Service forecast office, and field trips to explore geological landforms. Students stay in college dorms and spend a week at the UW–Madison working with data and computers in various earth science education activities. Case studies and activities span a variety of topics in the physical sciences, such as:

- **Earth Science**: Plate tectonics, earthquakes, and glaciology;
- **Atmospheric Science**: Weather satellites, map analysis and forecasting, global climate change; and
- **Satellite Remote Sensing**: Monitoring of natural resources from earth orbiting satellites, digital image processing, and geographic information systems.

A majority of the students go on to pursue science majors in college and work. A recent informal survey conducted via Facebook and postcards sent to the childhood homes of past workshop participants indicated that respondents (n=12) had continued in science-related careers. For example, several cited graduate school while older workshop graduates listed jobs that ranged from the US Forest Service to masters-prepared social work to CIMSS research assistant.

CIMSS has also trained over 400 middle and high science teachers at two-day workshops in Madison and elsewhere, funded by NOAA, NASA, the Wisconsin Space Grant Consortium and NSF with partners that include the AMS, other ESIP member organizations, Sally Ride Science, the Satellite Educators Association, and collaborating universities.

The following is a list of CIMSS educator events over the past decade:

2003 – Satellite Meteorology Teacher Workshop, CIMSS, UW-Madison
– Wisconsin Weather Stories (http://weatherstories.ssec.wisc.edu/), CIMSS, UW-Madison
2004 – Satellite Meteorology Teacher Workshop, CIMSS, UW-Madison
2005 – Satellite Meteorology Teacher Workshop, CIMSS, UW-Madison
2006 – Satellite Meteorology Teacher Workshop, CIMSS, UW-Madison
2007 – Satellite Applications in Geoscience Education Teacher Workshop, CIMSS, UW-Madison
2009 – ESIP Teacher Workshop, University of California-Santa Barbara
2009 – Climate Change Awareness for all Educators Workshop, CIMSS, UW-Madison
2010 – Climate Change Awareness for all Educators, NOAA Science Center, Silver Springs
– Climate Literacy Ambassadors Teacher Workshop, CIMSS, UW-Madison
– ESIP Teacher Workshop, University of Tennessee- Knoxville
2011 – Climate Literacy Ambassadors Teacher Workshop, CIMSS, UW-Madison
– ESIP Teacher Workshop, Santa Fe, New Mexico
2012 – Climate Literacy Ambassadors Teacher Workshop, CIMSS, UW-Madison
– ESIP Teacher Workshop, CIMSS, UW-Madison
2013 – ESIP Teacher Workshop, University of South Carolina-Chapel Hill

Figure 25. These pictures are from the 2010 ESIP Teacher Workshop in Knoxville Tennessee. On the left is a group shot and the right features a scene from a breakout session taught by CIMSS Director Steve Ackerman.

In 2012, CIMSS launched a unique technology lending library for middle and high school science teachers. The **CIMSS iPad Library** loans iPads to science teachers for an entire school year. The first units were distributed at the 2012 ESIP Teacher Workshop where participants learned about several climate-related Apps, including SatCam, an application for iOS devices where users collect observations of cloud and surface conditions coordinated with an overpass of the Terra, Aqua, or Suomi NPP satellite.

iv. Formal Education - Professional Training

Most of our efforts in this area focus on Web-based training and teletraining, support of the CIMSS Satellite Blog and intensive workshops on satellite remote sensing for graduate students and early career scientists. Examples of our activities are noted below.

CIMSS provides distance learning tools, lesson modules, and related materials to the NWS through the VISIT program. VISIT prepares and presents case studies and examples of satellite data in AWIPS format for NWS forecasters with the instructional goal of optimizing satellite data to increase situational awareness and improve near-term forecasts (Figure 26).

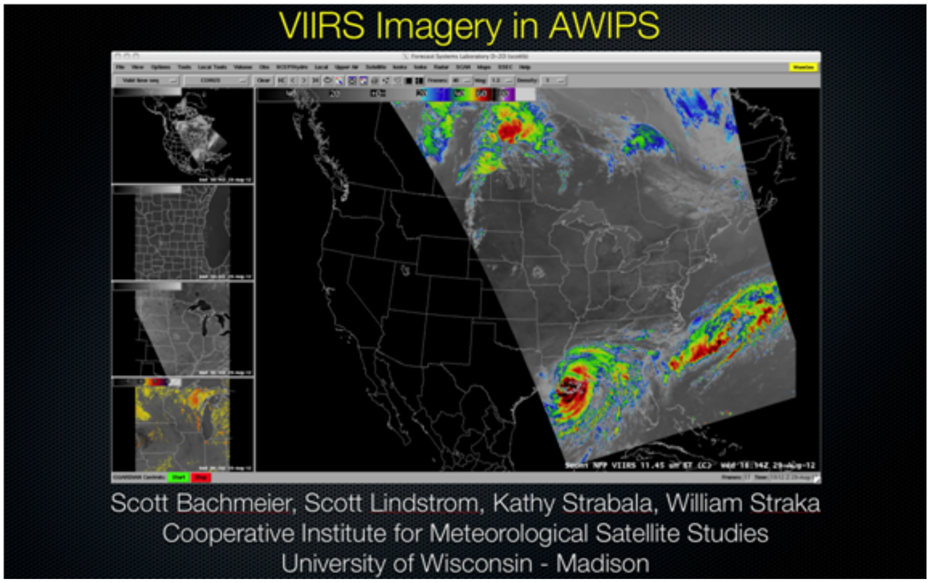


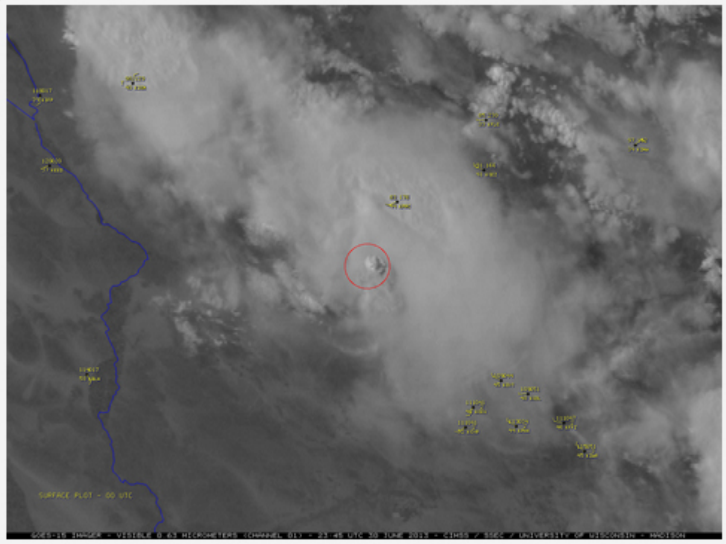
Figure 26. Title slide from the recently-developed VISIT module "VIIRS Imagery in AWIPS."

Training module development has focused on products and methodologies that will be useful for the upcoming JPSS and GOES-R satellite era. These include the UW-Madison Cloud-Top Cooling algorithm, the UW-Madison Objective Overshooting Top Detection algorithm, and the Fog/Low Stratus data fusion product. One of the most recent training modules describes Suomi NPP VIIRS data that are available now in AWIPS. Recorded versions of these training modules have been inserted into the Department of Commerce Learning Center, and a number of live instructor-led versions of the training modules have also been offered. To date, seventeen training modules have been developed at CIMSS.

CIMSS developed the VISITview collaboration and teletraining software toolkit that delivers the VISIT lessons. Along with frequent use by the NWS, VISIT and VISITview are also being employed by the WMO for use with their Virtual Lab. The software is freely available. A spin-off of the VISITview software is the Animations applet (AniS), which was adapted by hundreds of sites world-wide to show animations of weather-related data. AniS was re-coded in Flash as "FlAniS" in 2008. The NWS uses FlAniS software for their Web-based radar animations.

Recognizing the importance of working with NWS formats, CIMSS scientists have further refined AWIPS (and AWIPS-II) capabilities at CIMSS. A stable AWIPS-II platform at CIMSS allows for manipulation of CIMSS-produced datasets into formats that are compatible with AWIPS-II. Thus, CIMSS researchers can continue to create the products and AWIPS-II-based training modules that forecasters wish to see (for example, Cloud-Top Cooling, or MODIS-based Sea-Surface Temperatures) .
CIMSS continues to develop the SHyMet training course through close collaboration with experts at CIRA at Colorado State University. Specifically, CIMSS has assisted in the development of modules for the following courses: Intern, Forecaster, Tropical, Severe Thunderstorm Forecasting, and the pending GOES-R. Much of the data for training modules has been placed on the CIMSS Satellite Blog (http://cimss.ssec.wisc.edu/goes/blog).

The CIMSS Satellite Blog and @CIMSS_Satellite Twitter feed showcase meteorological satellite images and products created by scientists and researchers at CIMSS. The main target audience is professional meteorologists, but the CIMSS Satellite Blog has been cited by several newspapers and magazines, including the *New York Times* in a July 2013 article about the Yarnell Fire tragedy. (http://go.wisc.edu/39s18r).



GOES-15 0.63 µm visible channel images (click image to play animation)

Figure 27. Screenshot from the CIMSS Satellite Blog post on the Yarnell Fire.

CIMSS also supports the GOES-R proving ground activities. A proving ground provides resources for testing and validating ideas, technologies, and products before they are integrated into operational use. Implementation of a NWS proving ground for GOES-R ensures that all changes, either technological or procedural, undergo rigorous integrated testing before implementation. The proving ground concept allows developers at CIMSS and other research centers to be involved at an early stage in product development with forecasters, providing the opportunity for interaction between developers and users. Several GOE-R proxy decision support products developed at CIMSS were demonstrated with operational forecasters to obtain feedback, including:

1. HWT Spring Experiment (7 May – 15 June, 2013). Participants included 28 forecasters and 16 visiting scientists.
2. NHC Tropical Cyclone Demonstration (1 Aug. – 30 Nov. 2013) Participants included forecasters from NHC
3. AWC Summer Experiment (4 June – 15 June). Participants included AWC forecasters and FAA representatives.
4. HPC/OPC/TAFB/ and SAB demonstrations (ongoing: focus on precipitation and ocean applications).
5. High Latitude and Arctic Testbed (ongoing: focus on snow/ cloud/ volcanic ash/ and aviation applications). Participants include NWS Alaska Region
6. Air Quality (ongoing: focus on aerosol detection).
7. Pacific Region OCONUS Demonstration (ongoing: focus on tropical cyclones/ heavy rainfall/ and aviation applications). Participants include NWS forecasters and scientists from the University of Hawaii.

In addition, the Milwaukee-Sullivan National Weather Service Forecast Office receives the real-time data feed via AWIPS. This collaboration provides additional operational feedback. During forecaster shifts from 1 June – 31 October 2012 CIMSS developers traveled once per week to the WFO in Sullivan/WI to work a 6-8 hour GOES-R PG shift one-on-one with a forecaster. Feedback included:

- Bandwidth is an issue and may limit our ability to get all the data into AWIPS-II when GOES-R becomes operational in a few years. Forecasters emphasized that any solutions to overcome bandwidth limitations still provide them with the highest spatial resolution and the fastest temporal resolution. Lag times between image and availability in AWIPS-II should be minimal. If the whole image can't be provided, then send WFOs a high resolution sector to preserve the native resolution.
- In general, the raw products are preferred over derived products. One exception is the fog product, which is provided at high resolution. The forecasters prefer products with quantitative properties, rather than "yes/no" formats. For example, providing the actual Cloud Top Cooling Rate versus "Convective Initiation Likely" points.

Finally, CIMSS organizes and participates in 'boot camps' in satellite meteorology and remote sensing. These boot camps are intensive one- to two-week all-day workshops that train participants in various aspects of satellite remote sensing of the Earth. For example, CIMSS participated in three EUMETSAT summer schools in workshops held in Bracciano, Italy (in collaboration with Italy's Centro Nazionale di Meteorologia e Climatologia Aeronautica). These workshops train forecasters and scientists on how to get the most from EUMETSAT satellite data and products, which requires for them to gain an understanding of satellites and remote sensing (http://training.eumetsat.int/course/index.php?categoryid=50).

v. Informal Education and Public Outreach

Advancing science literacy via informal venues has a high priority in the CIMSS EPO program. Our efforts include reaching audiences through multiple mediums, ranging from on-line digital resources to written reports and exhibits to hands-on interactions at public events. For example, CIMSS will often take a traveling version of the 3D globe to science festivals and State Fairs. Recently, CIMSS staffed a table at the Wisconsin Capitol Building in April 2013. The exhibit featured the ever-popular weather applets and other Internet displays of CIMSS digital resources, as well as a poster hand-out of Hurricane Sandy showing the hurricane as it merged with a cold front (captured under moonlight by the VIIRS instrument on the Suomi NPP satellite). The Suomi legacy and ensuing world-renowned satellite remote sensing research at CIMSS/SSEC are integral to every CIMSS outreach effort.

Figure 28. Wisconsin mascot Bucky Badger holds a VIIRS poster image of Hurricane Sandy in the Wisconsin Capitol Building.

Another recent example of informal outreach at CIMSS took place on August 22, 2013 when CIMSS Director Steve Ackerman emceed a Town Hall discussion featuring Louis Uccellini, the Director of the NWS, who presented on the NWS Weather-Ready Nation initiative. Uccellini noted that 99% of the data that the NWS uses is remotely sensed, mostly from satellites, at which point Uccellini acknowledged CIMSS founder, Vern Suomi, and his pioneering contributions to satellite remote sensing.

CIMSS has also been a leader in educational software design for decades, pioneering distance learning software and computer-based education tools like the popular applets that are highly interactive teaching and learning activities which allow users to explore physical processes or phenomena such as tornadoes, air density effects on baseballs, thunderstorms, rainbows, snowflake crystals and more. To keep up with software changes, CIMSS scientists have been converting the applets from Java to HTML5, a large but important task. These applets are also featured in The Why Files, a Web-based repository of articles that help explain the science behind the news. Initially started as an adjunct to the NSF funded National Institute for Science Education, this Web resource has proved to be enormously popular, and is now funded from UW–Madison and is run out of the UW–Madison News Service.

CIMSS is active in social media with two Twitter feeds and a Facebook page. The CIMSS Facebook page has over 1400 fans and features resources from the CIMSS Tropical Cyclones site, the EarthNow Blog, the CIMSS Satellite Blog, the Weather Guys Blog and imagery from CIMSS/SSEC or NOAA and NASA. The @CIMSS_Satellite Twitter feed has over 3200 followers.

CIMSS is leading an effort to create visualizations for SOS exhibits using near real-time data such as the NCDC monthly climate reports and Climate Prediction Center (CPC) seasonal outlooks. Concomitant to producing large animations for SOS with background content and trainings for museum docents, small videos (with audio) are being produced for mobile viewing and made freely available in the digital domain via a blog-style website called EarthNow (http://sphere.ssec.wisc.edu). Because the videos demonstrate what datasets look like on an SOS exhibit, they are spherically shaped (like Earth) and intuitively educational. Watching a monthly climate digest product can convey a global climate briefing in less than four minutes.

Another CIMSS climate literacy effort for informal audiences involved collaborating with UW-Madison and NOAA hydrologists to design a modern water cycle diagram that was included in a 2011 report issued by the Wisconsin Initiative on Climate Change Impacts (WICCI) on Wisconsin's Changing Climate.

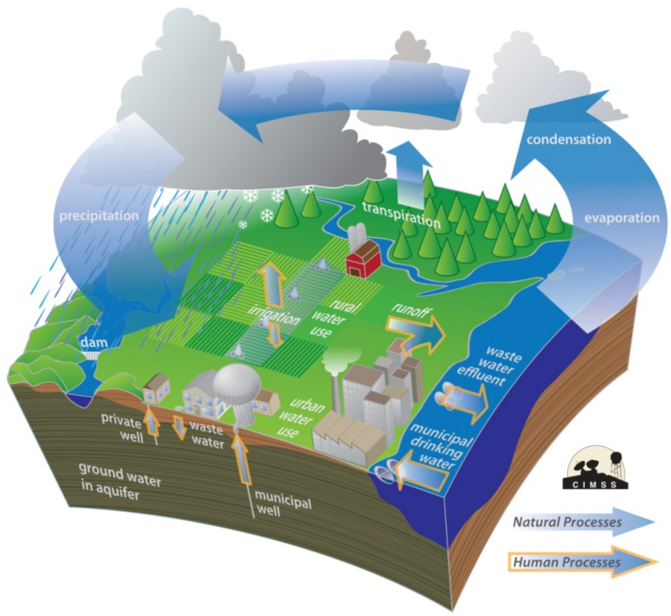


Figure 29. Water Cycle Diagram developed by CIMSS to show human processes and public water use.

UW–Madison has a long history in public outreach, with a philosophy known as "The Wisconsin Idea" which holds that University initiatives benefit the entire state and beyond. CIMSS researchers and educators take ownership of the Wisconsin Idea and seek to find suitable ways to collaborate with appropriate audiences. CIMSS EPO initiatives embrace and echo this philosophy. CIMSS staff routinely makes guest presentations and webinar lectures at workshops, conferences and science fairs. Advancing science literacy is a priority at CIMSS. This ethos is epitomized by CIMSS Director Steve Ackerman who takes every opportunity to share science in formal and informal education settings, such as his *Weather Guys* blog (http://wxguys.ssec.wisc.edu/) and monthly radio show on Wisconsin Public Radio. The *Weather Guys* also have a weekly column in the WI State Journal regional newspaper and an eBook of the columns between 2008 and 2011. Whenever possible, they discuss NOAA activities and research, as well as their benefits to society.

B. What are the current and planned outreach efforts?

CIMSS plans to continue the active outreach program documented in this report via social media, workshops, online training, public outreach events, professional training and digital resources.

CIMSS is deeply involved in GOES-R education and outreach, starting with the development of a new module on next generation satellites that was added to the Satellite Meteorology for Grades 7-12 on-line course. CIMSS/SSEC has also been creating Super Rapid Scan (1-minute interval) picture-in-a-picture animations for SOS exhibits to demonstrate future GOES-R capabilities. CIMSS is now establishing a **GOES-R Education Proving Ground** to engage middle and high school science teachers and their students in activities based on the GOES-R mission. Working in teams of two, teachers will develop and test lesson plans related to GOES-R satellite instruments. Some or all of these teachers will present their lesson plans at the 27th Satellite Educators Conference, scheduled to take place in Madison at CIMSS in 2014.

Figure 30. Screenshot from the Next Generation Satellites Module of *Satellite Meteorology for Grades 7-12.*

The 2014 NOAA Satellite Week has also been scheduled to take place at CIMSS with approximately 50 researchers gathering on the UW-Madison campus and a virtual attendance of around 600 meteorologists.

CIMSS will continue its bootcamp training activities. We are planning the next EUMETSAT training activity in June 2014 CIMSS is dedicated to maintaining the CIMSS Satellite Blog and ancillary more focused blogs on PyroCumulonimbus (http://pyrocb.ssec.wisc.edu) and Fog/Low Stratus detection (http://fusedfog.ssec.wisc.edu), and the climate digest product on the EarthNow Blog.

Furthermore, CIMSS works with the SSEC media team to ensure that communications go out in terms that the public will understand. This approach ensures the greatest possible exposure from media interactions so individuals with and without a science background become intrigued with science initiatives at CIMSS and SSEC. To that end, CIMSS contributes to two YouTube Channels: http://www.youtube.com/user/UWSSEC and http://www.youtube.com/user/satelliteblog. In addition to the examples discussed above, the media team has worked to have CIMSS satellite products displayed in the lobby of the new NOAA Center for Weather and Climate Prediction. The media team also organized the public presentation by Dr. Louis Uccellini; attendance was over 200 and provided a unique opportunity to introduce CIMSS to our new chancellor.

C. Does CIMSS have a communications plan?

Yes, SSEC has a media team that recently updated its communication plan. As a cooperative institute, CIMSS helps to educate and train the next generation of NOAA's workforce. To help meet this challenge, the SSEC media team developed an effective communication plan that sets measureable goals to generate awareness of CIMSS within NOAA, the University and the public. CIMSS leadership works with the media team to inform our target audiences of our accomplishments and how those accomplishments are relevant to them. The plan is included in Appendix I and includes a variety of tools, mechanisms and communications professionals that CIMSS utilizes to reach its audiences.

Individual PIs are an important source of breaking news and important science advances. Communicating this news is accomplished though the CIMSS Satellite Blog, social media, media team press releases and also through submitting routine short updates (referred to as 'weeklies') to the ASPB team leader.

Collecting evidence of success in our communications is a challenge. The media team is developing a manageable monitoring program that:

1. Monitors mentions of CIMSS, programs and research in order to track trends and monitor the strength of image or brand with stakeholders/audiences;
2. Compares various media platforms, trying to evaluate trends, identify strengths, shortfalls or errors;
3. Assists in evaluating the effectiveness of CIMSS media.

The communications strategies and mechanisms of today must match the needs and strengths of the audience to be reached. We work with the media team to find ways to analyze current communications tools and their effectiveness, adapting our strategies as appropriate while continuing to build effective and long-lasting relationships with our audiences and partners.

5. Science Management Plan

A. How does the Institute identify new intellectual opportunities?

The primary avenue for identifying and supporting new opportunities is through new budget resources funded through proposals to NOAA or other agencies. CIMSS resources are then devoted to these specific funded projects. Task 1 funding is used to support education and outreach efforts and internal management of CIMSS. In addition, some innovative projects are provided seed funding from SSEC resources to support initial research activities. Many of these efforts subsequently lead to fully funded proposals or provide the necessary infrastructure to support successful proposals. These efforts will be discussed below.

CIMSS scientists have numerous formal and informal methods to exchange ideas and identify new opportunities. A sample of these methods is listed below.

- Many CIMSS PIs have strong partnerships with NOAA and NASA collaborators who work together to identify new opportunities and research directions.
- There is an annual building wide poster session held in the spring where collaborations are discussed and ideas exchanged.
- CIMSS also sponsors a Science Symposium each semester where individuals are invited to present on their research or their vision for new ways of doing things.
- CIMSS conducts monthly PI meetings to discuss broad program issues, student recruitment, proposal opportunities and other issues.
- At the CIMSS Seminars, individual PIs and visitors give presentations of their research work, which enables other PIs to offer suggestions or to identify opportunities for collaboration. These seminars allow extended discussion on scientific opportunities.
- CIMSS scientists travel to present papers at conferences and attend workshops, both nationally and internationally. These face-to-face interactions are excellent sources of new ideas and often lead to collaborations.

- Many CIMSS scientists are on mailing lists for agency announcements of opportunity.
- The SSEC library also sends out a regular list of proposal opportunities.
- The Web site http://www.grants.gov has provided online information on research opportunities.

B. What are some recent examples of intellectual opportunities?

The previous section discussed some new directions that CIMSS scientists are pursuing. Recently, one of the ASPB scientists stationed here, Dr. R. Bradley Pierce, has helped to create a new research opportunity. He is an expert in air quality and chemistry modeling and data assimilation and is working with CIMSS scientists to develop this research activity at UW-Madison. By leveraging his expertise in these areas, CIMSS researchers are involved in the Tropospheric Emissions: Monitoring of Pollution (TEMPO) mission, which is part of NASA's Earth Venture Instrument program that promotes small targeted science investigations that are designed to complement NASA's larger research missions. TEMPO spectroscopic measurements in the ultraviolet and visible spectrum will provide a tropospheric measurement suite that includes the key elements of tropospheric air pollution chemistry, namely ozone, nitrogen dioxide, sulfur dioxide, formaldehyde, glyoxal, water vapor, aerosols, cloud parameters, and UVB radiation. At CIMSS, led by Dr. Pierce, Realtime Air Quality Modeling System (RAQMS) and WRF-CHEM chemical data assimilation activities will utilize TEMPO ozone and nitrogen dioxide measurements to improve air quality forecasting capabilities. Through this activity, and others like it, we have been able to leverage NASA resources to build infrastructure for CIMSS and NOAA.

Recent end-of-year funding from STAR has also enabled us to begin a new science program investigating pyrocumulonimbus (pyroCb) clouds that can occasionally develop above intense forest fires. Strong convection during pyroCb events can inject huge amounts of plume emissions containing soot, mineral dust, and “brown carbon” into the upper troposphere and lower stratosphere; however, the frequency of these events is unknown. The focus of this effort is to identify pyroCb over North America events during 2013-2014 fire seasons and to investigate the impact of these events on water and ice cloud properties inferred from geostationary and polar-orbiting platforms (i.e., current GOES and Suomi NPP). We anticipate that this seed funding will provide a new research opportunity for CIMSS.

C. What is the strategy for new starts (projects, techniques, campaigns, etc.)

Through the support of the SSEC administration, there is a great deal of infrastructure in place to assist new program starts. When a new opportunity arises, the CIMSS Director and Associate Director work with the PI to define the project goals, determine the science support needed and identify candidate scientists to participate in the program. The PI works with SSEC financial personnel to develop a budget identifying computing and other resources required for the work pursued in the proposal. Upon funding notification, SSEC administration sets up the financial account for the program (see Administrative Overview). All SSEC services are available to the project, including accounting, purchasing, travel planning and human relations support. The Director and Executive Director (ED) are available to the PI/PM (Program Manager) to resolve any problems or concerns that arise.

Since CIMSS is a ‘soft money’ institute, our strength lies in the talent of our science leadership. Part of the CIMSS philosophy is to support young investigators and assist them in getting their research program started. One area of focus is improving the CIMSS satellite data assimilation and modeling operational area. The CIMSS Director and ED chose a young scientist, Jason Otkin, to coordinate efforts between scientists at CIMSS and with collaborators at other research centers. Mr. Otkin has program management experience and a strong science background in data assimilation, numerical modeling, and model validation and is actively working on several projects closely related to the goals of this research area. With the support of the Director and ED, staff members best suited to the project goals were identified.

Several proposals were submitted to NASA and NOAA funding agencies, and when funding was awarded, teams were formed and smoothly transitioned to the research phase. Recently promoted to the "Scientist" personnel category, Mr. Otkin is active in a number of research programs, including performing data assimilation studies with researchers at the National Severe Storms Laboratory, and assessing the ability of a drought index computed using a land surface flux model and GOES satellite observations to provide early warning of worsening drought conditions to vulnerable stakeholders across the U.S.

SSEC/CIMSS has a monthly review process established for all programs, as described in the Administrative Overview. The process can be adjusted based on program size and activity. To briefly summarize, monthly financial information is generated by the tenth day of the month and distributed to the PI/PMs. At that point, the SSEC Administrative Assistant (AA) and the CIMSS Associate Director review the financial information to identify any areas of concern in spending rates and will then contact the PI/PM to discuss further if necessary. Formal meetings are also held each month between the SSEC AA and the CIMSS ED for the larger NOAA programs (GIMPAP, PSDI, Ground Systems, GOES-R). The PI/PMs attend these meetings as needed, but at least quarterly.

The program PI/PMs hold science team meetings, with the frequency and formality of these meetings typically based on program size. For smaller programs, these meetings are often held in the PI/PM's office; however, for larger groups (e.g., GIMPAP, PSDI, Ground Systems, GOES-R), the meetings are usually held in conference rooms. The CIMSS Director and/or ED are normally present at the larger group meetings. During these meetings, monthly activities are discussed and near and far term work plans are created.

D. How much of the Institute resources are reserved for new opportunities or bright ideas?

In the 1980s through early 1990s, approximately 10–20% of the CIMSS Base Grant was allocated to support 'seed' projects that were unfunded, good ideas that would likely lead to the development of a formal proposal outside of CIMSS. At that time, three or four studies were typically funded each year in this way (an example is discussed below). However, because the Base Grant funding has remained essentially unchanged during the past 20 years (around $235K per year), the real value of this funding is now less than half its original value due to inflation. The lack of growth in Base funding has eroded the ability of CIMSS to support novel ideas because there is virtually no discretionary funding available from the Base Grant. Within CIMSS, all other funding is obtained from grant and contract awards, so there are no other funding sources within CIMSS to support new opportunities or bright ideas.

In SSEC, all budget indirect charges from SSEC/CIMSS proposals are recovered by SSEC. SSEC is required to pay for all its expenses and infrastructure that supports CIMSS (e.g., everything from desks and chairs to administrative staff, to rooftop satellite receiving antennas). This arrangement with the UW–Madison Graduate School enables SSEC, if they run efficiently, to realize a small portion of the overhead for discretionary spending. Most if not all discretionary spending is invested in future research opportunities for the Center (i.e., seed money). SSEC has established a formal process for scientists to submit ideas for funding through Center discretionary funding. The SSEC Director and EDs consider these internal proposals on a case by case basis, with advice from the SSEC Science Council. This policy provides the means for a limited subset of CIMSS seed ideas to be supported.

A prime example of SSEC seed funding is the support provided to Tim Olander to incorporate the Advanced Dvorak Technique (ADT) into the McIDAS-V visualization and analysis system. The ADT is an objective tropical cyclone (TC) intensity estimation algorithm developed at CIMSS, which has become very popular with both the TC research and forecasting communities. While the CIMSS TC Web site has provided the primary portal for user dissemination of ADT output, requests for the ADT algorithm to be run locally by users are increasing. However, current platform and data requirements are limiting the distribution of the ADT to interested parties. Implementation of the ADT within McIDAS-V solves many of these issues, while also giving McIDAS-V a valuable and popular science application as part of its toolkit. Internal SSEC departmental funding was awarded to bridge McIDAS-V and end-user need to display ADT output for the National Hurricane Center.

SSEC has also supported funding for post-doc positions in CIMSS that align with new directions for the institute. The post-doc is hired half time on a particular CIMSS project, allowing the post-doc to meet CIMSS scientists and learn about the types of projects supported. SSEC funds the other half of the post-doc salary providing an opportunity for them to explore new directions. For example, Dr. Colleen Mouw was hired in this way to support remote sensing of lakes. More recently, we are pursuing the hire of Dr. Shane Hubbard who is receiving his PhD from the University of Iowa this fall. He models geographic events during hazard scenarios and how these events can be used by decision makers as they prepare and protect their communities from the socio-economic impacts of weather related disasters. His current research focuses on identifying areas of flood risk during a disaster using criteria such as road accessibility caused by flooded roadways, land use, and household income. As waters rise the magnitudes of risk change over space and time. As decision makers move resources, initiate evacuations, or construct temporary flood protection measures, having information on the level of risk over time can be helpful. The alternative event model and flood risk model are being incorporated into a spatial decision support system for flooding. This system will allow its users to model alternative events and model the change of flood risk over time within the floodplain. In addition to continuing his research efforts and seeking funding for his projects, Dr. Hubbard will also collaborate with the volcanic ash research group on methods of disseminating their products.

SSEC is also using internal funds to upgrade its mobile instrumentation vehicle called SPARC. This upgrade will have a very positive benefit to CIMSS researchers who participate in field programs. SSEC has developed a mobile capability to study the atmosphere and to make surface emissivity measurements. Several instruments are integrated into a 36-foot trailer (Figure 31) that is configured for remote operation either by using internal generators or through connections to electrical power sources found in the field. The current complement of instruments in the SPARC includes an Atmospheric Emitted Radiance Interferometer (AERI), a ceilometer, a meteorology surface station, a radiosonde launch receiver, and a GPS total precipitable water instrument. The facility was acquired in 2013 to replace the 36-foot long Winnebago which provided a similar function. When the mobile laboratory is not supporting field experiments it is continuously operated at SSEC and used for UW-Madison educational purposes.

Figure 31. The new SSEC Portable Atmospheric Research Center (SPARC) facility.

E. What is the demographic structure of the Institute employees?

CIMSS has experienced a steady increase in the size and scope of its research programs over its 33-year history. Figure 32 shows the number of CIMSS Associates over the past 18 years. The size of the CIMSS staff has nearly tripled during this period. Figure 33 shows the current composition of the CIMSS staff. It should be noted that many of the NOAA/NESDIS scientists stationed at CIMSS are also PIs, raising the number of PIs associated with CIMSS who are submitting proposals and leading research projects to over 30. The CIMSS research staff are primarily meteorologists and programmers, but their expertise is wide ranging, providing strong support for a variety of programs. CIMSS conducts its research by building teams to accomplish program goals. The staff can move from one project to another or work on multiple projects to provide expertise and stability to the CIMSS research program.

Every 5 years SSEC does a survey of its employees to gather input on demographics and job satisfaction. In 2010 the response rate was 40% and included 21% women and 79% men. The age distribution was: 25 and below: 9%, ages 26-35: 28%; ages 36-45: 23%; 46-55: 14% and ages 56 and above: 26%. The average years at UW-Madison was about 15 years, and the average years in their current position was almost 9 years.

CIMSS currently supports 16 graduate students. These students have an academic advisor in the AOS, and a science advisor within CIMSS that is part of the student's thesis committee. Director Ackerman is a tenured professor within AOS and meets with all CIMSS-supported students in weekly meetings and on an individual basis.

CIMSS has a long history of scientist exchange, especially through international collaborations. Extended term scientist exchange programs exist with agencies in South Korea, China, and Europe.

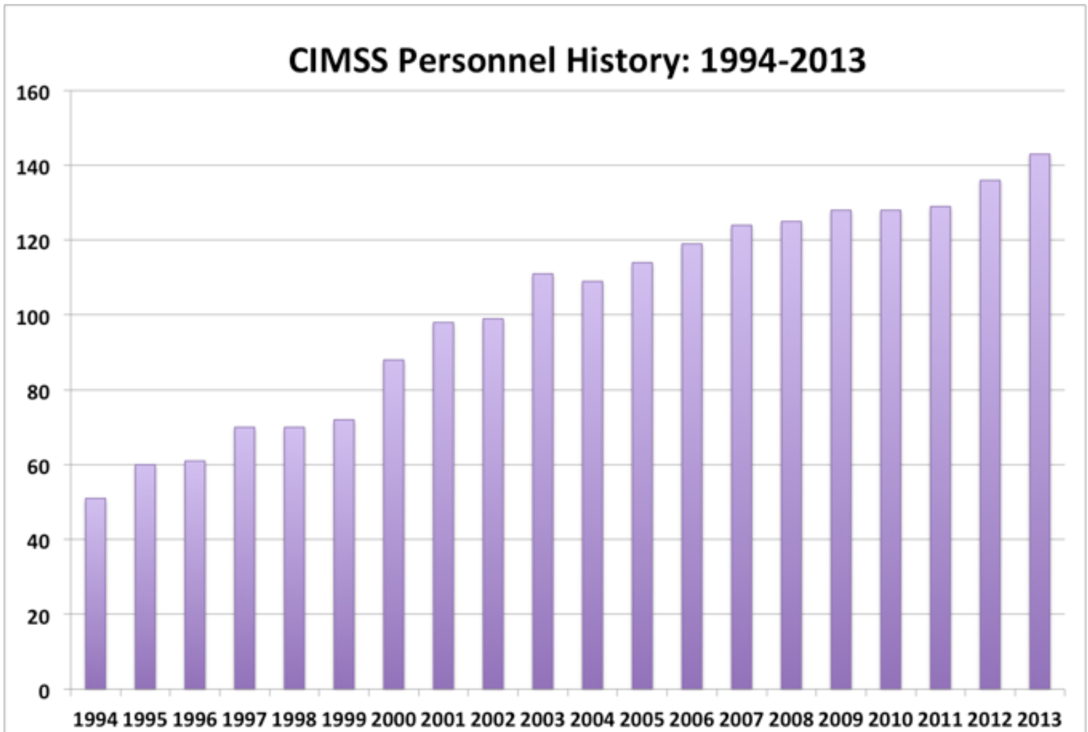


Figure 32. The number of CIMSS staff over the past 18 years.

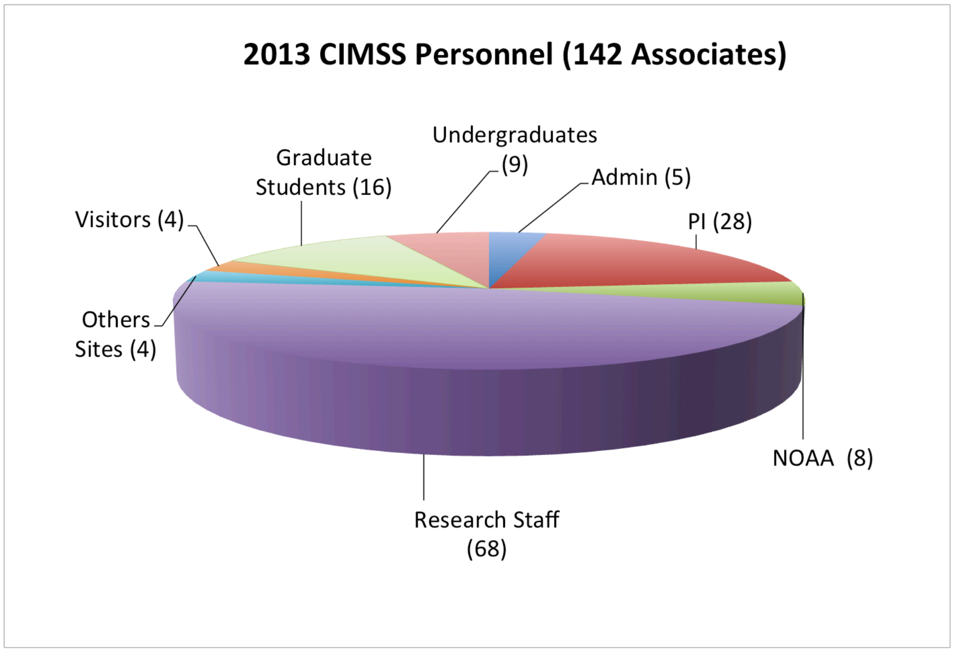


Figure 33. CIMSS staff including NOAA scientists.

F. What is provided for human resources development (recruitment, rewards, training, etc.)?

CIMSS makes use of the SSEC Human Resources (HR) Department to help address personnel issues. At the forefront of SSEC's success are the dedicated and talented people who work here. Each member of the SSEC team has a unique and important part they play in our continued success, no matter what position they hold. People are our organization's most important resource. The HR office is responsible for the Center's personnel needs and strives to be a positive resource for all staff members. HR oversees all aspects of recruitment, performance evaluations, employee relations and personnel administration, as well as taking responsibility for payroll and benefits for the Center's classified, academic and student staff.

In addition to ensuring personnel needs are met, we recognize the importance of acknowledging the successful efforts and hard work of our staff. When ASPB scientists receive NOAA medals for their work, the CIMSS Director asks the medal winner if any CIMSS scientists assisted. As a reflection of the team nature of these honors, those employees then receive a framed certificate from CIMSS denoting their contribution. The certificate is signed by the CIMSS and SSEC Directors, along with the Vice Chancellor for Research/Dean of the Graduate School. There is a small awards ceremony sponsored by the CIMSS Director in the SSEC library in the morning with coffee, bagels and juice.

To help our staff continue to grow and gain the experience and expertise they need, there are annual reviews of all people in the center where professional planning is conducted. Goals are discussed as well as recent achievements and how they matched with the previous year's discussion. During the annual review, CIMSS personnel discuss with their supervisors any training opportunities they need to advance their careers. These can include course work, workshops and advanced degrees. If training is deemed appropriate, the activity is supported by SSEC resources. On an individual basis, SSEC may support personnel seeking to attain a higher degree. For example, Mr. Tommy Jasmin is an outstanding programmer that works with several research groups in CIMSS. He is interested in attaining an M.S. degree in remote sensing through the Nelson Institute at UW-Madison. He is seeking this degree to improve his understanding of our research and how he could better support our work. SSEC is partially supporting the costs of that degree.

SSEC conducted extensive Climate Surveys in 2005 and 2010 to gauge personnel satisfaction and to identify potential workplace issues. A summary report with suggested recommendations to address any issues was written by a committee. The SSEC Director responded to those recommendations and report. The survey addressed topics such as being a welcoming work environment, openness to others, professional development opportunities, feedback about supervisors and suggestions to further improve the system. For example, the 2010 report indicated the need for more clarity about opportunities for professional development. As a result, the SSEC Director discusses this at the annual all hands meeting, and it is often discussed at yearly reviews with staff.

G. What is the state of the financial health of the Institute? (Provide a budget summary and identify imbalances or needed adjustments.)

CIMSS is currently in a good financial situation; however, we are concerned about future federal budget cuts and the impact on CIMSS personnel. NOAA can provide single year grants, sometimes too small to fund one person full time. When this type of financial support comprises too much of the portfolio, it is not good for long-term planning of CIMSS' research agenda. Seed money is beneficial and NOAA end-of-year funding has led to new endeavors and opportunities.

The CIMSS funding history (Figure 34) shows strong growth over the past 30 years. The growth in the 1990s can be partially attributed to participation in the NASA Earth Observing System (EOS) program. The growth in the early 2000s can be partially attributed to the expansion of the high spectral resolution activities sponsored by NOAA and NASA. Most of the 2012-2013 sequestration/continuing resolution and deep cuts in GOES-R AWG program are not reflected in this figure, as this figure represents spending, not funding acquisition. The significant AWG budget cuts started in earnest in 2011-2012 and explain the start of the dip in funding.

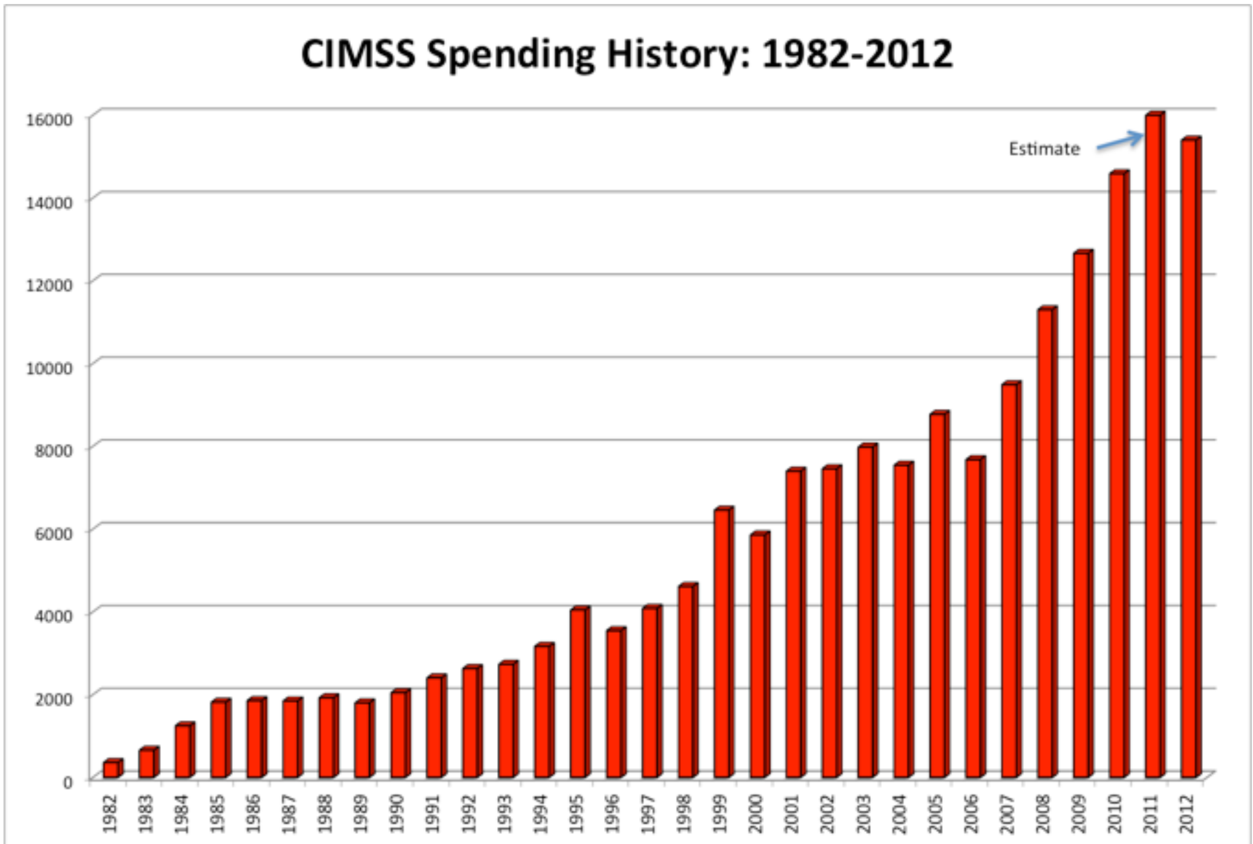


Figure 34. CIMSS spending history from 1982 to 2012.

Current CIMSS research funding by agency is shown in Figure 35. In the past, CIMSS had a strong diversity of funding sources, receiving approximately 30-40% of its annual funding from NOAA and a similar amount from NASA. Recently, there has been a shift to more funding from NOAA than NASA. Part of this shift is due to increased AWG and JPSS funding. The Department of Defense (DOD) and the Department of Energy (DOE) provide support for key research activities that often leverage projects with NOAA and NASA, while providing a specific focus to meet those agency's goals. There is a small amount of funding from the National Science Foundation (NSF).

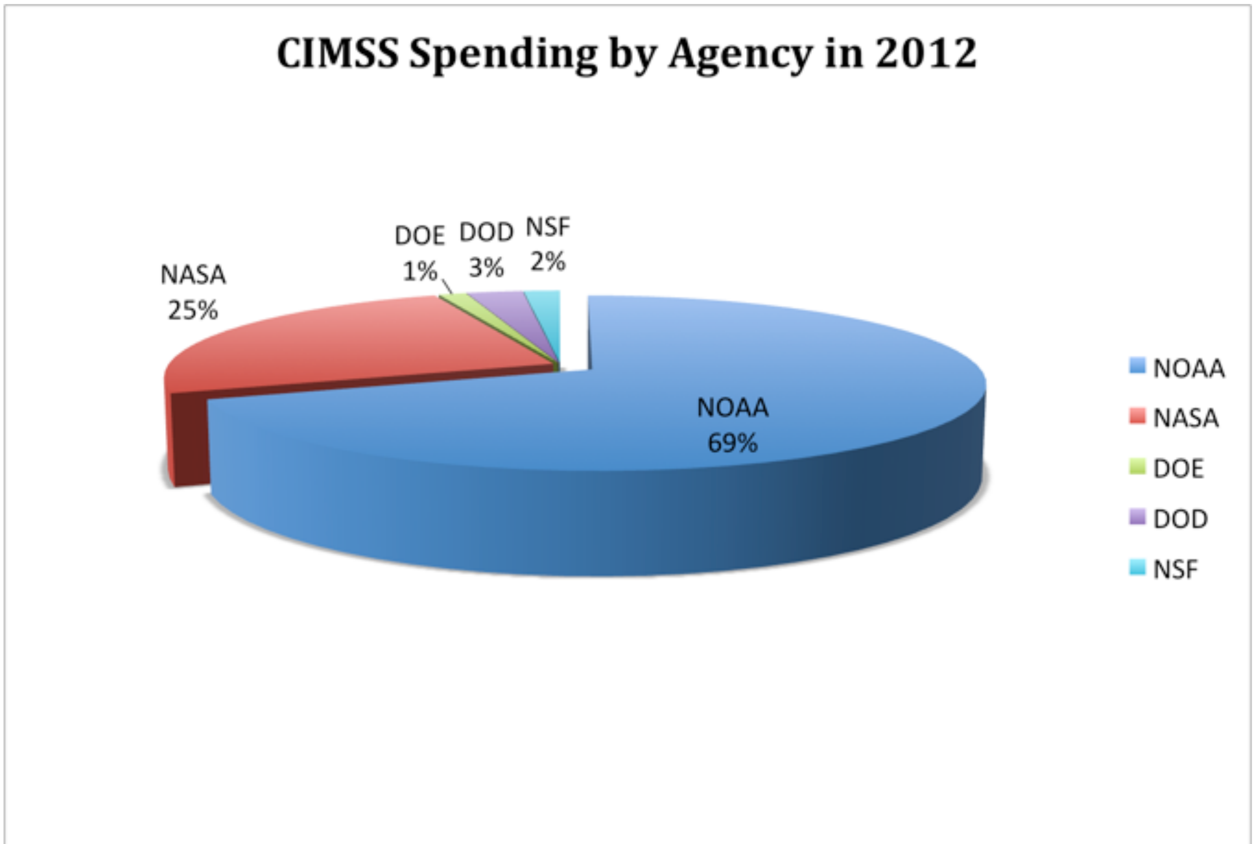


Figure 35. Distribution of CIMSS research program funding in FY2003.

The most significant funding changes in the past five years are depicted in Figure 36. The NASA funding/spending for the most part has been steady, while NOAA funding/spending has shown a steady growth over the past four years. An important reason for this growth around the turn of the century was the arrival of new ASPB scientists who act as PIs (e.g., Jeff Key, Andy Heidinger) and have developed strong research programs in collaboration with CIMSS scientists. The development of the GOES-R Risk Reduction program is another significant reason for the expansion of CIMSS / NOAA research collaborations. More recently, the GOES-R AWG, JPSS programs and S4 have come through the cooperative agreement and resulted in a recent increase of support.

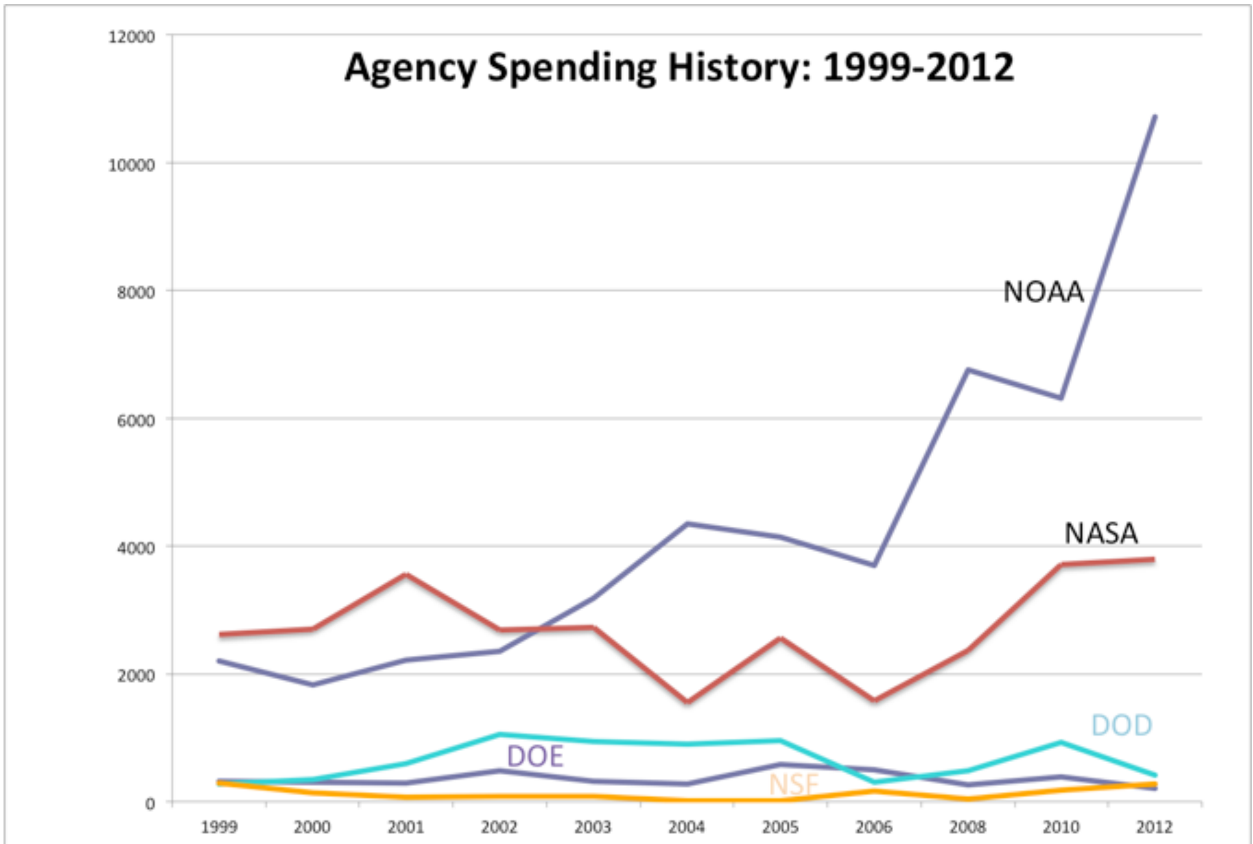


Figure 36. Five year spending history from research sources.

H. How does the Institute intend to work towards accomplishing its financial goals?

CIMSS is in good financial health and we intend to maintain a balanced budget with the assistance of the SSEC administrative team. To support the PIs in maintaining this balance, the SSEC accounting offices developed an electronic system that feeds into the UW–Madison accounting system. This accounting system is used in the preparation of CIMSS financial reports. The accounting system has a Web-based component and all CIMSS employees have access to the financial information through the SSEC private network. Monthly financial reports are also produced and distributed to the PIs and PMs electronically. Effort reporting is scheduled quarterly to assure that spending aligns with project commitments. When hiring needs arise, we first look to see if there is someone within CIMSS available to address those needs before seeking new hires.

The SSEC Web site has an *Employees Only* page that contains a great deal of support information for employees, including accounting information, employee guidelines, advice for new employees, how to make purchases, computing technical support, and Web information. CIMSS can maintain financial stability for as long as the PIs continue to win grants, awards, and contracts. There has traditionally been strong support from the federal government to not only maintain, but grow the nation’s remote sensing capabilities and CIMSS is in excellent position to continue assisting with this effort.

I. Are there any issues in interacting with NOAA that require attention?

A current challenge is to derive stable support in an era of tight budgets and a lack of continuity of resources. The current emphasis on one-year proposals that are task-oriented needs to be balanced by innovative projects that lead to new discoveries.

Support for student fellowships, vital to the training of the next generation of NOAA scientists and staff, has been difficult to obtain via NOAA grants. Many funded activities, such as algorithm development, do not meet the PhD philosophy of atmospheric science departments. Many funded projects are 1 or 2 years and that is often too short to support a graduate student. Even with these constraints, we can support some students with NOAA funding, though more are funded with NASA and NSF resources. CIMSS has partnered with NASA Goddard to support a PhD fellowship, where a one-year NASA grant supported the entire research assistantship and during the follow-on years the student was supported by a NASA collaborating scientist and a CIMSS scientist.

The Cooperative Agreement as managed by NOAA sometimes exhibits fiscal pressure to show immediate costing of allocated resources. Unfortunately the late arrival of funding in the federal fiscal year has become the norm, and, thus costing and outcomes almost always lag NOAA's expectations. Moving cooperative agreement funding forward in the fiscal cycle would obviously help, though it is likely a process we cannot change.

J. Are there any issues in interacting with the University that require attention?

With the current environment at the University and State, it is difficult at times for us to financially reward our staff. While many of our staff are paid better than their campus counterparts, in the last SSEC-wide survey only 39% of the respondents said they were satisfied with their pay. The type of important work we are engaged in keeps our employees energized and we are fortunate to have many loyal staff, though morale may lag at times.

6. Summary

CIMSS is a collaboration between NOAA and UW–Madison that has increased the effectiveness of research and the quality of education in the environmental sciences. In a *Space Policy* article in 1986, William Bishop, former acting Director of NESDIS, noted, "Remote sensing from space can only thrive as a series of partnerships." He used CIMSS as a positive working example of the government-academia partnership, noting "The Institute pioneered the computation of wind speeds at cloud heights by tracking cloud features from image to image. These are now a stable product provided from the satellites to the global models at the National Meteorological Center." CIMSS continues to be a leader in the measurement of winds from satellite observations and leads the way in many other research endeavors as outlined above. There is great value to NOAA and UW-Madison in this long-term collaboration known as CIMSS.